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Citizen Science-Informed Co-Design: Community Devised Technologies for Sustainability Awareness

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Abstract

This dissertation investigates the intersection of Citizen Science, sustainability, and technological innovation, emphasizing the co-design of interactive digital tools to foster sustainability awareness. Framed within participatory methodologies, it examines how Citizen Science democratizes knowledge, engages diverse age groups, and aims to encourage sustainable behaviors and civic participation. Leveraging Human-Computer Interaction (HCI) principles, the study integrates tools like serious games and digital platforms to enhance education and community involvement.

Through four case studies—*GameOn!*, *CitizER Science in action*, *AlmAware*, and *Adrinclusive*—this work examines the role of co-design in democratizing technology and fostering active engagement. Each initiative highlights the interplay between Citizen Science, co-design, and HCI, demonstrating how these frameworks empower users to co-create solutions while cultivating ownership and agency. Employing workshops, iterative prototyping, and mixed-method evaluations, the PhD Thesis underscores the effectiveness of these processes in fostering community-driven innovation.

This research offers a nuanced framework for Citizen Science-informed co-design, emphasizing its capacity to merge diverse perspectives and foster practical, creative solutions for technological innovation for sustainability awareness. By engaging four cohorts as main actors in the design processes, this dissertation investigates the benefits of Citizen Science-informed co-design of interactive digital tools for addressing complex challenges ranging from ecological challenges to inclusive and sustainable tourism.

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Chapter 1

Introduction

In this chapter, the thesis is introduced, starting with its founding motivations and some necessary background setting. Subsequently, the research objectives are presented as well as the research questions (RQs). In the second part of the chapter, the theoretical framework that supports the research is discussed, as it lays the basis for the methodologies employed in the four case studies reported in this thesis. Finally, the chapter concludes with a brief overview of the thesis structure.

1.1 Motivation and Background

1.1.1 Agenda 2030: the sustainability guidelines

The adoption of the 2030 Agenda for Sustainable Development by the United Nations in 2015 established a global framework to tackle poverty, inequality, environmental degradation, and conflict. The 17 Sustainable Development Goals (SDGs) are central to this, which address interconnected economic, social, and ecological dimensions. These universal goals require collective action to create a more sustainable and equitable future.

Achieving the SDGs demands a multidisciplinary approach involving governments, industries, civil society, and communities. Educational institutions hold a key role, not only in fostering knowledge but also in cultivating the values and skills needed for sustainability. By embedding sustainability principles into curricula and activities, schools and universities empower learners to take informed actions that reflect equity, justice, and environmental stewardship.

Education bridges the gap between knowledge and action by integrating experiential and project-based learning. It encourages students to tackle real-world problems like climate change, social inclusion, and resource management. These efforts foster both individual empowerment and systemic change, positioning educational institutions as pillars of the global sustainability movement.

1.1.2 Sustainability through Collaboration

Advancing the SDGs requires collaborative innovation, emphasizing collective efforts, knowledge sharing, and creative problem-solving. The interconnected challenges of sustainability call for multi-stakeholder approaches that engage individuals and communities to co-create solutions addressing local needs and global goals.

By fostering cooperation and mutual engagement, collaborative innovation transforms abstract goals into concrete actions. This approach bridges the gap between awareness and impact, highlighting the power of collective action to advance systemic change and achieve the SDGs.

1.1.3 Citizen Science

Citizen Science (CS) is a highly collaborative research approach, inviting public participation in scientific projects. Engaging people, most often non-professionals, in activities ranging from data collection and analysis to project design opens new ways to contribute to scientific knowledge. This approach has been instrumental in breaking traditional barriers, bringing together diverse groups not reliant on formal scientific training, and advancing various fields through mass participation.

The roots of CS trace back to ancient practices. For instance, court diarists have recorded the exact dates of cherry tree blossoms [185], while in China, officials and citizens monitored recurring locust outbreaks for over 3500 years [224]. In France, farmers have documented grape harvest dates for over 640 years [54]. Participatory data collection also predated the professionalization of science; before the late 19th century, much scientific research was driven by amateur efforts [154]. These early activities set the stage for today's CS.

Modern CS emerged as a more structured practice, though it remains rooted in these informal collaborations. The Audubon Society's Christmas Bird Count, initiated in 1900, is often considered the first modern CS initiative [70]. This annual project engages citizens in monitoring bird populations and has provided invaluable data for ornithological studies. Interestingly, it replaced a traditional Christmas Side Hunt, shifting from hunting to conservation-focused efforts [149]. The success of the Christmas Bird Count highlights the efficacy of CS in both environmental conservation and fostering community engagement.

The term "CS" gained prominence in 1989 through an MIT Technology Review article [132]. Since then, CS has attracted attention across various research fields, leading to diverse definitions. Ornithologist Rick Bonney described it as a means of gathering scientific data through public engagement with professional researchers [27]. Sociologist Alan Irwin emphasized the value of knowledge held by non-experts, framing CS as an inherent capability of individuals (Irwin, 1995 in [27]). Despite their contributions, these definitions do not fully capture CS's broader impact on both research and participants [105]. Participants gain opportunities for personal growth, such as understanding scientific processes [13, 179], developing an interest in project topics [105], and engaging in community-building [41].

To address its multifaceted nature, the European CS Association (ECSA) proposed the "10 principles of CS" in 2015 [72]. These principles encompass educational, scientific, and social dimensions, offering a comprehensive framework for understanding CS.

CS contributes significantly to research and society. One of its key contributions is the democratization of science, fostering an inclusive and transparent approach [101, 113]. By involving the public in problem-solving and promoting open science, CS strengthens the relationship between academia and communities, enabling individuals to explore scientific issues more deeply and apply knowledge in everyday life [106]. Additionally, it supports large-scale data collection over broad geographic areas and long periods, which is critical for projects such as tracking bird migrations, monitoring water quality, and cataloging biodiversity changes [164].

CS also creates mutually beneficial contexts for researchers and participants. Researchers gain access to large datasets that would be difficult to achieve through traditional methods, enabling studies requiring extensive spatial and temporal tracking [56, 222]. Participants contribute diverse perspectives and ideas, enriching scientific inquiry [66]. Moreover, participants become more scientifically literate, gaining insights into research methods and their real-world applications [28].

CS's impact extends to policy and societal change, particularly in environmental protection, public health, and urban planning [101]. For example, environmental data collected by citizens has informed policy reforms on pollution control and climate change [246]. Community-driven projects empower local populations to advocate for better environmental conditions and advance environmental justice [118]. Additionally, CS inspires new generations of scientists, fostering curiosity and ensuring a scientifically literate public capable of addressing global challenges [38].

From a methodological perspective, CS enables iterative research design. Feedback from participants helps refine methods, improving data collection and analysis protocols in real-time [56]. This adaptability enhances data quality and ensures the research findings' relevance. Engaged participants often become advocates for projects, increasing their visibility and societal impact [139].

CS enriches participants by allowing them to explore topics of personal interest while contributing to meaningful discoveries. Participants acquire hands-on knowledge of scientific methods, from hypothesis formation to data analysis, fostering respect for the scientific process and promoting scientific literacy [119]. They also develop project-specific skills, such as species identification or data logging, which enhance engagement and personal growth [117, 180]. For young participants, CS can serve as an entry point into science-related careers, offering first-hand experience and inspiration [111].

CS projects vary widely in scope, design, and methods. Contributory projects primarily involve data collection by participants, with professionals managing design and analysis. Examples include Galaxy Zoo, where volunteers classify galaxy images [146], and Project FeederWatch, which collects data on bird populations [31]. Foldit engages participants in solving protein-folding puzzles with medical applications [104]. Similarly, the Smell Pittsburgh project involves citizens reporting air quality issues via a mobile app [109].

Other projects emphasize active roles for participants, often engaging local communities and leveraging cultural heritage and traditional knowledge [97, 217, 238]. For instance, the Mbendjele hunter-gatherers in Congo contributed to anti-poaching efforts by reporting data to combat illegal activities [238]. Similarly, the Sapelli app enables illiterate users to document and manage natural resources, promoting sustainable practices and environmental justice [217]. These projects demonstrate the value of local knowledge and the importance of community cohesion.

Despite its strengths, CS faces challenges. Data quality is a common concern, as non-professional participants may lack expertise [136]. To address this, researchers provide standardized protocols and toolkits and communicate potential biases [84, 99]. Participant engagement and retention also pose challenges, which can be mitigated through user-friendly technologies, gamification, and community-building practices [45, 226].

Ethical considerations are crucial, particularly in projects involving personal data or sensitive topics. Transparency, informed consent, and data protection are essential to ensure participant safety and research integrity [193].

CS represents a transformative research approach, fostering collaboration, innovation, and societal impact. By addressing its challenges and leveraging its strengths, CS can continue to drive meaningful contributions to science and society.

1.1.4 Human-Computer Interaction in CS

Human-Computer Interaction (HCI) plays a crucial role in shaping the CS project's experience and effectiveness. As CS heavily relies on public engagement and active participation, HCI provides tools and methods to allow such interactions to be intuitive, accessible, engaging, and impactful. Thanks to the HCI focus on design, usability, accessibility, and user interfaces (e.g. mobile apps, web platforms, data visualization), it can enhance volunteers' interactions and support them in the scientific tasks they pursue [184]. Such innovations actively structure the modalities and roles that define the project streamlining; consequently, HCI tools design can deeply influence CS work and their communities, creating a unique cultural environment for each project, and making it pivotal to understand what tools should be employed based on each community's necessities [253].

Additionally, HCI can contribute to increasing engagement by applying gamification strategies to a given tool, for example, by leveraging competition or collaboration [201] within the members of a community [33]. Again, HCI can provide solutions to facilitate knowledge exchange or data interpretation by providing accessible interfaces and clear data visualization, ultimately increasing the educational value of CS.

On the one hand, CS represents a transformative practice: a change in the very structure of scientific research that allows new avenues of participation and reframes scientific research in a collaborative approach [22]. On the other hand, the field is growing, rapidly increasing public interest in engaging with science, hence calling for technological innovation [165]. CS and HCI mutually benefit each other as they provide each other input for innovation aligned toward the ultimate goal of contributing to the increment of scientific knowledge [184] and fostering informed, engaged, and empowered communities capable of tackling the many challenges of the contemporary world.

1.1.5 Context

This dissertation is the result of research developed in the context of a PON green PhD scholarship[1], in the PhD program of Computer Science and Engineering at the University of Bologna. Moreover, as part of the PON's mandatory period working in a company, I collaborated with RomagnaTech [2], where I had the opportunity to manage European Projects by organizing and conducting research activities and producing the required deliverables. Over three years, the research has actively engaged with local and international communities and industry, supported multidisciplinary dialogue, and helped achieve SDGs.

The interdisciplinary approach to the research reflects the expertise in the CREATE4Impact laboratory, which I had the pleasure of being part of during these three years of work. The laboratory hosts experts in different fields, from computer science to gamification, from data visualization to sociology. For this reason, the research approach is a result of the different expertise available to the group, generating a multifaceted approach that nurtured creativity and a diverse approach to research that often led to original ideas and unique perspectives in the field of Human-Computer Interaction (HCI).

[1] A *green* PON PhD scholarship refers to a doctoral scholarship funded under the National Operational Program (PON) for Research and Innovation. These scholarships are focused on themes related to environmental sustainability, energy efficiency, green technologies, and the broader objectives of ecological transition.

[2] https://www.romagnatech.eu/

1.2 Research Objectives

This thesis elaborates on an extensive investigation of interactions among CS, sustainability, co-design, and technological innovation, which are harnessed as driving forces for improving societal and environmental benefits. Focusing on participatory and collaborative methods, the present research sets its target to take up the most urgent problems in the sustainability domain with fundamentally new ways, connecting scientific inquiry with civic participation to increase sustainability awareness.

In this participatory frame, on the one hand, the research investigates the potential of CS to democratize scientific understanding, raise environmental awareness, and encourage action toward more sustainable behaviors. On the other hand, through technological innovation, this research found powerful catalysts - with tools such as serious games, digital platforms, or apps - to spark interest in educational content and active participation and co-creation processes.

Ultimately, this work presents a comprehensive framework for using CS and co-design to address complex global problems. By intertwining academic rigor with implementation practices, it shows the potential of inclusive and participatory approaches in creating significant and long-lasting impacts. The final chapter weaves together the different research strands and reaffirms that CS and co-design are integral to creating sustainable futures and forming pathways for further research.

1.2.1 Research Hypothesis

The initial hypothesis that stemmed from the research is that CS-Informed Co-design benefits communities, from children to elderly people, by engaging them in devising interactive digital tools that can boost sustainability awareness.

1.2.2 Research questions

To investigate the validity of this hypothesis, two RQs were crafted and led the research.

RQ1 Can CS-informed co-design processes engage diverse age groups (children to elderly people) in the creation of interactive digital tools to enhance sustainability awareness?

RQ2 What are the observed benefits of involving communities in CS-informed co-design for the development of interactive digital tools that promote sustainability awareness?

1.3 Theoretical framework

This section provides a brief overview of the foundational theories and concepts underpinning this research. It begins with Actor-Network Theory, progresses to Communities of Practice, and concludes with an exploration of Constructionism and its connection to Human-Computer Interaction (HCI).

1.3.1 Actor-Network Theory

Actor-network theory (ANT) sprouted from science and technology studies (STS) as an innovative approach to allow scholars to examine how interactions between human and non-human entities, and how such interactions intertwine to form networks, which in turn influence social and technological innovation and outcomes.

Amongst the major authors of this theory stand Bruno Latour, Michel Callon, and John Law, who challenged the traditional distinction between human and non-human actors by bringing them on the same level. ANT states that all actors (human and non-human) should be considered equally influential in the processes of shaping social relations, structures, and innovations. For these reasons, ANT proposes a unique perspective on the previous understanding of technologies, organizations, institutions, and social relations.

The symmetry between human and non-human actors is a concept known as “generalized symmetry”, which entails that non-human actors participate in equal parts with human actors in the formation and perpetuation of networks [143]. This concept depicts a complete fracture from traditional sociological studies that tend to prioritize human actors as the entity responsible for network structuring, while considering non-human actors as passive elements in such processes. Differently, in ANT, both human and non-human are defined as “actants”. Actants are capable of influencing the networks of which they are part as well as other related networks [141]. Therefore, the term actant acts as an umbrella term that can comprise humans, machines, objects, or even policies, and they are intended as actors who exert agency in their network of reference.

Interactions are another key element in ANT and are conceptualized as “translations”. Translations describe the negotiation between actors that lead them to define their role within the network [44]. An example of this, in the context of a research project, might be that researchers, universities, stakeholders, partners, funding bodies, and the technology employed all must align their interests, focus, and actions to pursue their goal in the meanwhile hierarchies and relations are formed. This process of formation of social bond networks is the observable result; some aspects within the network might change in time, and others might solidify, hence networks have nuanced borders, which through further translations are ever-shifting.

The process that allows actants to join a network and stabilize it as an institution undergoes three main steps: i) “enrolment”, ii) “obligatory passage points”, and iii) “blackboxing”. While describing these three steps, I report the example made by Callon regarding the domestication of scallops and the relation between fishermen and researchers [44].

i) “Enrolment” marks the start of the process for an actant to join a network, specifically explaining how each actor is brought into the network and plays their dedicated role. In Michel Callon's case study, the scientists studying scallops must enroll fishermen and scallops into their network. Fishermen are convinced that the scientists' research will help increase the scallop population, while the scallops are "represented" by the scientists as organisms that need protection and monitoring. Both fishermen and scallops are assigned roles that support the scientists' research objectives.

ii) "Obligatory passage points" are mandatory goals that an actant must achieve to reach a designated goal. These points work as a junction where the interests of different actors converge, setting the milestones of a network that allows actors to align their efforts. For the scallop study, the scientists create an obligatory passage point by convincing all actors that they must protect scallop larvae, requiring fishermen to agree not to harvest scallops in certain areas. This stage sets the framework through which both scientists and fishermen can achieve their shared objective of boosting the scallop population.

Lastly, iii) "blackboxing" is the spontaneous phenomenon that occurs in complex and stable networks, causing it to hide certain relationships between actants, creating the illusion of the network as a self-sustained entity. In this case, once the scientists' method of protecting the scallops proves effective, the network stabilizes, and the complexity of the process, scientific research, fishermen's compliance, and scallop behavior are no longer questioned. The network achieved smooth functionality, and the black box obscures the collaborative efforts behind the scenes. However, if a disruption occurred, such as a sudden collapse in scallop populations or non-compliance by the fishermen, the hidden complexities of the network would re-emerge, revealing the once-blackboxed relationships before stability could be restored.

ANT has also been strongly criticized due to their disruptive perspective on traditional understandings of social networks and their effects on innovation. Hence, the main criticism is the idea that by comparing human actors to non-human actants ANT can incur the risk of downplaying the relevance of human intentions, social relations, and ethics leading to a misunderstanding, or even overlooking, issues in power relations, inequalities and more broadly in judging the moral footprint of human actions [218].

Nonetheless, ANT retains value in its field as it provides a different lens for analysis, specifically when the interest of research revolves around technologies, their innovation, and their capabilities to spark innovation. On the other hand, ANT provides a theoretical framework that allows the interpretation of scientific knowledge as a result of social, technical, and material factors, allowing for a deeper understanding of the hidden processes that lead to the construction of scientific knowledge. On the other hand, ANT provides a theoretical framework that allows the interpretation of scientific knowledge as a result of social, technical, and material factors, allowing for a deeper understanding of the hidden processes that lead to the construction of scientific knowledge. By illustrating that scientific knowledge is constructed through the interactions and negotiations among diverse actants, Latour emphasizes in *Pandora's Hope* that science is not merely a neutral pursuit of truth but a contingent product of various relationships [140]. This perspective challenges traditional views of science, urging a reevaluation of the power dynamics and ethical considerations inherent in scientific practice.

Overall, ANT proves to be a tool adaptable to different fields of study, from environmental studies to organizational studies, infrastructure development, and technological and scientific innovation, thanks to its neutrality in the analysis of complex socio-technical networks, providing valuable insights into the actant relations that shape innovation.

1.3.2 Communities of practice

The concept of Communities of Practice (CoPs) emerged for the first time by the cognitive anthropologist Jean Lave and the educational theorist Etienne Wenger in their work "Situated Learning: Legitimate Peripheral Participation" [142] in which they describe the learning process as a mainly social and participatory activity occurring between members of communities. CoP defines a group of people dedicated to a shared objective, which is pursued through shared experiences, practices, and/or professions. In a CoP, the process of learning is considered a social process that occurs using social interactions. In this light, the process of learning can be considered a social process occurring between a group of people who share an interest in a specific domain of expertise.

Such groups can have different characteristics, but they are all characterized as self-organized and informal; they all provide a space for participants to join the group's activities, discuss, share knowledge, and train their skills in a cooperative environment.

For these reasons, social relationships play a central role in the learning process as it occurs in the context of a community with specific cultural features. Furthermore, it is to be noted that in CoP, knowledge is not passed down from an expert to a novice in a unilateral way, but rather, knowledge is shared via a participatory process. Moreover, CoPs emphasize the learning-by-doing approach, fostering active participation in real-world situations. The core idea behind this approach is to provide education through practice so that the gained knowledge can be applied immediately to help the CoP pursue its goal, making the learning process feel more impactful.

Wenger [245] expands on the topic by discussing the progression of actors within the CoPs. New members engage with other members in shared activities and discussions, and as they gradually gain expertise, they progress from peripheral participation, where they begin as newcomers, to full engagement, where they are recognized as experienced, competent members of the community, and they take on more central roles. Furthermore, as Wenger remarks, the "key to good community participation and a healthy degree of movement between levels is to design community activities that allow participants at all levels to feel like full members".

A central element of CoP stands in the sense of community that sprouts through the shared expertise on a specific domain and through the shared efforts and practices used to pursue common goals. Another key feature is the practice itself, referring to the shared culture (composed of the body of knowledge, the tools, the available resources, the ever-growing expertise, and the social bonds and habits). What differentiates CoPs from other social groups or groups of interest is the "practice", meaning that the participants of the said group do not simply discuss their domain of interest, instead, they actively pursue their objective by actively collaborating for the creation and improvement of practices that can enhance their understanding and/or performance in their field of interest. The exertion of such practices and their improvement allows the CoP to improve with time and perpetuate its institution by recruiting new members and embroiling them in the discussions and collaboration, allowing them and the CoP to face new challenges and progress toward their objective.

Fluidity is another key element of CoPs, which are usually *organic (Durkheim) networks (Latour)* [71] [141] where roles are rather nuanced and can shift easily, moving the boundaries of the group and evolving along with the engagement between its members. The dynamic and versatile nature of CoPs allows them to evolve and shift as their members change, providing a welcoming environment for newcomers who can participate in the activities based on their level of expertise and knowledge, and opportunities for more experienced participants to take on leading or central roles [39]. This delineates a participatory model that is both flexible and inclusive, enhancing recruitment and engagement opportunities to facilitate recruitment by welcoming participants at any level.

Although CoP provides many positive elements for participatory activities, it comes with some challenges. First, the long-term engagement of participants can be problematic as their collaboration is voluntary, and they invest their free time in the CoP activities. For this reason, if the members of a CoP are not motivated, the group may fade out or have an excessive drop-out rate among new members, slowing or stopping their growth. To address this, successful CoPs often rely on strong leadership or facilitation, even if it is informal. Leaders or facilitators help to keep discussions focused, encourage participation, and ensure that the community remains active and relevant to its members' needs.

Secondly, a key disadvantage of the communities of practice approach is that its broad applicability across different organizational settings can lead to misuse or inappropriate application in contexts where it may not be suitable [194].

Lastly, the success of a community of practice in generating and sharing knowledge largely depends on the context in which it operates. Additionally, broader socio-cultural factors can either support or hinder the effectiveness of communities of practice as a knowledge management tool. National competitiveness, driven by the ability to create and share knowledge, may differ based on socio-cultural traits unique to each country, such as the degree of trust or the balance between individualism and collectivism within the society [194].

1.3.3 Constructionism

Constructionism is a learning theory that revolves around the core idea that learning happens primarily through the creation of tangible or digital artifacts, which enable learners to form mental models with which they can interpret the world around them. Seymour Papert is recognized as the father of Constructionism, which can be considered as an elaboration of Piaget's constructivism [175]. Papert introduced constructionism at MIT's Media Lab in the 1980s by recognizing the potential of computers as innovative tools for education. Papert's work began with the development of the programming language named LOGO [177]. This language was devised to foster mathematical thinking as, according to Papert, programming represents a constructive process wherein learners progressively deepen their understanding through ongoing practice and iterative refinement.

The main principle of the constructionist theory is that learning is an active process, where learners engage with abstract concepts through the practical activities of a hands-on project. Through this process, the individuals can experiment and reflect directly on the subject matter through first-hand experiences [190]. The process of creation poses a series of challenges that must be overcome for the completion of the project, allowing the individuals to learn by problem-solving. Hence, the knowledge emerges from the interaction between the environment and the learner, leading to a modality of education that passes through self-discovery rather than memorization.

The constructionist approach to education can be applied to a wide number of fields, not only to technology-related domains, and there are numerous examples of its application in art, science, and engineering contexts. Teaching, and foremost learning, in a constructivist classroom, happens through projects, like building models, making experiments, or more broadly developing and completing projects. All these activities hold value as long as they ignite reflection and understanding in the students, fostering critical thinking through the creative process and the problem-solving that such activities lead to.

One further element of this theory is the importance of the project's relevance for the students. Constructionism aims at engaging learners through projects that align with their interests in order to enhance their investment in the learning process. Contrarily, in traditional education, the abstract is passed passively, and it does not take into account students' personal preferences or experiences.

The learning process in constructionism is often a group effort. Peer interaction provides a further layer of complexity and an opportunity for personal and professional skill development. Kafai and Resnick [124] argue that technology can be used as a tool for collaborative problem-solving, as it can provide many cues for creative work and exploring innovative ideas. At the same time, learners acquire knowledge through and for practical application, rendering traditional testing obsolete.

In this context, the role of the teacher is swapped with that of the facilitator. In this role, an educator cares for guiding their students through the learning process without imposing a pre-established path. The primary purpose of having a facilitator is to empower learners by encouraging them to take responsibility for their own choices [4]. This approach fosters independence and creativity, with the facilitator providing support only when needed, allowing learners to make decisions on their own.

Constructionism and technology: new practices in the making Constructionism and technology, on the other hand, are interrelated in deep synergy. Technology provides a wide array of tools and platforms for learners to construct, experiment, and reflect on new ideas and problem-solving. In this regard, technology shifts from being a simple medium to an active actant in the knowledge creation process. It does so by enabling learners to engage in new kinds of practices that were once unimaginable, and technological innovation keeps pushing these frontiers, allowing for an ever-changing approach to education through technology.

The tremendous growth in technology, since the formulation of Papert's learning theory, has greatly widened the constructionist learning possibility: computers have become smaller, easy to operate, and more affordable; smartphones [10], 3D printers [83], robotics kits [7], and VR joined their ranks [93]. These new technologies give learners unprecedented possibilities of creation, exploration, and engagement in constructionist practices that blur boundaries between the physical and digital. For example, 3D printing enables students to design and create physical models of items that they have imagined, while VR provides a simulated environment in which learners can construct virtual worlds and interact with them in real-time.

Technology is also playing a role in making collaboration easier for learners. With updated digital tools, it's relatively easy for learners to share projects, work with others, and receive feedback from anywhere in the world. For example, Scratch - a visual programming language developed at MIT - allows kids to create and share their own interactive stories, games, and animations with an online community of peers. The collaborative environment created in a constructionist classroom tends to foster idea sharing and mutual feelings of discovery in which learners take over each other's ideas and learn from each other's experiences while continuously reiterating what they create.

The Human-Computer Interaction (HCI) field is closely intertwined with constructionism [174]. Firstly, because of the focus of HCI on the modalities of interaction between people and computers, technology is designed to enhance support of human activities, including learning. HCI research strives to innovate and produce new interfaces [211], devices, and systems that allow learners to engage in creative, hands-on exploration. For example, touchscreens, gesture-based interfaces, and AR technologies provide an easier, more direct way to manipulate digital objects, thus being particularly close to the principles of constructionism because building and experimenting with ideas becomes much more intuitive and natural for them.

Another example of the intersection between constructionism and technology is most evident in the rise of maker culture and maker spaces. Makerspaces are generally high-tech spaces, featuring tools such as laser cutters, 3D printers, and robotics kits, all under one community-driven atmosphere where learners may engage themselves in designing and building projects of their personal choice. The maker spaces reflect the constructionist ideal of learning through making: doing, trying out, building, and tinkering to construct knowledge using physical and digital artifacts. The maker movement emphasizes creativity, problem-solving, and collaboration [25], core values of constructionism. Schools, libraries, and community centers worldwide have embraced this movement [81][183].

Another interesting place of intersection between constructionism and technology falls within the area of computational thinking. Computational thinking is recognized as an important 21st-century skill, where knowledge in computer science can be used to solve problems [248]. Programming, or coding, is, as in Papert's experience, a great tool to deploy in constructionist classrooms. Coding allows students to design algorithms and programs that can solve a given problem. Tools like Scratch, Tynker, and Code.org teach young students to code through engaging, project-oriented learning spaces where students may create their games, animations, and simulations. This process helps students learn the practice of computational thinking: breaking down problems into smaller pieces, attempting solutions, and debugging their code.

There are, however, plenty of complications when incorporating technology into the constructivist learning practice: in the first place, digital tools and resources are not universally available; their unequal access creates inequity in learning opportunities [243]. Efficient use of technology in the processes of constructivist learning also requires a change in teachers'/educators' roles from instruction to facilitation and mentoring. This transition is complex, and it would require great efforts by the education professional to develop the skills to guide students in constructionist learning practices that effectively incorporate technology [103]. Furthermore, schools and other organizations would have to adapt accordingly, calling for major institutional changes. Such a change would also call for learning how to support students in self-directed and project-based learning environments, which would require a few years to fine-tune and adjust the education curricula.

It remains crucial that technology, while offering powerful tools for constructionist learning, does not shift the focus away from the learning process itself. The goal should be to provide tools that enable creativity, exploration, and critical thinking, not to make technology an end in itself. The constructionist approach values making, reflecting, and iterating, and this philosophy should be central to technology-enhanced learning environments. Simply using technology is not enough; it must be used in meaningful ways to construct knowledge, solve problems, and express ideas.

1.4 Methodologies

This section outlines the methodologies employed in this research, focusing on semi-structured interviews, co-design workshops, and evaluation processes. These methods were selected to ensure an inclusive, participatory approach to designing and assessing tools and applications for sustainability and citizen engagement.

1.4.1 Methods

Qualitative and quantitative research methods

Qualitative and quantitative research methods were employed to further investigate the workshop sessions. In the following paragraphs, different methods are presented while briefly explaining the main benefits in the context of this research.

First, semi-structured interviews were conducted with key stakeholders, including educators, game designers, policymakers, and representatives from relevant community groups. This method provided rich, qualitative insights into their experiences, needs, and expectations, which informed the design and development of the case studies [5]. The flexibility of the semi-structured format allowed for open-ended discussions, fostering a deeper understanding of the socio-cultural and contextual factors influencing sustainability and CS projects.

Second, systematic observations became a methodological key to getting at the subtle and complex information embedded in the user behaviors, verbal exchanges, and non-verbal signals of co-design workshop participation [115]. This helped in exposing some deep-seated needs and preferences that the participants wouldn't normally mention or think about in everyday life. Furthermore, the knowledge gained through such observations was utilized for continuous adaptation of the methodologies used; this ensured that they were congruent with the dynamic changes taking place in the workshop setting. Such observations, therefore, helped in fostering a better understanding of participants' engagement in the design processes and further allowed the identification of emergent patterns and relational dynamics to develop a better overall assessment and improvement of the co-design framework. This adds to the importance of the methodology, where observation is a mechanism for pinpointing contextual and interactional nuances that may otherwise be overlooked in traditional data collection methodologies, hence making the technological design outcomes more inclusive and responsive.

Third, qualitative surveys and quantitative questionnaires were used as supplementary tools in the assessment of participant involvement, gathering feedback about the activities and prototypes, and assessing the learning potential inherent in the proposed activities. While both methods provided important insights, their divergent features fulfilled separate functions in the data collection process. Qualitative surveys allowed participants to provide expansive, detailed responses, thereby encapsulating the complexity and richness of their individual experiences, reflections, and nuanced viewpoints regarding the co-design activities. On the other hand, quantitative questionnaires were designed with fixed scales and closed-ended questions for the collection of quantifiable data to identify patterns, compare responses, and measure degrees of engagement or satisfaction with particular aspects of the workshop. Collectively, these approaches facilitated a comprehensive comprehension by linking personal insights with empirical data, thus guiding the ongoing enhancement of the workshop's design and techniques.

1.4.2 Co-design

As defined by Sanders and Stappers, co-design refers to the "creativity of designers and people not trained in design working together in the design development process" [203]. Hence, co-design as a methodology is an integral part of developing user-centered solutions, where participants are actively involved in the design process. This approach ensures that users are not only the end consumers but rather active contributors in shaping the tools and applications to fit their special needs and preferences. In this way, this methodology cultivates a collaborative and inclusive environment that creates opportunities for people with diverse backgrounds to share their own experiences and knowledge. This approach is particularly versatile thanks to the different expertise of the participants, giving way to creative problem-solving for a wide variety of challenges. Ultimately, in co-design, the resulting tools and applications are continuously re-created and adapted through an ongoing feedback loop, which provides practical and meaningful development solutions for their communities.

Participants, Users, and Cohorts Participants in the co-design sessions included a diverse cohort of students, educators, community members, and subject matter experts. This diversity ensured a broad spectrum of perspectives, fostering creativity and inclusivity in the design process. The recruitment strategy prioritized stakeholders with varying levels of familiarity with digital tools and sustainability topics to create an inclusive and representative group.

Culturally Informed Collaborative Design Workshops The workshops were designed with cultural sensitivity in mind, recognizing the unique socio-economic and environmental contexts of the participants. To embrace this diversity, the workshops created an inclusive and supportive environment where every voice could be heard and valued. A conscious effort was made to keep the activities engaging, the knowledge sharing meaningful, and the learning process collaborative among participants. These workshops provided a space for open communication and creative problem-solving, fostering cooperation. In addition to generating new ideas, the workshops served to refine and improve solutions through an iterative process. By adhering to the principles of human-centered design, the workshops ensured that the outcomes were practical, relevant, and reflective of the shared perspectives and lived experiences of the participants.

Evaluation The evaluation process involved both formative and summative assessments to measure the effectiveness of the tools and applications developed during the case studies. Feedback was collected through post-workshop surveys, usability testing, and focus groups, providing qualitative and quantitative data. Metrics such as user satisfaction, engagement levels, and perceived impact on sustainability behaviors were analyzed to refine and validate the designs.

1.5 Case Studies

In this chapter's section, the case studies are briefly presented, and their key distinctive elements are summarized in the following table 1.1

1.5.1 GameOn!

GameOn! is a serious game, born in the context of the CreativeEurope Project [3] that leverages Minecraft Education Edition as its core platform, enriched with tailored educational pathways. This serious game incorporates gamified learning experiences to deliver entertaining yet instructive gameplay, aligning with specific educational objectives. Its iterative design ensures an engaging and pedagogically sound experience for its target audience.

The development process involved several co-design sessions with an array of international educators, artists, game developers, and other experts. Participants contributed feedback on prototypes through iterative cycles, helping to refine the game mechanics to ensure they were both entertaining and effective in achieving learning goals. This collaborative approach guarantees that the final product resonates with the needs of its intended users.

GameOn! was designed for young learners aged 6 to 11, along with their teachers or tutors. This cohort actively engages in educational pathways that promote peace, inclusiveness, and sustainability. Through role-playing and active citizenship activities, participants develop critical thinking and collaboration skills while exploring key sustainability concepts.

Finally, the evaluation of the *GameOn!* world involved structured playtest sessions in primary schools, combining guided gameplay, free exploration, and feedback collection to refine the game's design and enhance its educational and entertainment value.

[3] https://finland.accac.global/en/projects/game-on/

1.5.2 CitizER Science in action

CitizER Science in action [4] is a workshop format conducted as part of the broader project *CitizER Science* [5], and within the context of the "AFTER festival" [6]. These initiatives are promoted by the Emilia-Romagna county.

This case study engages a diverse group of participants: teenagers, specifically classmates aged 12 to 19. They play a central role in the co-design process, ensuring that the applications developed are accessible, engaging, and relevant to their needs. The workshop's focus on CS aims to foster a sense of community participation in sustainability projects, particularly within the students' local geographical area.

The *CitizER Science in action* project utilizes CS applications that incorporate social media principles combined with gamification. Key features include leaderboards and collaborative challenges, which drive user engagement, foster community involvement, and encourage the sharing of data related to sustainability initiatives. The co-design process in *CitizER Science in action* involved interactive workshops with students from different schools. These sessions emphasized integrating features that balance usability, scientific rigor in data gathering through CS activities, and engaging game mechanics.

At the end of each workshop, the evaluation happens through participants' plenary sessions, where each group presented and discussed their paper-based prototypes. During these sessions, they provided further insights about the applications they devised and the creative process they followed to ensure their prototypes effectively promote competition and collaboration to stimulate the conduct of CS activity from the target user while remaining practical and scientifically sound.

[4] https://digitale.regione.emilia-romagna.it/citizer-science/laboratori/laboratori-per-ragazzi

[5] https://digitale.regione.emilia-romagna.it/citizer-science

[6] https://www.afterfestival.it/

1.5.3 AlmAware

AlmAware is a project funded by the University of Bologna via the 2022 Almaidea competitive call [7]. *AlmAware* was co-designed with university students, ranging from 20 to 30 years old, to address their specific needs and preferences regarding the sustainability of their life at the university campus, comprising transport, water, energy consumption, inclusiveness of services and structures, and more. This cohort plays a pivotal role in shaping the platform to ensure it effectively supports sustainability efforts on campus while being user-friendly and accessible, and yet effective in communicating punctual data about the campus' sustainability with a focus on the SDGs.

AlmAware presents itself in two different systems, the first is a web-based platform that can be accessed through public touch-screen displays inside the campus, and the second is a smartphone app accessible by individual users; they both promote sustainability on university campuses, leveraging collective efforts and individual behaviors. *AlmAware* emphasizes transparency in data and user ownership, allowing individuals to share their progress toward achieving sustainability goals. The platform features data visualizations and gamification elements, focusing on key resources such as energy and waste management. The concept of *AlmAware* emerged through the conduct of semi-structured interviews with students from the Cesena and Navile campuses, which helped understand what are the main themes of interest regarding campus sustainability, and later from the co-design workshops with several groups of students from the university campus of Cesena. These workshop sessions helped provide structured ideas for the platform's functionality and ensure its visualizations and gamification elements are both engaging and aligned with the overarching sustainability objectives.

Lastly, the final prototypes were evaluated through several tests with some students who did not take part in the workshop, who later answered a questionnaire asking their opinions on different aspects of the system, ranging

[7] `https://edu.unibo.it/it/ricerca/progetti-di-ricerca/periodo-di-programmazione-2014-2020/progetti-ateneo/almaidea`

from usefulness, level of engagement, and ease of use. The quantitative nature of the questionnaire allowed us to quantify the level of appreciation for the different aspects of the system, providing useful data for future improvement while validating the elements that are already effective.

1.5.4 Adrinclusive

Adrinclusive is an EU-funded Interreg HR-IT project and it seeks to promote inclusive tourism for people with dementia (PwD), particularly addressing [8]. *Adrinclusive* focuses on yet another cohort, which corresponds to the population over 65 years old, specifically including travelers with cognitive impairments, dementia, or Alzheimer's disease, as well as their caregivers. Stakeholders from the tourism and caregiving sectors, as well as policymakers, are actively involved in the participatory design process of an online platform that will address the specific needs of the target users, namely the family members of the person with Alzheimer's or Dementia and their professional caregivers.

The main goal of the *Adrinclusive* system is to provide an accessible digital web platform that promotes inclusive and sustainable tourism. The platform prioritizes user accessibility, featuring a light and simple user interface to accommodate a wide range of users and mitigate the effects of the digital divide, as statistically, the familiar caregivers tend to be people over 65 years old. Furthermore, its design ensures easy navigation and usability for individuals with varying abilities.

The platform is currently under development, led by RomagnaTech developers informed by co-design sessions where the key stakeholders are participating in an international effort to create a simple, yet effective, omnicomprehensive tool that can facilitate the organization and coordination of vacations for and with people with dementia, Alzheimer's, and other cognitive impairments. This iterative process ensures that the platform meets user requirements, balances functionality with simplicity, and effectively supports

[8] https://www.italy-croatia.eu/it/web/Adrinclusive

equitable participation in tourism activities.

Project	**Cohort**	**System**	**Evaluation**
GameOn!	6-11	Serious Game	Test events in primary schools with 100 kids
CitizER Science in action	12-19	CS apps, paper-based mock-ups	Plenary presentation and discussion of prototypes
AlmAware	20-30	Web platform and mobile app	Prototype test and online questionnaires
Adrinclusive	65+	Accessible web platform	Future work

Table 1.1: Overview of projects and their key elements

1.6 Thesis Structure

This thesis illustrates the state of the art and our approach to the mentioned research questions. In particular, each case study aims to answer our research questions.

The thesis is structured as follows.

Chapter 2 focuses on *GameOn!*, a serious game designed to promote sustainability and active citizenship within Minecraft Education Edition [9].

[9] https://education.minecraft.net/en-us

Chapter 3 highlights the *CitizER Science in action* workshops, emphasizing collaborative exploration of tourism, digital well-being, urban accessibility, and environmental emergencies.

Chapter 4 introduces *AlmAware*, which underscores institutional efforts and data ownership.

Chapter 5 examines *Adrinclusive*, which centers on accessibility and inclusive tourism solutions.

Chapter 6 concludes the thesis by summarizing key contributions and insights, emphasizing the impact of serious games and digital tools on critical thinking and active citizenship, and suggesting future directions for research and practice in Citizen Science, co-design, and sustainability.

Chapter 2

GameOn!

This study introduces *GameOn!*, a serious game crafted to promote themes of peace, inclusivity, and sustainability by utilizing the interactive environment of Minecraft Education Edition (MEE). In addressing these themes, *GameOn!* includes three distinct educational pathways. The Sustainability pathway, in particular, engages players in active citizenship and CS initiatives both within and outside the game environment. Educational content is seamlessly integrated into gameplay to foster critical thinking and social responsibility among players.

The potential of serious games to deliver impactful educational experiences is exemplified by *GameOn!*. This research underscores the adaptability of serious games, serving as both educational tools and platforms for fostering active citizenship.

This chapter is based on the author's article "GameOn! Residency: Promoting Peace, Inclusivity, and Sustainability Through Serious Games" [252] presented at GoodIT'24 and published in the conference proceedings.

2.1 Introduction

The digitization of education in Europe is actively transforming and reshaping traditional teaching and learning methods. Innovative tools are paving the way for various educational models [192], enhancing the quality and accessibility of education [91], and preparing students with diverse needs for an increasingly digital future [12].

However, this transition poses significant challenges. Disparities in access to digital resources at the individual, state, and regional levels persist, alongside the urgent need for effective digital literacy among educators [59] [52]. The impact of integrating digital tools on educational quality and equity is a focal point in academic literature [96]. Additionally, the reorganization of educational content and materials necessitates a standardization of digital products used in classrooms.

Despite the call for standardization, there is a simultaneous demand for personalized learning experiences that resonate with students' cultural backgrounds [30] [159]. This highlights the importance of local contexts in redesigning educational experiences, as the European education system reflects a diverse cultural, linguistic, and historical landscape. Each country has its unique approach to education, with institutions adapting to regional realities. Nevertheless, a foundation for collaboration exists across Europe.

Over the past two decades, the public education system has increasingly embraced digitization, promoting innovative tools to support educators in their classroom activities [68][125]. Shared objectives, such as the Agenda 2030 and the Sustainable Development Goals (SDGs), demonstrate a commitment to collaborative efforts within national education systems[1]

In light of these developments, this study focuses on *GameOn!*, a serious game designed to promote themes of peace, inclusivity, and sustainability within the interactive environment of Minecraft Education Edition (MEE). The game includes three distinct educational pathways, with the Sustainability pathway particularly emphasizing active citizenship and CS initiatives both within and outside the game environment. Educational content is seamlessly integrated into gameplay, fostering critical thinking and social responsibility among players.

[1] EU SDG strategy

Moreover, the increasing popularity of CS, with its inclusive approach that welcomes participants from diverse educational backgrounds [197], presents opportunities for incorporating CS projects into educational curricula. These projects facilitate experiential learning, introducing children to the scientific method through practical activities rather than theoretical instruction.

GameOn! highlights CS as a valuable practice in educational support. By employing interactive digital tools, the game promotes the learning of the scientific method, encourages discussions on local issues and sustainability, and fosters positive behaviors that support active citizenship. The potential of serious games to deliver meaningful educational experiences is underscored by this research, which showcases their adaptability as both educational tools and platforms for fostering active citizenship.

Games and education Games serve a pivotal function as educational tools for primary school students, providing a dynamic and engaging platform for learning. The incorporation of simulations and games in elementary, secondary, and undergraduate classrooms offers the unique ability to personalize learning experiences, allowing them to align with each student's pace, interests, and capabilities. By immersing students in dynamic virtual settings, these games enhance engagement and relevance, making the learning process more enjoyable and effective [108].

Beyond traditional academic teachings, the use of interactive gameplay facilitates the development of essential cognitive, social, emotional, and ethical skills among young learners [208]. For instance, critical thinking, problem-solving, and decision-making abilities are nurtured as students navigate through various challenges and puzzles presented in the game. These interactive scenarios require players to think creatively and strategically, ultimately fostering a deeper understanding of the subject matter.

Moreover, multiplayer experiences promote collaboration and communication skills, teaching children the importance of teamwork and cooperation. Engaging in shared gameplay not only enhances their social interactions but also boosts their social motivation to work effectively with others [128]. This aspect of gaming is particularly beneficial, as it encourages students to build relationships and develop interpersonal skills that are crucial both in and out of the classroom.

In addition to academic benefits, games contribute significantly to the development of personal and social skills, such as resilience and perseverance [166]. Through repeated attempts to overcome challenges within the game, students learn the value of persistence in the face of adversity. Furthermore, sportsmanship is cultivated as players learn to navigate winning and losing scenarios, fostering a spirit of fair play [78].

Games also play a vital role in promoting positive mental well-being among students [199][241][215]. By providing enjoyable and rewarding experiences, games can help reduce stress and anxiety, creating a more conducive learning environment.

By integrating educational content into gameplay, teachers can create immersive learning environments that captivate students' attention and enhance their understanding of various subjects. This approach not only makes learning more interactive but also ensures that students are more engaged and motivated to explore new concepts, ultimately leading to a richer educational experience.

Serious Games Games are frequently employed by educators to achieve specific pedagogical objectives, with serious games emerging as particularly effective tools in this endeavor. Unlike traditional games that primarily focus on entertainment, serious games are designed as interactive digital tools with the explicit intent to accomplish specific educational, training, or societal aims [62]. A distinguishing feature of serious games is the integration of educational content within the gameplay experience, which serves to enhance the learning process.

By harnessing the motivational aspects inherent in gaming, serious games aim to engage users in a profound manner, thereby improving learning or training outcomes within a dynamic and immersive environment. To cultivate such an engaging atmosphere, a variety of gaming mechanics are utilized in serious games, including clearly defined goals, challenges, reward systems, feedback mechanisms, and narrative structures. These components are meticulously fused to create compelling experiences that align with the intended educational or societal objectives.

Moreover, serious games are recognized for their versatility and effectiveness in addressing complex real-world issues, such as sustainability and the Sustainable Development Goals (SDGs). They simplify the narration of multifaceted topics through interactive digital tools and visual representations, rendering these subjects accessible and engaging for learners [126, 254].

In addition, serious games find extensive application in game-based learning due to their capability to simulate real-world tasks within a virtual environment. This approach enables students to engage in experiential learning through "learning by doing" or "learning by playing" experiences [206]. Game-based learning encompasses the overall process and practice of learning through games, while game-based pedagogy focuses on the teaching practices from the educators' perspective that incorporate games as a tool [20].

Thus, while both game-based learning and pedagogy represent methodologies aimed at enhancing educational experiences, serious games function as effective tools employed within these methodologies. They are particularly well-suited for tackling complex subjects, allowing learners to explore challenging topics interactively and engagingly.

Minecraft Education Edition Minecraft Education Edition (MEE) is recognized as a widely popular platform for serious games, with new educational experiences continually uploaded and shared among users. The literature documents a diverse range of educational experiences facilitated through MEE-enhanced classes. These experiences span various subjects, including programming [134], mathematics [156], and STEAM (Science, Technology, Engineering, Arts, Mathematics) education, particularly focused on the Sustainable Development Goals (SDGs) [131]. Additionally, MEE supports the development of numerous soft skills beyond traditional curricula [213].

The strength of MEE lies in its foundation as an extension of the immensely popular video game, Minecraft. Consequently, MEE is not merely a generic tool for serious gaming; rather, it functions as a fully developed game that incorporates engaging elements, making it intriguing for millions of users worldwide. Games, in general, serve as pivotal educational tools for primary school students, offering a dynamic and engaging platform for learning.

Through MEE, personalized learning experiences are enabled and tailored to accommodate students' pace, interests, and abilities. This immersive approach engages learners in interactive virtual environments that significantly enhance their motivation and relevance in education [108]. By embedding educational content within the gameplay, teachers can create immersive learning environments that not only captivate students' attention but also deepen their understanding of various subjects [158].

Active citizenship in Education through Citizen Science CS serves as a powerful tool that empowers students to actively participate in scientific research and contribute meaningfully to real-world projects. These projects may include monitoring local ecosystems, tracking wildlife populations, or gathering data on air and water quality. Through these hands-on experiences, critical thinking skills are developed among children [173]. Students also learn the scientific method [168][74][163][23][187], gaining a deeper understanding of environmental issues and their societal impacts [171]. Furthermore, engaging in CS fosters collaboration, communication, and empathy, as students work together to address pressing challenges facing their communities [48].

By instilling a sense of civic duty and environmental stewardship from an early age, CS enriches children's education while cultivating a generation of informed and empowered global citizens. These individuals are prepared to tackle the complex issues of the 21st century [130].

Additionally, CS projects play a crucial role in making scientific knowledge more accessible. They engage and simplify science for a broader audience, breaking down barriers that often hinder understanding of complex scientific concepts. Jenkins [116] highlights the transformative potential of CS in education, emphasizing that it not only teaches students but also empowers them by turning theoretical knowledge into practical, actionable skills. This accessibility is essential for developing informed citizens ready to participate in civic life and contribute meaningfully to discussions on scientific and environmental matters.

However, challenges arise when integrating CS into educational settings. Concerns exist regarding the specific skills and knowledge required for accurate participation in scientific research, as well as the risk of data bias, such as over-reporting or under-reporting certain phenomena [195, 209]. Despite these challenges, the benefits of engaging young students in CS, promoting active citizenship, environmental stewardship, and community involvement, far outweigh the potential drawbacks.

Thus, CS is recognized as a vital component of the educational framework, preparing a new generation to confront the complex issues of the 21st century with informed and active civic engagement.

GameOn! context *GameOn!* is a Creative Europe project funded by the European Education and Culture Executive Agency (EACEA) that aims to enhance awareness of critical issues such as peace, inclusivity, and sustainability through an educational experience within the Minecraft Education Edition (MEE) environment [2]. This serious game is the result of collaboration among four partners from different European countries: RomagnaTech (Italy), ACCAC - Accessible Arts and Culture (Finland), Seals - Stichting for Education on Agility Liberating Structures (Netherlands), and Politistiko Parko (Greece).

[2] `https://finland.accac.global/en/projects/game-on/`

The project focuses on gamification, specifically targeting the development of interactive digital tools for children aged six to eleven years. *GameOn!* is structured into two main components. The primary component is the *GameOn!* MEE world, where players and their classrooms can embark on shared learning adventures. The second component is a website called "Go-ToolKit", which educators can utilize to enhance their lessons with additional educational content recommended by the *GameOn!* designers. These resources are designed to boost educational outcomes for children by stimulating motivation through engagement and entertainment mechanisms.

The project set out to achieve several key objectives. Firstly, the aim was to develop digital learning products for children grounded in a gamification approach. By integrating game-like elements, *GameOn!* is designed to make learning more interactive and enjoyable, thereby fostering deeper engagement with educational content. This effort particularly concentrates on themes such as sustainability, inclusion, and peace.

To realize these goals, the partners involved in *GameOn!* created a cross-disciplinary kit of digital educational products tailored specifically for children. This kit leverages gamification to address various disciplines within the arts and humanities. The development process involved a series of brainstorming sessions and a transnational creative residency, ensuring a collaborative and innovative approach to the design of this interactive digital tool. Tailored guidelines were established to steer the development, and the resulting game was tested through dedicated events to ensure its effectiveness and appeal.

The project anticipated several significant outcomes. One of the primary results is an expanded range of cross-disciplinary digital educational products in the arts and humanities, specifically designed for young audiences. By incorporating gamification, the project promotes a digital-oriented approach to education in these fields, making learning more attractive and accessible to children. This approach not only enhances the appeal of cultural promotion but also strengthens the relationship between digitized educational methods and traditional educational institutions.

Moreover, *GameOn!* seeks to increase educators' awareness of tools and methodologies derived from a gamified, digital, and technological approach to cultural education. In doing so, the project aims to inspire a new generation of educators capable of effectively integrating these innovative tools into their teaching practices. This integration ultimately enriches the educational experience for children and fosters a lifelong love of curiosity and learning.

To support this objective, the GoToolKit website[3] has been created as a primary landing platform for educators interested in incorporating *GameOn!* into their classrooms. On this platform, educators can find instructions for playing the game along with useful links and information to enhance the teaching experience while utilizing *GameOn!*. The GoToolKit website is still under development and will be continually populated with more content relevant to *GameOn!* over time.

2.2 Related work

2.2.1 Tools and practices: serious games for game-based learning

Serious games are interactive digital platforms designed not just for entertainment but to achieve specific educational, training, or societal goals [62]. Unlike traditional games, serious games integrate educational content into gameplay to engage users deeply and enhance learning or training outcomes in dynamic and immersive environments. They employ gaming mechanics like goals, challenges, rewards, feedback systems, and narratives to create compelling educational experiences aligned with their intended goals. Serious games are versatile tools capable of addressing complex real-world issues such as sustainability and Sustainable Development Goals (SDGs), using interactive digital tools and representations to simplify and engage learners

[3] https://www.gotoolkit.eu/

[254].

MEE is a widely popular platform for serious games, on which new educational experiences are constantly uploaded by and shared between users. The literature reports an array of different educational experiences carried out through MEE augmented classes; the subjects range from programming [134], mathematics [156], STEAM (Science, Technology, Engineering, Arts, Mathematics) education on the SDGs [131] and many other soft-skills outside the mere curricula subjects [213].

2.2.2 Residency as a Co-Design approach

The evolution of co-design methodologies originates from participatory action research [19] and sociotechnical systems theory [11], extending to user-centered design [3] and design thinking [40]. These methodologies are rooted in frameworks such as social constructionism [9] and deliberative democracy [200], highlighting their relevance for collaborative design.

Applying these frameworks involves various co-design techniques to facilitate participatory decision-making and problem-solving. Ethnographic research methods [181] , co-design workshops [144], digital platforms, and prototyping techniques for serious games [148] [76] all foster engagement, empathy, and dialogue among stakeholders. Ethical considerations in co-design emphasize inclusivity [235], transparency, reciprocity, and navigating power dynamics and stakeholder challenges [8].

Residencies, unlike traditional workshops, which are shorter and focus on immediate skill-building, offer an immersive experience lasting from days to weeks. They provide dedicated time and space for artists, writers, researchers, or professionals to focus deeply on their work, fostering collaboration and networking opportunities. Participants bond outside scheduled activities, enhancing team-building and co-design activities [219].

2.3 Methodology

2.3.1 Methods for data gathering

The research team oversaw the *GameOn!* project, organizing and conducting various phases and activities. They managed critical tasks such as orchestrating the residency, facilitating work groups, and contributing to data analysis and report collaboration post-residency. This ongoing involvement ensured continuity and depth in the research.

During the research, a main researcher was assigned a central role in the development of the Minecraft environment for *GameOn!*. The same researcher continued to contribute insights from their extensive engagement in subsequent events, including debriefing sessions and workshops, offering nuanced perspectives derived from their multifaceted project involvement.

This degree of engagement enabled the researcher to conduct ethnographic fieldwork via participant observation across different project stages. Specifically, participant observation proved valuable for gathering multifaceted data about dynamics in collaborative design work between experts, decision-making processes, and to definition of informal roles within each group, offering a nuanced understanding of the residency work mechanisms. Furthermore, the systematic immersion into the evolving day-to-day relations unravelled layers of insights beyond surface-level observations. By delving into "behind the scenes" aspects, this approach provided insights that highlighted the interplay of power dynamics in decision-making and other nuanced interpersonal relations, capturing the essence of the phenomena and enhancing data interpretation.

2.3.2 GameOn! Residency organization

In the first stage, organizing the residency involved scanning participants' curriculum vitae to ensure effective collaboration and knowledge exchange. Three groups of work were created to be heterogeneous, thus enhancing interdisciplinary interaction and cross-pollination. Specifically, each group included individuals with diverse expertise, ensuring a broad spectrum of perspectives and skills. Attention was also given to maintaining a balance of nationalities, mixing experts from Italy, Finland, the Netherlands, and Greece. This approach fostered cross-cultural understanding and enriched collaboration with diverse cultural insights. Additionally, each group was assigned a specific theme to develop in their section of the game, the three themes are the core content of the *GameOn!*, namely: inclusivity, peace and sustainability. Each theme corresponds to one in-game pathway.

In the second stage, the GameOn residency's activities schedule was organized to optimize participant engagement. It began with a pivotal introductory meeting where the conductor utilized methods of theatrical warm-up exercises to foster a playful atmosphere conducive to creativity [107]. This session also clarified the project's goals to align residents with the overarching vision.

Essentially, each day followed a structured schedule with morning activities, a lunch break, and evening group work. Plenary sessions and presentations were strategically timed to encourage intergroup collaboration and mark project milestones. Halfway meetings provided opportunities for groups to present project blueprints, receive feedback, and adjust their designs. These sessions facilitated reflection, celebrated achievements, and identified areas for improvement, fostering an innovative and collaborative environment. The residency concluded with a wrap-up session on its final day, where residents showcased their collaborative outcomes, marking the culmination of their efforts. Additionally, recreational activities like guided visits and communal dining promoted relaxation and camaraderie.

2.3.3 GameOn! Facilitation

Three facilitators and one conductor were chosen to oversee the workshop. To a degree, the success of the *GameOn!* residency can be attributed to the capacity of the facilitators and the conductor to intertwine four crucial elements.

Firstly, achieving cohesion among three educational pathways within a single MEE world required balancing the thematic groups' work while maintaining a unified vision. Facilitators ensured this coherence through strategic plenary sessions held at the residency's outset, midpoint, and conclusion, aligning individual efforts with overarching project goals.

Secondly, given the workshop's complexity, a conductor was indispensable in orchestrating its various elements. The conductor maintained the schedule rigorously and facilitated interactive plenary sessions, pivotal for feedback and collaboration, essential in guiding the residency's progress.

Thirdly, facilitators noted how cross-pollination of ideas enriched the *GameOn!* world's design during plenary sessions. Collaborating closely, facilitators exchanged insights across groups to enhance the level design, narratives, and content cohesiveness.

Lastly, the compressed four-day timeframe posed logistical challenges in refining complex design concepts and integrating extensive educational content and SDGs. Participants and facilitators navigated this challenge with a goal-oriented approach, prioritizing efficiently to uphold the depth and quality of the final-level designs.

2.3.4 Co-design, development and test-events

Minecraft Education Edition (MEE) was chosen as the foundational platform for *GameOn!* due to its adaptability and the rich opportunities it offers in educational settings. During the *GameOn!* residency, participants were organized into three distinct groups, each responsible for developing a game pathway centred around one of three core themes: inclusivity, peace, and sustainability. The residency was structured to maximize engagement and creativity, beginning with an introductory session that outlined the project's vision and included theatrical warm-up exercises to foster collaboration among participants. The daily schedule consisted of plenary sessions, group work, and feedback meetings, which were crucial for aligning individual contributions with the overarching goals of the project. The residency culminated in a final showcase, where participants presented their collaborative outcomes, demonstrating a cohesive design while highlighting the unique ideas for each pathway in the *GameOn!* world.

Following the co-design residency, RomagnaTech's team embarked on the creation of the *GameOn!* world. This process involved transforming the conceptual designs and educational goals into a fully functional digital environment. Various elements, including interactive challenges, narrative arcs, and educational content, were integrated to create an engaging and cohesive gameplay experience. The team's expertise ensured that the final product met educational objectives while providing an intuitive and user-friendly interface for students. Additionally, by leveraging the advanced features of Minecraft Education Edition, RomagnaTech developed a virtual space where players could explore, learn, and interact with the content in meaningful ways. This development phase was critically important in converting initial ideas into a practical and impactful educational tool, showcasing the potential of serious games in modern education.

Subsequently, the *GameOn!* world was tested in three primary schools, involving 100 students aged six to eleven. In each school, two classes participated in sessions conducted in specially prepared classrooms equipped with laptops. Students were organized into player-observer pairs, switching roles every 10 minutes during the 40-minute playtest. The first half of each session included a guided introduction to the game and its educational content presented via an Interactive Whiteboard. In the second half, students explored the game independently, which provided insights into their engagement levels without supervision. After each session, students completed a brief survey and engaged in discussions about their experiences, focusing on enjoyment, challenges, and comprehension of the content. Initial unstructured sessions underscored the need for guided play, leading to significant improvements in the quality of subsequent tests.

In a separate evaluation, ten educators aged 28 to 64 participated in testing, familiarizing themselves with basic commands and exploring *GameOn!* freely, with facilitator support as needed. Post-session, educators provided feedback through a questionnaire and verbal discussions on *GameOn!*'s classroom applicability. Facilitators analyzed survey data and feedback to compile a comprehensive report, highlighting both positive and negative feedback. Insights were used to enhance and refine the GameOn MEE world based on participant experiences and perceptions.

2.4 GameOn! World and Educational activities

The *GameOn!* Minecraft Education Edition (MEE) pathways have been meticulously developed to provide players with a comprehensive educational experience, integrating continuity and a rewards system to enhance progression. The game world structure is anchored in the Central Square Hub, which serves as the main starting point for three distinct pathways 2.1-A, each dedicated to a specific theme: sustainability, peace, and inclusivity. These pathways reflect the cultural contexts of Italy, Finland, the Netherlands, and Greece, incorporating landscapes 2.1-D and fictional settings, such as Dante's Inferno 2.1-B, the world of the Moomins, other original fantasy settings tailord-made for *GameOn!*, finally within each setting there are different kinds of exercises or activities 2.1-C.

Upon entering the game, players begin at the Central Square Hub, where they encounter three non-playable characters (NPCs) and informational signs that provide essential instructions for navigating the game 2.2. Surrounding the hub are small, unadorned houses assigned to each player. These initial houses are basic and can be customized and improved based on rewards collected through exploration of the educational pathways.

Players can interact with NPCs located in the central square to select and teleport to one of the pathways, starting from the first level of their chosen path. Each level is designed with guiding elements such as signs, colored

Figure 2.1: GameOn! overview of world and level design;Different level styles; Citizen Science activities proposed by an NPC

streets, fences, and natural barriers that help direct players toward their objectives at various stations. These stations are designated areas within the game where players engage in tasks or challenges, offering opportunities for educators to provide direct instruction and feedback.

The game is specifically tailored for players aged six to eleven, taking into account the varying levels of familiarity with Minecraft among participants. Levels are constructed to be straightforward and accessible, featuring clear paths for younger or less experienced players while also providing additional routes for those seeking further exploration. This design supports a structured learning process while allowing for free exploration, with natural barriers and invisible walls preventing players from becoming disoriented or lost.

Figure 2.2: GameOn! classroom central hub view, the three NPCs give the player access to the different pathways and activities

Customization is a key aspect of player interaction within the game. Initially, players' houses in the Central Square Hub are basic, but they can be upgraded using rewards gained from the educational pathways. In the Sustainability pathway, specific level design choices guide players within the intended space of each level, providing enough freedom to explore without feeling constrained. Players receive rewards at the end of each level in the form of decorative items, and by further exploring the level, they can discover hidden areas that often reward them with tools and rare items.

The educational content within MEE is both varied and extensive. For instance, in the Sustainability pathway, the first level transports players to Greek beaches, where they are welcomed by the mayor and a dustman. They are encouraged to help clean the beach, which is littered with trash 2.4, so they can enjoy the beach and the sea alongside their classmates and other tourists. By the fourth level, players arrive at the "Hidden Garden", a large and colorful garden 2.3 set against the grey backdrop of a bustling city. In this level, educators can teach about the significance of green spaces in urban areas, emphasizing both their social and environmental importance, as well as the critical role of pollinators even in city landscapes 2.1-C.

Figure 2.3: GameOn! representation of an urban garden filled with tulips in the Nethrelands.

In this context, classrooms can engage in real-world activities, such as reflecting on where in their local areas the city or village could accommodate bee hotels or gathering data on pollinators by counting them in either their local environment or school gardens. Educators are encouraged to facilitate discussions around these activities, providing local examples and context to enhance the educational experience. This approach leverages MEE's capabilities to promote sustainable behaviors through CS initiatives, while also allowing for content adaptation to meet the specific needs of students.

2.5 Results

2.5.1 EvaluatiOn! Test events results and feedback

The *GameOn!* world underwent an evaluation phase that involved testing events in three different primary schools. In each school, two classes

Figure 2.4: GameOn! representation of a Greek beach filled with trash, the player must pick it up and sort it in the right bins to proceed along the level.

participated in the testing, totaling 100 young students aged between six and eleven years old.

The methodology for each test session was consistent. Each class entered a pre-arranged classroom equipped with laptops and ready-to-use *GameOn!* software to conduct a playtest session. The structure of each session involved dividing the students into pairs, with one acting as a player and the other as an observer. Each pair received a laptop, and the playtest lasted a total of 40 minutes, during which the children switched roles every 10 minutes. After the initial switch, they had the freedom to choose their roles based on preference.

During the first 20 minutes of the test, the facilitator (the author of this dissertation) guided the class through the game by projecting their desktop onto an Interactive Whiteboard (IWB). This classroom simulation allowed the educator to lead students through the pathways while explaining the educational content at various stations, providing a general overview of the game. This introduction was designed to prepare the students for independent enjoyment of the game later on.

In the second half of the playtest, the final 20 minutes, the children were allowed to explore the *GameOn!* MEE world freely. This unsupervised exploration enabled the facilitator to gather valuable information about critical elements of the game. After each 40-minute playtest session, the students completed a brief survey, taking 5 to 7 minutes to provide feedback. Additionally, the facilitator solicited their opinions on various topics, including enjoyment, boredom, challenges, educational content, and suggestions for improvement.

The only deviation from this protocol occurred during the first class of the initial testing session, where the children were given complete freedom to explore the game. This led to significant confusion due to the lack of guidance. However, the implementation of the new structured protocol markedly improved the quality of subsequent tests and significantly enhanced the students' enjoyment of the game. Furthermore, this structured approach closely mimicked the normal usage of *GameOn!* in a classroom environment, creating a more appropriate context for the testing event.

Following the playtests, the facilitator reviewed and analyzed the surveys and notes from informal feedback sessions. This process involved collecting all data, highlighting key points of both positive and negative feedback, and synthesizing these insights into a comprehensive report. The report provided an overview of the participants' experiences and perceptions by combining survey results with feedback session insights. This consolidated feedback was then used to inform updates and enhancements to the *GameOn!* MEE world.

2.5.2 Survey results

In this subsection, we present the data gathered from surveys completed by students who participated in the testing events at three primary schools: Scuola primaria Don Carlo Baronio, Scuola primaria Carducci, and Scuola primaria Aurelio Saffi.

The age distribution of the students participating in the events is as follows: Don Carlo Baronio included 27 students aged 8 and 2 students aged

	Age				
Schools	**8**	**9**	**10**	**11**	**Tot x School**
Don Baronio	27	2	0	0	29
Carducci	0	33	5	0	38
Saffi	0	1	28	4	33
Tot x Age	27	36	33	4	100

Figure 2.5: Number of students that took part in the evaluation events of *GameOn!*

9; Carducci had 33 students aged 9 and 5 students aged 10; and Saffi consisted of 1 student aged 9, 28 students aged 10, and 4 students aged 11. In total, across all three schools, there were 27 students aged 8, 36 students aged 9, 33 students aged 10, and 4 students aged 11, as shown in 2.5.

First, we inquired about the level of enjoyment users experienced while testing the game. The survey question, "How much did you enjoy playing this game?" offered three response options: "Very much", "Just a little bit", and "I didn't like it at all". Among the 100 participants, 95 responded "Very much", 5 said "Just a little bit", and none selected "I didn't like it at all" (see Figure 2.6).

Second, we investigated the educational potential of *GameOn!* by asking, "Did you learn anything new or interesting by playing the game?" Participants could answer with "Yes" or "No." In total, 89 students responded "Yes", 10 answered "No", and one student provided a custom response of "So and so" (see Figure 2.7).

Third, to assess how easy it was for users to start playing the game, we asked, "How easy was it to play?" Responses were scored on a Likert scale [121], ranging from 1 (complicated) to 5 (easy). The distribution of responses was as follows: 1) 2, 2) 7, 3) 13, 4) 31, and 5) 47 (see Figure 2.8).

Fourth, to gauge the level of facilitation needed in a classroom context, the survey asked, "Did you need help from anyone in order to play?" Participants could respond with "Yes" or "No." A total of 61 students answered "No", while 39 responded "Yes" (see Figure 2.9).

Additionally, the second section of the survey included three open-ended

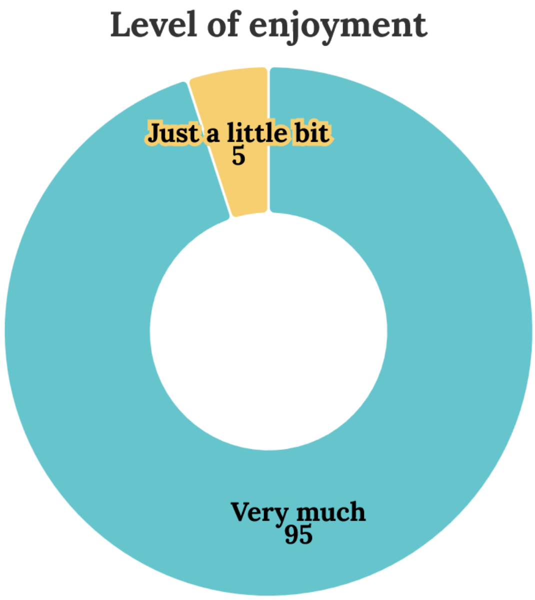

Figure 2.6: Answers to the question "How much did you enjoy playing this game?"

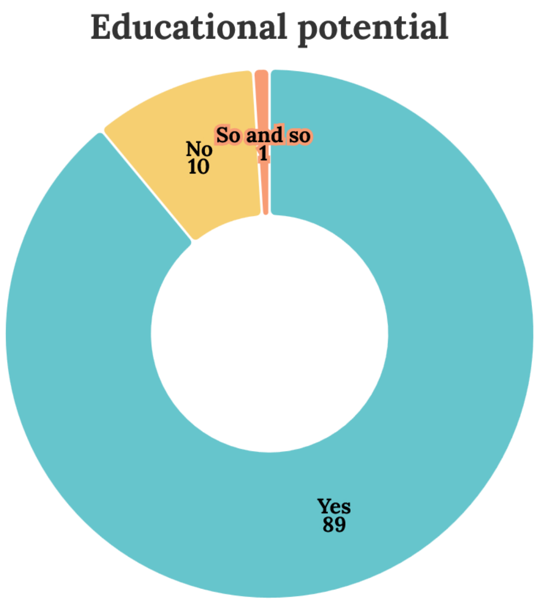

Figure 2.7: Answers to the question "Did you learn anything new or interesting by playing the game?"

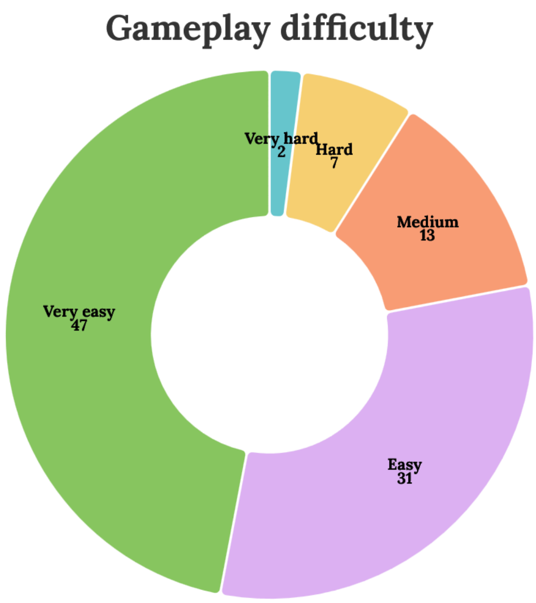

Figure 2.8: Answers to the question "How easy was it to play?"

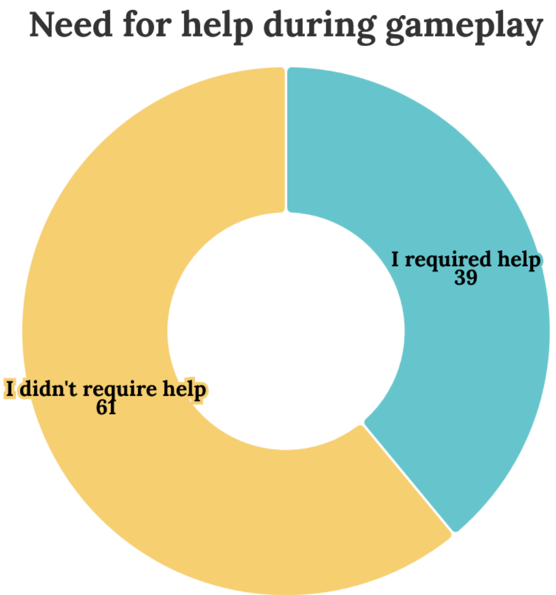

Figure 2.9: Answers to the question “Did you need help from anyone in order to play?”

questions, providing valuable qualitative data. Finally, facilitators conducted a plenary session for feedback by asking open questions in the classroom. All qualitative data gathered were taken into account and used as feedback for the further development of *GameOn!*.

2.6 Discussion

2.6.1 Answer to RQ1

This chapter largely explores RQ1 through its focus on the deployment and assessment of the *GameOn!* prototype among children aged 6 to 11. Whilst this gives only a partial answer, the findings are informative and encouraging. For this age group, engagement levels were high, and participants demonstrated a high degree of ability to adapt to the interactive digital environment.

In spite of differing levels of experience with Minecraft Education Edition (MEE), most of the students, both inexperienced users and familiar players, demonstrated ability in utilizing the platform, achieving the assigned tasks, and reporting enjoyment as well as learning.

Structured support was necessary in enhancing engagement and comprehension. For the context of guided play activities, students received scaffolding to focus on significant objectives. Quantitative feedback supports this finding: 95 of 100 students reported that they liked the experience "very much", and 89 reported that they gained new knowledge. These results suggest that young children can take part in co-design activities and benefit from interactive resources designed to foster sustainability awareness."

A standout feature was how digital play was integrated with real-world reflection and scaffolded narrative inquiry, supporting early learners in linking virtual worlds to wider sustainability principles. Supported discussion and written reflection assisted in consolidating learning outcomes, demonstrating that rich engagement is possible even with early learners.

Although the evaluation sessions were constrained in explicit co-design activities, the children's interests and feedback strongly influenced the game development. Their contributions guided many design changes and improvements, demonstrating the benefit of incorporating younger users' perspectives in iterative design processes. Considering the age range being targeted, engaging children in this level of feedback and design iteration is an acceptable exercise, aligned with their development and cognitive capacities. But the data set available is restricted to one age group. The participation of adolescents, adults, and elderly in computer science-based co-design activities is yet to be researched. These populations will be the focus of the subsequent chapters, which will look for similarly positive participation and results within a wider age bracket.

Thus, while preliminary findings are promising, RQ1 can be completely addressed only once additional data are collected and examined.

2.6.2 Answer to RQ2

The evaluation processes demonstrated several concrete advantages in engaging communities in the co-design of learning digital resources. Firstly, the feedback from the community gathered assisted in informing the development of *GameOn!* version 2.0. Observation and survey response data allowed for key enhancements in gameplay mechanics, tutorial progression, and balance between freedom of exploration and guided learning. This demonstrates the value of iterative, user-centered design approaches in tool usability and pedagogical quality improvement.

Second, evidence from qualitative and quantitative sources confirms the value of co-designed, guided play experiences in sustaining extended engagement. Compared to open-ended exploration, structured sessions facilitated students' focus, reduced disengagement, and clarified learning goals. Such findings suggest that co-design does not just democratize tool-development processes but also strengthens both the pedagogical efficacy and emotional appeal of the final product.

Moreover, the team-based approach of the project facilitated a sense of ownership and commitment among participants, particularly as their ideas were easily incorporated into subsequent versions of the tool. Empowerment is higher for cognition and reflects key tenets of Citizen Science. Some weaknesses were mentioned, though. There was a significant percentage of students (39 out of 100) who needed support in engaging in the gameplay, particularly in the younger age group. This suggests there are still some aspects of the design to be worked on. Also, given the limitations in time and content, the Sustainability pathway and some Citizen Science (CS) activities were not tested in the first sessions. Therefore, the direct effect of CS-content-based content on students' learning could not be comprehensively tested. In summary, community co-design holds tremendous returns on engagement, motivation, and ongoing improvement. Yet, to fully comprehend its impact on sustainability awareness requires further trials in other age cohorts and full evaluation of the CS components. These results emphasize the necessity of longitudinal research and greater involvement to achieve the maximum promise of CS-based co-design in education.

2.6.3 Future Work

Unfortunately, during the test events described in this chapter, we were unable to implement the Sustainability pathway and its associated CS (CS) activities due to time constraints. Consequently, we employed the Peace pathway instead, which limited our engagement in the CS activities that would have been better supported by the Sustainability pathway.

To address this gap, future iterations of *GameOn!* will be tested in additional primary schools to collect specific data on the CS activities integrated within the game. This approach will enable us to investigate how CS concepts are learned and applied by primary school children while playing *GameOn!* in the Sustainability pathway. Such research will provide a more balanced contribution between general educational aspects and a specific focus on CS. Future work will be crucial not only for further refining and improving the game but also for demonstrating its effectiveness as a teaching tool in the field of CS.

2.7 Summary and key insights

The present chapter has outlined the conceptual underpinning, design process, and preliminary assessment of *GameOn!*, a serious game that has the potential to assist primary school students in learning about the interrelated concepts of peace, inclusivity, and sustainability. Created in the Minecraft Education Edition (MEE) ecosystem, *GameOn!* illustrates the potential of digital play, participatory design, and Citizen Science (CS) to converge and provide engaging and interactive learning experiences.

In the backdrop of Europe's growing digitalization of education, *GameOn!* tackles the twin challenge of creating standardized yet locally applicable educational content together with promoting active citizenship and environmental awareness. Its creation was based on an immersive international co-design residency, which involved heterogeneous stakeholders from four countries. The residency format created three unique educational pathways,peace, inclusivity, and sustainability,each within separate narratives and interactive levels. The co-operative framework, underpinned by theatre-based facilitation methods and structured feedback mechanisms, maintained team cohesion even where time pressures were a factor.

Preliminary findings from our pilot events suggest a high level of engagement: 95% of players enjoyed the experience "very much", and 89% reported learning something new. These outcomes are heartening, especially in light of the diversity of digital literacy and experience with Minecraft. Facilitated structure emerged as a key factor in allowing students to connect virtual play to broader civic and environmental questions.

Nevertheless, limitations remain. A large number of the youngest players (39 out of 100) needed help; however, this issue would easily be addressed by providing the user with an opportunity to play the tutorial that MEE offers, named Tutorial World, which instructs players in the foundational aspects of the game.

Additionally, the Sustainability path, in particular its CS activities, was not tested because they exceeded the time we had available in the evaluation events. This limited testing how CS-informed content can build scientific literacy and civic engagement in children. In summary, the *GameOn!* project demonstrates the potential of serious games to positively engage young students on crucial social and environmental issues when games are co-designed with stakeholders and situated within well-considered pedagogical models. The results presented provide a sound basis for advancing the research in the future, which will aim to trial the Sustainability path in classroom settings, involve older age ranges, and assess the longitudinal effects of the community service activities integrated in serious games. Such studies will enhance our understanding of how participatory digital tools

Chapter 3

CitizER Science in action

This study introduces *CitizER Sciece*, a series of workshop conducted in the context of "AFTER festival" ([1]). These workshops engaged students from middle and high schools in the co-creation of paper-based mobile app prototypes making use of concepts ranging from design thinking to citizen science, all this applied to different field and themes of interest related to the SDGs. *CitizER Science* collected a number of prototypes resulting from a co-design process, highlighting the strength of co-design and the possible interrelation between the themes of discussion of each workshop with the recurring concepts (like game thinking and citizen science).

The potential of serious games to deliver impactful educational experiences is exemplified by *GameOn!*. This research underscores the adaptability of serious games, serving as both educational tools and platforms for fostering active citizenship.

This chapter is based on the author's article "GameOn! Residency: Promoting Peace, Inclusivity, and Sustainability Through Serious Games" [252] presented at GoodIT'24 and published in the conference proceedings.

[1] `https://www.afterfestival.it/`

3.1 Introduction

In today's interconnected digital world, digital skills have become fundamental across various aspects of life, including the workplace, education, and civic life. With technology permeating nearly every aspect of modern society, proficiency in digital literacy is no longer just advantageous but essential for navigating and thriving in this digital era [237]. For example, in social contexts, digital literacy enables individuals to communicate effectively, critically evaluate information, and participate responsibly in civic engagement [152]. Thus, in our digital-centric reality, cultivating digital skills is imperative for personal and professional success as well as for active engagement in contemporary society.

In this context, teaching digital skills to children and youth is crucial to preparing them for the increasingly digitalized world we live in [147]. Fostering digital skills among youth empowers them to become active participants and contributors to the digital economy and society [55]. From coding and programming to digital communication and critical thinking, these skills not only enhance their academic and professional prospects but also enable them to innovate and solve problems creatively [67]. Moreover, digital literacy is essential for promoting digital citizenship and responsible online behavior [147]. Overall, by providing children and youth with the necessary digital skills and knowledge, we enable them to become active agents of change in shaping a more inclusive, sustainable, innovative, and digitally literate society [210].

Given this, we conceptualized a workshop-like experience to teach digital literacy by exploiting (i) design thinking, (ii) CS, and (iii) game thinking to stimulate enjoyable strategies to tackle social issues and educate about the relevance of participation and civic engagement. We exploited (i) design thinking through co-design since it is a recognized way of empowering children and youth [32]. We took into consideration (ii) CS since it is a very intriguing concept to discuss data accuracy and management [216], civic engagement and citizenship [26, 120], and sustainability-related issues [122].

Finally, we take advantage of (iii) game thinking as a way to creatively enhance problem-solving while creating playful and engaging solutions to solve issues with digital tools [151].

The rest of this chapter is organized as follows. Section 3.2 presents related works behind the foundational elements of our workshop (i.e., design thinking, CS, and game thinking) and similar workshop experiences with teenagers and youth, while Section 3.3.1 describes the workshop-like experience through the theoretical framework and the key elements. Section 3.4.1 presents four different case studies (i.e., tourism, digital wellbeing, urban accessibility, and environmental emergencies) and the outcomes engaging 149 students, and Section 3.5.5 discusses the workshop assessment by the participants. Finally, Section 3.6 concludes the chapter with a discussion on how to empower teenagers with digital skills.

3.2 Related work

In the following subsections, we illustrate the literature concerning the conceptualization of our workshop-like experience.

3.2.1 Design thinking and participation for and with teenagers

Competence has long defined the distinction between childhood and adulthood. The result of this perspective is a dichotomy that separates childhood (age of lack of competence) from adulthood (age of achieved competence) [244]. The image of the teenagers should then transcend this dichotomy by acknowledging their power of (re)shaping their environments [242, 244]. In this scenario, co-design proves its importance when addressing complex and very different issues: social, environmental, educational, or technological, to name a few. Moreover, it enables individuals and their communities to take control, adapt, and shape their own lives and spaces [255]. For the above reasons, co-designing with teenagers can prove to be a beneficial approach to let them feel empowered and capable of active citizenship [32]. However, we can't simply consider teenagers as young adults, as they constitute a distinct user demographic defined by their particular culture, norms, symbols, style, and shared experiences [247]. Co-designing with teenagers is a multifaceted venture [50, 255], requiring us to consider various factors attentively. First, a straightforward narrative of the activity and the crucial role that the participants will play is critical to sparking the right level of engagement [36]. The success of a co-design session is strongly influenced by the level of engagement and the sense of ownership that the participants feel toward their projects [240]. Many factors are in play to determine the level of perceived ownership and engagement: number of participants, personality traits, social relations, institutional relations, the morphology of the physical spaces where the workshop is conducted (and more) [240]. Second, it is important to create a sense of affiliation between the co-design workshop and its participants. One way to create this sense of affiliation can be achieved by implementing cultural elements of the local territory in the narration. The Cultural Historical Activity Theory [114] revolves around the idea of creating bonds through reflections, jokes, and facts about the participant's local context. This strategy helps to establish a sense of membership that introduces the participants to the activity and helps them feel more engaged. Third, a well-defined set of tools, as reported by the experience of Read [189], can improve the efficacy and efficiency in the context of reproducible co-design workshops. The advantages of such kits are scalability, reproducibility, and simplification of the process [21]. Using different tools and items can ease the transition between different workshop stages while clarifying the process objective. Finally, experts' facilitation still represents a crucial element in the co-design activity as the diverse groups and their individuals (age, scholarly level, cultural background) have different expertise, interests, and relations [53].

3.2.2 Citizen Science and active citizenship

CS initiatives involve the public in the research process to generate genuine scientific outcomes [102]. The literature about CS implementation in teenagers' education processes widely emphasizes its beneficial potentials, while pointing out some limitations [122, 195, 209]. CS can be used in the education of teenagers, and it comprehends a threefold potential: i) generating knowledge, ii) creating learning opportunities, and iii) enabling civic participation [230].

First, knowledge generation. CS, even when employed in educational contexts, provides valuable data for the scientific community. Ballard et al.'s study points out how engaging young individuals in CS boosts the learning process while providing substantial advantages for environmental science agendas [18]. Additionally, CS innately promotes the open-access approach to research; hence, it plays a fundamental role in democratizing access to scientific knowledge, as it proves to be an open avenue through which complex scientific concepts can be shared with the broader public.

Second, creating learning opportunities. CS provides a learning environment through unique opportunities for students to take part in real and practical science projects. This way CS translates abstract concepts and scientific principles into practical skills for students [92], bridging the gap between theoretical knowledge and real-world problem-solving.

Third, fostering civic participation. CS plays a pivotal role in promoting civic engagement by actively involving individuals, especially teenagers, in societal issues through hands-on participation in scientific research. By working on projects that address community-relevant problems, participants not only develop a deeper understanding of these issues but also a sense of ownership and responsibility towards their communities. This participatory approach cultivates civic skills such as critical thinking, communication, and teamwork, which are essential for active citizenship [6]. Studies highlight that involving students in such collaborative scientific efforts leads to enhanced civic awareness and long-term civic behavior, as they begin to see how their contributions impact both local and global challenges [29, 130]. Moreover, CS encourages dialogue between scientists, educators, and citizens, bridging the gap between research and societal needs. This alignment of science with public interests empowers students to advocate for evidence-based policy changes, thus contributing to democratic processes [116, 197]. Ultimately, CS not only enhances participants' scientific literacy but also reinforces their role as informed and engaged citizens committed to improving their communities.

Another element to consider as a possible concern is data and knowledge production quality [17, 112, 136]. For this reason, it is crucial to understand if it is an appropriate approach to use in education settings and institutions. Farzan discusses knowledge production and validation by non-expert volunteers [77]. With his research, the authors report the unique experience of 640 students who wrote and published different Wikipedia articles, respecting the quality standards required by the platform. Furthermore, in its study, the author underpins that the articles produced achieved a standard akin to a PhD level of expertise. Both students and educators highlighted the beneficial effects of the project, acknowledging its motivational properties and the quality of the resulting work. The sense of ownership, affiliation, and responsibility given through the students' authorship highlights the empowering role that a CS approach can play on the participants.

Despite these advantages, CS in-the-field activities often share many elements of complexity, such as the prolonged times of scientific research (from data gathering to analysis, from evaluation to publication), and even more, the challenge of effectively engaging the volunteers.

3.2.3 Engagement through Game Thinking

Considering engagement issues as one of the primary limits of CS activities [202, 253], finding ways to help participants keep a high level of commitment is crucial.

To overcome this limitation, game thinking, defined as "the use of games and game-like approaches to solve problems and create better experiences" [151], can help transform tasks into games or challenges or playful tasks, making activities enjoyable [162]. In other words, game thinking is an umbrella term that includes four categories: game-inspired/playful design, gamification, serious games, and games. It can also be seen as a shared characteristic or dimension of the four above-mentioned categories.

Game thinking effectively leverages the psychological aspects of the human brain, thus epitomizing a profoundly Human-Centered Design philosophy. Consequently, involving the intended users in the design phase becomes pivotal for effectively enhancing engagement [256]. Furthermore, game thinking captivates participants by incorporating components, such as urgency, complexity, scoring systems, motivation, and assessment [170]. Engagement holds paramount importance, particularly in volunteer-based activities like CS. Harnessing these mechanisms and implementing strategic game thinking actions can significantly bolster participation levels, especially in the long term [43].

Regarding the use of game thinking in education settings, it has a greater impact when used in creating games or gamified experiences. In both cases, the creation process has proved to have great potential in supporting a constructivist approach in which the students learn how to synthesize and express information and knowledge [162].

3.2.4 Workshop-like experience with teenagers

Design thinking is widely recognized as a human-centered methodology employed in HCI studies to foster innovation through prototyping activities. Design thinking orbits around the themes of collaboration and problem-solving, which allows it to intertwine with co-design practices and the user-centric aims that participants seek to ideate [225].

In the literature, there are diverse reports of such workshops utilizing co-design methodologies with teenagers as participants in this kind of workshops, as these activities relate to Maker-Centered Learning (MCL) where the participants delve deep into a specific topic by means of research to understand how to solve problems that may arise through the devise or creation process [204]. This approach to design with teenagers proves particularly effective as it empowers the students, making them cover the role of "authority figures", increasing their engagement and dedication [90]

Co-design can be applied in workshops with teen students while addressing the most different topics based on the pedagogical needs of the context in which it is employed, from health [220], STEM studies [196], urban planning [214], sustainability, accessibility, and more [48]. These workshops provide the opportunity to discuss real-world issues, enabling participants to empathize with the end users and fostering their engagement by reflecting on impactful activities, overall developing a sense of agency [100].

Davies [60] extensively analyzed the pedagogical impact of an MCL approach to education with three different groups of teenagers, taking into consideration their learning process, their level of engagement, and how they are affected by different elements, such as the tools employed in the creation process and the role of facilitators in making the activity interesting and meaningful for them.

The complexity and cognitive demands of co-design workshops call for the need for warm-up activities to mentally acclimate the participants to the creative and open-ended tasks they will be facing [249]. These preparatory exercises are shown to boost confidence, stimulate creative thinking, design thinking, and enhance participants' focus, making the subsequent activities less daunting and more engaging [138]. These activities also foster a sense of community and mutual understanding among participants, which is critical in group settings where collaboration is key. By encouraging shared experiences and building trust early on, warm-ups lay the groundwork for more effective teamwork and communication throughout the workshop. Additionally, facilitators can use warm-ups to introduce thematic elements or contextual frameworks relevant to the workshop, helping participants connect abstract ideas to concrete objectives [204].

3.3 Methodology

3.3.1 The workshop-like experience walkthrough

Building on the literature discussed in Section 3.2, we conceptualized a workshop-like experience by combining the techniques and principles of (i) design thinking, (ii) CS, and (iii) game thinking to transmit knowledge to teenagers about new computational and technological spaces, skills, and practices.

In this section, we first discuss the theoretical framework behind our workshop; then, we present the workshop's key elements.

3.3.2 Theoretical framework

For our workshop, we were inspired by constructivist theories, particularly the principle that learning is most effective when learners actively engage with content through direct experiences. To put this into practice, we incorporated warm-up activities designed to leverage participants' prior knowledge and personal experiences [85], aligning with the specific theme of the workshop.

These activities serve as a transition from the theoretical components of the workshop to its more practical aspects. Drawing on Cultural Historical Activity Theory [114], the warm-ups emphasize that CS endeavors are not only tangible but also deeply connected to participants' local and personal contexts. By highlighting how science can intersect with familiar environments and shared experiences, these activities set the stage for collaborative and meaningful engagement.

We were also inspired by constructionist theories, which emphasize learning as an active process where participants construct knowledge through direct experience and the creation of tangible outcomes [124, 176, 177].

In the co-design context, the creation process, whether it involves reshaping physical spaces or developing new tools, becomes an educational experience itself. As Papert's Constructionism describes, this represents an efficient way for individuals to learn by actively finding solutions to make something tangible, something external to themselves. In this process, they learn by addressing new problems and discussing their options and preferences with their peers [124, 175]. According to Papert, learning-by-making empowers learners by crafting their own knowledge rather than receiving it from a tutor or teacher, creating a more profound and personal learning experience [176, 177].

Aligned with these principles, Make-Centered Learning further builds on the idea of learning-by-making by situating it within collaborative and creative environments. It integrates hands-on activities with interdisciplinary approaches, fostering innovation and critical thinking [124]. Through designing and creating artifacts, participants not only gain technical skills but also develop a deeper understanding of the underlying concepts and their practical applications [123]. This perspective guided the design of our workshop activities, aiming to enable participants to explore, experiment, and reflect while engaging with the co-design process.

Accordingly, the outcomes of the co-design workshops are not merely end-products; they are an integral part of the participants' learning experience. They are tokens of the knowledge and skills developed by the participants through their choices and efforts during the design workflow.

3.3.3 The key workshop elements

We conceptualized the workshop-like experience as a two-and-a-half-hour workshop format, specially tailored to high school students (aged 14-18).

As depicted in Figure 3.1, the workshop protocol comprises five key elements (steps):

1. Explanation and interactive quizzes;
2. Warm-up activity;
3. Co-design session;

4. Mobile apps presentation,

5. Evaluation.

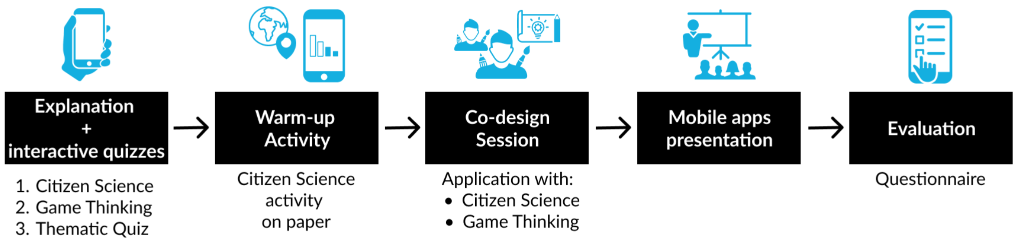

Figure 3.1: The five key elements (steps) comprising the workshop protocol.

Explanation and interactive quizzes

The first phase (30 minutes) introduces the theoretical background, which includes Citizen Science, game thinking, and design thinking, using a presentation with slides. In doing that, the facilitator alternates explanation moments with interactive quizzes to gauge the participants' prior knowledge of the concepts probed during the activity: CS, game thinking (gamification, in particular), and the workshop theme. After collecting most of the responses, we exploited the collected answers to drive a brief discussion and explanation of the aforementioned concepts. The style of this narrative and the slides are kept informal and fun to minimize attention loss and engage students in an out-of-classroom activity.

Warm-up activity

In the second phase, which we call *warm-up activity* (20 minutes), we introduce a CS task related to the workshop theme and ask students to perform a hands-on exercise. This warm-up activity is used to ease the transition from the theoretical part of the workshop to the more practical one. Specifically, fostering Cultural Historical Activity Theory [114], the warm-up activities introduce the crucial idea that science endeavors, in the form of CS, are tangible and can affect their personal and familiar experiences, scenarios, and local environment, easing their work through the participants' shared background. Inspired by the constructivist approach, which carries forward the idea that knowledge is built through direct experiences [85], the warm-up is conceptualized as a hands-on activity where the participants are directly engaged in a task that resonates with their local and personal experiences.

The activity's objective changes based on the particular workshop focus. In every case, it is a paper-based activity, where students can creatively use colors, stickers, post-its, etc., to fulfill the requested task, which is always about providing data (based on a personal point of view) to solve a CS problem.

Co-design session

During the third phase (60 minutes), we first explain the main goal of the activity (rooted in the workshop theme), then we organize participants into groups consisting of 5 to 6 individuals and encourage them to co-design low-fidelity prototypes for a gamified CS mobile application. Each group should start with a brainstorming phase and then move toward the selection of the best idea (exploiting a democratic approach) that will be the one prototyped. The resulting mobile app should integrate CS principles (e.g., data collection) and game-thinking elements to solve societal issues and increase awareness. For this activity, we equip them with color supplies, sticky notes, stickers, and paper-based smartphone mockups where they can draw the screen interfaces and app functionalities. During this phase, the main facilitator, helped by at least two young researchers (e.g., PhD students and/or Post-doc researchers), supports the students in case of any issues and helps them keep track of the time passing. Inspired by the constructionism approach [176], which carries forward the idea of learning by creating, the aim of the co-design activity is twofold. On the one hand, it lets participants learn about the three main concepts and practices about digital competentcies which are the foundation of this workshop (we are going to address in further detail this concept in

3.6.4); while on the other hand, it allows us to evaluate how much they have learned based on their solutions for the mobile applications.

Mobile apps presentation

At the end of the co-design phase, each group must present their work in front of the other groups by showing their mock-ups while illustrating the functionalities of their user interfaces (5 minutes per group - usually 5 or 6 groups). The group has the option to choose either a single presenter to deliver the presentation or have multiple presenters involved in delivering it.

Evaluation

In the final stage, we request participants to complete a concise questionnaire to gauge their learning outcomes from the workshops and identify the most memorable concepts (5 minutes). Specifically, they are prompted to elaborate on the purpose of CS, the advantages of game thinking (and, gamification, in particular), and the concepts they find most challenging to comprehend. Furthermore, they are asked to recall the three concepts that stand out most to them. Additionally, using a 5-point Likert scale, participants are invited to express their level of engagement and interest in the activity, assess whether they gained any new knowledge, and indicate if they would recommend the workshop to their peers. On the one hand, the resulting data grants feedback for future improvement of the workshop; on the other hand, it provides data for evaluation and comparison of the different sessions.

Eventually, the authors collect the workshops' outcomes (data from the questionnaires and paper-based mock-ups) for later analysis and research purposes.

3.4 Methodology

3.4.1 The workshops: description and results

To test and evaluate our workshop, we conducted four editions, in different Italian cities, engaging 149 students, 7 classes, in total. We conducted the workshop as part of the "AFTER festival" ([2]), specifically the laboratory is called *CitizER Science in action* [3] as part of the regional project CitizER Science [4] aimed at advocating digital culture organized by the Emilia-Romagna region (Italy).

Each workshop focused on a specific theme that correlates with at least one of the Sustainable Development Goals (SDGs) as defined by Agenda 2030 [2], covering four case studies:

1. Tourism and sustainable tourism;
2. Digital wellbeing;
3. Urban accessibility;
4. Environmental emergencies.

In this section, we first provide details about the selection process and students' participation. Then, for each workshop, we present the outcome of the warm-up activities and the co-design sessions, which are strongly related to the workshop theme.

The results of the co-design session are a way of demonstrating the effectiveness of our workshop model, proving that each group was capable of creating a suitable idea for the design of a mobile application, thanks to their understanding of the workshop's theme, the concept of CS, and game thinking. In this light, the outcomes are indicators of the workshop's educational

[2] https://www.afterfestival.it/

[3] https://digitale.regione.emilia-romagna.it/citizer-science/laboratori/laboratori-per-ragazzi

[4] https://digitale.regione.emilia-romagna.it/citizer-science

value. By these results, we can evaluate how the workshop has achieved its educational objectives, ensuring that participants not only learned the concepts but were also able to apply them in practical and innovative ways. This approach is consistent with the constructionist perspective.

The interactive quizzes and evaluation results, common to all the workshop editions, are presented in Section 3.5.5.

3.4.2 Field preparation and participants

As anticipated, the workshops were conducted as one of the activities of the "AFTER festival", an event aimed at advocating digital culture organized by the Emilia-Romagna region (Italy). AFTER is an itinerary festival that is run in different cities and public facilities. We, as experts and facilitators, were invited to organize the workshop, while the Emilia-Romagna-related office took care of all the organizational aspects. In particular, for each workshop, they formally invited the local high schools and collected at least two responses of interest in participating (2 classes). Once the classes were identified, they provided their teachers with the consent form informing them about the activity and all the information about using the collected data, according to the European General Data Protection Regulation (GDPR). The informed consents were then signed by the legal guardians of students under 18 and directly by students over 18, collected by the school teachers, and sent to the Emilia-Romagna legal office, in compliance with the EU GDPR.

3.5 Results

3.5.1 WS1: Tourism

In the first case study, we focused on the theme of sustainable tourism or eco-tourism, given that the workshop was held in a well-known tourist destination. As mentioned by the World Tourism Organization, tourism possesses the characteristics to directly or indirectly contribute to all of the SDGs, since it can be viewed from multiple and diverse perspectives [250]. Expressly, it has been directly incorporated into the targets of SDG 8 (decent work and economic growth), 12 (responsible consumption and production), and 14 (life below water) [250]. 23 fourth-year high school students (17-18 years old) participated in this workshop.

Warm-up activity

In the warm-up activity, our intention was for participants to engage in CS by gathering data about the most culturally significant and special locations in their city. Specifically, we instructed the students to mark the different Points of Interest (PoIs) on paper map of their city center. Some of the results can be seen in Figure 3.2-A. To facilitate this, we equipped them with markers, pencils, and post-its, allowing them the flexibility to complete the task using their preferred methods, even encouraging a more creative approach, as visible in Figure 3.2-A.

Figure 3.2: Results of the Warm-up activities.

A represents the touristic PoIs identified in the first workshop about tourism; **B** the data and the visualization collected from the second workshop about digital wellbeing; **C** the places in the city that are not accessible, and

D the city divided based on the level of risk during flooding.

Co-design session

In the co-design session, we asked the participants to design a mobile application that would motivate people to collect data about touristic and cultural PoIs playfully, enhancing sustainability. Some of the results of this activity are shown in Figure 3.3.

Trip to Mutina stands out as one of the applications crafted by participants. This group, in particular, conceptualized an app aimed at familiarizing tourists with Points of Interest (PoIs). Their vision included a feature similar to Google Maps but enhanced with Virtual Reality to guide users along the path to the PoI. Upon reaching the designated PoI, users were envisioned to engage in entertaining activities to earn points and unlock rewards.

Mò-Raccolgo is another application designed by the participants. The concept behind this app extends beyond tourism, utilizing the data gathered about PoIs to enhance waste collection practices in the city and influence visitor behavior. Users can discover and visit PoIs and actively participate in waste collection, earning points that translate into discounts for shops, food, transportation, and cinemas.

Highlighter was conceived to encourage users to explore the city, discover, and collect various PoIs such as bars, parks, and more. The participants also envisioned incorporating user preferences related to PoIs for quality assessment, enhancing the experience for subsequent users. To captivate users, the concept included rewards aligned with the 17 SDGs.

Mò-clean represents the last app designed, and its concept bears similarity to Mò-raccolgo. Essentially, this group amalgamated the tourist viewpoint with waste collection, focusing mainly on urban parks. Their approach involved guiding users to explore new parks while also aiming to influence their daily behavior positively.

The first interface belongs to **Trip to Mutina** and represents the homepage of the application, also displaying the different levels of the application

Figure 3.3: Some interfaces designed during the co-design session (Step 3) in the tourism workshop.

itself. The second one is **from Mò-Raccolgo** and shows the idea of recycling different materials while exploring the city. The third one is from **Highlighter** and displays the path on the city's map, once the user has selected a category to personalize the trip around the city. The last belongs to **Mò-clean** and shows the rewards that the users can gain using the applications.

3.5.2 WS2: Digital Wellbeing

In this second workshop, we decided to focus on a critical topic that recently emerged about teenagers, named digital wellbeing. Where "digital wellbeing" refers to the impact of digital technologies on a person's ability to lead a balanced, healthy, and meaningful life [42]. The wellbeing (physical, mental, or in our case digital) of all is mentioned in SDG 3, which wants to promote healthy lives and well-being [234].

45 high-school students (17-18 years old) participated in this second workshop.

Warm-up activity

In the warm-up activity, our intention was for participants to engage in CS by gathering data about their digital activities and the applications most used in their daily lives. Specifically, we provided the participants with a paper diary wherein they were asked to record their perception of usage of social applications (e.g., WhatsApp, Instagram, TikTok). Afterward, participants were instructed to access their smartphone settings to determine their daily screen time spent on social apps and identify the three apps most frequently used. Finally, we asked them to illustrate their time spent online without resorting to conventional graphical representations like bar charts or pie charts to create a more engaging and creative activity. Some results are visible in Figure 3.2-B.

Co-design session

In the co-design session, we asked the participants to collectively design a mobile application to motivate people to collect and visualize digital wellbeing data creatively and playfully to increase awareness about digital wellbeing. Some of the results of this activity are shown in Figure 3.4.

Study Movie is an app designed to harmonize its users' digital wellbeing and study time. This group, in particular, devised a system where users select a movie, and to watch it, they must dedicate a predetermined time to studying. Once the allocated study time elapses, the app prompts users to take a test on the studied topic. Successfully passing the test grants users the opportunity to watch the chosen movie.

You time is an app meticulously created to track users' activities, both digital and otherwise. It offers features like reminders and allows users to declare their intentions, such as committing to stay away from the phone after 10 pm. Users accumulate points for each action undertaken, and these points can subsequently be converted into discounts for shops, books, or events.

Hit by alber is the third app drawing inspiration from the Christmas period, coinciding with the time of our workshop, and the concept of an advent calendar. Specifically, for each day in December, users are presented with a challenge (such as limiting Instagram usage to under 30 minutes) to earn points. By the end of the month, the Christmas tree featured in the application will be adorned with Christmas balls as a visual representation of completed challenges.

Tik-Tak is an app designed to monitor the duration of online and smartphone usage. In an effort to enhance users' behavior, this group conceptualized a friend-ranking system, informing users about more productive activities that could have been undertaken during the time spent on the phone and using aspects of sonification.

TEC (Time Eater Caterpillar) is yet another app dedicated to monitoring app usage time. In this instance, the group devised a user profile feature to gather information about users' interests. Utilizing this data, the app then suggests alternative activities. Additionally, the app encourages users to set notifications and challenges to limit app usage. If a user succumbs to the temptation and uses the apps during the designated period, the app employs a visual metaphor, like a caterpillar losing a life, to signify the lapse.

Monkey Clock is the final app designed to bring joy to a virtual monkey by earning bananas. Users can acquire these bananas based on the time they spend away from their smartphones. Similar to other apps, Monkey Clock also provides users with suggestions for activities that can be enjoyed without the use of the phone.

The first interface belongs to **Study Movie** and shows a library with different blocks representing different films to watch and the hours the users need to study before having the possibility to watch them. The second one is from **You time** and displays a pie chart to show the time spent on the phone and a bar chart that displays the activity done by the users. The third one is from **Hit by alber** and shows a tree with different Christmas balls, representing a different challenge to stay away from the phone. The fourth one is

Figure 3.4: Some of the interfaces designed during the co-design session (Step 3) in the digital wellbeing workshop.

the homepage of **Tik-Tak**, which highlights the data sonification behind the idea of the app. The fifth interface is from **TEC** and shows a visualization of a caterpillar with the time spent on the different apps. The last one is from **Monkey Clock** and displays customization options for the user's monkey avatar purchasable through in-app currency.

3.5.3 WS3: Urban accessibility

In the third case study, we investigated SDG 11, whose aim is to "make cities and human settlements inclusive, safe, resilient and sustainable" [233]. In particular, we focused on urban accessibility, which is related to the ability of individuals or groups to reach different locations on foot or using means of transport [89]. In particular, we delved into the individual component, as referenced in the work by Geurs et al. [89], which considers users' needs based on factors such as age and physical condition. This analysis explored how these characteristics influence an individual's level of access to transportation and their ability to reach destinations.

Two third-year high school classes participated in the workshop (16 and 17 years old) for a total of 43 students.

Warm-up activity

In the warm-up activity, we wanted students to become citizen scientists and report data about the accessibility of the city center in terms of barriers or dangerous areas concerning mobility. In this step, many participants used Google Maps with the street view to be as precise and accurate as possible. Some of the results are visible in Figure 3.2-C.

Co-design session

In this step, we asked the participants to co-design a mobile application to motivate people to collect data about urban accessibility playfully and increase awareness. The results of this activity are shown and described below, and some of them are visible in Figure 3.5.

Sith-down is an application that focuses on urban accessibility and includes two types of users: those who want to help identify barriers or obstacles inside the city and those who need help in finding a suitable path to reach a destination. On the one hand, users who want to help have the opportunity to see the map and add, in their GPS position, a photo of the obstacle, its information, and the type of users for whom it constitutes a barrier. By doing this, the users have the chance to earn points. On the other hand, users who need help can indicate their difficulty (e.g., motor disability, children in strollers, etc) and see all the barriers relating to it on the map with a personalized marker. This group considered both permanent and temporary difficulties, such as crutches for a short period or tourists who have suitcases.

Sommobile is a map-based application that shows pedestrian crossings, audible traffic lights, traffic light failures, ramps, and architectural barriers. Users can explore the map and receive directions to a specific destination, or can report via photos the lack of accessibility of a specific area, poor roads, breakdowns, or, through a voice recording, the noise pollution of the area. It is also possible to report parking spaces. Depending on the type of report and after a check by the administrators, the user receives coins, which makes it possible to obtain discounts for public transport (bus or bike), parking, and sustainable clothing shops. A ranking is also provided to incentivize users even more.

BoloScaping is a game whose aim is to escape from the city (Bologna) by completing missions such as reporting architectural barriers and collecting tortellini (typical food of the city), which are equivalent to points in the game. These points can be used to customize the avatar, represented by a *umarell*[5] (a typical character that is part of the city's cultural heritage) in terms of physical appearance and clothing. To obtain specific objects for customization, it is also possible to participate in themed events (for example, Halloween or autumn) in which, in addition to reporting obstacles, the user must also locate decorations or roasted chestnuts.

BarrierGO is an application where you can explore or map barriers via the map or see all reports in a list. The more reports users make and photos they take, the more points they can receive to move to the next level, customize their character (changing their skin), and climb up the rankings.

MoveAbility is an application that uses an interactive map to see obstacles and to report barriers for strollers, children, people with motor or visual disabilities, elderly people, and traffic conditions. Each barrier is marked with a different color depending on the type and has the photo and GPS position linked. The more users report obstacles, the more they receive discounts for cultural activities, such as theaters or museums.

On the road is a multilingual application designed with tourists in mind. It focuses on transportation, allowing users to report the efficiency or inefficiency of public transport (such as trams and trains) and issues related to road infrastructure, including lighting, traffic signals, and road conditions. Users can report problems like potholes, speed bumps, missing pedestrian crossings or sidewalks, and malfunctioning traffic lights. The app also sends notifications to remind users to report any issues they encounter. The more reports a user submits, the more they can earn bonuses, displayed through data visualizations, which can be redeemed for discounts on fuel or public

[5] http://languagelog.ldc.upenn.edu/nll/?p=40333

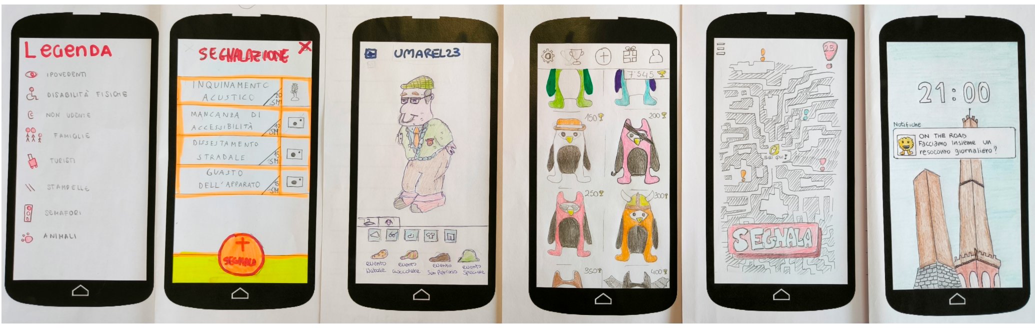

Figure 3.5: Some of the interfaces designed during the co-design session (Step 3) in the urban accessibility workshop.

transport passes.

The first interface belongs to **Sith-down** and represents the legend used in their map, highlighting different types of users who can benefit from the app. The second one is from **Sommobile** and shows the data that can be collected (audio or photo) based on the problem detected. The third one is from **BoloScaping** and shows the *umarell* with the wearable item that can be purchased inside the app. The fourth interface is from **BarrierGO** and shows a character that can be further personalized through the use of the app. The fifth is from **MoveAbility** and shows the map with the reports made by all the users. The last one is from **On the road** and shows the app notification to engage the users in making a new report.

3.5.4 WS4: Environmental emergencies

Following the flood that damaged much of the Emilia-Romagna region and being the workshop held in one of the most affected cities, we opted to center its theme around environmental emergencies. In particular, we wanted to inform the participants of the importance of data in such risk contexts. To do so, we analyzed SDG11, with a specific focus on target 11.5, which seeks to mitigate the negative impacts of natural disasters, particularly those related to water, by reducing the number of casualties and affected individuals [233].

A third-year high school class (16-17 years old) and a fourth-year high school class (17-18 years old) participated in the workshop (38 students).

Warm-up activity

In the preliminary activity, we aimed for participants to assume the role of citizen scientists, gathering data on the risk levels in different areas impacted by the flood. Clearly evident from the findings is the correlation between proximity to a watercourse and elevated risk, indicating that areas closer to water sources were associated with higher risk levels. Some exemplary results are visible in Figure 3.2-D.

Co-design session

In this step, we asked the participants to co-design a mobile application to motivate people to collect data relevant during the flood emergency. The results of this activity are described below, and the most relevant are visible in Figure 3.6.

Mud Guys is a map-based application where the markers represent the mud level in the relevant area. Each marker also indicates a call for help, which may be needed for gloves, mud boots, pumps, or food. The users who help can level up by earning points for each request fulfilled and can purchase items in the shop. Each level corresponds to an item earned in the shop: ranging from bare hands (level 0), gloves (level 1), and boots (level 2) up to becoming a mud angel (figuratively renamed following the flood and the help given by citizens to flood victims). The application also includes timed missions to provide immediate aid and a section where the user can view statistics as graphs and streaks.

BooRiver is an application that focuses on the water level of rivers. The users select their city and can see the river situation and related alerts in real-time. Each user can take photos of the river and enter data on the level of criticality of the banks, and see a history of the data entered. Each picture leads to earning points that can be used for discounts on groceries in various supermarkets in the city.

S.A.D. (Shot A Danger) is a game created to provide information to scientists who analyze areas during emergencies. Each area has a different emergency level (depending on its current conditions), visible on a map through different colors. The application is therefore aimed at two types of users. The first are individual citizens who provide photos and information on the affected areas to earn points (the number of which is proportionate to the criticality of the area), which will be converted into discounts for cameras or e-commerce platforms. The latter are the scientists, whose competence will be verified during the first access to the application, who can take advantage of the photos and information provided by citizens.

Blobby is an application focused on donations during emergencies, such as floods. On the main screen, you can select whether you need help or want to donate something. In particular, you can donate (and therefore receive) clothing, accessories, food, household items, tools, hygiene products, or manual help. Each donation corresponds to a score, and every 100 points corresponds to 2 euros earned. The application shows information about donations made or received, reviews of donations received, and your points.

Emergency 360° is the last application that differs slightly from those mentioned before. In particular, its central aspect is the social component, as the aim is not to leave people alone in times of emergency. The application is therefore intended to be a collection of advice during possible emergencies (like earthquakes, floods, tornadoes, etc.). Each user can provide pieces of advice on what to do, who to call, and how to behave, and if they are deemed helpful by those who need it, they can receive points. Again, points can be converted into discounts on clothing or groceries.

The first interface belongs to **Mud Guys** and shows the items that can be purchased while leveling up in the app. The second one is from **BooRiver** and shows the city's rivers with a photo and some information about the alert level and the situation of its banks. The third one is from **S.A.D.** and displays the map of the region with exclamation marks showing the alert level of the areas. The fourth one is from **Blobby** and shows the mascot of the

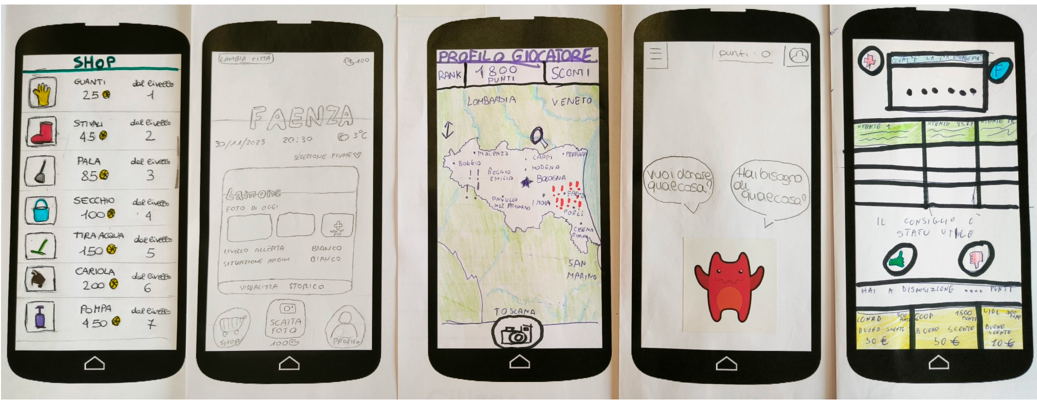

Figure 3.6: Some of the interfaces designed during the co-design session (Step 3) in the environmental emergencies workshop.

app while asking the users if they want to donate something or whether they may need something. The last one is from **Emergency 360°** and displays the advice given to an emergency, asks if the advice was useful, and shows the discounts available.

3.5.5 Workshop assessment

To assess the effectiveness of our workshop-like experience, we exploited two methods: i) an analysis of the mobile applications created during the co-design session (already presented in the previous Section) to verify that participants were able to clearly understand the objective of the application and successfully develop it while applying the key concepts and theme of the workshop (as a proof of their learning process about DigComp); and ii) a questionnaire administered as the final activity of the workshop to investigate participants' engagement in the experience and awareness of acquiring new knowledge. Before presenting the findings from the questionnaire, relating them to the answers collected with the interactive quizzes (step 1 of the workshop) is important.

Interactive quizzes findings

During the interactive quiz phase, we gained insights into the participants' familiarity with CS, revealing that but a small percentage of them were previously acquainted with the term (Figure 3.7). Nonetheless, they generally provided correct answers when presented with a multiple-choice question probing their understanding (Figure 3.8).

Our exploration extended to the concept of game thinking, particularly gamification, uncovering that the overwhelming majority of respondents were unfamiliar with it. All the answers are visible in Figure 3.7. Intriguingly, when tasked with defining gamification, many accurately identified the relevant keywords despite their initial lack of awareness. For example, one student wrote: "Gamification means to make a common activity a game to make it more pleasant", and another one claimed "Gamification makes concepts funnier and can be a way to learn something". Other students wrote: "to add a gameplay element where it isn't normally found", "the revival of classic game structures in everyday life", and "make an activity that could be heavy, lighter, making it a game itself".

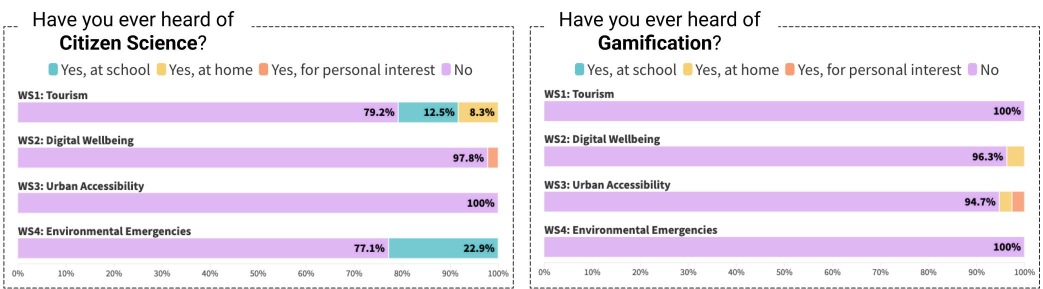

Figure 3.7: Answers related to the participants' knowledge about CS (on the left) and Gamification (on the right) divided per workshop.

3.5.6 The results of the Evaluation phase

The quantitative results collected during the Evaluation phase revealed that the workshop was both interesting and engaging. Indeed, we requested

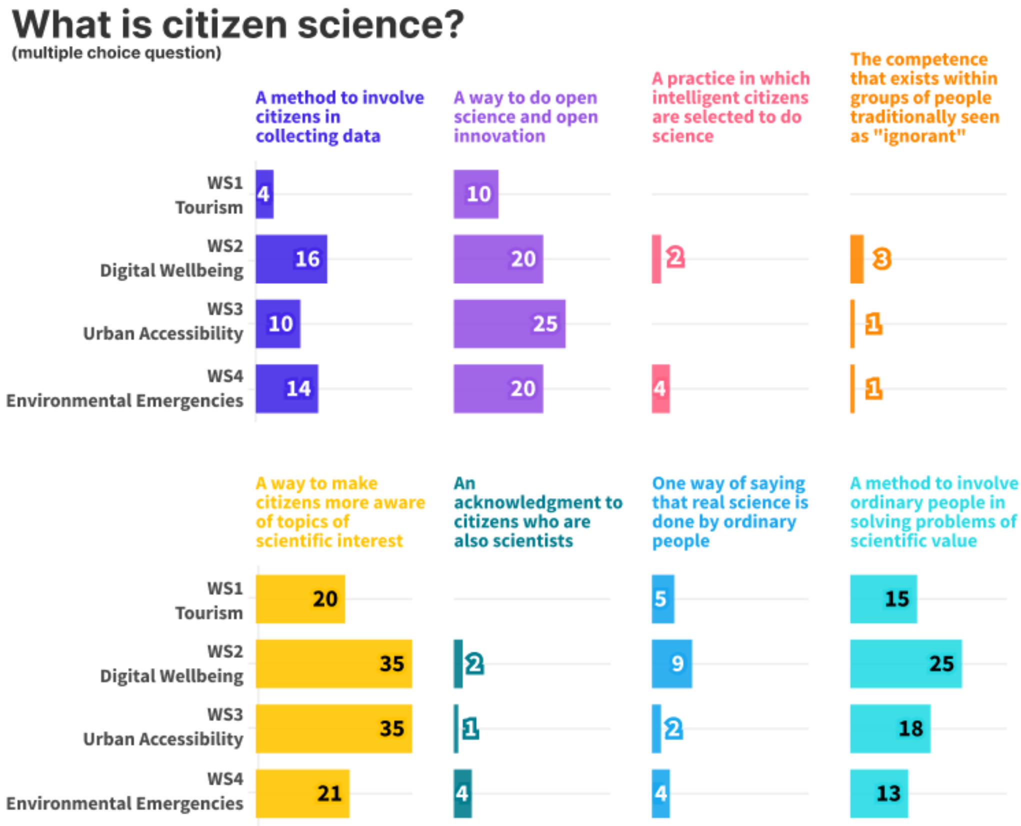

Figure 3.8: Answers about the definition of CS collected through a multiple-choice question during the interactive quiz (Step 1).

participants to assess the workshop engagement level using a 5-point Likert scale. The results indicated consistently high levels of engagement, with median values exceeding 4 in all workshops. Specifically, the mean (μ) and standard deviation (σ) for engagement were as follows: $\mu = 4.7$ ($\sigma = 0.5$) in the first workshop, $\mu = 4.3$ ($\sigma = 0.7$) in the second, $\mu = 4.3$ ($\sigma = 0.5$) in the third, and $\mu = 4.2$ ($\sigma = 0.9$) in the last. Furthermore, every participant across all four workshops was willing to recommend the activity to their peers, except for one individual who believed the workshop might be better suited for children.

Additionally, we aimed to assess participants' awareness of acquiring new knowledge using a 5-point Likert scale. The results were predominantly positive, with mean (μ) and standard deviation (σ) values as follows: $\mu = 4.8$ ($\sigma = 0.4$) in the first workshop, $\mu = 4.0$ ($\sigma = 0.8$) in the second, $\mu = 4.2$ ($\sigma = 0.8$) in the third, and $\mu = 4.2$ ($\sigma = 1.2$) in the last. As evidence of this, upon reviewing the qualitative data, we found numerous accurate definitions of CS in all the workshops.

For example, participants articulated that CS is "the participation of citizens in organized groups in data collection and information production activities". They emphasized its utility as a way of "collecting information involving those who do not belong directly to the scientific world" and "actively involving citizens in addressing urban problems". Furthermore, they highlighted its role in "integrating even non-scientists to assist research by collecting data" and, specifically related to one of the workshop themes, as a means to "unite and engage citizenship on the topic of digital well-being and beyond". Similarly, responses regarding gamification were mostly accurate, spanning from "the integration of game elements to enhance motivation" to "transforming tasks that could be complex and dull into enjoyable activities." Participants also demonstrated comprehension of the ultimate goal of gamification, such as "making people have fun so they are motivated to engage in tasks that contribute to the community."

Moreover, we asked them to list the three concepts that stuck the most in their mind. Figure 3.9 presents a word cloud result by analyzing the outcome, which highlights that gamification was indeed the most remembered term in each workshop edition, followed by CS, and the workshop theme. Interestingly, in WS1 (Tourism), biodiversity emerged as very important, probably because we made strong use of that concept to explain CS.

We also collected feedback and comments using open-ended questions. Overall, the feedback indicated a pronounced level of interest in the workshops, portraying them as both enjoyable and educational. Here we report some of the comments left by the participants (comments are identified by *workshop code-participant id*): "It was a fun and interesting activity" [WS3-

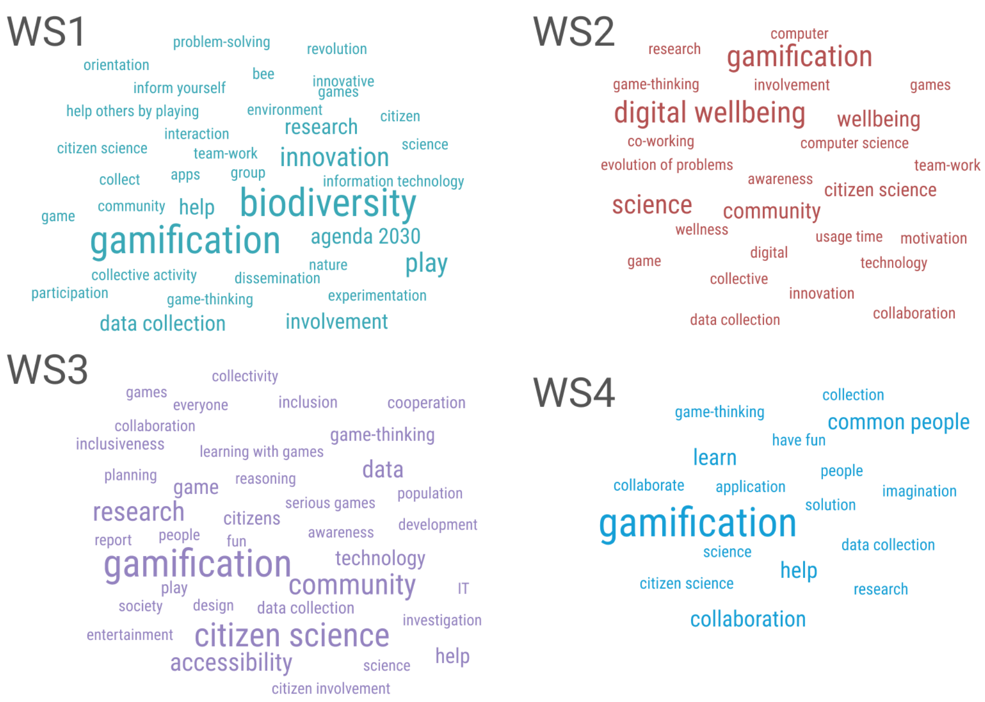

Figure 3.9: The concepts most remembered by the participants in the four workshops: **WS1** Tourism, **WS2** Digital Wellbeing, **WS3** Urban Accessibility, and **WS4** Environmental Emergencies.

4]; ‘Very nice, fun, and interesting lessons” [WS2-7]; “it was a fun and informative activity” [WS1-8]; “facilitators were very kind and helpful throughout. I managed to understand easily and without getting bored” [WS1-12]; “The activity was very interesting and stimulating” [WS1-17]; “Pleasant workshop with a high degree of involvement, well and logically structured” [WS4-2]; “nice presentation and in my opinion excellent time management” [WS4-10]; “innovative and original workshop” [WS1-9].

3.6 Discussion

3.6.1 Design Thinking and Co-Design

The co-design sessions proved to be an exciting experience for the participants as they could collaboratively work hands-on on a project strictly related to their local realities or daily practices (specifically in the Digital Wellbeing workshop). The workshop showed the participants an easy-to-exploit method to actively express their citizenship (meant as a sense of belonging to a community) through CS activities. The responses to the open questions in our questionnaires portray the participants' genuine interest in the activity, specifically one of the participants stated the importance of working on public issues: "It was nice to design something together as a group that shared our interests" [WS4-5]; another comment reflects the experience of a teenager realizing the existence of tools (co-design in this case) for decision-making: "It was really nice to participate in a project that included us and made us realize that saving the world isn't difficult" [WS4-42]. One comment emphasized the civic empowerment properties and their interest in exploring such workshops with more regularity: "It would be nice to involve these projects as civic education in schools" [W5-31].; Lastly, a participant in WS1 expressed the feeling of inclusion, emphasizing the appreciation for being included as a youth in a workshop for their city, reinforcing the concept of generational membership [247] and public participation: "As a person of the new generation, I felt very integrated as a member of the society, and I appreciated being involved in such an activity." (WS1-21). The empowering effects of co-design, as highlighted by [255], are reflected by the participants' comments and manifest some links to the DigComp framework, specifically to actions: collaborating through digital technologies (2.4); and identifying needs and technology (5.2). Regarding action point 2.1 (Interacting through digital technologies), a few students feel missing the *digital* phase. One student acknowledged "interesting workshop that introduced me to the first-stage app design" [WS2-29], while others explicitly reported: "I would like to understand how to make the app design digital" [WS1-11], and "I would like to learn how to make my ideas digital" [WS1-33]. To overcome this issue, the workshop could be extended as a full-day activity and include a session about prototyping mobile apps through a visual programming environment as MIT App Inventor[6].

3.6.2 Citizen Science

The different groups in the various iterations of the workshop devised interesting ideas for data gathering. The majority of the mock-ups presented tools centered around maps. Notably, two primary methods surfaced for reporting data: i) capturing and uploading images and ii) utilizing maps and GPS functionalities to pinpoint elements of interest. These observed patterns are intricately tied to the workshop's overarching goal of conceptualizing a mobile app for CS, emphasizing the smartphone as both the interface and the instrument for data collection. Nonetheless, other examples rely on sharing knowledge through other means, such as expertise sharing in the form of guidelines in case of emergencies (Emergency 360°), audio recordings (Sommobile), or even providing knowledge through active interaction with the environment (Mò-clean, Mò-Raccolgo).

The proposed mock-ups all work in favor of civic responsibility [197] and active citizenship [130], in different ways and modalities for engagement, and target users. The devised mockups focus on the opportunity for collaboration as a method for environmental or cultural transformation through the collaborative approach of CS [116].

Considering the warm-up activities, technologies were surprisingly exploited in all the case studies to gather data. Indeed, technology was exploited in WS2, where we asked them to check their digital well-being using the official built-in app. Furthermore, in the other case studies, participants actively leveraged Google Maps/Earth's street view to enhance precision,

[6]https://appinventor.mit.edu/

thereby illustrating an increased dedication to collecting comprehensive information and generating a more extensive and accurate dataset.

In summary, the warm-up exercises and the final mock-ups reflect the DigComp framework in the following points: managing data, information, and digital content (1,3), sharing information and content through digital technologies (2.2), engaging in citizenship through digital technologies (2.3), protecting health and well-being (4.3), and, eventually, protecting the environment (4.4).

3.6.3 Game Thinking

Overall, the co-design sessions provided a wide array of examples of the application of game thinking in the mock-ups, many of which resorted to the knowledge coming from the user experience of the very participants. Ranging from in-game rewards (skins, cosmetics), leaderboards, or scoring systems, and rewards in the form of money or discounts. Furthermore, the mock-ups also went beyond the idea of rewards in their gamification, by presenting funny mascots to motivate the user in their endeavors, or even themed events to renew interest and motivation in the users, showing resonance with Cairns [43] and the importance of game thinking about the user attention while promoting creatively using digital technologies (DigComp 5.3).

Adding more details, we can categorize game-based mechanisms into two main groups: i) in-app rewards and ii) monetary compensations. For i) in-app rewards, the options typically involve customizing the user experience. Examples include skins for in-app characters or other aesthetic elements that can be acquired using accumulated “points” earned during gameplay. ii) In eight out of twenty-one mock-ups, groups proposed rewards in the form of monetary compensations. Specifically, these included discount coupons applicable to cultural activities or for expenditures at various shops and services.

3.6.4 Digital Literacy

The skills learned during our workshop-like experience about design thinking, CS, and game thinking can be mapped to a well-known digital competencies framework to assess our workshop as a methodological strategy to educate about emerging literacies related to digitization. Considering both the cultural background and geographical dimension of our case studies and involved students, we noticed a similarity with the "The Digital Competence Framework for Citizens" (DigComp, version 2.2), defined by the European Commission [239]. DigComp provides a comprehensive vision of what is needed in terms of competencies to overcome the challenges arising from digitization in almost all aspects of modern lives and therefore provides a basis for framing digital skills policy [236]. The declared final aim is to develop a confident, critical, and responsible use of, and engagement with, digital technologies for learning and participation in society [239].

The framework comprises 21 competencies grouped into five main areas that outline what digital competence entails and has been used in different countries and scenarios as a reference and strategic support for training and monitoring the development of digital competencies (e.g., [79, 228, 229]).

Critically analyzing the different methods and strategies composing our workshop, we can notice how they cover several digital competencies, as defined in DigComp. In particular, Figure 3.10 presents the association between our methods and strategies and the DigComp competencies.

Design thinking for "Communication and Collaboration", "Digital Content Creation", and "Problem Solving" In our workshop, design thinking was put into practice through co-design: a hands-on activity where students collaboratively work to find a single solution to a problem by exploiting mobile app mock-ups. Even though we didn't let them use digital tools to co-design the solution (everything is paper-based), students need to collaborate to design the mobile app functions and interactions with the envisioned digital content that will be eventually developed through the

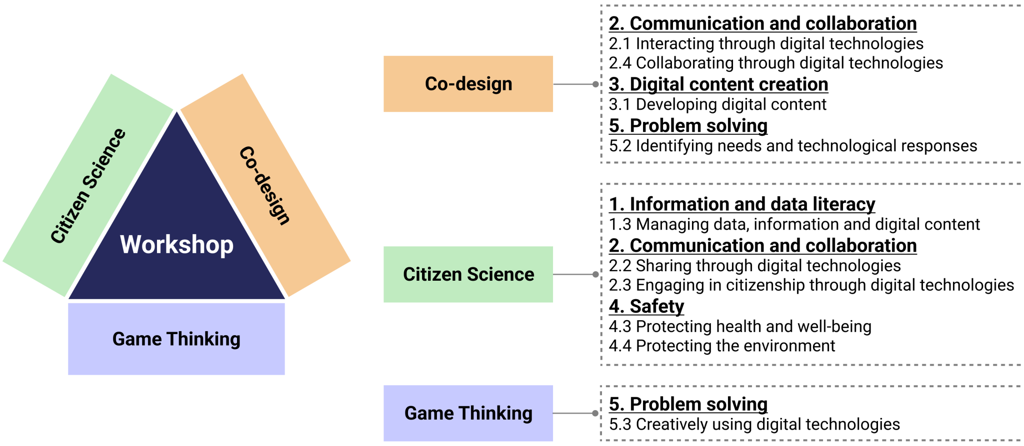

Figure 3.10: Connection between our workshop-like experience and the DIgComp framework.

mock-ups (DigComp - 2.1, 2.4, 3.1). Finally, while co-designing solutions, we instruct students to consider the end-users' needs and how technologies can respond to those needs (DigComp - 5.2).

CS for "Information and Data literacy", "Communication and Collaboration", and "Safety" Scientific practices are a fundamental component of modern standards for science education [137, 172]. Learning and practicing CS can let students acquire competence related to managing data, information, and digital content [216] - (DigComp - 1.3). These practices involve students in utilizing scientific knowledge and principles to explore complex phenomena through activities such as questioning, forming hypotheses, conducting experiments, visualizing, modeling outcomes, and constructing knowledge [60]. Data are central in any CS project, and participants need to collect, share, validate, and manage data [82] - (DigComp - 2.2). Additionally, CS initiatives, in most cases, exploit digital tools to engage participants in social challenges and active citizenship (defined as one's sense of belonging, for instance, the sense of belonging to a community that you can shape and influence directly) [120] (DigComp - 2.3). Lastly, we exploited CS in the context of Sustainable Development Goals (SDGs), while explaining issues about digital wellbeing and environment (DigComp - 4.3, 4.4).

Game thinking for "Problem Solving" Concepts such as games, gamification, and game-based learning have always been linked with the possibility of acquiring problem-solving skills [127] (DigComp - 5.3). Through game thinking, we push students to creatively identify and create playful strategies to potentially solve complex problems.

3.6.5 Findings

The workshop's experiential format would appear to contribute to the development of digital competencies in adolescents, but this happens within the limited duration of the sessions. Even though the improvements detected are by nature bound by what can be achieved during the workshop, the progress made by participants in that short span represents a promising foundation for the learning and empowering potential within this type of approach. Participants delved into notions of design thinking, CS, and game thinking and, by collaborating, built creative solutions for solving real-world challenges. The competencies demonstrated by participants in the co-design of low-fidelity app prototypes contribute to increased critical thinking, problem-solving, and collaboration competencies. Also, the very iterative workshop structure, including interactive quizzes, warm-up exercises, co-design sessions, and presentations, has been successful in making difficult concepts accessible and engaging. Data from evaluations consistently revealed elevated levels of engagement among participants, significant acquisition of knowledge, and broad support for the workshop from the adolescents involved. However, several participants articulated a desire to expand the workshop to incorporate practical digital prototyping activities. Such an enhancement could bolster the practical application of digital skills as specified in the DigComp framework, especially in domains pertaining to the creation of digital content and the resolution of technological challenges.

The findings reveal the adaptability of the workshop format to different sustainability themes, such as tourism, digital wellbeing, urban accessibility, and environmental emergencies. In all runs, participants successfully adopted and enacted the core principles of the workshop, adapting them to the particular thematic focus. The use of locally relevant themes was key to securing a higher level of participation with more significant contributions. This was particularly evident in the workshop on environmental emergencies, where the relevance of the theme to recent regional events heightened emotional interest and participation. While the structure of the workshop remained consistent, the outcomes varied according to the thematic focus, which shows the flexibility of the approach. For instance, themes such as urban accessibility and environmental emergencies underlined the need for shared data collection and civic responsibility, while the digital wellbeing workshop led to reflective behavior change. These variations demonstrate the ability of the workshop to address various issues related to sustainability without losing its effectiveness as an educational intervention. Further work might explore additional thematic domains and incorporate digital prototyping tools to see if these gains in enhancing the development of digital competencies are sustained in a wider range of contexts.

3.6.6 Answer to RQ1

Moreover, the results presented in this chapter are replete with answers to both the original research questions proposed in the introduction 1. Regarding RQ1 (Sec. 1.2.2), the workshops have shown how CS-informed co-design approaches can be effective for engaging teenagers (16–18 years) in the development of interactive digital tools for raising awareness about sustainability. This iterative workshop structure proved effective in encouraging active participation, collaboration, and creative problem-solving among the participants through the integration of design thinking, game thinking, and CS. This does seem to have much more engaged participation, as witnessed by the higher willingness to engage with workshops tackling problems such as environmental crises. Although this chapter has a specific focus on adolescents, the demonstrated flexibility of the methodology suggests it could be applied to other age groups, a question that future research will explore.

3.6.7 Answer to RQ2

Furthermore, to answer RQ2 (Sec. 1.2.2), results clearly show some tangible benefits for communities in such CS-driven co-design research. They also reported significant gains in their digital competencies, critical thinking, and civic engagement. Furthermore, the workshops' adaptability to many themes of sustainability, which vary from digital well-being to urban accessibility, has evidenced the flexibility of the approach. Additional comments made by respondents, for example, suggesting that workshops of this kind should be incorporated into curricula, further illustrate the empowering nature of these activities. These insights confirm the potential of co-design workshops in raising awareness about sustainability and arming the participants with tools to address real-world challenges.

3.6.8 Reflections

The constructivist approach, exploited in warm-up exercises, and the constructionism one, exploited in the co-design session, were proposed in the workshop, allowing the participant to work hands-on on their projects and fostering a learning process through learning and making [162]. The young students affirm their interest with different feedback: "The lesson was very nice, enjoyable, and interesting" [WS4-33]; "Fun and interesting activity" [WS4-29]; "I really liked the co-design part" [WS2-16]; "I really enjoyed this workshop because it is a very unique method to learn something that is very relevant to us" [WS3-12].

While acknowledging the positive feedback regarding the workshop's clarity in terms of objectives and educational purposes, we recognize the opportunity to introduce elements that foster diversity and space for creativity.

Notable general similarities emerge among the mobile mock-ups created by various groups during each workshop. This convergence can be expected, given the shared theoretical foundations, particularly concerning the concept of CS, and the nature of the warm-up activities, which consistently follow a similar approach. Similarities manifest in the outputs of the WS1, WS3, and WS4 workshops. Regarding data collection, the majority of the mock-ups presented tools centered around maps (as in the warm-up activity). The outcomes diverge significantly in the case of Digital Wellbeing, where the emphasis shifts towards personal behaviors rather than the surrounding environment. In this context, users predominantly engaged in data collection related to their app/phone usage, incorporating features such as timers and systems to regulate smartphone access.

Additionally, we want to highlight the fact that on the occasion of WS4, we addressed a sensitive and very heartfelt subject, as described in 3.5.4. During this event, we felt an increased engagement in the warm-up activity, as the participants could identify their homes, neighbors, and the city areas most afflicted by the flood reporting, and exploited the activity to share information and news between themselves about the emergency. This experience highlights how collective trauma can change the activity's focus and the workshop's priorities. This is not intended as an issue, but rather as an opportunity to enhance the meaningfulness of the workshop for the participants while further engaging them in the educational activity.

In conclusion, the outcome of the post-activities surveys reflects a tangible demonstration of students' interest in active citizenship engagement. Feedback from participants emphasized the empowering nature of such activities, with responses indicating a positive sentiment and an understanding that contributing to global betterment is within their capabilities: "It was very nice to participate in a project that included us and made us understand that saving the world is not difficult". Moreover, a participant also expressed their interest in the workshop, suggesting its implementation as a curricular activity for civic education teachings at school, rather than as an external project: "It would be nice to involve these projects as civic education in schools and not only in special occasions like this one". This testimony reinforces the call for institutional spaces where teens can actively participate in citizenship endeavors.

3.7 Summary and key insights

In this chapter, a workshop-like experience is presented comprising different methods and concepts: design thinking, game thinking, and CS.

Through the development of four case studies, engaging 149 students (16-18 years old), the workshop technique has demonstrated its efficacy in fostering both educational and enjoyable experiences, empowering a sense of citizenship and civil engagement in the participants.

This study not only contributes valuable insights to the field of workshop-like experience design but also sets the stage for ongoing advancements in experiential learning methodologies, positioning them as dynamic tools for knowledge dissemination and skill development, in the actual context of digitalization and emerging literacies.

Nonetheless, the insights gained through the output analysis can play a pivotal role in refining and tailoring future workshop editions. By adapting the experience to contexts and themes, facilitators and educators can enhance the impact of such initiatives, fostering a continuous cycle of innovation and improvement in educational practices.

Chapter 4

AlmAware

AlmAware is a project funded by the University of Bologna through the Almaidea competitive call 2022 [1]. For this reason, the project focuses on the SDGs achievement of the University campus in Cesena and it vastly included the students as the main participants.

4.1 Introduction

Sustainability has emerged as a critical issue in modern society, capturing the attention of policymakers, businesses, and individuals, especially after the release of the 2030 Agenda for Sustainable Development [15]. In this agenda, the United Nations identified 17 Sustainable Development Goals (SDGs) encompassing environmental, social, and economic perspectives to improve sustainability by 2030. As the effects of climate change, resource depletion, and environmental degradation become increasingly evident, the urgency to adopt sustainable practices has never been greater. According to the United Nations, global CO_2 emissions reached a record high of 57.4 gigatons in 2022 (Emissions Gap Report 2023 by the United Nations [186]), underscoring the need for immediate action to mitigate environmental im-

[1] https://edu.unibo.it/it/ricerca/progetti-di-ricerca/periodo-di-programmazione-2014-2020/progetti-ateneo/almaidea

pact. At the same time, it is important not to lose sight of the social and economic aspects of sustainability. As proof of this, the alarming data from the 2023 Sustainable Development Goals Report shows that the probability that young women were not in education, employment, or training was 32.1%, compared to that of young men, which was 15.4% (more than double) [161].

In this context, universities play a pivotal role in the transition towards sustainable development [80, 178] and face a growing demand for heightened accountability [157]. These institutions are not only centers of learning and research but also serve as exemplars of sustainability in practice. By releasing comprehensive data on their sustainability efforts linked to the 17 SDGs, universities can demonstrate their commitment to sustainability stewardship and transparency. This practice also aligns with the broader trend of data democratization [16, 145], often used within corporate contexts, where making information accessible to the public (both technical and non-technical individuals) empowers communities and fosters informed decision-making, as they can find, access, interact, and share data.

The United Nations Educational, Scientific and Cultural Organization highlighted the importance of universities in implementing and conveying sustainability practices by releasing the General Guidelines for the Implementation of Sustainability in Higher Education Institutions (HEI) [87]. Based on these guidelines, there are 10 stages to incentivize a transition towards sustainability within HEI. The university community (i.e., students, academics, and administrative staff) is involved in many of these stages, especially from the beginning, where an alignment based on the meaning of the sustainability concept should be established, until their active participation in sustainable practices. Unfortunately, from a preliminary survey conducted with students enrolled in courses Mobile courses, we found out that 37 students out of 41 (90.2%) were not aware of the sustainability report released by the university. Hence, to ensure active participation, students need to be informed about the university's initiatives and practices, as well as ways they can contribute to sustainability both on and off campus. Having a system to raise awareness about these issues has become crucial, as it can also help address feelings of powerlessness and anxiety about the environment, particularly among younger people [37].

This study seeks to demonstrate the effectiveness of CS-informed co-design methodologies in developing interactive digital tools that enhance sustainability education, improve usability, and highlight the importance of personal relevance and engagement in sustainability awareness efforts in a collective context such as a University campus.

4.2 Related Work

4.2.1 Sustainable user experience and green-action

In contemporary digital contexts, there is a notable shift towards emphasizing sustainable user experience (SUX) design [88], which has become a central concern in digital product development and human-computer interaction. SUX underscores the importance of imbuing digital artifacts with features that not only meet users' needs but also encourage environmentally conscious behaviors [212]. Drawing from environmental psychology [58], design theory [110], and user-centered design principles [3], SUX proponents advocate for a comprehensive approach that prioritizes usability and aesthetics [223] while integrating considerations of ecological impact and long-term sustainability. Given the pressing challenges of climate change and resource depletion, there's a compelling urgency for digital designers to embrace sustainability principles. Using Efkolidis [73] words: "there is time to pass from *human-centered design* to *humanity-centered design*, creating a better world for the present and future generations of this planet". Thus, the ongoing discourse on SUX design marks a significant stride towards harmonizing technology with ecological stewardship in the digital era. At its core, this paradigm underscores the necessity of integrating principles of environmental stewardship, social equity, and ethical governance into computational systems and digital infrastructures. Furthermore, responsible computing for sustainability transcends mere mitigation strategies, encompassing proactive interventions aimed at leveraging technology as a driver for positive environmental and social change [135]. From renewable energy production forecasting to crop disease monitoring, and from agent-based modeling to stochastic network design, from renewable energy production forecasting to crop disease monitoring, and from agent-based modeling to stochastic network design [51], from promoting eco-friendly user behaviors to democratizing access to digital resources [98], the multifaceted pursuit of responsible computing for sustainability signifies a paradigm shift towards technologically innovative practices that are both ethically grounded and environmentally conscious.

4.2.2 HCI and green-awareness

Human-Computer Interaction studies are also investigating the opportunities and effects that technology can be crucial in enhancing environmental awareness [69], mobile applications play a critical role in catalyzing behavioral shifts towards sustainability in users' daily lives. Apps have emerged as powerful tools for fostering awareness [35], facilitating behavior change, and promoting sustainable practices among individuals. Through personalized recommendations, gamification elements, and interactive features, these platforms can effectively engage users [24] in adopting eco-friendly habits, such as reducing energy consumption, minimizing waste generation, or opting for sustainable modes of transportation. Furthermore, by providing real-time feedback and tracking mechanisms, apps empower users to monitor their progress towards sustainability goals, instilling a sense of accountability and motivation [86]. Thus, the integration of technology-enabled solutions not only enhances the user experience but also amplifies the impact of sustainability initiatives by fostering widespread adoption of environmentally responsible behaviors at scale [231].

4.2.3 Higher education students' eco-powerlessness

In the field of Human-Computer Interaction, the concept of eco-powerlessness among university students has garnered increasing attention [47, 167], reflecting the intersection of a generational eco-habitus and digital engagement [46]. Eco-powerlessness refers to the feelings of helplessness and lack of control individuals experience concerning environmental issues. This phenomenon has been explored in various studies, highlighting its prevalence and impact on mental health and behavioral intentions among lower social classes [129]. Similarly, findings from Klers et al. study [133], underscore that other groups, such as university students, often feel disempowered by the magnitude of ecological crises. University students, despite being characterized by high levels of environmental awareness [1], perceive themselves as unable to produce meaningful change with their actions [169], hence leading them to a high level of environmental awareness but mediocre environmental attitudes [14].

HCI interventions have aimed to mitigate these feelings through the design of interactive systems that promote environmental education and activism [69]. For instance, initiatives such as gamified applications, participatory platforms, and persuasive technologies are being developed to enhance students' sense of agency and efficacy [47]. These tools leverage principles of engagement [182], social support, behavioral feedback [198], and data-driven practices [34] to transform eco-anxiety into proactive environmental stewardship. The integration of HCI strategies in addressing eco-powerlessness thus represents a promising avenue for fostering sustainable behaviors and empowering young adults in the face of global environmental challenges.

4.2.4 Sustainability and Universities

The discourse on university campus sustainability and students' perceptions of sustainability [75] within campus life has garnered significant attention in academic research. Numerous studies have explored various dimensions of this topic, including institutional policies, infrastructure developments, student engagement programs, and the integration of sustainability principles into academic curricula [191]. Through these investigations, scholars have highlighted the pivotal role of universities in fostering a culture of sustainability and cultivating environmentally conscious behaviors among students.

Researchers have provided insights into the diverse array of sustainability initiatives undertaken by universities, shedding light on the strategies employed to mitigate environmental impact and promote sustainable practices within campus communities [47]. Additionally, studies have explored the correlation between exposure to campus sustainability programs [49] and students' attitudes and behaviors towards sustainability [232], emphasizing the importance of fostering a supportive environment that encourages active student participation in sustainability initiatives [227].

4.3 Methodology

Awareness can be difficult to assess effectively. For this reason, we approached the evaluation of awareness at both micro and macro levels. To achieve this, we utilized three primary techniques: semi-structured interviews, data search and analysis, and co-design.

After analyzing the data collected, we synthesized the findings into an informative booklet, which was shared with the co-design participants. The booklet served as a common starting point for the co-design activity. In the following sections, we provide a detailed explanation of the three main steps of our research.

4.3.1 Step 1: Interviews

To explore sustainability awareness, we opted for semi-structured interviews. The decision to use semi-structured interviews stemmed from their flexibility, allowing us to cover predetermined questions and explore addi-

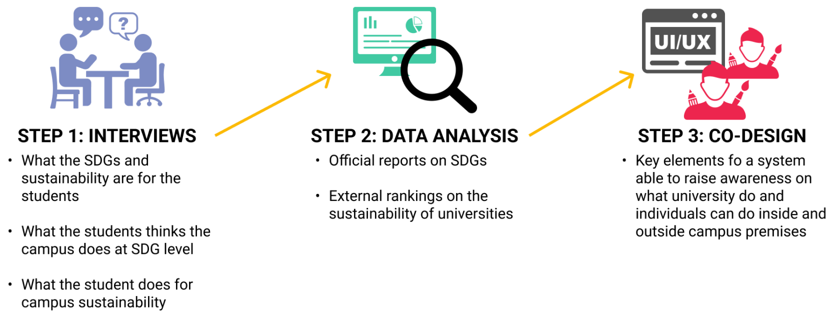

Figure 4.1: The three-step process carried out in this study.

tional topics that emerged naturally during the interviews [57]. This method helps facilitate informal conversations, making interviewees feel more at ease and enabling them to share insights on topics they deem important [188]. The informal tone also promotes discussions of sensitive issues, such as critiques, authority, relationships within academia, and emotions.

Given the setting (a university campus) and the participants (students), we designed a concise set of questions to encourage participation. This led to the creation of "quick interviews", which consisted of four questions and one optional drawing task. The questions were:

1. "What does sustainability mean for you?";
2. "How is sustainability manifesting at the campus?";
3. "What do you do for sustainability when you are on campus?";
4. "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? Feel free to explain your drawing choice if you like."

The advantage of these quick interviews was that they were not time-consuming for the participants, allowing us to conduct them during student breaks. While limiting the duration inevitably constrained the depth of the responses, participants were free to elaborate on any points of interest. The goal of these interviews was to gain a general understanding of students' sustainability behaviors on campus, and we found this method to be an effective tool for this purpose.

The data gathered from the interviews was used to identify key elements, which were then compiled into an informative booklet. This booklet was intended to present a clear view of how sustainability is perceived and experienced in everyday campus life, and how individual behaviors are influenced by it.

4.3.2 Step 2: Data Search and Analysis

The second step aimed to provide the university community with real data from both the University and external sources, examining the performance of various universities in terms of sustainability and the SDGs.

We expanded upon the SDGs identified during the interviews (Step 1) by extracting corresponding data from official sources. This allowed us to create a booklet that juxtaposed community perceptions of the most relevant SDGs in the university context with the official data.

The three sources we used for the official data were as follows:

1. The official annual report from the University of Bologna, which details the contributions of various institutional activities toward achieving the 17 SDGs [64].

2. The UI GreenMetric World University Rankings [95], which evaluates environmental sustainability in universities based on six dimensions: setting and infrastructure, energy and climate change, waste, water, transportation, and education and research.

3. The Times Higher Education Impact Rankings [221], which assesses universities based on SDGs, utilizing four dimensions: research, stewardship, outreach, and teaching.

We focused on data from the calendar year 2021, as it was the most recent available year for rankings and reports.

4.3.3 Step 3: Co-Design

After collecting qualitative data from the interviews and the subsequent analysis, the third step involved engaging the university community in a co-design activity. The primary objective of our co-design activity was to create low-fidelity mock-ups for an interactive web-based application that would raise awareness of individual contributions to sustainability on campus and inform users about the university's sustainability efforts and alignment with the SDGs.

The co-design activity was planned to last for 1.5 hours, structured as follows:

- **Introduction** (15 minutes): Participants were introduced to the project and the goals of the activity. We provided an overview of co-design and low-fidelity mock-ups, as well as suggestions on how to raise awareness through data visualization, gamification [63], and eco-feedback. At the end of this phase, participants were divided into groups of 3-4 people.

- **Co-design** (50 minutes): Participants engaged in creating paper-based low-fidelity mock-ups. To guide their work, we provided materials derived from the first two steps (interviews and data analysis), including three documents: i) a summary of the interview results, ii) the University's reports with a focus on the dimensions highlighted in the interviews, and iii) external rankings from Step 2.

- **Presentation and Questions** (5 minutes per group): Each group presented their mock-ups to the rest of the participants, who were encouraged to ask questions.

4.3.4 Interviews

The interviews aimed to provide insight into the perceived elements of sustainability on the campus. Despite the limited time allocated for the interviews, the topic of sustainability and sustainability awareness was effectively addressed. 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 taking too much of their time. Each interview lasted between 4 and 11 minutes. We conducted a total of 21 interviews with 36 interviewees.

The first interviews were conducted with one interviewee at a time, but this posed a difficulty in recruiting participants in the cafeteria. Students were more inclined to participate if a friend accompanied them. Therefore, we conducted the majority of the interviews with two interviewees at a time.

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

1. 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, and renewable energy.

2. Concerning sustainability inside the campus, 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, they noted that the heating in winter is always very high, even in empty rooms, the lights and computers in the laboratories are often left on, and the campus is somewhat unkempt, with a lack of transport options.

3. Regarding students' actions on campus, they mentioned the sorting of waste, refilling water bottles at public dispensers, attempts to limit water waste in bathrooms, and using public transport or bicycles to reach the campus.

4. The interviewees also suggested ways to increase sustainability on campus, such as further investment in solar panels or other renewable energy sources and better management of heating and electricity. They also suggested a wider selection of public transport options to reduce car usage. Additionally, they would like to see more initiatives for inclusion, such as providing sanitary pads in bathrooms.

5. Bonus: The drawings made by the participants served as a visual explanation and summary of their answers to the previous questions. As shown in Figure 4.2, the main aspects that emerged were waste sorting, the idea of circular economy, the green and environmental aspects of sustainability, and the notion that everyone should collaborate to make an impact on sustainability.

The content of these interviews was interpreted through the lens of the SDGs. The main SDGs addressed were:

- Sustainable cities and communities (SDG 11) for heating management, 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 transport,

- Clean water and sanitation (SDG 6), considering water waste, and

- Gender equality (SDG 5) regarding gender perceptions in some areas where gender balance is missing.

Based on the knowledge gathered from the interviews, we selected these SDGs as a starting point for the data search. Using this material, we proceeded with the informed co-design process by compiling the data into an informative booklet.

Figure 4.2: Drawings made by the interviewees.

4.3.5 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. Given the number of participants, we divided them into 5 groups.

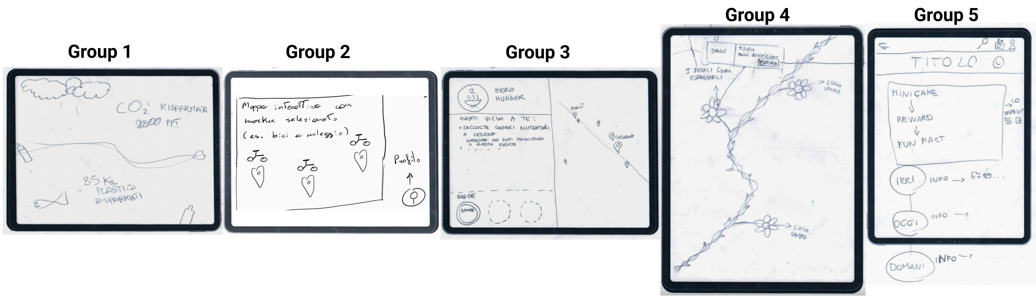

Figure 4.3: Mock-up of the five applications (one selected for each group).

Group 1: H_2unib0 The first group focused on encouraging the use of water bottles to reduce plastic on campus. They designed the home screen of the application to feature a water bottle with the water level rising according to the percentage of students who use the water dispenser on campus. This is achieved by scanning a QR code attached to the dispenser, which logs the user into the system and updates the visualization.

The application also features two additional screens: environmental impact and ranking. The environmental impact screen provides a dual visualization, as shown in the first mock-up of Figure 4.3, with the sky and sea reflecting the amount of CO_2 saved and plastic spared. As the percentage of students using the dispenser increases, the sky clears and the sea becomes cleaner.

The ranking screen displays the total liters of water dispensed by the water dispenser and ranks the community members based on their water usage, with gold, silver, and bronze awards for the top three users.

Group 2: UniboEcoMap The second group focused on encouraging more sustainable mobility to reach the campus. They designed an application in which users can log in using their university credentials, which then displays a map of their current location and shows available ecological vehicles in the area. Users can earn points for using eco-friendly transportation, such as walking, biking, or using public transport. The application tracks CO_2 saved and kilometers traveled in real-time.

The profile section of the app displays the total points earned and the user's level of experience, with additional tasks related to sustainable mobility that can be completed to earn bonus points for discounts at campus facilities.

Group 3: UniversityWheel The third group focused on creating an application based on all 17 SDGs. The app features a competition between different universities or campuses, where actions taken by users to improve each SDG contribute to the overall ranking. The app distinguishes between "quantifiable" and "non-quantifiable" SDGs. For quantifiable goals like SDG 12 (responsible consumption), users can earn points by filling water bottles at dispensers, while for more complex goals like SDG 1 (no poverty), the app suggests nearby donation opportunities.

The app also features daily and quantitative quests for each SDG, which users can complete to earn bonus points. The SDG progress is visually represented by a tree, and a public display at the campus shows the real-time progress of the university's efforts on each SDG.

Group 4: FlowersApp The fourth group focused on designing an app that represents all 17 SDGs. The home screen features a climbing plant with three flowers, each representing an SDG. By touching a petal, users can access more information about each SDG, including what they can do to improve their behavior and what the university is doing. The app also features a questionnaire where users declare their actions to support each SDG and earn points.

The profile section displays the user's progress, with graphs and a ranking system. Extra points can be earned through daily questionnaires and QR code scans at sustainability points on campus.

Group 5: AlmaHUB The final group focused on an app that includes all 17 SDGs and ranks users based on their actions. The main screen displays SDG cards, each with a simple animation. Users earn points by scanning QR codes linked to sustainability actions on campus, such as using the water dispenser or participating in eco-friendly activities. The app features mini-games related to each SDG, with rewards and fun facts at the end.

The profile section shows badges and achievements earned through daily and weekly tasks. A leaderboard with friends encourages healthy competition to complete "green" actions and contribute to sustainability on campus.

4.3.6 The system

We aimed to create a system able to raise community awareness on two fronts: i) what the university has done and is currently doing for each SDG; and ii) what each member of the community can do in daily life to improve sustainability inside and outside the campus premises and to promote a more responsible and sustainable behavior.

We designed and developed the system based on the guidelines extrapolated from a co-design session with some students of our campus [**?**]. In particular, six guidelines emerged:

- **G1: Technology.** The system should make use of some kind of technologies, in addition to the main application, to increase engagement and daily life usage;
- **G2: Content.** The system should display information and data about all the 17 SDGs to convey a more complete idea of what sustainability is (highlighting that it includes social, economic, and environmental aspects) and what can be done to improve it in daily life;
- **G3: Data producer.** The system should display individuals' data to make them aware of their impact and to mitigate eco-powerlessness feeling;
- **G4: Learning strategy.** The system should include at least one explicit learning strategy (e.g. fun fact or quiz) in order to make the users learn directly through the system's usage;
- **G5: Gamification.** The system should make use of gamification strategies, as a way to engage the community, exploiting a sense of competition between individuals;
- **G6: Data Visualization.** The system should make use of data visualization techniques in order to make the data easier to understand.

G1: Technology Considering the technological aspect derived from G1, we opted for a solution that integrates a public display version and a mobile version. We chose these two versions for their intrinsic nature. The public display, situated at the entrance of the campus, allowed us to have a public visualization accessible to everyone. This visualization has all the basic information (as shown in the upper part of Figure 4.4), allowing each community member to learn something about i) the SDGs, ii) what the university is doing, and iii) what he or she can do in daily life. The advantages are two-fold. On the one hand, the users don't have to install anything to have the basic information, and, on the other hand, based on its position, it can reach a larger population, that can casually explore the visualization.

On the contrary, the mobile version is a way to uniquely target a community member and increase his or her engagement through techniques connected to gamification and data humanism, with the final aim of promoting a more responsible and sustainable behavior both inside and outside the campus premises. As visible in the lower part of Figure 4.4, the mobile version has all the information provided by the public version to always have that information at hand, but, at the same time, it provides some tasks that the user has to complete to obtain a badge.

G2: Content There is a tendency to identify sustainability as a monolithic concept, often identified with just the environmental sphere. As emerged from the interviews we conducted during a preliminary phase of this study, the word "sustainability" was strictly linked to Earth and the environment, conscious consumption, and renewable energy, often ignoring the economic and social sphere [47]. Hence, in our system, we decided to include all the 17 SDGs to display all the different facades of sustainability. For each one, we arranged an explanatory section (part A in Figure 4.4) with a few lines of text to introduce the SDG and its main goal and three key numbers to make people reflect on its importance. All the data and information displayed are from the United Nations' official site about SDGs [160]. Moreover, since sustainability is something that can be achieved at different levels, from the "upper" level of bigger organizations or universities to the "lower" level of individuals, we structured our system's interface in a way that can display: i) information on what our university is doing for each SDG, shedding light on the reports released each year (part B in Figure 4.4), and ii) advice to accomplish a sustainable behavior about each SDGs (part C in Figure 4.4).

As shown in 4.4 **A** represents the general information about the SDG; **B** the data on what the university is doing in terms of courses related to that SDG, publications, projects, and significant data; and **C** some advice on what a person can do to improve the behavior in relation to that SDG.

Considering the university section, we analyzed the report released and selected four types of data that reflected the complexity of this kind of institution which revolves around teaching, research, third mission, and institution. For the teaching aspect, we displayed the number of courses related to that specific SDG. This data came from a survey conducted by asking all professors the link between their course unit of a study program and the SDGs. For the research side, we selected the total number of publications taken from the Scopus database, considering all articles since 2016 that contain a specific sequence of keywords (related to each SDG) and an author affiliated with the university. For the third mission, we selected the number of cooperation and social engagement projects active, providing some information in the form of a word cloud for each of them, to convey a general idea to the user. Finally, for the institution part, we selected a key number indicating what the university (institution) has made to achieve that SDG (e.g., reducing water consumption for SDG 6).

G3: Data producer The third guideline is partially connected with the previous one. In this case, the focus is on the users themselves, who will be the data producers for a section in the app, and their impact on sustainability and SDGs. Since the attention is on the individual user, we included this section only in the mobile version of the system (visible in the lower part of screenshot C in Figure 4.4). In particular, we asked the users to complete certain tasks (e.g., fill their reusable water bottles or put a timer on their shower). We identified three kinds of tasks, as visible in Figure 4.5: i) a practical activity that should be done (e.g., go to a museum [SDG 4] or reuse a water bottle [SDG 12]), ii) answer a questionnaire to test their knowledge on the topic (e.g., green power [SDG 7]) and the connection with the topic

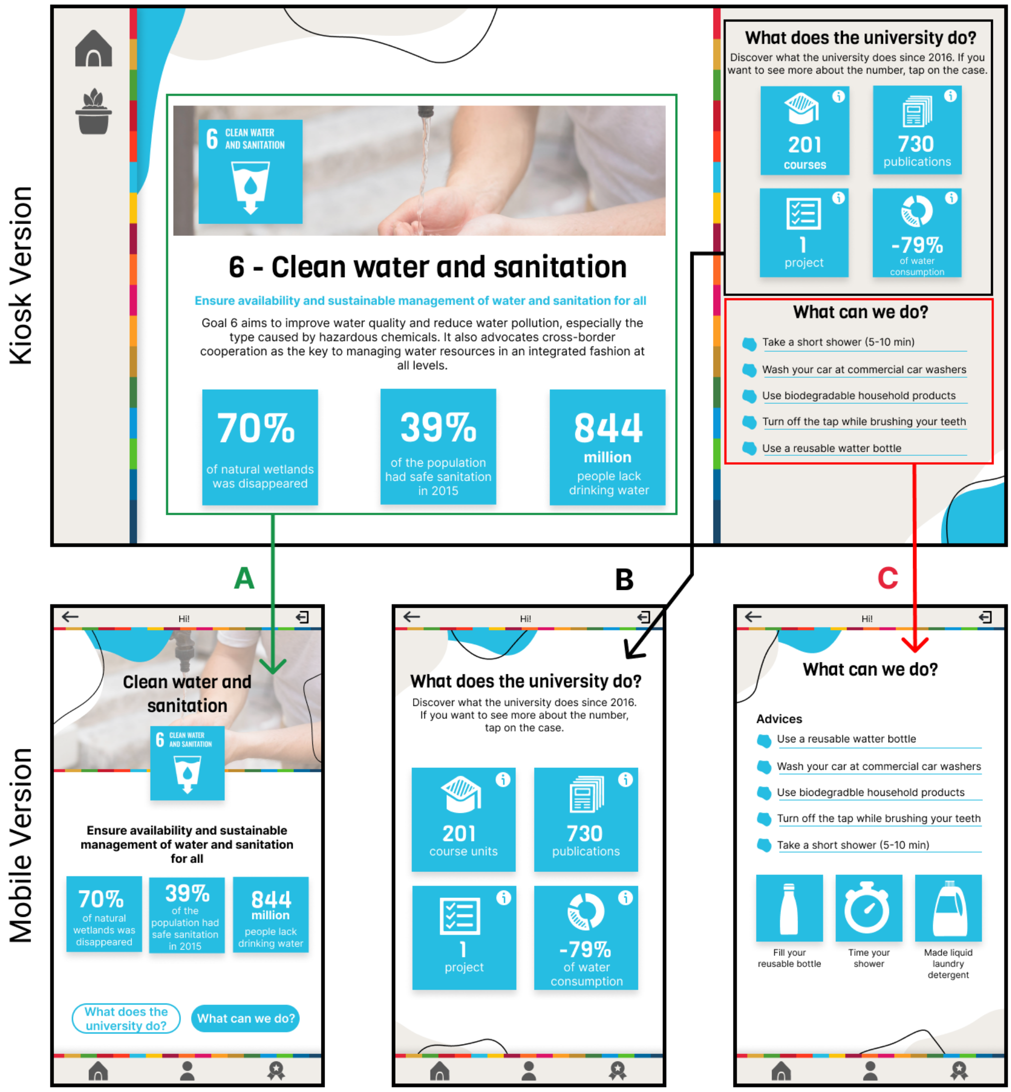

Figure 4.4: The interface of one SDG (SDG 6) both in the kiosk version (above) and in the mobile version (below).

and their daily life, and iii) read a fun fact on a topic (e.g., the negative impact of common detergents [SDG 6]). The first two types of tasks will be the source of the individual data we will display in the application to make the users more aware of their impact. We had two reasons for choosing the tasks as a form of data production inside our system. Firstly, we aimed to create practical and achievable tasks that people can incorporate into their daily lives to help them improve their behavior. Secondly, we wanted to address the feeling of eco-powerlessness that people often experience when it comes to sustainability issues. By completing these tasks, people can see that they too have the ability to make a positive impact on the environment in their own small way.

G4: Learning strategy In line with the fourth guideline, in our final prototype, we included two explicit learning strategies in the form of quizzes and fun facts, an example of this is shown in Figure 4.5, where the user is asked to i) read a fun fact about common detergent (in blue), ii) take a quiz on green power (in yellow), and ii) visit a museum at least three times (in red). The second screenshot represents the badges page, where the users can see their achievements, their badge collection, and how to collect the missing ones. Based on what emerged in the previous co-design session, almost all the groups that participated in the activity exploited fun facts or some sort of hint to inform the users about sustainability notions and curiosities that can create the desire to improve their daily behavior. Moreover, we added some quizzes to make the users learn interactively and engagingly. We believe the system can be utilized as a powerful educational tool to inspire users to make sustainable choices and act responsibly in their daily lives. By using the system, we want users to gain knowledge and insights to make well-informed decisions that will have a positive impact. Our system recognizes the importance of individual user knowledge, which is why we have included these two learning strategies in the mobile version. This ensures that users have access to personalized information relevant to their needs. On the other

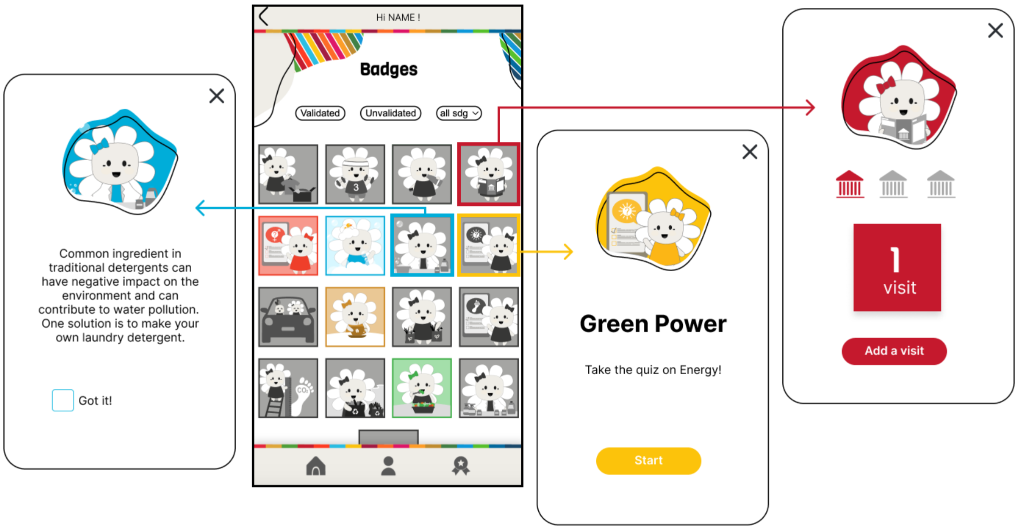

Figure 4.5: Examples of tasks and rewards in mobile version of the app.

hand, the kiosk version only displays "static information" (i.e., the general explanation of SDGs, information on the university's work, and the advice, as visible in the upper part of Figure 4.4), which is suitable for more general purposes.

G5: Gamification Based on the insights from the co-design session, we have identified four main gamification elements that can drive user engagement and enhance the overall experience. These elements include a ranking system, badges, and avatars, all of which leverage different psychological mechanisms and motivations. Inspired by the taxonomy made by Schöbel et al. ([205]), we exploit the leaderboard as intrinsic motivation in the sense that the users will do something not for an expected outcome but for the pleasure or interest it brings. Moreover, leaderboards also rely on the sense of competitiveness with other users who are members of the campus community. We decided to include only the best three positions in the leaderboard (visible in Figure 4.6). On the contrary, to spark interest in users who may not be motivated by competitiveness, we exploited badges, avatar customizations, and a communitarian representation of the app users in the form of the "university greenhouse" as an extrinsic motivation. As shown in image 4.6, the greenhouse (on the left) is visible in the kiosk version of the system, where every plant is the avatar for each community member. In this interface is also visible the leaderboard showing just the three top users. On the right, the mobile version shows the menu where every user can customize their plant and pot based on their progress in the system, where the users are forced to complete an action to obtain an outcome (a badge). All of our badges include a consistent element of surprise, as they are displayed on the badge board within the mobile version of the system (shown in the second screenshot in Figure 4.5) so to both intrigue players in unlocking them to access new colors while giving them the information on how to unlock them. Although we implemented both static and developing badges. The static badges (e.g., reading the fun fact on detergent or answering the green power quiz in Figure 4.5) are obtained for doing quizzes or one-time actions. On the contrary, the developing badges are obtained after doing a positive action several times (e.g., going to a museum three times). Finally, we included an avatar, in the form of a plant with its pot, to represent each user. The avatar relies on intrinsic motivation, and in our case study, we exploit a developing user avatar, where the avatar became the visualization for the user's progress in the system. As a matter of fact, the users can personalize their plants and plots. In particular, the users can change the color of the plot by choosing between the 17 solid colors of the 17 SDGs and some colorful textures. The color is unlocked based on the badges earned: once the users complete all the tasks for an SDG, its color is unlocked and can be used for the plot. Moreover, the users can personalize the plant, choosing between different kinds of leaves and flowers. This personalization is linked to the number of badges earned: by increasing the number of completed tasks, the users increase the possibilities of choice.

G6: Data Visualization As our system wants to convey a lot of data and information, we included different kinds of data visualization techniques

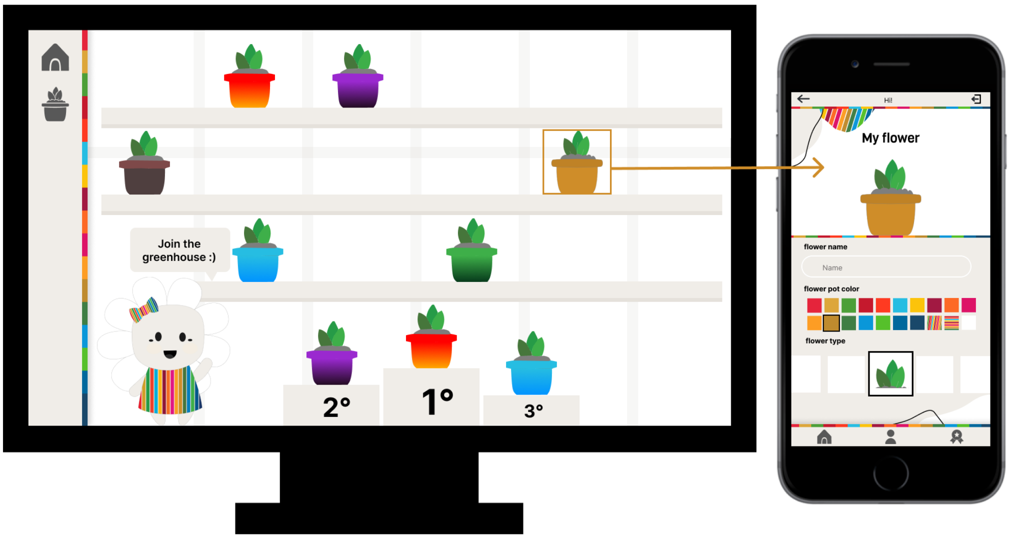

Figure 4.6: The greenhouse and leaderboard visible in the kiosk, and the avatar customization menu available in the mobile version.

to make them more understandable and insightful for the final user. In particular, we decided to exploit a word cloud to synthesize the description of the different projects carried on by the university, highlighting the most important keywords to give the users a general idea at first sight. At the same time, for some SDGs, we have some historical trends to provide more details instead of just a key number. For example, going back to Figure 4.4, we implemented a click on the block "-79% of water consumption" that will show a line chart displaying water consumption data from 2015 to 2021 (the year of the last report released at the time of the study, due to the long release times of the report itself). Both visualizations are visible in Figure 4.7, and the users can see them by clicking on the relative block to gain an explanation (the two lower blue blocks in Figure 4.4). Finally, we exploited the plant and the plot as a form of data visualization, in line with the data humanism concept [150] to show the progress of the users and their positive behavior and impact, thanks to the actions undertaken: more the plant is personalized and thriving, the more the user has done good deeds. All the data visualizations produced are visible in both the mobile and kiosk

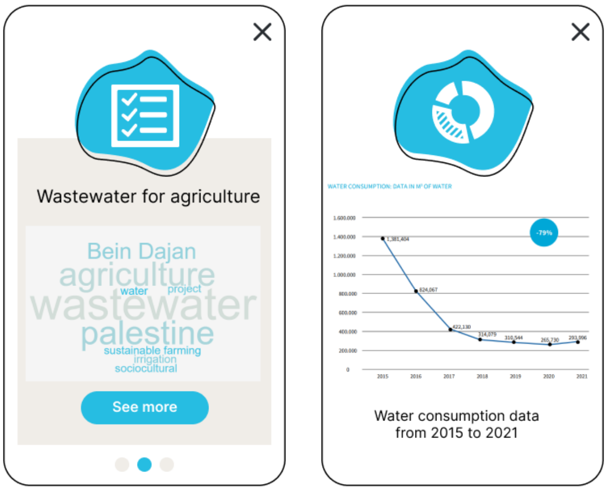

Figure 4.7: Examples of two data visualizations. Project keyword in word cloud and the decreasing water consumption trend through a line chart.

versions.

4.4 Evaluation

To address our RQs (Sec. 1.2.2) and investigate the effectiveness of i) the guidelines extrapolated from the co-design session and ii) our prototype, we designed an evaluation in two phases. The first was the direct interaction with our prototype, and the second was an online questionnaire addressed to the university community to gain both quantitative and qualitative data.

4.4.1 Interaction with our prototype

First of all, we made the participants interact with our prototype (both the kiosk and the mobile version) using Maze[2]. In particular, we created some tasks to guide their interaction and make sure that they will discover all the sections of our system. For both the kiosk and the mobile version, we asked the participants to:

[2] https://maze.co/

1. learn more about SDG 6;
2. discover more about the course number and how this number is calculated;
3. discover more about the number of publications and how this number is calculated;
4. discover more about the projects;
5. discover more about the water consumption trend based on the university policies.

After that, for the kiosk version, we focused on the plant and the greenhouse. In particular, we asked the participants to explore the greenhouse and discover more about the user who is currently in second place on the leaderboard. For the mobile version, we focused on the user, making the participants discover more about the task they should complete in order to obtain badges (like "time your shower"), their user's profile, their plant with the options to customize it, and the badges page.

Once all the tasks were completed, we redirected the participants to our questionnaire.

4.4.2 Online Questionnaire

Before accessing the online questionnaire, we provided the participants with a brief explanation of the project and explicitly asked for their informed consent to store and analyze the data, in an anonymous and aggregated form.

Our online questionnaire consisted of four sections. The first section (Q1-Q18) revolves around the user experience, the second one (Q19-Q30) wants to test the effectiveness of the guidelines extrapolated from the co-design session with students, the third one (Q31-Q33) investigates the relationship between the university (and its sustainable practices) and the community member, and the last one (Q34-Q38) asks for feedback on the project and demographic information.

Section	ID	Question
User Experience	Q1-Q8	User Experience Questionnaire [Kiosk version]
	Q9	How clear is the information communicated? [Kiosk version]
	Q10-Q17	User Experience Questionnaire [Mobile version]
	Q18	How clear is the information communicated? [Mobile version]
Guidelines effectiveness	Q19	How useful is it to have **general information** on each SDG?
	Q20	How useful is it to have information and data on what the **UNIVERSITY** does for each SDG?
	Q21	How useful is it to have information on what **YOU** can do for each SDG?
	Q22	How useful is it to have both the **KIOSK** version (available for everyone) and the **MOBILE** version (customizable for the individual)?
	Q23	How useful is it to have **QUIZ** as a way to learn new things about SDGs?
	Q24	How useful is it to have **FUN FACTS** as a way to learn new things about SDGs?
	Q25	How much the **VISUALIZATION** with the plants and the greenhouse will influence the use of the system?
	Q26	How much the plants and the greenhouse can create a **sense of community**?
	Q27	How much **BADGES** can influence the use of the system?
	Q28	How much **BADGES** can improve the user behavior in daily life?
	Q29	How much **LEADERBOARD** can influence the use of the system?
	Q30	How much **LEADERBOARD** can improve the user behavior in daily life?
	Q31	How useful is it to have **TASKS** connected to BADGES to get feedback on your behavior?
Relationship user-university	Q32	Did you know that the university releases reports every year on what it does for each SDG?
	Q33	Could knowing that the university is moving towards sustainability be a criteria for choosing a university?
	Q34	Does the fact that the university context promote sustainability influence your behavior on campus (or off)?
General questions	Q35	Please, share any comments you might have on the project
	Q36	What degree are you enrolled in?
	Q37	What gender do you identify with?
	Q38	How old are you?
	Q39	What is your background?

Figure 4.8: Questions asked in the online questionnaire divided in the four sections.

First section: User Experience In the first section, we investigated the user experience in both the kiosk (Q1-Q8) and the mobile version (Q10-Q17). In particular, we exploited the short version of the User Experience Questionnaire (UEQ-S), which consists of eight 7-point Likert scale questions to evaluate pragmatic and hedonic quality [207]. The pragmatic interaction qualities encompass the product's capacity to effectively assist users in completing their tasks, its ease of use, which includes intuitive navigation and user-friendly features, its efficiency in enabling users to achieve their goals promptly, and its ability to provide clarity and minimize confusion in the user experience. The hedonic qualities refer to the emotional and experiential aspects of user interaction with a system, rather than its ability to help users achieve specific goals. Specifically, the questionnaire aims to evaluate the level of excitement and interest elicited by the system, as well as how cutting-edge and inventive the users perceive the system. Finally, to complete this section, we included two questions (one for the kiosk version and one for the mobile) related to the clarity of the information communicated (Q9 and Q18).

Second section: Guidelines effectiveness In the second section, we focused on testing the effectiveness of the guidelines extrapolated from the co-design session. In particular, focusing on the system's content (G2), we wanted to verify the benefit of displaying i) general information about each SDG to give a context for our system (Q19), ii) information and data on what the university is doing toward sustainability (Q20), and iii) information on what an individual can do to improve its behavior in terms of sustainability (Q21). Then, we focused on the technological aspect (G1), asking an opinion on the usefulness of having both a kiosk version, which will be made available for everyone at the entrance of the campus, and a mobile version, which will be customizable for the individual (Q22). Concerning the learning strategy (G4), we included two questions on the effectiveness of quizzes and fun facts as a way of learning new things (Q23-Q24). For the guideline on gamification (G5), we investigated the influence of badges and leaderboards on the system's usage (Q27 and Q29) and the improvements in users' behavior (Q28 and Q30). Concerning G3 ("data producer"), we did not include any particular question, but we exploited a combination of the previously mentioned questions, and, in particular, Q21 and Q27-Q31. As a matter of fact, the way for the individual to "produce" data or see his/her impact is through the information on what he or she can do and through the badges obtained with the task. Finally, to test the guideline on data visualization (G6), we included two questions on the effects of plant visualization and greenhouse. In particular, we investigated whether this kind of visualization can foster the system's usage (Q25) and can eventually create a sense of community inside the campus (Q26).

Third section: Relationship between the user and the university The third section wanted to investigate the relationship between the user, as a university member, and the university. In particular, we were interested in discovering whether the users already knew the existence of sustainability reports released by the university (Q32), as well as a way to improve the importance of this system within the community. Then, we wanted to investigate if the sustainability actions and practices carried on by the university can be a way to help teenagers in their choice of the university, as a form of discernment (Q33). Finally, we explored whether studying in a context that emphasizes improving sustainability would positively impact individuals, both on and off campus (Q34). These two last options are only possible if the university's sustainability efforts are clearly and effectively communicated to everyone.

Fourth section: General questions Finally, in the last section, we asked the participants for qualitative feedback on the project (Q35) and their demographic data, like their degree (Q36), gender (Q37), age (Q38), and background (Q39).

4.5 Results

The evaluation of the interactive system designed to raise sustainability awareness within the university community provided valuable insights into its effectiveness and areas for improvement. Participants included 66 students, who engaged in a co-design session and subsequently interacted with both the kiosk and mobile versions of the prototype. This section presents the key findings, emphasizing quantitative results, guideline validation, and behavioral impacts.

4.5.1 Quantitative Insights

The information gathered through the questionnaires gives insight into the perception of the respondents regarding the KIOSK and MOBILE applications, both designed to increase knowledge about sustainability goals. The results show that, in general, there is a positive response toward the educational support and usability of both prototypes, although there are some areas identified for improvement in terms of user engagement and the perceived usefulness of additional features.

Respondents rated both apps as highly effective in supporting learning about sustainability. The KIOSK app averaged 5.67, and the MOBILE app averaged a slightly higher 5.88, thus showing that both apps are viewed as useful in education. Moreover, when asked about the efficiency of the applications in conveying sustainability information, the KIOSK scored 5.71 and the MOBILE application scored 5.92, which again gives support to the idea that both are perceived as efficient in delivering educational content.

Usability was another area where both applications did well. The KIOSK application scored 6.20 for ease of use, which was equal to the MOBILE application, which also scored 6.20. The high ratings suggest that the participants found both applications to be user-friendly and easy to navigate. In terms of clarity, both apps were rated highly, with the KIOSK application receiving a rating of 5.97 and the MOBILE application achieving a slightly higher rating of 6.21, indicating that participants found the information clear and easy to understand.

Regarding engagement, both applications were considered moderately engaging. The KIOSK application was rated 4.92 for the attribute of "passionate", while the MOBILE application achieved a score of 5.27. These are indications that there is some level of engagement, but also that the applications were not overwhelmingly engaging for all participants. On the question of interest level, the KIOSK application had a score of 5.68, while the MOBILE application had a score of 5.52, indicating that the content was viewed as interesting, even if it might not have been exciting for all the users. Speaking about the originality and modernity aspects, both applications were rated positively. The KIOSK application was rated with a score of 5.91 for originality and 5.77 for modernity, while the MOBILE application reached scores of 5.80 for originality and 5.91 for modernity. Those kinds of scores indicate that participants indeed considered both applications innovative and up-to-date.

The usefulness of the sustainability-related content was, however, rated somewhat lower. The general rating of the sustainability goals was 4.27, while the rating of UNIBO's performance regarding these goals was 4.03. In contrast, the rating of data on personal actions for sustainability obtained a slightly higher score at 4.45, thus showing that respondents felt more personal relevance in this particular aspect. An average score of 4.30 on bringing out a KIOSK and customizable MOBILE version meant the suggestion received mixed views about the importance of having both formats available.

Overall, the impact of the added interactive elements, such as quizzes, fun facts, plant visualizations, badges, and leaderboards, was mostly deemed as minimal. Quizzes scored 4.23, fun facts 4.58, plant and greenhouse visualizations 4.11, and badges 3.85, indicating that these features did not significantly enhance user engagement or perceived effectiveness. These showed means of 4.17 for the use of the systems and 4.06 for the perceived capability to affect daily habits, reflecting moderate interest in these gamified aspects but low confidence in their effectiveness in bringing about behavioral change.

4.6 Discussion

These results give several important insights into the perceived efficacy and usability of the KIOSK and MOBILE applications designed for user education on sustainability goals. While both platforms received largely positive reviews concerning educational facilitation, clarity, and user-friendliness, some elements of both require further examination and improvement, particularly in terms of user engagement and the perceived effectiveness of some of the interactive features.

An additional, distinct advantage that both apps enjoy lies in their perceived ability to make learning possible or more likely. The interview respondents provided KIOSK and MOBILE prototypes with fairly high effectiveness and clarity ratings in bringing out information relating to sustainability, ranging from 5.67-5.92 for effectiveness and between 5.97 and 6.21 for clarity. The results of this study correspond with the aims of the project, indicating that the applications achieve their primary purpose of enhancing understanding of sustainability. This is especially important given the growing demand for accessible and efficient educational resources designed to elevate awareness regarding sustainability issues and potential solutions.

Usability was another area where both applications performed well. The usability ratings for both prototypes (6.20) suggest that users perceived them as intuitive and accessible. This is a promising result, as it indicates that the applications do not present significant barriers to user interaction, which is important in achieving widespread adoption and continued use. The high usability scores suggest that users are more likely to use the platforms more frequently, thus fostering regular learning and exposure to sustainability-related content.

However, despite these positive results, there were also considerable concerns regarding the level of user engagement and perceived usefulness of additional features.

The applications were deemed intriguing, as evidenced by the KIOSK application attaining a score of 5.68 and the MOBILE application achieving a score of 5.52; however, both were rated relatively low on the metrics of engagement or "passion" (KIOSK: 4.92, MOBILE: 5.27). These findings indicate that although the content is perceived as pertinent and informative, it is reasonable to conclude that the attractiveness of the applications may not reach the anticipated levels. Given that the prototype is a low-fidelity version that features a simple user interface and limited interaction capabilities, one would expect user engagement to be relatively modest. Taking these facts into consideration, the findings provide a very strong foundation for further developing a fully functional application in the future. With much better user interfaces, more interactive functionalities, and generally more colorful designs, later versions can significantly improve levels of user engagement and satisfaction. The relatively low ratings for the interactive elements, such as quizzes, fun facts, plant visualizations, badges, and leaderboards, really point out the need for improvement in this area. In particular, badges were rated extremely low at 3.85, which suggests that gamification elements may not be as effective as expected in motivating users to use the application or in changing their behavior. These findings will hint at the fact that, in subsequent versions of these applications, there will have to be an investigation into possibly quite different user engagement strategies by providing even more dynamic, personalized content or social functionalities that offer a sense of community and competition.

Another interesting finding was the participants' moderate ratings for usefulness related to the sustainability content.

While participants found general information about sustainability goals and personal actions useful, the evaluations of contributions made by UNIBO to sustainability, as well as the impact of the KIOSK and MOBILE formats, were less positive. This suggests that people may not feel a strong personal connection to the institutional efforts described in the apps; this gap might be partially bridged by making the content more relevant to users' personal lives and experiences. Correspondingly, the idea of offering both a KIOSK and customizable MOBILE version was seen as somewhat useful, which might indicate that users would not see the need for multiple formats if the content is sufficiently flexible within a single platform. Scores as to originality and modernity were also positive, both the KIOSK and MOBILE applications satisfied the participants, indicating they felt the designs were modern and innovative. To be specific, this implies that the applications correspond with contemporary standards for digital applications and may attract a wider audience. In a nutshell, while the KIOSK and MOBILE applications show tremendous promise in their educational value, clarity, and usability, there are certainly opportunities to make improvements in terms of engaging users and optimizing interactive elements. Any future developments should focus on increasing user engagement by adding more dynamic, personalized content and exploring options for including more interactive, behavior-modifying gamification elements. Further, increasing the personal relevance of the content and researching how to strengthen the rapport between users and sustainability goals may help in developing a more pleasant overall user experience as well as the effectiveness of the applications.

4.6.1 Answer to RQ1

Ultimately, the results, which are presented in this chapter, provide an answer to the RQs (Sec. 1.2.2), therefore providing an insight into how CS-informed co-design processes impact the development of interactive digital tools intended to raise sustainability awareness. On the one side, concerning RQ1 (Sec. 1.2.2), these findings underline the effectiveness of the employed methodologies in terms of engagement and collaboration among participants. Participants in the *AlmAware* case study are represented by university students, who took an active part in the design process through interactive workshops and prototype evaluation, proving their ability to create meaningful digital products that aim to raise sustainability awareness in their specific cohort. While this chapter focuses primarily on university students, the data, paired with the other case studies' findings, shows broader potential for CS-inspired co-design methods for engaging diverse groups of people.

4.6.2 Answer to RQ2

On the other side, hence answering RQ2 (Sec. 1.2.2), the benefits of such community participation in those co-design processes are various. Participants not only gained knowledge about the sustainability goals but also showed much appreciation for the usability, clarity, and educational value of the tools. By addressing real-world challenges through creative and collaborative design, the co-design process allowed participants to reflect on their sustainability issues and assess possible behavior changes. Although some limitations have been identified concerning user engagement and the effectiveness of interactive features, the findings emphasize the importance of community-oriented approaches in designing influential digital tools.

In summary, the outcomes of this research confirm the ability of CS-informed co-design methods to engage participants and deliver tangible benefits in raising awareness of sustainability. While challenges remain, including how to enhance user engagement and optimize interactive elements, this study highlights the effectiveness of this approach in achieving educational and participatory outcomes. These findings further the general understanding of how co-design methods might be applied to create impactful and meaningful tools for sustainability.

4.7 Summary and key insights

The case study of *AlmAware* is emblematic of what can be achieved with the use of technology-based applications to raise awareness about sustainability in education. Through its application of gamification, data visualization, and customized user engagement, the program has created a platform where participants not only learn about issues related to the UN SDGs but also actively become part of their implementation. The inclusion of user-centric features, such as customizable avatars and progress-linked visualizations, demonstrates how intrinsic and extrinsic motivators can be used to increase participation in sustainability efforts.

Preliminary feedback indicates that there is a high degree of usability and intuitive design, with user engagement in interactive features such as quizzes and badges providing an area that possibly needs further development. This gives us insight into the fact that future iterations should explore more immersive and socially engaging features. Additionally, the difference between users' interest in institutional contributions and personal relevance to the content underlines the great importance of tailoring applications so that they are more closely aligned with individual experience and community context.

AlmAware sets a standard for university responsibility in the promotion of sustainable practices, correlating effectively institutional goals with individual behaviors. The learning gained allows for the creation of not only instructive but also instrumental educational tools in the promotion of global sustainability goals.

Chapter 5

Adrinclusive

Adrinclusive is a Croatia-Italy Interreg [1]. The project focuses on the creation of a valid touristic offer for people with dementia and Alzheimer's and for their caregivers. Within this project, Adrinclusive is looking to design digital tools to educate tourism professionals about dementia and Alzheimer's and a web platform to collect all the projects' touristic proposals in a user friendly way as the main target users are seniors over 65 years old. In the chapter, we present the first results of the preliminary research that enabled the first steps in the design process of the Adrinclusive web platform and the first round of workshop with stakeholders to discuss the educational skills necessary for tourism professionals who wish to create dementia-inclusive travel experiences.

5.1 Introduction

The rising prevalence of dementia within European Union countries, as highlighted by Graham [94], is a trend that is closely tied to demographic shifts and an aging population, particularly in countries like Croatia and Italy. This growing prevalence presents significant challenges for the near future, especially in sectors like tourism, where there is an increasing need

[1] `https://www.italy-croatia.eu/it/web/Adrinclusive`

for inclusive and accessible options to accommodate all travelers, including those with cognitive impairments. This chapter offers a detailed analysis of the types, numbers, and characteristics of tourists with dementia and cognitive decline within the Italy-Croatia Interreg region. Drawing on a comprehensive review of existing research and epidemiological studies, the report provides valuable insights into how this demographic can be effectively integrated into sustainable tourism initiatives. However, it is important to note the lack of specific national data for both countries, particularly in Croatia, where there is no official national registry for People with Dementia (PwD) [155]. This absence of precise data adds a layer of complexity to the analysis of this population within this particular geographic region. As a result, the literature reviewed often relies on broader studies focusing on the Italian, European, or global populations, necessitating the use of estimates to depict the situation of PwD in this area. The report also highlights the importance of understanding the Severity Distribution of Dementia (SDD), drawing on findings from Yuan's study [251]. This data is crucial for a subsequent market analysis, which aims to assess the economic sustainability of offering inclusive vacation options for PwD in the HR-IT Interreg region, where the *Adrinclusive* project operates [2]. The emphasis on the severity of dementia is key to tailoring tourism initiatives that not only meet the needs of this group but also ensure that such ventures are economically viable in the long term.

5.1.1 Preliminary research

In *Adrinclusive*, some background information was investigated in order to contextualize the efforts to answer the RQs 1.2.2 in the next steps of this project. Given the early stage of the project, this case study presentation will provide preliminary data used to prepare the base on which the project will then develop. On the one hand, in the context of *Adrinclusive* was mandatory to deepen the knowledge of the demographics of dementia and Alzheimer's

[2] https://www.italy-croatia.eu/it/web/Adrinclusive

population in Italy. On the other hand, it is necessary to address the main stakeholders to get a grasp on their real-world experiences in caring and providing services for people with these conditions. Firstly, to resolve the gap in the demographic knowledge of dementia illness, we created the first, to the best of our knowledge, an indicator that allowed us to map the demographic distribution of people with dementia on the Italian territory. Secondly, we invited the major stakeholders to a focus group event to provide answers to some pressing questions on the topic that will provide a solid working ground for the next project steps.

5.2 Related work

The characteristics of persons with dementia in Italy have been extensively examined through a variety of studies, each contributing valuable insights into the epidemiology, demographic trends, and the complex challenges associated with managing dementia within this population. These studies consistently indicate that the majority of PwD in Italy are elderly, predominantly over the age of 75, with a significant proportion being women. This gender disparity is largely attributed to the higher life expectancy of women, resulting in a larger population of elderly women who are more susceptible to developing dementia, particularly Alzheimer's disease [65]. The disproportionate impact on women also highlights the importance of gender-sensitive approaches in both research and the provision of care.

Among the key studies, the Conselice Study of Brain Aging and the Italian Longitudinal Study on Aging (ILSA) [153] offer critical data on the incidence and risk factors associated with dementia in the Italian population. These studies confirm that age remains the most significant risk factor for dementia, with incidence rates increasing sharply among the oldest age groups. Furthermore, the research suggests that educational attainment plays a protective role against dementia, with lower levels of education being associated with a higher risk of developing Alzheimer's disease. This correlation emphasizes the importance of social and cultural contexts in shaping behaviors, lifestyle choices, and cognitive resilience, which collectively may contribute to delaying the onset of dementia symptoms. The ILSA study also highlights a gender-specific risk pattern, where women are found to be more prone to Alzheimer's disease, while men show a higher risk for developing vascular dementia. This finding suggests that the pathophysiology of dementia may differ between genders, necessitating tailored approaches in both prevention and treatment strategies.

The studies also reveal significant gaps in the current state of dementia care in Italy, particularly within nursing homes, where there is a concerning level of underdiagnosis. Many cases of dementia go unrecognized due to inadequate screening protocols, which are often insufficiently rigorous or inconsistently applied. When dementia is diagnosed, the treatment approach tends to rely heavily on pharmacological interventions, despite the growing body of evidence supporting the efficacy of non-pharmacological therapies. These alternative treatments, which can include cognitive stimulation, physical activity, and social engagement, are underutilized in the Italian healthcare setting. The over-reliance on medication, combined with the underuse of holistic and patient-centered care strategies, underscores the urgent need for systemic improvements in dementia care. This includes enhancing diagnostic accuracy, ensuring early detection, and integrating a more comprehensive array of treatment options that address the multifaceted needs of PwD. Ultimately, these insights point to the necessity of a more robust and holistic approach to dementia care, one that not only improves the quality of life for individuals with dementia but also supports caregivers and healthcare providers in delivering more effective and compassionate care.

5.2.1 Severity Distribution of Dementia and relevance for tourism

The SDD among PwD is a crucial factor in understanding and evaluating the potential market for tourism services tailored to this population. This distribution not only influences the type of accommodations and activities that would be appropriate but also has significant implications for the design of support services and care during travel. Yuan's comprehensive study [251] on the severity distribution of Alzheimer's disease, which draws on extensive data from the Framingham Heart Study [61], provides a detailed breakdown of dementia severity levels. According to Yuan's findings [251], the distribution of Alzheimer's disease dementia among patients aged 50 to 94 years is as follows: 50.4% of individuals are in the mild stage of dementia, 30.3% are in the moderate stage, and 19.3% are in the severe stage. These statistics suggest that a substantial proportion of PwD are in the early stages of the disease, where they retain a degree of independence and could potentially benefit from specially designed tourism experiences. This demographic represents a significant market segment that could be catered to with the appropriate infrastructure and services, such as guided tours that are sensitive to cognitive limitations, accommodations that provide a safe and supportive environment, and staff trained to assist PwD with their specific needs. Moreover, the moderate stage of dementia, which affects 30.3% of PwD, presents a different set of challenges and opportunities for the tourism industry. Individuals at this stage may require more intensive support and care, yet they still may be able to enjoy travel experiences with proper planning and accommodations. For instance, organized group travel with medical supervision, specialized transportation services, and access to healthcare facilities could make tourism a feasible and enjoyable activity for those in the moderate stage of dementia. The 19.3% of individuals in the severe stage of dementia, although representing the smallest group, highlight the importance of highly specialized care and the need for significant medical support if travel is to be considered. For these individuals, travel may be more about providing comfort and familiar surroundings rather than exploration, emphasizing the role of respite tourism services for caregivers and families.

The symptoms of dementia vary significantly across its different stages, each requiring distinct approaches to support and care. The mild stage of dementia (50.4%) involves memory lapses, difficulty concentrating, and occasional confusion, but individuals can still maintain independence in familiar environments. Tourism for this group could include guided tours and accommodations with light support and dementia-trained staff. In the moderate stage (30.3%), individuals need assistance with daily tasks and experience greater memory loss and confusion. Tourism options might include structured group travel with medical supervision and specialized accommodations for increased support. The severe stage (19.3%) is marked by profound cognitive decline and complete dependence on caregivers. Travel for this group would focus on providing comfort and familiar surroundings, with highly specialized care and medical support.

5.2.2 Implications for sustainable tourism

The insights gained from these studies have profound implications for the development of sustainable tourism initiatives for PwD in Italy. As the population continues to age, the significant proportion of individuals in the mild stage of dementia represents a considerable, yet often untapped, market potential for inclusive tourism services. These services not only address the specific needs of PwD but also contribute to a broader understanding of how tourism can be made more accessible and enjoyable for all individuals with cognitive impairments.

However, successfully integrating PwD into the tourism sector requires a comprehensive understanding of their unique needs and the challenges posed by the progression of dementia. This includes recognizing the diverse ways in which dementia can impact an individual's ability to engage in travel and leisure activities, as well as identifying the specific accommodations necessary to support their participation in tourism. Such understanding can lead to the creation of tourism offerings that are not only accessible but also enriching and fulfilling for PwD and their caregivers.

Tourism services must be designed with flexibility and accessibility in mind, particularly for those in the mild and moderate stages of dementia.

This approach entails offering tailored travel experiences that provide cognitive stimulation, social interaction, and a supportive environment that promotes a sense of independence and well-being. For individuals in the severe stage of dementia, more specialized care may be necessary. While this might limit their participation in traditional tourism activities, it also opens up opportunities for niche markets focused on respite care and specialized vacation settings that cater to the needs of both PwD and their caregivers.

Moreover, the findings emphasize the critical need for enhanced training for tourism professionals to effectively handle the unique challenges presented by PwD. This training should encompass a deep understanding of the progression of dementia, including the ability to recognize early signs of cognitive decline and to provide appropriate support throughout the tourist experience. Additionally, it should prepare professionals to offer a safe, respectful, and enjoyable experience for all tourists, ensuring that the tourism industry is truly inclusive and responsive to the needs of a diverse population.

As outlined in this chapter, people with dementia, as well as their caregivers, often seek vacations that are calm, predictable, and supportive. These travelers tend to prefer environments that minimize stress, with clear signage, safe and easily navigable spaces, and activities that promote relaxation and well-being. Their habits and behaviors while traveling typically reflect a desire for familiar routines, slower-paced activities, and guided experiences that can offer a sense of security. Preferences in tourism services and accommodations for people with dementia further include well-trained staff, accessible facilities, and accommodations designed to reduce confusion and anxiety. This might involve dementia-friendly hotel rooms equipped with visual cues, sensory-friendly environments, and accessible designs. Travel providers should also consider offering experiences that encourage social interaction in small, manageable groups or provide private spaces where individuals and their caregivers can unwind.

5.2.3 Italian national dementia report

The *Osservatorio Demenze* [3], established under the *Istituto Superiore di Sanità* (ISS), plays a crucial role in monitoring, researching, and addressing the growing challenge of dementia and related cognitive disorders in Italy. The ISS, Italy's leading public health institution, has been at the forefront of health research and policy for decades, providing critical insights and guidance on various health issues, including neurodegenerative diseases.

One of the key initiatives of the Osservatorio Demenze is the ongoing production of comprehensive national reports on Alzheimer's and other forms of dementia. These reports offer vital estimates and trends related to dementia in Italy. Over the years, they have become essential tools for policymakers, healthcare providers, and researchers, helping to shape strategies and interventions aimed at improving the care and quality of life for those affected by these conditions.

The latest report, published in 2024, continues this tradition by providing updated estimates on the prevalence of dementia and Mild Cognitive Impairment (MCI) in Italy, using data from a variety of high-quality sources. These estimates are crucial for understanding the current impact of dementia and for planning future healthcare services and interventions.

In their latest report, estimates of dementia cases in Italy were derived using age- and sex-specific rates. For late-onset dementia, these rates were based on a systematic review of high-quality European population studies. For early-onset dementia, rates were gathered from data specific to the province of Modena. Mild Cognitive Impairment (MCI) estimates were calculated using sex- and age-specific rates from a systematic review of 11 population studies covering the United States, Europe, Asia, and Australia. As of January 1, 2023, based on ISTAT data [4], there are an estimated 1,126,961 cases of dementia among individuals aged 65 and older in Italy, and 23,730

[3] https://www.demenze.it/

[4] https://noi-italia.istat.it/pagina.php?id=3&categoria=3&action=show&L=0

cases of early-onset dementia among those aged 35 to 64. Additionally, the number of people with MCI is estimated to be 952,101. The female-to-male ratio for late-onset dementia is 2.3:1 for those aged 65 and older and 1.08:1 for early-onset dementia in the 35-64 age group. For MCI, the female-to-male ratio is 1.3:1.

5.2.4 Severity Distribution of Dementia in the Italian context

Starting from the data from the Italian National report, we proceed here with an extension of their analysis to assess the SDD thanks to the work of Yuan [251]. In doing so, we create the metadata useful for estimating the SDD in Italy. This will allow us to start speculating on the number of people that *Adrinclusive* and inclusive tourism proposals could reach.

As the population ages across Europe, the number of individuals living with dementia continues to rise, particularly in regions like Italy and Croatia. This demographic shift presents a unique challenge but also a significant opportunity for the tourism industry in the Adriatic area. The *Adrinclusive* project aims to address these challenges by promoting inclusive tourism that caters specifically to the needs of PwD in this region. In this chapter, we explore the market potential for such services, focusing on key Adriatic regions, and offer insights into how these opportunities can be harnessed effectively.

5.3 Methodology

5.3.1 Focus groups

The *Adrinclusive* project used focus groups as a core qualitative research method to explore and address the educational needs of tourism professionals who wish to create dementia-inclusive travel experiences. Focus groups are particularly well suited to such exploratory and participatory research because they actively engage multiple stakeholders in a rich ex-

Severity Distribution of Dementia on the Italian territory						
	Tot (%)			Mild (%)	Moderate (%)	Severe (%)
	100			50.4	30.3	19.3
County	Popolazione 65+	Casi	Tot (%)	Mild (N.)	Moderate (N.)	Severe (N.)
Abruzzo	321,260	25,876	8.05	13,042	7,840	4,994
Basilicata	133,637	10,683	7.99	5,384	3,237	2,062
Calabria	434,715	32,954	7.58	16,609	9,985	6,360
Campania	1,150,367	80,706	7.02	40,676	24,454	15,576
Emilia Romagna	1,086,041	90,940	8.37	45,834	27,555	17,551
Friuli Venezia Giulia	320,870	26,724	8.33	13,469	8,097	5,158
Lazio	1,322,946	104,656	7.91	52,747	31,711	20,199
Liguria	434,824	38,498	8.85	19,403	11,665	7,430
Lombardia	2,327,672	187,773	8.07	94,638	56,895	36,240
Marche	383,785	32,395	8.44	16,327	9,816	6,252
Molise	76,754	6,369	8.30	3,210	1,930	1,229
Piemonte	1,120,821	92,132	8.22	46,435	27,916	17,781
Puglia	930,009	70,372	7.57	35,467	21,323	13,582
Sardegna	414,217	31,449	7.59	15,850	9,529	6,070
Sicilia	1,100,032	81,159	7.38	40,904	24,591	15,664
Toscana	958,136	80,596	8.41	40,620	24,421	15,555
P.A. Bolzano	108,187	8,682	8.02	4,376	2,631	1,676
P.A. Trento	126,120	10,067	7.98	5,074	3,050	1,943
Umbria	228,572	19,472	8.52	9,814	5,900	3,758
Valle D'Aosta	30,721	2,445	7.96	1,232	741	472
Veneto	1,167,759	93,014	7.97	46,879	28,183	17,952
TOT	14,177,445	1,126,962	7.95	567,989	341,469	217,504

Figure 5.1: Severity Distribution of Dementia in the Italian territory

change of perspectives and collaborative problem solutions. This aligns well with social constructivist perspectives, which emphasize that knowledge is co-constructed through dialogue and shared experiences.

Within this framework, the focus groups were planned to achieve several interrelated objectives. First, they were intended to assess the current status of educational programs for tourism professionals, with specific consideration given to inclusivity and the delivery of services to people with dementia. This assessment was necessary to identify gaps in existing curricula and to understand how these deficiencies impact professionals' ability to meet the needs of travelers with cognitive disabilities. Second, the dialogues were trying to discover and identify what skills, knowledge, and competencies should be included in training programs to better arm tourism professionals. Finally, the focus groups aimed at developing practicable suggestions on how the curriculum could be improved, based on the real experiences of participants and grounded in practical situations.

The focus group methodology was particularly appropriate for the *Adrinclusive* project for several reasons.

First, it provided an occasion for engaging stakeholders in the process with diverse backgrounds, which helps to ensure that all difficulties and opportunities related to the promotion of dementia-inclusive tourism are well understood. Second, it fostered in-depth discussion; this method allowed for detailed exploration by participants regarding educational resources, professional practice, and policy implications. Third, the participatory nature of focus groups encouraged the production of innovative ideas and assisted in consensus-building among the participants.

5.3.2 Organization, structure, and conduction

Participants engaged in the focus groups were selected from four principal stakeholder categories to guarantee a diverse and equitable representation. These categories comprised professionals from the tourism industry, educators affiliated with tourism-related academic institutions and vocational training programs, experts in dementia care and caregiving, as well as policymakers and local government officials engaged in the oversight of tourism governance.

Ethical considerations were fully explored to protect participants' privacy and safeguard the integrity of the research method. Participants were fully informed about the purpose of the focus groups and how the results would be used. Informed consent was obtained, particularly concerning recording sessions, and precautions were taken to ensure confidentiality to safeguard sensitive information. The findings that emerged from the focus groups provided evidence of significant gaps in current educational programs, but at the same time, opportunities to make the tourism industry more inclusive. The conclusions pointed out the need for the inclusion of dementia-related content in professional development and collaboration between sectors. The *Adrinclusive* project showed the effectiveness of focus groups as a methodological tool, through a participatory approach, to address complex social issues and promote inclusive practices in tourism.

Each focus group session was conducted according to the agreed-upon agenda. The first portion of the sessions started with its introductory stage, whereby the facilitators introduced themselves, explaining clearly the purpose of the whole discussion and the importance of Dementia-Inclusive Tourism about the *Adrinclusive* project. Participants in the discussion were then encouraged to introduce themselves, after the icebreaker, which outlined their relationship with the discussion topic. The main discussion phase thematically followed the categories reviewing current methodologies, challenges, and problems encountered in the training period, future possibilities for curricular improvement, and the impact of technology on professional development. To provoke reflective responses, the participants were asked open-ended questions that stimulated them to relate their own experiences and views.

During the main part of the focus group event, participants were asked to consider the differences between supporting travel for people with physical disabilities compared to those with cognitive impairments, and also to identify specific skills or areas of knowledge that could improve services to support dementia inclusion. This stage also included discussions about how collaboration between tourism educators, dementia specialists, and carers could be used to improve training programs. Lastly, building on the previous arguments, the discussion finished with a last question about what kind of new technology could help in the formative process of tourism professionals on the theme of inclusive vacations, or directly support the organization of inclusive vacations and policies for social inclusion.

The last segment of each workshop enabled participants to reflect on important takeaways and outline the next steps. Facilitators summarized current trends and concrete suggestions, thus reassuring participants that their input was listened to and appreciated. These results were then integrated into *Adrinclusive*'s general strategic plans for education reform.

Facilitators played a critical role in ensuring that the focus groups went smoothly. They guided the discussions, ensured that all members participated fairly, and created a setting that allowed for the sharing of different viewpoints. A dedicated note-taker recorded important discussion points, common themes, and group dynamics, thus enriching the qualitative data collected during the sessions. The facilitators and the note-taker collaborated in analyzing the findings and cross-checking the results against the project's objectives.

5.4 Results

The results related to this study are twofold. Firstly, the study produced relevant knowledge concerning the SDD in the Italian territory, providing new state-of-the-art knowledge about both the statistical distribution of dementia between the severity ranges of the illness in the Italian population, and in the meantime comparing this data with the geographical distribution of the illness in the Italian territory with specific regard for each region. This new set of data provides a brand new basis on which policymakers, caregiving associations, healthcare structures, and tourism professionals can make informed decisions and take action to create new opportunities for social and inclusive innovation.

Secondly, the focus groups provided a first set of new ideas for inclusive technological innovation. In the next paragraph, the innovative technological solutions are reported to provide a first glimpse of options to improve accessible tourism for people with cognitive impairments, specifically dementia. The technologies can be used in the training of tourism professionals and also in the development of accessible, dementia-friendly travel experiences.

Practical Applications for Booking and Assistance Services A practical technological solution envisaged is the creation of a user-friendly mobile application aimed at enhancing the reservation of accessible services. This app would, for instance, enable one to book services related to water sports or other tourist services that are specially tailor-made for individuals with intellectual disability. In so doing, such an app will enable greater access to accessible tourism for both tourists and operators.

Gamification for Inclusive Tourism Training Gamification has become a powerful tool to improve the engagement of tourism professionals in the learning environment. One such concept is designing a role-playing game (RPG) or a simulation game where the participants, through role reversal, experience the needs of people suffering from dementia or any other cognitive impairments in tourism-related environments. The game will thus involve situations where professionals will be faced with different problems related to inclusion, and their decision-making and problem-solving skills will be tested. Rewards and progress tracking would motivate participants, making the training process both engaging and educational.

Virtual Reality (VR) for Empathy and Sensory Simulation Virtual reality technology was put forward as a powerful tool for creating immersive, empathetic experiences. Tourism professionals could, through the use of VR headsets, take a step into the world of people with cognitive impairments or sensory disabilities. It could simulate things like navigating through a dementia-friendly environment, giving insight into what a tourist with cognitive impairments may have to face. This technology could also be used in the simulation of specific cognitive changes associated with dementia, for example, altered spatial perceptions or difficulties with environmental cues, to enhance the knowledge and preparedness of practitioners working in inclusive tourism.

Sensory Simulation for Understanding Disabilities Another technological solution envisioned is the development of sensory simulations that would recreate the experiences of people with specific disabilities. For example, sensory simulations could be created to show how those who suffer from dementia experience loud noises or to demonstrate how they can get confused in new environments. This, if included in training curricula, would make practitioners more aware of the wide range of needs that exist among tourists with cognitive disabilities. This would enhance their ability to create tourism experiences that are more inclusive and welcoming.

5.4.1 Limitations

For the *Adrinclusive* project, there was an effort to include people with a diagnosis of dementia and their caregivers in the focus group events, as they could have contributed by bringing critical insights into the experiences of travelers with cognitive impairments. Nonetheless, this would have posed a complex level of preparation in terms of an appropriate location to ease the participation of people with dementia, and also, the participation in a 3-4-hour discussion could be overwhelming for some of them. For these reasons, it was not possible to achieve this objective, but in the next phases of the project, some dementia-friendly events for collaborative design of either services or digital and inclusive tools. Moreover, the proposed ideas in this chapter are merely imaginary solutions that could be interesting to further investigate and develop, as they are the result of the first stage of focus groups. For this reason, they are not proposed as valuable and actionable solutions, rather, they are presented as they represent the ideal solutions to the current issues faced by the stakeholders working for inclusive tourism services.

5.5 Discussion

The *Adrinclusive* project highlights the necessity for deeper knowledge on the issue of dementia and cognitive impairments, as they are relatively unexplored and discussed themes of high social and health relevance. *Adrinclusive* tries to approach this issue on two fronts of innovation, the social and the technological ones.

The *Adrinclusive* project findings bring to the fore both the needs and opportunities crucial to developing dementia-inclusive tourism within the Italy-Croatia Interreg area. The current study enlightens various challenges and prospects intrinsic to formulating inclusive tourism strategies for people living with dementia (PwD), mixing quantitative data analysis with qualitative insights from focus group discussions. This makes the SDD analysis a fundamental basis for understanding the extent of the problem in Italy. Starting from the results of the Italian National report and, methodologically, on Yuan's (2021) framework, this research introduces novel metadata explaining the severity and spatial distribution of dementia in the Italian region.

The findings are quite meaningful to inform policymakers, health professionals, and tourism professionals about the varying needs of PwD, hence guiding the creation of targeted interventions and inclusive practices. Areas with a higher concentration of severe cases, for example, might need more holistic support services coupled with tailored tourism offerings. The focus groups provided a very important means of exploring the educational needs of tourism professionals while identifying practical solutions that will make tourism more dementia-inclusive. There were diverse members from the panel: tourism practitioners, educators, dementia care experts, and policymakers. Essentially, these groups helped in an all-around understanding of existing deficiencies in training initiatives and wider concerns regarding inclusivity. The dialogues highlighted key gaps in current curricula, especially relating to the need for curricula to address the unique needs of travelers with cognitive impairments. In addition, they identified ways to move forward, such as incorporating dementia-specific content in current training courses and promoting cross-sector sharing.

The cooperative essence of the focus groups played a crucial role in producing authentic insights. Participants shared the need to develop certain specific skills and competencies of tourism professionals that could be put into use in tourism work, such as empathy, effective communication, and adaptability. These competencies would be needed to create a welcoming and supportive environment for PwD and their caregivers. The focus groups also underlined the use of technology to improve both training and service delivery. It was pointed out that innovative tools to cultivate empathy, improve practical skills, and simulate experiences of PwD are gamification, virtual reality simulations, and sensory simulations. These technologies could change the chasm between theory and practice and thus better prepare professionals to understand and meet the needs of this demographic group. The study also noted a few limitations, especially the involvement of people with dementia and their carers in the focus group activities. Their input may have provided crucial first-hand views, but considerations both practical and ethical, for example, tying up resources to create a dementia-friendly environment and potentially burdensome in-depth discussion, precluded this. This is, therefore, a limitation that extends to a further recommendation: that engagement methods developed in the future are accessible and inclusive in nature, for example, via shorter, dementia-friendly workshops or collaborative design activities. The important message is that tourism for people with dementia represents both a pressing social need and a huge opportunity to develop new ideas, products, and services in collaboration. Only by addressing the educational gaps and using new technologies can those involved bring about a more inclusive and sustainable tourism system. The *Adrinclusive* project well illustrates what collaboration in different fields and the involvement of people can do to make important progress on complex social problems. This contributes to a greater goal of inclusivity, which not only benefits people with disabilities but also the wider community, building a culture of empathy, accessibility, and shared humanity.

5.5.1 Future Work

Adrinclusive contribution to the advancement of dementia-inclusive tourism stands in the creation of a substantial base of data and insights regarding the SDD in the Italian territory and in providing insights from the main stakeholders on the opportunities for technological innovation to support the future development of inclusive tourism. Yet, there remains much research and implementation to fully achieve its objectives. The future work will now go in the direction of addressing the limitations identified at the current stage while expanding the scope of activities to ensure a comprehensive and lasting impact.

The first attempts will be to actively involve PwD and their carers, through collaborative initiatives in co-design workshops and pilot programs with a view to drawing valuable insights from experiential narratives, key to enhancing tourism services and ensuring they are aligned with the requirements of PwD. Such events will also ensure that PwDs have inclusiveness and a voice in shaping the tourism services they need to use. This participatory approach will also help bridge the gap between theoretical approaches and real-world applications, ensuring that the solutions proposed are practical and effective.

Designing and testing new technology solutions will be a key part of the future's work. It is founded on this understanding that concepts arising from focus groups will be the basis for developing and assessing prototypes of tools, including gamified training modules, virtual reality simulations, and intuitive mobile applications. The interventions aim at the enhancement of competencies among tourism professionals, empathy and understanding, and increased accessibility of tourism services for people with cognitive disabilities. Particular emphasis will be placed on the development of technologies that prove scalable and adaptable in different contexts of the Italy-Croatia Interreg area.

The engagement of policymakers, carers, and stakeholders in the tourism industry will continue to be a critical feature throughout the project's course in the future. Based on this stage's findings, specific policy suggestions and education frameworks will be designed to formalize dementia-inclusive services. The establishment of transnational networks and cooperation will provide the opportunity for the sharing of best practices and foster the adoption of inclusive tourism models throughout the Adriatic region. Finally, future work will focus on the monitoring and evaluation procedures required to ensure the longer-term sustainability of the project's outputs. By devising metrics to measure the outcomes of the solutions implemented, as well as by collecting feedback from all stakeholders, *Adrinclusive* will implement a flexible framework capable of addressing emerging challenges and opportunities in the field of inclusive tourism.

In this scenario, it is anticipated that the process of technological innovation will utilize Citizen-Science-informed Co-design as its foundational framework. The hypothesis for future work and research is that Citizen-Science-informed co-design sessions could stimulate the ideation of innovative digital tools that provide significant benefits for individuals with dementia and Alzheimer's, their caregivers, and tourism professionals seeking enhanced training. The anticipated benefits include: i) the collection of data on the inclusiveness of various tourist locations; ii) opportunities for collaborative activities that tourists with special needs and their caregivers can engage in, promoting sensory and mental stimulation; iii) the generation of data valuable for policymakers addressing inclusive tourism, sustainable tourism, or environmental issues; iv) an increase in sustainability awareness among users of the project's final system.

Lastly, the Adrinclusive platform will take into account all the gathered knowledge, and will be tested by publishing the pilot-action vacation proposals of the project to gather feedback for improvement by the users

5.6 Summary and key insights

The *Adrinclusive* project has improved the understanding of the prevalence of dementia throughout Italy and highlighted the resulting barriers related to it for inclusive tourism. The evaluation of SDD in the Italian context consolidated very important information on regional differences and levels of severity of dementia among the population. This data provides a key basis for tailoring inclusive tourism policies and identifying regions where intervention programs are most important. It says that the rising prevalence of dementia diagnosis in a country with negative demographic trends calls for the improvement of the caregiving system and the setting up of a sufficient social network to accompany the aging population.

The use of qualitative methods in this study sheds light on the present educational gaps among professionals in the tourism industry and underlines the necessity for interdisciplinary collaboration. Bringing several stakeholders from different backgrounds and institutions together meant taking a first step, making it possible for experts from diverse fields to discuss topics around dementia for the very first time. It is in this collaborative process that new technological concepts were chiseled out to advance formative experiences for those working in tourism and caring. The concepts realized include the integration of game techniques, virtual reality, and sensory simulations into applications considered in facilitating deep engagement among trainees during their formative journey to make tourism experiences even more inclusive. They not only respond to the specific needs of PwD but also empower professionals to design and deliver services that are empathetic, accessible, and engaging.

The way *Adrinclusive* has integrated the health, education, and tourism sectors shows clearly the potential of inclusive tourism as a catalyst for social innovation and regional development. The results and recommendations developed under this project will lay the foundation for creating environments that are supportive of people with dementia, helping them to maintain their dignity and independence. This continuously developing project works to sustain cooperation, while improving its methods and further increasing its impact, to embed inclusive tourism within the context of the Sustainable Development Agenda.

Chapter 6

Conclusive remarks

This chapter synthesizes the insights gained throughout the research, connecting theoretical frameworks, methodologies, and findings from the case studies, and reflecting on the overarching themes of CS, co-design, and sustainability. By drawing connections between these elements, the discussion highlights the transformative potential of participatory approaches and technological innovation in fostering sustainability awareness and active citizenship.

6.1 Bridging Theory and Practice

The integration of CS and co-design approaches in sustainability projects resonates well with the theoretical concepts of ANT, CoPs, and Constructionism. This is how these case studies demonstrate in what way the abovementioned theoretical concepts are put into practice, making the development process more effective and user-centered for any solution.

Firstly, throughout the experiences of the four case studies, the ANT proved to be central as it highlights the role of both human and non-human actors in forming collaborative networks, which proved to be a key theme throughout every project - every target group had different pieces of technology for reference, and similarly every different piece of technology is assigned to a specific space which ultimately defines its modes of usage, and hence its the context and goal for its employment. For instance, the *AlmAware* project shows two different pieces of software: the KIOSK and the MOBILE app. In this case, different actors (students, teachers, institutions, and digital tools) are brought together to achieve shared goals of sustainability, namely, reducing water consumption. This approach underpins how challenges for sustainability are active and interconnected, putting forward the fact that working in cooperation means adapting to one another and negotiating roles in a network.

The group workshops and co-design activities emphasized in CoPs gave a sense of working together and constructing knowledge as a team. Through the act of getting participants to solve problems together and learn from each other, CoPs created spaces where trust and respect helped develop new solutions. These interactions show how important informal networks and support from peers are in reaching sustainability goals. The research shows that these communities are not unchanging but grow as members improve their skills and share new ideas. This highlights how CoPs can adapt and stay strong when facing new challenges.

Constructionism emphasizes learning through making and creating. Concretely, this approach was employed successfully in HCI-based workshops. The co-creation of interactive digital tools helped participants make sense of sustainability concepts in hands-on and meaningful ways. The research shows that learning by doing not only increases engagement but also allows for a deeper understanding of complicated subject matters. By integrating such sustainability concepts into actual projects, participants could relate abstract concepts to real-life applications; this made them more predisposed to learning valuable lessons from these and implementing elements that deeply resonated with them. This method also shows that creativity and experimentation are crucial in learning. It finds that when participants believe that they are the ones directing the projects, they are more likely to stay involved and apply what they have acquired outside of the specific project.

6.2 The Role of Technology in Sustainability Awareness

Technology emerged as a critical enabler of engagement and learning across the case studies. From the *AlmAware* app to the educational paths of the *GameOn!* serious game, the findings reinforce the idea that well-designed digital tools can significantly enhance participation in sustainability initiatives.

The gamified elements, such as the rewards in the *GameOn!* project, the leaderboards in many of the *CitizER Science in action* prototyped apps, and finally the avatars in the *AlmAware* campus's greenhouse, proved effective in maintaining user interest. However, on the one side, the findings of the *AlmAware* study highlighted the importance of balancing gamification to avoid superficial engagement, suggesting that future designs should prioritize meaningful interaction rather than playfulness. On the other side, the *GameOn!* and *CitizER Science in action* results proved that gamification proves to be a valid strategy with kids and teen users. Furthermore, the evaluation test provided us with insightful knowledge, which will be followed in future work and future development of the *AlmAware* app, such as the improvement of the badge system to further stimulate long-term engagement. Nonetheless, personalization and customization features appear to deepen the connection and ownership felt by the users, hence allowing individuals to strengthen their bond with the digital tool and consequently positively impact their sustainability awareness. Despite these benefits, the *Adrinclusive* project highlighted some major challenges around inclusivity and digital literacy. Specifically, it underscored the need for iterative design processes and user feedback to create equitable tools, specifically when referring to fragile portions of the population, as their needs may be more difficult to grasp, considering that their target was not involved as extensively as it could have been, due to organizational and time limitations.

6.3 Participatory Approaches: Benefits and Challenges

The participatory methodologies employed across the case studies, *GameOn!*, *CitizER Science in action*, *AlmAware*, and *Adrinclusive*, highlight both the strengths and challenges of collaborative approaches to sustainability awareness and action.

6.3.1 GameOn!

GameOn! utilized serious gaming within the Minecraft Education Edition platform to engage younger audiences in sustainability education. By integrating gamification into an environment familiar to students, the initiative fostered active participation and critical thinking about sustainability. The primary benefit was the immediate engagement of participants, as the game mechanics tapped into intrinsic motivations such as curiosity and competition. Additionally, *GameOn!* facilitated creative problem-solving by allowing participants to experiment with sustainability scenarios in a simulated environment.

However, challenges arose in ensuring equitable access to the technology required to participate. Not all students had prior familiarity with Minecraft, creating disparities in engagement levels. Furthermore, while the gamified approach was successful in capturing initial interest, sustaining long-term engagement proved difficult without iterative content updates and ongoing incentives. Addressing these challenges would require integrating personalized feedback loops and additional layers of complexity in the gameplay to keep participants motivated.

6.3.2 CitizER Science in action

The *CitizER Science in action* initiative focused on participatory workshops addressing diverse topics, including tourism, digital well-being, urban accessibility, and environmental emergencies. These workshops emphasized collaborative exploration and co-design, enabling participants to contribute directly to identifying problems and crafting solutions. One notable benefit was the diversity of perspectives brought to the table, as participants spanned different age groups and backgrounds. This inclusivity fostered richer discussions and more innovative solutions tailored to real-world challenges.

However, maintaining equitable participation across all demographic groups presented a significant challenge. Teenagers, in particular, require tailored engagement strategies to sustain their interest and involvement. Another challenge was ensuring that the outcomes of the workshops translated into actionable insights for stakeholders. Bridging the gap between participatory outputs and implementation remains an area for future improvement.

6.3.3 AlmAware

The *AlmAware* project fostered a gamified app to promote sustainability awareness and behavior change among university students. The app's features, such as leaderboards, rewards, and data visualizations, successfully engaged users by making sustainability efforts tangible and trackable. Participants could visualize their contributions to broader goals, such as reduced water consumption, which reinforced a sense of agency and accomplishment.

Despite its successes, the *AlmAware* project faced challenges in balancing gamification with meaningful engagement. Over-reliance on extrinsic rewards risks undermining intrinsic motivations for sustainable behavior. Additionally, the varying levels of digital literacy among participants affected the uniformity of engagement, highlighting the need for more inclusive design practices. Future iterations of the app should focus on adaptive learning elements and deeper personalization to cater to diverse user needs.

6.3.4 Adrinclusive

Adrinclusive tackled inclusive tourism through participatory approaches, emphasizing accessibility for individuals with disabilities. Focus groups and workshops enabled stakeholders, including people with disabilities, to share their experiences and co-design solutions. This participatory process ensured that the solutions were not only innovative but also deeply relevant to the target audience's needs. The initiative highlighted the potential of participatory design to foster a sense of empowerment and ownership among marginalized groups.

Challenges in *Adrinclusive* included navigating logistical and communication barriers inherent in working with diverse stakeholder groups. Additionally, translating participatory insights into actionable policy recommendations required significant effort and collaboration among institutional actors. Ensuring continuity and long-term impact remains a critical area for further development.

6.4 Contributions to the Field

This study brings together the expertise of several disciplines and fields: Human-Computer Interaction (HCI), participatory design, education, policy-making, and, more broadly, sustainability, both in terms of environmental collaborative science and SDGs. Combining these fields highlights how technological advancement and community engagement can be brought together to develop substantial solutions for both local and global challenges.

The knowledge gained through the experience with the case studies pushes the field of Human-Computer Interaction forward by showing how digital artifacts can mediate knowledge and motivate behavioral change. In this respect, applications like *AlmAware* show how gamification and data visualization may support individual and collective action toward sustainability. The outcomes explored in the four different case studies contribute to HCI by calling for a widening of the scope of attention from usability to societal impact. Thus, the Human-Computer Interaction should strive toward a Culture-Computer Interaction, meaning that the development of ecological consciousness through technological innovation can take place only through a process of culturally relevant co-creation of innovative technology. By taking principles from HCI and co-design, culturally informed innovation of technology has the potential to pursue the sustainability goals, by empowering technological innovation to jump to social innovation, thanks to the mediation of a Culture-Computer Interaction-like relation determined by the deep sense of ownership of the digital innovative tools derived from the co-design experience.

One of the ways to create a strong bond between technology and culture is mediated by a common practice shared between members of a community (like in the case of CoPs). The integration of CS in the co-design process is an example of how a group can transfer engagement from the digital realm into real-world practices, moreover, it can also bridge diverse stakeholders, consequently enhancing both the relevance and effectiveness of sustainability initiatives. The iterative approaches used emphasize the need for shared ownership, which fosters continued participation and adaptability. This study highlights a model for collaborative initiatives that are inclusive both in its collaborative processes and in its goals. As an example, the *CitizER Science in action* series of workshops take into account teenagers as young adults, marginalized from the political life of their country, but empowered through collaborative approaches to design and science to take action towards their goals and to actively impact their spaces (3.33.6); another example would be the *Adrinclusive* project, which through the collaborations of different stakeholders for the design of targeted services for the inclusive vacations it is ensuring that the beneficiaries of such efforts aren't to privileged or marginalized communities, but rather, focuses on providing inclusive solutions keeping in mind that inclusivity is a broad concept that applies to all and not only to the people with cognitive divergencies. In doing so, the project pursues its goals while broadening the sense of ownership to a wider public, ensuring a greater level of engagement and a more durable network of inclusive services.

Moreover, regarding education, the findings show the tremendous potential of citizen-science based activities to improve critical thinking and ecological literacy. These interactive resources, both workshops (Ch. 3) and serious games (Ch. 2) have a way of giving students experiences that relate theoretical knowledge to practical application. In effect, by showing people the tangible effects of their actions, these activities foster a sense of responsibility and active participation. This study takes educational methods a step further by showing the scalability of technology-integrated learning in solving complex environmental issues while also providing customizable solutions and frameworks that can adapt to local and specific necessities.

These results carry important policy implications in demonstrating feasible and influential means for integrating sustainability into institutional structures (schools, associations, and political institutions). Documenting successful participatory approaches, this research provides practical recommendations for policy-makers who hope to weave community engagement and technological innovation into sustainability initiatives. These kinds of contributions are very relevant for educational entities and local governmental bodies that try to advocate systemic transformation. As demonstrated by the different array of case studies provided, it is possible to adapt co-design for sustainability to several settings, participants, and settings while answering different needs to reach yet again different goals.

6.4.1 Answer to RQ1

In the following paragraphs, the research questions proposed in (Sec. 1.2.2) will be addressed. The first RQ (Sec. 1.2.2) asks "How can CS-informed co-design processes engage diverse age groups (children to elderly people) in the creation of interactive digital tools to enhance sustainability awareness?".

Given the multifaceted nature of the question, it is necessary to elaborate answers on multiple fronts.

First, co-design processes, informed by CS, engage a variety of age demographics by ensuring inclusive participatory approaches through tailoring engagement techniques and methodologies to fit a large array of needs and preferences. The case studies, analyzed in this study, namely *GameOn!*, *CitizER Science in action*, *AlmAware*, and *Adrinclusive*, demonstrate that effective engagement largely depends on creating an enabling environment where participants feel valued and perceive meaning in their contributions. For instance, the participatory workshops used in *CitizER Science in action* leveraged concepts close the the teenagers, such as social media, apps, and games; meanwhile, in the Almaudea study, the most discussed elements were the data representation and the aggregation value of a campus app. The interest of participants in the different themes gave rise to solutions that were both more relevant and effective for them. Moreover, interactive digital tools created in these processes mirrored the different capabilities of participants, one leveraging on knowledge of the local environment and mechanics of games, whilst the second made use of the participants' knowledge of computer science, information systems, and data visualization.

Second, in *GameOn!*, children and young people have been engaging with a serious game based on Minecraft Education Edition, using familiar interfaces in an attempt to make sustainability concepts both usable and enjoyable. Similarly, *AlmAware* used data visualization with gamified components in the form of leaderboards and rewards to increase the level of engagement among university students so that their contribution toward sustainability goals was made visible and valued. Nonetheless, a lesser interest in gamified aspects is observed in the second group, while for the first, it was the major driving force to fuel their interest in the project. For this reason, as demonstrated through the *Adrinclusive* experience, the stakeholders proposed gamified and immersive technological solutions for the formation of young and future tourism professionals, reinforcing the findings from the other case studies, but they rose different ideas for the specific target of elderly people such as the implementation of user-friendly interfaces to ease technological obstacles. This underscores the necessity of adaptive designs that mitigate entry barriers and promote active involvement among diverse demographics.

Third, throughout the four different case studies, the activities proposed were often set in terms of local concerns, as represented by the *CitizER Science in action* workshops that looked at topics such as urban accessibility and environmental disasters in ways that are related to participants' lived experience. This tie to tangible outcomes motivated people, who could see directly that what they were doing would have an impact. Keeping people engaged over time was difficult, especially in gamified projects like *GameOn!* and *AlmAware*, where initial excitement risked waning without iterative updates and evolving content. Iterative feedback loops, adaptive learning elements, and personalized recommendations were mentioned as strategies that are good for the long-term sustenance of engagement.

In conclusion, CS-based co-design processes create a platform that allows for inclusive and meaningful engagement by fostering intergenerational collaboration, gamification where appropriate, and emphasizing the contextual relevance of the tools being developed. These procedures allow participants to connect their activities to broader sustainability goals while taking into account different levels of digital literacy and motivation. The effectiveness of such initiatives demonstrates the high transformative potential of participatory approaches in creating tools that not only raise awareness about sustainability but also foster a sense of ownership and active citizenship among divergent age groups.

6.4.2 Answer to RQ2

The second research question (Sec. 1.2.2) asks "what are the measurable benefits of involving communities in CS-informed co-design for the development of interactive digital tools that promote sustainability awareness?".

The case studies, *GameOn!*, *CitizER Science in action*, *AlmAware*, and

Adrinclusive, show how participatory approaches can yield substantial outcomes related to the relevance of the tools, community empowerment, and educational impact. Therefore, to best answer RQ2 in this paragraph, the results of the four case studies will be summarized.

First, *GameOn!* demonstrates the measurable benefits of participatory co-design in creating engaging and educational digital tools. Testing events revealed that the majority of participants enjoyed the game "very much" and reported learning something new or interesting, highlighting its success in both entertainment and education. Although most players found the game easy to use, a significant portion required assistance, particularly with complex gameplay elements. Facilitators observed that guided play sessions were more effective than independent exploration, as they reduced confusion and maintained engagement. These findings affirm *GameOn!*'s potential as a valuable tool for teaching sustainability, with opportunities to improve accessibility and support.

Second, *CitizER Science in action* demonstrates the benefits of participatory co-design in fostering critical thinking, collaboration, and civic responsibility among adolescents. The workshops engaged participants in designing low-fidelity app prototypes on themes like urban accessibility and environmental emergencies, with locally relevant topics driving heightened engagement. Feedback highlighted the empowering nature of the experience, inspiring confidence in their ability to contribute to societal challenges. While highly effective in promoting knowledge acquisition and active participation, suggestions for incorporating practical prototyping tools point to opportunities for enhancing hands-on skill development. These findings affirm the workshop's adaptability and impact as a tool for sustainability education.

Third, *AlmAware* highlights the potential of participatory co-design in creating educational tools for sustainability, though with opportunities for improvement. Surveys revealed high ratings for usability and clarity, with both the KIOSK and MOBILE applications scoring over 6 for ease of use and user-friendliness. Both tools were also perceived as effective in supporting sustainability education, averaging above 5.7 for delivering relevant information. However, engagement levels were moderate, with interactive features like quizzes and badges receiving limited enthusiasm. Personal relevance was more impactful, as data on individual actions scored higher than general sustainability content. These findings suggest that while *AlmAware* successfully educates users, enhancing engagement through more compelling interactive features could further its effectiveness in driving behavioral change.

Lastly, the early stage of the *Adrinclusive* project doesn't provide the necessary data to establish a measurable impact on the sustainable goals of inclusive tourism that the project aims at, but the new knowledge generated regarding the SDD and the conceptual ideas for technological support of this services foreshadow a positive path towards the increment of awareness on the topic of cognitive illnesses and dementia in the IT-HR Interreg area.

6.4.3 A CS-informed Co-Design Framework for Sustainability Technologies

To synthesize the insights derived from the analysis of case studies and participatory protocols, we propose a conceptual framework that supports the design and evaluation of participatory sustainability technologies. This **CS-informed Co-Design Framework** highlights six key components that integrate principles of Citizen Science, Human-Computer Interaction, and sustainability-driven participatory design.

1. **Contextual Grounding** Initiatives should be grounded in local, culturally and environmentally relevant sustainability challenges. This ensures resonance with participants' lived experiences and enhances relevance.
   Key questions: What sustainability issues are most pressing in the local context? How do they affect participants' daily lives?

2. **Participant-Centered Engagement** Design must account for the characteristics, motivations, and capacities of the intended participants

(e.g., age, digital literacy, cognitive ability). Different modalities—including gamified platforms, visual storytelling, and tangible tools—can improve inclusivity and engagement.

3. **Collaborative Stakeholder Dynamics** Successful initiatives involve a wide range of actors (citizens, NGOs, researchers, policymakers), fostering meaningful collaboration and shared responsibility. This includes integrating stakeholder feedback, encouraging co-decision making, and aligning with institutional agendas when possible.

4. **Iterative Co-Creation** Participatory design should unfold through iterative cycles of ideation, prototyping, testing, and reflection. Co-design sessions should allow flexibility and adaptability, ensuring that outputs evolve in response to user feedback and contextual changes.

5. **Sense of Agency and Ownership** Participants should feel that their contributions matter and that they have a stake in the outcomes. This can be achieved through mechanisms like personalized visualizations, narrative elements (e.g., avatars or stories), and tools that communicate real-world impact (e.g., feedback dashboards).

6. **Embedded Evaluation and Transferability** Initiatives should include mechanisms for ongoing evaluation using both qualitative and quantitative methods. Moreover, results should be documented and shared in reusable formats (e.g., toolkits, guidelines) to encourage replication or adaptation in other contexts.

This framework can be used *diagnostically*—to analyze and improve existing participatory sustainability initiatives—or *generatively*—to guide the design of new ones. The six components are not rigid steps but interdependent dimensions that may overlap and evolve throughout the process.

6.5 Future Directions

This PhD does not determine the end of this line of research; rather, it paved the way to the concept of Citizen-Science informed based co-design framework, and it calls for future refinement, enhancement, and new areas and opportunities for its implementation.

Above all, an important area for future research is how participatory design and CS projects achieve long-term behavioral change. A longitudinal study may benefit this line of research as it would follow participants for extensive periods to observe sustained actions and broader impacts of such actions at the community level. In so doing, such study results will go on to further improve new project designs so that both participants' engagement in their work and long-term impact are maximized hand in hand.

In conclusion, examining the incorporation of more sophisticated personalization methods, such as adaptive feedback systems customized to individual user behavior, has the potential to improve both engagement levels and educational results.

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