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# Unleashing the Awareness of Sustainable Human-Computer Interaction (HCI) Among Youth:

Bridging the Knowledge Gap and Empowering Future Sustainable Designers

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## **Abstract**

This research paper aims to explore the knowledge gap among young designers in relation to sustainable human-computer interaction (HCI), focusing on Interaction Design, and investigating the necessary resources for designing sustainable HCI. Lack of knowledge among young designers regarding sustainable practices in digital design contributes to the overconsumption of energy, and increased carbon emissions, highlighting the need to raise awareness and bridge the knowledge gap in Sustainable Human-Computer Interaction (HCI) design among youth. Using qualitative methods, including 14 semi-structured interviews with informatics students in Jönköping, Sweden, the study identifies three main themes: Lack of Knowledge, Resource Needs, and Concerns About the Design Process. The findings highlight a limited understanding of sustainable HCI among young designers, emphasizing the significance of educational modules in sustainability within digital design. This study provides insights and recommendations for digital designers, educators, and policymakers to implement sustainable digital design practices in order to lessen environmental impact and promote sustainability within the digital world. The implications of this study include addressing the knowledge gap, fostering educational initiatives, and serving as a foundation for future research in sustainable digital design and HCI. This study addresses the challenge of motivating young designers to learn more about sustainable HCI while identifying essential resource requirements, education, design tools, eco-feedback technology, and support.

*Keywords: Sustainable HCI, Sustainable Interaction Design, Digital Technology, Digital Carbon Footprint, Digital Sustainability, Eco-feedback Technology, Young Designers, Digital Design.*

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# 1 Introduction

The digital technology industry contributes to a significant and growing portion of global greenhouse gas emissions, accounting for around 4% of global emissions in 2019. Moreover, the growth of digital technology is expected to increase its carbon footprint, and it may account for up to 8% of global emissions by 2025 (Sharma & Dash, 2022). The proliferation of digital devices and services has increased energy consumption, which in turn has led to a greater carbon footprint (Ibid.). Digital technology also has indirect environmental impacts, such as e-waste generation and resource depletion (Ibid.). There is an urgent need for digital technology companies and policymakers to take action to reduce the environmental impact of digital technology and promote a more sustainable future (Ibid.). Greater attention needs to be given to the issue of digital carbon footprint and to the development of strategies to mitigate the environmental impacts of digital technology; moreover, implement sustainability in digital designs. The framework for sustainable digital design includes understanding the principles of sustainability, incorporating sustainability into the design process, and evaluating the environmental impact of design decisions.

This bachelor's thesis explores the knowledge and awareness of young designers on sustainable HCI design and the impact of HCI on environmental sustainability (referred to as 'sustainability'). HCI (Human-Computer Interaction) is a “discipline concerned with the design, evaluation, and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them” (Sinha et al., 2010). The primary focus is on interaction design when mentioning HCI in this given thesis work. Interaction design could be defined as “the creation of a dialogue between a person and a product, service, or system” (Connors, 2010, p. 11). More information about the definition of HCI can be found in Chapter 3. Additionally, the thesis finds out what resources young designers need to incorporate sustainable practices into the design process by interviewing students within the geographical area. As sustainability is growing within the print design industry as more people are becoming aware of it, the same cannot be said for digital design. For that reason, we aim to learn what young people’s knowledge is nowadays about this topic and the reason they aren’t fully aware of it.

## 1.1 Problem statement

The digital world is rapidly advancing and although digitalization is occurring in every aspect of society, it is currently more part of the problem than the solution due to the significant environmental costs associated with rising demand and consumption

(Duporte, 2022). This increase poses a threat to achieving a sustainable future and needs to be addressed urgently (Sharma & Dash, 2022). A previous study has highlighted the importance of an ethical shift and an alternative perspective on development in achieving sustainable development (Hanks, 2009, p. 36). They argue that current approaches to sustainability often overlook the fundamental relationship between humans, the environment, and knowledge (Ibid.). Based on this information, we can conclude that the overconsumption of energy caused by the lack of knowledge among digital designers is a contributing factor to global warming and the eventual degradation of the natural environment. With digital design becoming a more prevalent part of everyday life, it could be important to consider the ways in which it can be made more environmentally sustainable. Environmental sustainability is the responsibility to conserve natural resources and protect global ecosystems in order to uphold the health and welfare of both present and future generations (Sphera Solutions, 2022). Whereas digital environmental sustainability could be defined as the process of applying environmental stewardship principles to digital products, services, and data delivered in order to reduce digital waste which is the environmental consequence of poor data stewardship.

Sustainable Human-Computer Interaction (HCI) design is a promising approach that not only reduces the carbon footprint of digital technologies but also promotes the ethical usage of technology as a response to these environmental issues. (Hansson et al., 2021). Digital technologies use a lot of energy, and sustainable HCI can make these technologies leave less of a carbon footprint. Additionally, by considering how technology affects people, society, and the environment, sustainable HCI design encourages ethical technology use (Ibid.). Moreover, considering sustainability within HCI design drives innovation by allowing researchers to challenge themselves into finding new and creative solutions to design problems, resulting in advancements in digital technology.

Producing sustainable digital products can make a positive impact on the world and promote responsible technology use. Since the youth are the future, it would be crucial that they are educated about sustainability in this aspect as well as know the impact carbon footprint has on the environment. Students must be equipped with the knowledge and skills necessary to create designs that are not only aesthetically pleasing but also sustainable as the next generation of digital designers. According to some estimates, the carbon footprint of our technology, the internet, and the systems that support it contributes to around 3.7% of the world's greenhouse gas emissions (Griffiths, 2022). It is comparable to the volume produced globally by the airline industry, and by 2025, these emissions are expected to double (Ibid.). Wonderland Studio, a digital studio, has produced a report to find out how much of an impact digital designs have on global carbon emissions. The average digital designer emits

319 kg of CO<sub>2</sub> annually, or 1.36 kg per day, according to data from their report, demonstrating significant environmental harm (Gorny, 2022). This is comparable to the environmental impact of a one-way flight from Amsterdam to Lisbon, which weighs 338 kg (Ibid.).

According to a 2020 estimate, an additional 34.3 million tons of carbon dioxide and other greenhouse gas emissions would have been produced globally if remote working and other physical distance requirements had persisted through 2021 (Obringer et al., 2021). This is due to the enormous increase in the usage of digital platforms like Netflix and video conference tools like Zoom (Ibid.).

In addition to the carbon footprint of individual digital designers, it's important to consider the impact of the information and communication technology (ICT) industry on the environment since it is closely related to the work of digital designers. The Green Deal, developed by the European Commission, is a comprehensive plan that addresses climate change and encourages sustainable growth in a variety of economic sectors, with the goal of making Europe the first carbon-neutral continent by 2050 (*A European Green Deal*, 2021). To achieve the Green Deal, the European Commission depends on ICT, which, like other industrial value chains and green technologies, rely on various critical raw materials such as indium, lithium, rare earths, tantalum, gallium, copper, and silver due to their exceptional properties enabling diverse applications (Duporte, 2022). An estimated 1.4% of the world's greenhouse gas emissions — or 730 million tonnes CO<sub>2</sub>-eq — are produced by the ICT sector (Ericsson, 2020). Despite the exponential growth in data traffic and the increasing number of ICT users worldwide, the sector's carbon footprint has remained largely stable since 2010, and it continues to play a sizable role in the production of greenhouse gasses on a global scale (Ibid.). Therefore, understanding the causes of this footprint and choosing workable mitigation strategies are essential for finding a solution (Ibid.).

The usage of energy is the primary factor in how digital design increases carbon emissions (Weeks et al., 2014). The Sustainable HCI community should concentrate on finding ways to help citizens and authorities make their communities' infrastructure more sustainable, despite the fact that changing one's own behavior can save energy and there are benefits to studying behavior change in the community (Weeks et al., 2014). This is because of the relatively low potential energy savings. Even if it is a harder task to complete, this can result in more profound and long-lasting answers (Ibid.).

In order to keep greenhouse gas emissions under control and achieve sustainability goals, it's important to further research and raise awareness within this topic of the environmental impact of digital design and the ICT industry. By doing so, we can find

effective methods for digital design students to develop sustainable solutions and reduce carbon emissions as we move forward into the future.

## **1.2 Purpose and research questions**

The purpose of the research is to investigate the gaps in youths' understanding of sustainable HCI design and identify the resources they require to practice sustainability. The aim is to provide insights and recommendations to design educators, policymakers, and digital designers on enhancing students' knowledge and awareness of sustainable design practices in the digital realm.

The specific research questions that address the purpose are as follows:

*1) How can young designers be incentivized to learn more about sustainable HCI?*

This question focuses on exploring strategies and motivations that can encourage young designers to engage with and learn about sustainable HCI. By understanding the incentives that can drive their interest and participation, effective educational approaches and interventions can be developed.

*2) What resources do young designers need to integrate sustainability into their design process?*

This question aims to identify the specific resources that young designers require to effectively integrate sustainability into their design processes. Understanding their needs can guide the development of educational resources and support mechanisms tailored to their requirements.

By addressing these research questions, the study aims to contribute to the development and practice of sustainable HCI design. It seeks to bridge the gap between young people's knowledge and understanding of sustainable design principles and their practical application in digital technology. The findings will provide insights into the challenges faced by young designers and offer recommendations for fostering sustainable design practices that minimize the environmental impact of digital products and services.

## **1.3 Scope and limitations**

This thesis focuses on exploring the knowledge gap in young people's understanding of sustainable Human-Computer Interaction (HCI). Additionally, the study investigates the challenges designers face in implementing sustainable design practices. The research focuses on young people who are in the field of HCI and how much knowledge they have on sustainable HCI and the harm it has on the environment.



This study is limited to only exploring the knowledge gap in young people's understanding of sustainable HCI, sticking to only the interaction/UX design field. Moreover, we are finding out what the young designers lack, and what resources they need, to integrate sustainability. Therefore, we are not coming up with new methods. The research does not explore the technical aspects of sustainable HCI, such as software development or hardware engineering. Additionally, the study does not explore the environmental impact of digital technology beyond the carbon footprint. The availability of participants and resources also limited the study due to these students being easily accessible to us, as we do not have the resources to expand.

## 2 Method and implementation

To conduct the literature review for this study, we followed a systematic approach. We first identified the relevant databases and search terms to use in our search. The databases we used were Google Scholar, ACM Digital Library, and IEEE Xplore, which cover a wide range of HCI and sustainability-related articles. The search terms we used were "sustainable HCI", "sustainable interaction design", "green computing", "environmental sustainability", "green technology", and "young people".

After identifying the initial set of articles, we conducted a screening process to identify articles that were relevant to our research question. We initially screened the articles based on their title and abstract. Articles that were not relevant to our research question were then excluded. The inclusion criteria were peer-reviewed articles that focused on sustainable HCI or sustainable interaction design. The articles needed to be published in English.

Once we had identified the relevant articles, we evaluated the quality of the articles based on their research design, the quality of the data, and the relevance of the findings to our research question. Additionally, we identified additional relevant articles from the reference lists of the relevant reviewed articles.

For both of our research questions, we use a qualitative research method, as the aim is to explore the gap in students' knowledge of HCI in-depth. When using this method, interviewers can explore answers given by interviewees in more detail and ask follow-up questions to expand on their responses (Rubin & Rubin, 2005).

### 2.1 Data collection

Semi-structured interviews were used to gather data. We have a set of predetermined questions to ask but also have the flexibility to ask follow-up questions or explore topics in more depth based on the interviewee's responses (*see Appendix 8.1*). "The flexibility and ability to probe with follow-up questions along with the dialogic nature of the interview enable the researcher to attempt to see issues from the perspective of the interviewee and to achieve a degree of empathy and understanding with research participants" (Coiro et al., 2014). This allows for a deeper understanding of the interviewee's thoughts and ideas. Qualitative interviews conducted in-depth enables researchers to explore and understand the experiences, motives, and opinions of individuals with knowledge or experience related to the topic of interest (Willig & Rogers, 2017). By establishing a conversational partnership between the interviewer and the interviewee, qualitative interviewing creates a trusting and cooperative environment where the interviewee feels valued, understood, and safe to share

personal opinions and viewpoints (Willig & Rogers, 2017). That gives us insights on the interviewee's perspectives, enriching our understanding of their point of view regarding sustainable HCI, which in turn enhances the depth and richness of our data.

However, it is important to know there are some challenges with interviewing. Some researchers, such as Schostak in 2006, argue that the act of listening to people's experiences presents a challenge to the researcher (Abudulai, 2020). They question how this moment of listening can be accurately translated into the transcript, and how the text should be interpreted (Abudulai, 2020). It is of great importance to focus on the moment of engagement between the interviewer and interviewee, where each is attentive and responsive to the other, as this moment is critical to understanding the full range of human experience. We gather data from the same interview for both research questions, therefore we do not conduct two separate interviews.

Choosing to conduct interviews as a method allows for a lot of space for subjectivity. This can be considered challenging however relevant to our thesis. The measurement of subjective states presents a unique characteristic where there are no definitive right or wrong answers (Bickman & Rog, 2009). Since our research question revolves around knowledge gaps, the data that we receive from the interviewees are almost entirely subjective. The subjectivity in itself is then somewhat a proof of credibility. However, this also leaves the researchers with a lot more work, as the subjectivity of the researcher and the interviewee both have to be questioned and analyzed.

The sample consists of young people, who are students in the design/informatics field. We conducted interviews with 14 students within the geographical area aged 18-25. We mainly recruited students within their last years of education so they would have an adequate level of knowledge to answer our questions. There are multiple reasons for choosing students. Students are readily available and accessible for our research study, especially since the research is being conducted at an educational institution. This makes the recruitment for the study easier and less time-consuming. They are likely to have recent and relevant experience with technology and digital devices, which can make their knowledge of sustainable HCI more insightful and useful for understanding current trends and practices. However, there are some challenges in interviewing students. The limitations of interviewing students can branch from the opportunity costs (interviewing someone with more experience, knowledge, or possibly a more insight-generating perspective) to the fact that the strict tunnel vision on a student perspective leaves you with results that can be far too similar for the researchers' liking. Students may also have busy schedules with coursework, extracurricular activities, and work, which can make it difficult to schedule and conduct interviews so the researchers might experience time constraints. Furthermore, students may have preconceived notions or biases about sustainable HCI, which could affect their responses during interviews.

Interviews are the best method to gather data for our research questions since we are looking into our target group's knowledge and views on the topic. Aside from that interviews in a qualitative study allow us to get a deeper understanding also about how the participants make sense of the topic and how their understandings influence their behavior (Maxwell, 2009). To kick off the interview, we gave our participants a short overview of what our topic is about as well as our aim. The interviews took about 10-15 minutes depending on the participant. We asked for consent to audio record the interview and made it clear to the participants that they are anonymous. Participants are asked about their knowledge of sustainable HCI, including their experiences with technology, perceptions of the impact of technology on society and the environment, and ideas for more sustainable and equitable technology design. By the end of the interview, we asked the participants whether they know what eco-feedback technology is. Then we introduce the concept of eco-feedback technology to our interviewees. It was explained to them how this technology can be used as a tool to consider sustainability when designing products or services. By introducing this topic, we hoped to gain insight into how our interviewees perceive sustainability and if they have considered incorporating eco-feedback technology into their design processes as well as see their views on how this could be challenging for them or if there are any limitations in order to know what resources they might need. Additionally, we highlighted the benefits of using eco-feedback technology in the design process, such as reducing environmental impact and improving user engagement with sustainable products.

The process of collecting and collating the data generated from the interviews started with audio-recording and transcribing verbatim for coding and analysis with the consent of the participants. All data collected from the interviews are stored in a secure location. Moreover, any identifying information, such as names, ages, etc. are removed from the data to ensure anonymity, in order to allow more comfort for the participant for them to not hesitate to give their honest opinion. Instead, participants are assigned a unique identifier. Multiple backup copies of the data are made and stored in secure locations to prevent data loss due to technical failures or other issues. Access to the data is limited to authorized individuals, such as the researcher and research team members, and only for research purposes. The data is retained for a specific period, and then securely destroyed to protect the confidentiality of participants.

## **2.2 Data analysis**

The data collected from the interviews were analyzed using thematic analysis. Thematic analysis offers a high degree of flexibility, making it well-suited for

analyzing various data types, including face-to-face data collection methods like the interviews conducted in our research (Willig & Rogers, 2017, p. 22). The data were transcribed and coded, with themes and patterns identified through an iterative process of analysis. Thematic analysis is a rigorous method; it provides a transparent process for analyzing data that allows for clear documentation of the analysis process and findings (Braun & Clarke, 2012). By following a set of established procedures, researchers can ensure the validity and reliability of their findings (Braun & Clarke, 2012). When attempting to comprehend a person's experiences, thoughts, or behaviors present throughout data collection, thematic analysis is a suitable and effective technique to employ (Braun & Clarke, 2012). It helps us search for a common and shared opinion or knowledge.

This method allows the researchers to identify themes, and trends in the data, making it a valuable tool for exploring complex and nuanced phenomena. It can help researchers identify the underlying meaning and significance of participants' responses, revealing deeper insights into the research question or topic.

This research's thematic analysis is inductive where the researchers allow themes to emerge from the data. By exploring the themes that emerge from the data, the researchers can gain a deeper understanding of the social and cultural context in which the research is situated (Clarke & Braun, 2014). Although thematic analysis is a flexible and accessible method that can be used in various research contexts, it can be time-consuming and subjective and requires the researchers to make decisions about which themes to prioritize (Clarke & Braun, 2014).

The semi-structured interviews were audio recorded and transcribed with Sonix AI while we also went through the transcriptions and fixed any errors to make sure it is accurate. Participants were coded with a number to ensure their confidentiality. Thematic analysis was used to analyze the interview data. This involved a systematic process of identifying patterns and themes in the data, using inductive approaches. The analysis was conducted in several steps. First, the researchers independently read and re-read the transcripts to familiarize themselves with the data. They then generated a list of codes, which were derived both from the research questions and from the data itself. Finally, the themes were organized into a coherent narrative that addressed the research questions and provided insights into the gap in young people's knowledge about sustainable HCI and the resources they need to design sustainable technologies. The analysis process was iterative, with the researchers going back and forth between the data and the themes until they were confident that the analysis accurately reflected the participants' perspectives.

### **2.3 Validity and reliability**

In order to ensure the data validity and reliability of the interviews, various measures were taken. Firstly, interview questions were initially created to be open-ended and neutral to prevent leading participants towards specific responses. Participants were assured that their responses were valuable, regardless of their level of knowledge on the topic, and that there were no right or wrong answers.

Secondly, it is acknowledged that the strict focus on a student perspective may limit the generalizability of the study's findings. However, this approach was necessary to achieve research objectives focused on exploring the knowledge gap in young people's understanding of sustainable HCI as well as the lack of resources and time for a broader target group.

Thirdly, precautions were made to assure participant comfort throughout the interview process, such as requesting their consent to be recorded and assuring them of anonymity in the presentation of the research findings. The recording of interviews was used solely for the purpose of accurate data transcription and was deleted after transcription. Additionally, to protect participant privacy and reduce interruptions, the interviews were held in a quiet, private setting.

To ensure the reliability of data analysis, two researchers independently conducted analysis and compared and discussed their findings to ensure agreement on identified themes. In order to base the study on the facts and away from the researchers' preconceived preconceptions, three themes were developed during the data analysis process to reveal patterns in the responses of participants.

The study does, however, have several drawbacks, such as the small sample size and limited geographical scope resulting from selecting interviewees based on accessibility. Interviewing students within the same learning institution does not answer for most students globally. Additionally, the study was limited by resource availability, like time and funding, which may have impacted the research's depth and scope. Finally, interviewees may have had preconceived notions or biases that could have influenced their responses during interviews.

Overall, we believe that some of the strategies implemented in this study have improved the validity and reliability of our results. Two researchers separately assessing the data gave another level of rigor to the study and ensured that the results were interpreted consistently. Measures to ensure participant comfort during interviews minimized the risk of participants feeling uncomfortable or frightened, thereby enhancing the quality of the data collected. However, we are aware some of the strategies are not helpful in terms of validity due to the lack of resources and time.

## **2.4 Ethical Considerations**

The qualitative researcher must guarantee that participants have the freedom to decide whether or not to participate in the study, protect participants' identities throughout the recruitment and dissemination processes, and encourage transparent and truthful research reporting that is free from misleading readers (Arifin, 2018).

Since we conducted interviews, there were a variety of ethical considerations taken into account. These ranged from obtaining informed consent from participants to ensuring all the necessary information about the research project was open for them to see (Information including the purpose of the study, the methods to be used, and the potential risks and benefits). Participants were given the opportunity to ask questions and provide informed consent before participating in the study. Ensuring the confidentiality and anonymity of participants was essential as well. Participants were assured that their responses are kept confidential and that their anonymity is maintained. We also explained how the data is stored and protected for them to have all the necessary information. It was explained to the participants that participation in the research study is voluntary, and they are able to withdraw from the study at any time without any negative consequences. They were treated with respect and dignity and using language or behaviors that may be offensive or disrespectful was avoided. The participants were given the opportunity to receive a debriefing after the study is completed. This includes an explanation of the study's purpose and the results obtained to give them insights on their contributions. The researchers were aware of cultural differences and respected the participants' cultural beliefs and practices throughout the interview. In addition, they ensured that the data collected during interviews were stored securely and only accessed by authorized individuals.

## **3 Theoretical framework**

The theoretical framework for this thesis draws on several theories and concepts related to sustainability, sustainable HCI, interaction design, and sustainable interaction design. The digital technology industry contributes to a significant and growing portion of global greenhouse gas emissions, and it is expected to increase its carbon footprint in the coming years. The study explores the ways in which digital designers can reduce carbon footprint and promote a more sustainable future.

### **3.1 The History of HCI (Human-Computer Interaction)**

HCI (Human-Computer Interaction) is a “discipline concerned with the design, evaluation, and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them” (Sinha et al., 2010). The development of the first mechanical computers in the early 20th century is seen as the emergence of the history of HCI however, the research on the relationship between humans and computers didn’t start til the 1950s (Myers, 1998). Vannevar Bush’s work can be seen as one of the first examples of HCI research; he developed the Memex, which is a theoretical device that allows users to create and organize information using a system of links (Myers, 1998). The development of hypertext and the World Wide Web was based on this idea (Myers, 1998). Licklider’s vision of a “man-computer symbiosis” in which humans and computers work together to solve problems was one of his noteworthy contributions (Licklider, 1960). The development of interactive computing systems that could be used by humans to solve complex problems was what Licklider's mainly focused on (Licklider, 1960). As the years passed, HCI research continued to evolve. "Mother of All Demos" is a concept introduced by Douglas Engelbart in 1968 that demonstrated the use of a mouse, hyperlinks, and video conferencing, which became fundamental elements of HCI and had significance to HCI research (Hintz, 2018). The research by Alan Kay on object-oriented programming and graphical user interfaces (GUIs) laid the foundation for the development of the Macintosh computer, which made graphical user interfaces (GUIs) popular in personal computing (Barnes, 2007). With Microsoft's Windows and Apple's Macintosh becoming the most popular operating systems in the 1980s, GUIs became widely used, which led to the standard practices in HCI: user-centered design and usability testing.

Card et al. (1983) highlighted the importance of exploring the mental procedures that are involved in using computers while also providing a framework for creating interfaces that are user-friendly in their groundbreaking book in the history of HCI.

The development of HCI, with the help of the development of GUIs, allowed for broader accessibility to computers, making it possible for non-experts and everyday users to interact with computers, rather than only technical experts.

### **3.2 What is Meant by HCI?**

When HCI is mentioned in this bachelor thesis, our focus is mainly on interaction design. Interaction design could be defined as “the creation of a dialogue between a person and a product, service, or system” (Connors, 2010, p. 11). Interaction designers design in a way users are able to interact with web interfaces.



HCI design is a process for creating user interfaces that simplify the communication between humans and machines in a human-machine system (Chao, 2009). It includes developing interfaces that are efficient for users to achieve their goals when using machines (Ibid.). Information technology serves as the foundation for HCI design, encompassing modeling, formalization, description, evaluation techniques, and software frameworks (Ibid.). In order to successfully create human-machine systems it is crucial to design human-computer interfaces since it enables effective communication and interaction between humans and machines (Ibid.).

The user interface is where humans and computers interact, comprising both hardware and software (Huang, 2009). It is developed through interaction design which is a process of designing interactive products to support people in their every day and working lives (Ibid.). Since HCI is about how a person and a machine interact with one another, designing a user interface requires a deep understanding of both the human and the computer sides (Ibid.).

Designers and developers who have a broad knowledge of various aspects of human behavior, technology, and interactions between them are better equipped to build effective user experiences. They must comprehend how individuals behave, respond to situations, interact, and communicate with one another (Rogers et al., 2011). They also need to comprehend how emotions function, what is meant by aesthetics, desirability, and the function of narrative in the human experience in order to be able to design compelling user experiences (Ibid.).

### **3.3 Sustainable HCI**

Since sustainable HCI is a relatively new topic with not a lot of research on it, it does not have a clear and unified definition (Nyström & Mustaquim, 2014). However, it can be thought of as the intersection of two fields: human-computer interaction (HCI) and sustainability. HCI is concerned with how people interact with technology, while sustainability is concerned with the long-term health and well-being of the planet and its inhabitants. Sustainable HCI emphasizes the need for integrating sustainability into all areas of HCI research and practice, from design to evaluation to use (Nyström & Mustaquim, 2018). It is a field of study that focuses on the design, development, and use of technology in a way that is socially and environmentally sustainable (Ibid.). The majority of Sustainable HCI research is limited to only addressing environmental sustainability, and Sustainable HCI has traditionally been concentrated on lowering carbon dioxide emissions, and resource reduction by altering people's consumption behaviors, and all of these initiatives through the design of systems (Ibid.).

In previous research, the authors interviewed people on sustainable HCI, and most of the participants said that there is no clear definition of sustainability as it is quite ambiguous (Silberman et al., 2014). All participants reached a consensus that sustainable HCI research needs to establish sustainability objectives that are tailored to each study or design project (Ibid.). Additionally, the majority of participants concurred that sustainability is an ongoing process rather than a final destination (Ibid.). This article proceeds to explain how a clear definition is not needed in the context of sustainable HCI, and that researchers should define it based on the specific project they're working on since there is not one definition that will fit every situation (Ibid.). Not much research has been dedicated to sustainable HCI, however, there's research about HCI that is somehow relevant to sustainable HCI (Silberman et al., 2014). In this article, the researchers provide examples such as work that assists the "sharing economy;" "collaborative consumption;" "do-it-yourself" activities; repair, appropriation, reuse, and maintenance; civic engagement; social movements; and effective democratic governance; as they could correlate with may align well with work that is focused on sustainability (Silberman et al., 2014). So far, sustainable HCI research has had little impact outside HCI according to this study however, over time there has become more awareness of the importance and seriousness of sustainability and the challenges that come with it (Ibid.). Thus, sustainability is now viewed as a moral and ethical obligation that requires practical action (Ibid.). Ultimately, the article outlines four steps to make sustainable HCI research more effective in promoting sustainability: (1) define and put into practice the work's sustainability objectives, and then evaluate it accordingly; (2) in order to gain a deeper comprehension of the social, economic, and ecological effects of design interventions, carry out research that takes into account longer time scales; (3) engage sustainability issues on appropriate social, physical, and temporal scales by collaborating with other fields and sectors; and (4) think about the role that information systems play in human institutions and natural systems, as well as a wider range of sustainability issues that go beyond consumer behavior (Silberman et al., 2014).

In one article, the authors argue that HCI has an imperative role in promoting sustainability, as computing and digital technologies are increasingly connected with everyday life and the environment (DiSalvo et al., 2010). The authors argue that sustainable HCI is important not just because of how it might have an impact on the environment, but also because it has the potential to address social justice issues (Ibid.). They write, "Sustainability concerns cannot be separated from social equity and justice concerns, because the environmental problems we face are the result of social and economic structures that create inequality and exploitation." (Ibid.).

A previous study argues for the importance of understanding the everyday practices that contribute to (un)sustainability in order to design more effective and equitable sustainable human-computer interaction (HCI) systems (Pierce et al., 2011). Current approaches to sustainable HCI often focus on reducing the environmental impact of technology, without considering the broader cultural and social contexts in which technology is used (Pierce et al., 2011). Additionally, there is a need to balance short-term and long-term sustainability goals.

Sustainable interaction design (SID) is an emerging concept within the field of human-computer interaction (HCI). The concept of Sustainable Interaction Design (SID) within the context of Human-Computer Interaction (HCI) is defined as a design approach that aims to promote sustainability by encouraging users to behave in more environmentally responsible ways (Nunes & Mont'Alvão, 2018). SID can be approached from two perspectives: an ecological perspective, which focuses on reducing the environmental impact of technology; and a social perspective, which emphasizes the role of technology in promoting social and economic sustainability (Nunes & Mont'Alvão, 2018).

In the paper, Nunes and Mont'Alvão highlight the significance of carrying out a multidisciplinary approach to SID which views the concept from both an ecological, and social point of view (Nunes & Mont'Alvão, 2018). The approach through this multi-perspective lens helps generate insight and elaborate on existing research in the field(s) of environmental science, psychology, sociology, and design (Ibid.). We can justify choosing a multidisciplinary approach due to the need for a comprehensive and detailed theoretical framework that helps integrate insights from multiple disciplines and perspectives (Ibid.).

### **3.4 Sustainable Interaction Design (SID)**

SID is "the study and practice of interaction design that is environmentally sustainable, socially responsible, and economically viable" (Blevis, 2007).

In SID, sustainability works as a lens to rethink the outcomes and the role of a design (Nyström & Mustaquim, 2014).

Sustainable Interaction Design (SID) is the primary goal of interaction design, which is characterized as the act of deciding between or influencing decisions about potential future states of being (Blevis, 2007). In addition to various principles to direct SID, the study suggests a framework for analyzing the material implications of interaction design in terms of use, reuse, and disposal (Ibid.). It illustrates how two of these principles may be applied to move the effects of designs towards more preferred

forms of use (Ibid.). Finally, the paper describes a vision for incorporating sustainability into the research and practice of interaction design (Ibid.). Because of its great relevance, this paper is referenced in research about sustainable interaction design and sustainable HCI (Ibid.).

As sustainable interaction design is starting to become implemented in the digital world, previous research has shown how designers of digital services can assess the impact of design decisions on greenhouse gas (GHG) emissions and determine the value of SID proposals (Preist et al., 2019). With their example on YouTube, they simulated the application of SID to the web application and showed that implementing one intervention could lead to significant emissions reductions (Ibid.). The authors of this research also highlighted the benefit of SID in lowering GHG emissions and the importance of using "evaluation beyond usability" for sustainable HCI (Ibid.).

The study "Sustainable Millennials: attitudes towards sustainability and the material effects of interactive technologies" surveyed undergraduate students to investigate their views on sustainability and the environmental impact of information technologies (Hanks et al., 2008). It utilized the Sustainable Interaction Design (SID) idea, which contends that Human-Computer Interaction (HCI) should give sustainability the highest priority by taking the environmental impacts of digital technology into account (Ibid.). The authors believe that SID can promote designs that are more ecologically conscientious (Ibid.).

According to the survey's findings, participants were generally concerned about sustainability and technology's influence on the environment (Hanks et al., 2008). The views toward sustainability did vary with some putting economic and social concerns at a higher priority than environmental concerns (Ibid.). According to the research, improving sustainable design necessitates cooperation between designers, engineers, and environmental scientists from many fields (Ibid.).

### **3.5 Digital Carbon Footprint**

In recent years, research into the digital carbon footprint has become more popular due to the increasing concern over the world's carbon footprint due to excessive data processing and digitization. Digital carbon footprint is an assessment of the carbon emissions caused by the usage of digital devices, the internet, and associated infrastructure. Data centers, network infrastructure, and end-user activities like streaming videos, using social media, and online shopping are all included in the digital carbon footprint.

Power consumption has significantly increased as a result of technology and data centers (Sharma & Dash, 2022). The quantity of CO<sub>2</sub> in the environment is

significantly impacted by this electricity use and as a result, this has been the key element contributing to a rise in the carbon footprint of digital technology (Ibid.). Due to the current growth in carbon emissions, the development of these technologies has all been characterized as having distinct environmental effects (Ibid.). Most businesses nowadays are building more data centers, which is thought to be the main cause of the total increase in carbon emissions (Ibid.).

In a previous research study, an estimation is presented regarding the global electricity usage that can be attributed to Communication Technology (CT) between 2010 and 2030 (Andrae & Edler, 2015). Three scenarios for the use and production of consumer devices, communication networks, and data centers were presented: best, expected, and worst. In the worst-case scenario, according to the analysis, CT could consume up to 51% of the world's electricity in 2030 (Ibid.). This might occur if there is an opportunity for improvement in the energy efficiency of fixed access networks, data centers, and wireless access networks. According to the current investigation, in the worst-case scenario, CT's use of power might also account for up to 23% of the world's released greenhouse gas emissions in 2030 (Andrae & Edler, 2015).

Another factor that has become an integral part of modern society, but it is also a significant contributor to the carbon footprint due to the large infrastructure constantly running behind each internet activity is the use of social media (Batmunkh, 2022). Previous research analyzed the carbon footprint produced by social media platforms and estimated the amount of CO<sub>2</sub> generated per hour of use for popular applications such as YouTube, Netflix, Facebook, and Tiktok (Ibid.). The results show that among all four applications, Netflix has the highest CO<sub>2</sub> emissions, producing 6 times as much CO<sub>2</sub> per hour as watching YouTube (Ibid.). In order to fulfill sustainability goals, the report underlines the significance of implementing green data centers, renewable energy, and energy-efficient internet consumption (Ibid.). In addition, technology needs to be improved through research and innovation to assist environmental sustainability (Ibid.).

### **3.6 Eco-feedback Technology**

A way to help digital designers become aware of their energy consumption while designing could be eco-feedback technology (Froehlich et al., 2010). The theory eco-feedback focuses on providing users with feedback about their energy usage and other resource consumption, in order to promote more sustainable behavior. Eco-Feedback technology is defined as “technology that provides feedback on individual or group behaviors with a goal of reducing environmental impact.” (Ibid.).

By tracking and analyzing energy use during design, digital designers can make informed decisions to reduce environmental impact (Ibid.).

It is discussed that several design principles for eco-feedback technology, including the importance of providing personalized feedback that is adapted to individual users' needs and preferences (Froehlich et al., 2010). Additionally, it is important to provide users with information about the environmental impact and consequences of their energy consumption, as well as the potential cost savings associated with reducing energy use, which could motivate users.

In order to design an effective eco-feedback technology, the need for accurate and timely data, user-friendly interfaces, and effective feedback mechanisms is crucial.

Despite eco-feedback technology being an imperative tool to help with sustainability, there are some challenges that come with it. For example, a study found that the level of prior knowledge about energy consumption can impact the effectiveness of eco-feedback, as consumers with more knowledge tended to use energy monitors more effectively (Buchanan et al., 2014). Additionally, the presence of social and environmental norms that encourage or discourage energy conservation can also impact the effectiveness of eco-feedback. There's also a chance for users to become overwhelmed or desensitized to feedback (Froehlich et al., 2010). These challenges should be taken into consideration to design effective eco-feedback technology for digital designers to be able to use efficiently.

Through Eco-Feedback, we can provide users with awareness of their consumption, which can lead to their eventual sustainable energy consumption. By providing some sort of value to the current energy consumption, it could motivate behavior change toward more sustainable practices

### **3.7 Summary**

As the digital world is growing, sustainable HCI practices and interventions in digital technology can significantly reduce the digital carbon footprint and contribute to a more sustainable future. By integrating sustainable interaction design principles and strategies into the design, development, and use of digital technologies, it is possible to mitigate the environmental impact and carbon emissions associated with digital devices, data centers, and online activities. The hypothesis implies that sustainable HCI and sustainable interaction design interventions such as energy-efficient design, optimizing data processing, promoting user awareness and behavior change, and adopting renewable energy sources can lead to a reduction in the digital carbon footprint.

The previous research shown in this theoretical framework shows how little research is done on the topic, and the need to create sustainable design practices to help designers design more sustainably and integrate it into their work.

A way to help integrate sustainability could be the theory of eco-feedback technology. As stated previously, eco-feedback technology focuses on providing users with feedback about their energy usage and other resource consumption, in order to promote more sustainable behavior (Froehlich et al., 2010). This would essentially help designers keep track of their energy usage, so they would be aware of any unsustainable choices.

Overall, this hypothesis provides a starting point for investigating the role of sustainable interaction design in addressing the environmental concerns associated with digital technology, and how it can contribute to a more sustainable and environmentally responsible future.

## **4 Results**

This chapter provides the results of the data analysis and the themes that have emerged from the data.

### **4.1 Interviews**

Here we will present the empirical data gathered from our interviews with a summary of each interview, with some direct quotes from the participants.

#### **4.1.1 Participant 1**

The participant acknowledges the importance of being conscious of the environmental impact of using computers and recognizes the harmfulness of digital design to the environment, such as the production of electronic devices and the energy consumption of servers. They state that they don't know much about the harmfulness of digital design. They also mention receiving little education on sustainable digital design during their studies.

*“Um, I mean, like, education-wise, I think it could get a lot more, um, extensive and also like, more detailed and like, more informative”*

*“Not really anything other than like, Oh, it's loading quickly and stuff like that. But other than that, I don't really know. “*

The participant believes that promoting sustainable HCI practices is crucial but acknowledges that designers are not currently doing enough, particularly in the software realm. They highlight the need for extensive and informative education to integrate sustainability into design work from the beginning. The challenges in implementing sustainable HCI practices include making it sensible for people outside the industry, addressing dependence on technology, and finding alternative ways to engage users without asking them to abandon technology entirely.

When asked about their own experience with sustainable HCI, the participant admits they have not yet incorporated it into their work. They express belief in the potential of sustainable HCI to reduce carbon footprints significantly if implemented effectively. Designers play a substantial role in promoting sustainable HCI practices, but they feel more could be done in terms of software design, as current efforts mainly focus on mental health aspects.

Regarding integrating eco-feedback technology into design practice, they mention challenges in making people feel it's worth their attention and getting them to reflect on their behaviors. They also anticipate changes in the design process itself, as more time and effort would be required to address environmental aspects. The participant concludes by expressing a need for more knowledge and motivation to engage with sustainable HCI practices, indicating a personal limitation rather than a lack of resources or support.

#### **4.1.2 Participant 2**

The participant acknowledged putting effort into reducing their carbon footprint in their personal life but admitted not considering it extensively in their digital design work due to a lack of knowledge and awareness. However, they expressed a desire to contribute positively to the environment through their work. They admitted having limited knowledge of the harmfulness of digital design to the environment and minimal exposure to education on sustainable digital design in their studies.

*“I don't have enough knowledge and knowing the, I guess the damage when I'm, for example, designing a website.”*

*“Um. I don't know. Too much. Like, I know more about products and product design and. But digital design I don't have as much knowledge in.”*

*“I think it's, uh, like through education. So like we were taught, um. Like we were taught about, as I said, like product design, how to be sustainable. And I'm I'm constantly thinking about like more physical stuff and how to be more sustainable and physical stuff, but not as much digitally. And so I think in education we could learn that more.”*



They also mentioned not having personal experience with using or designing for sustainable HCI. Regarding the role of designers in promoting sustainability, they emphasized the importance of designers' responsibility and knowledge in creating environmentally friendly designs. However, based on their experience, they did not encounter many designers actively promoting sustainability. When discussing the integration of sustainability into design work, the participant mentioned the need for education and resources that focus on sustainable digital design. They suggested that incorporating eco-feedback technology could be beneficial in promoting sustainable behavior. Moreover, they believed that incorporating eco-feedback technology would lengthen the design process but recommended it as a means of increasing environmental awareness. Lastly, the participant expressed the need for education and specific courses to support designers in integrating eco-feedback technology into their design practice.

#### 4.1.3 Participant 3

The participant discloses having limited knowledge about sustainable HCI and not actively considering it in their design process. They express awareness of certain guidelines for designing more sustainably, such as reducing digital waste and energy consumption. They mention personal efforts to reduce their environmental footprint, both offline and online (deleting unnecessary emails, conserving energy). However, they feel there is more to learn and acknowledge a lack of education on sustainable digital design throughout their studies. The participant identifies challenges in implementing sustainable HCI, primarily stemming from a lack of knowledge and a need for time to change existing habits.

*“The challenges I would face is probably the lack of knowledge because I don't know enough about it to be able to follow set guidelines or like act sustainable online.”*

*“I mean, I know that it helps. However, I don't know, like, how much it helps. But I know, like, one thing I think would be helpful is, for example, in our field of study, to be educated in the matter, or at least for it to be mentioned, because as it is now in the new media design program, like it has never been talked about even. Um, and it could also be the lack of knowledge about it in general. Um, because it's, I don't know if it's very new, but I feel like it's. Something a lot of people have overlooked before.”*

When asked about their experience with sustainable HCI, they indicate that they haven't specifically designed for environmental sustainability, although they have

considered inclusivity in their designs. Regarding the role of designers, the participant believes they play a significant role in promoting sustainable HCI by implementing sustainable practices and influencing clients to do the same. However, they also note a general lack of knowledge and conversation around sustainable design among designers they have encountered.

*“I think it's a big gap of knowledge. Like I don't I what I know like, I'm also thinking back, like in my internship as well. Like, it was never really talked about, um, in a way of how to design more sustainable.”*

*“I'm thinking back, like in my internship as well. Like, it was never really talked about by my mentors, um, in a way of how to design more sustainable.”*

In terms of resources and support needed, they suggest a checklist or simplified guidebook for designers, along with reminders to act sustainably.

*“There's so much information out there, it can be overwhelming. It would be helpful to have a curated list of resources that are specific to sustainable HCI.”*

They propose that education should incorporate sustainable HCI principles from the early stages of design training. They acknowledge the potential impact of eco-feedback technology, which provides users with information about their resource consumption to promote sustainable behavior. However, due to limited knowledge about its implementation, they are unable to provide specific examples. Finally, the participant emphasizes the need for education, workshops, and workplace policies to foster sustainable practices in the design field. They conclude by stating their own lack of knowledge on the topic and expressing a desire to learn more.

#### **4.1.4 Participant 4**

The participant defines sustainable HCI as designing websites with smaller file sizes, simpler designs, and reduced pollution from digital products. When asked about their efforts to reduce carbon footprint emissions, they admit to not putting any effort into it, simply because they don't think about it. They believe that sustainability is important in HCI due to the growing nature of the field and the potential problems it may cause in the future. However, their knowledge about the harmfulness of digital design to the environment is limited. The challenges identified by the participant in implementing sustainable HCI practices include senior designers who may resist change. They personally haven't considered sustainability much in their design work, although they conducted some research on the topic. They perceive the role of

designers in promoting sustainable HCI as primarily following the rules outlined in a book on sustainability. When asked about the resources or support designers need to integrate sustainability, they suggest a plugin that provides emission feedback during the design process, enabling them to make more informed decisions.

*“Maybe a nice Figma plugin? So when you do wireframes they can tell you what you just made here is energy consuming, and then you're going to be like, okay, I'm going to delete this feature and then make it more sustainable or something like that.”*

However, they are not aware of specific sustainable practices or technologies, apart from a book on sustainable web development and design. The participant has not heard of eco-feedback technology, but upon explanation, they associate it with a potential plugin or tool that provides users with information about their environmental impact. Concerns about integrating this technology into design practice include the possibility of homogenous designs and less creativity, as it may require designers to conform to specific guidelines. They suggest additional resources or support could be in the form of workshops that address the carbon emissions of designs. Overall, the participant demonstrates a limited awareness of sustainable HCI and the potential impact it can have on design practices.

#### **4.1.5 Participant 5**

In this interview, the participant initially struggles to define sustainable HCI but mentions considering the environmental perspective and the interaction between humans and computers in their understanding. When asked about their efforts to reduce carbon footprint emissions, the participant admits to not currently putting in much effort due to a lack of knowledge and research on the topic.

*“ I mainly haven't researched about it a lot. And plus, if I know how to do that and how to like reduce it if I know like some steps like you got to follow, then I would definitely follow it. “*

They also express a need for specific steps and education to implement sustainability in their designs. The participant acknowledges the importance of sustainability in HCI but feels that designers may not prioritize it unless explicitly required. They haven't encountered much emphasis on sustainability in their interactions with other designers. Regarding eco-feedback technology, the student is unfamiliar with it but sees the potential benefits of integrating it into designs to address carbon footprints. They believe additional design tools and resources would be helpful in implementing

eco-feedback technology. Overall, the interviewee reveals a need for education, awareness, and supportive resources to promote sustainable practices in HCI design.

#### 4.1.6 Participant 6

In the interview, the participant states they have limited knowledge about sustainable HCI.

*“I’ve never heard of the whole like I’ve heard about sustainability and about human computer interaction.”*

They confess to not actively considering their carbon footprint when working on design projects, although they have heard about some practices like using dark theme interfaces and reducing unnecessary communication to minimize energy consumption. They attribute their lack of consideration to not having the tools or awareness to address sustainability in their work.

*“It’s simply because it’s something that we’ve always been a little bit unaware of.”*

*“I don’t know much”*

*“Yeah. I simply didn’t really have the tools to do it, if that makes sense. I never even thought that this would be a problem in some way. Like, I never thought that this had this played a big enough role to be considered, like something that needed to put measures for, if that makes sense.”*

When asked about the importance of sustainability in HCI, the participant acknowledges that sustainability has often been overlooked and emphasizes the need for awareness and action in light of the climate emergency and the limited resources in the world. They believe that designers should adopt sustainable practices as a responsibility in every field, making it the standard rather than an exception. They mention some challenges in implementing sustainable HCI, such as integrating it into the design workflow and dealing with potential conflicts with clients or stakeholders. They also speculate that there might be conflicts between user experience design principles and sustainable HCI practices, but they do not have specific knowledge in that area.

*“I think like the actual workflow, it’s like something else, like just another component to take into account when doing design work. I see a problem, not a problem, but a challenge of working with other stakeholders or with a client because it’s something that you like. It’s another reason that you have to probably motivate when doing design work for a third party. It’s like, Yeah, I’m doing this because I’m following sustainable design practices. It’s probably yet another reason that you have to motivate when doing design work.”*

Regarding their own experience with sustainable HCI, the participant admits to not consciously considering sustainability during the interface design phase. However, they mention being more thoughtful about minimizing unnecessary emails and data storage, particularly in cloud environments, to optimize their workflow. They imply that designers play a role in promoting sustainable HCI practices by adopting more sustainable practices themselves and making sustainability the basis of any design. They mention that having guidelines or best practices to identify design choices that impact energy consumption would be helpful. The participant admits limited awareness of specific examples of sustainable HCI practices or technologies, apart from dark-themed interfaces that reduce energy consumption.

When introduced to the concept of eco-feedback technology, the participant expresses curiosity about its implementation and logistical aspects. They believe a setup or wizard that considers their design habits and provides best practices could be beneficial. They express that knowing their carbon footprint and seeing how their good practices reduce it over time would make them more aware and help them have a better impact. They also think that eco-feedback technology could streamline the design process by identifying less sustainable solutions. In terms of integrating eco-feedback technology into design practice, they suggest that designers need awareness about the impact of their work, along with tools that can track their current carbon footprint and provide guidelines for optimization. They propose translating the impact into measurable and relatable terms to enhance understanding.

#### **4.1.7 Participant 7**

When asked about sustainable HCI, Participant 7 shared their limited knowledge about sustainable HCI, stating that it involves designing environmentally friendly products and considering factors like accessibility and materials used.

When asked about their efforts to reduce carbon footprint emissions, Speaker 2 mentioned being environmentally conscious in their day-to-day life but expressed limited awareness of their digital carbon footprint. They acknowledged the importance of reducing emissions and believed in the collective impact of individual actions. They admitted to having limited knowledge about the harmfulness of digital design to the environment and mentioned receiving some education on sustainability in a product development course. However, the focus was more on the material aspects rather than digital sustainability.

*“I actually don't think I know much about it. So I would say I have a pretty limited idea of that, unfortunately.”*

*“Again, with the limited knowledge that I have on this, I think it's some challenges that could be faced, like new adaptations and implementations of products, or digital whatever systems used.”*

Regarding the challenges of implementing sustainable HCI practices, Participant 7 highlighted potential resistance to change and the need for people to adapt to sustainability in the digital space. They expressed a desire for sustainability to be taught more in their field and the digital world. They had not heard of eco-feedback technology before but recognized similar products related to water usage. Participant 7 discussed the challenges of integrating eco-feedback technology into design practices, including potential interruptions and the need for designers to constantly adapt; they mentioned the lack of information and the importance of providing resources and alternative approaches for designers.

*“Maybe if everyone had just a short debrief or a short course into sustainability, nothing too extensive. But just to give them options and to give them a bit wider perspective of what they could do to promote it. So maybe like a short course or a short introduction into it. And someone explained to them the importance of it, and the repercussions that could potentially happen if they don't implement these things, and I would love to have that as well.”*

#### **4.1.8 Participant 8**

This participant initially had a limited understanding of sustainability within HCI. They express their efforts to minimize their carbon footprint in real-life spaces by recycling, using public transport, and reusing materials. Digitally, they delete unnecessary data to reduce digital waste, although they were not aware of the environmental impact of doing so. They consider reducing carbon footprint emissions to be important but believe that individual actions alone cannot solve the larger environmental crisis and emphasize the need for action from large corporations. The participant acknowledges the importance of sustainability in HCI but feels the need to further explore its direct impact. They express limited knowledge about the harmfulness of digital design to the environment and believe that digital sustainability has less impact compared to real-life sustainability.

*“Within the human computer interaction I don't think that I'm aware of any.”*

They have not received education on sustainable digital design in their studies and see a challenge in integrating sustainability practices into both education and the industry. They have not consciously designed for sustainable HCI and believe that designers

play a significant role in promoting sustainable practices but are unsure how to do so implicitly. The participant suggests that designers need education, both formal and informal, to integrate sustainability into their work. Moreover, they are not aware of specific examples of sustainable HCI practices or technologies.

The concept of eco feedback technology is introduced to Jovtheman during the interview, and they recognize its role in promoting sustainable behavior through feedback on individual or group behavior. They see challenges in making designers care about their digital footprint and believe that education and practical training are necessary to integrate eco feedback technology into design practice.

*“ ...I think that the biggest challenge there would be to make people care, to make people notice that feedback, those notifications that they would get or in whatever form the feedback would be given.”*

Overall, the participant emphasizes the need for education and bridging the gap between sustainability and the design industry.

#### **4.1.9 Participant 9**

During the interview, the participant admits to having limited knowledge on the subject. They express their efforts in reducing their carbon footprint in general, such as recycling and buying sustainable fashion. However, they admit to lacking knowledge on how to increase sustainability in the digital realm. The participant acknowledges the importance of sustainability in HCI, highlighting its significant impact on everyday life and carbon emissions. They admit to not knowing much about the harmfulness of digital design to the environment or receiving education on sustainable digital design in their studies.

*“Oh, my God. I don't know. I actually I don't know.”*

*“...but when it comes to digital, I don't think I have enough knowledge to really know where I could acknowledge it, but I don't know what I could do to actually increase my sustainability.”*

*“Yeah, As I said, I don't know much.”*

*“I have no idea.”*

They believe implementing sustainable HCI practices faces similar challenges as implementing sustainable living in general, with the difficulty of changing behaviors and raising awareness. They emphasize the need for more information and knowledge to integrate sustainability into design work. They mention a lack of familiarity with

sustainable HCI practices, technologies, and eco-feedback technology. They express concerns about the balance between eco-feedback and other important aspects of human-computer interaction in design. When using eco-feedback technology, the participant expects a longer design process but hopes for better outcomes.

*"I think it will take me a bit longer maybe as well. Just because I have like another factor to focus on as well. So obviously it's going to take me longer."*

They suggest that designers need resources, support, tutorials, and knowledge to integrate eco-feedback technology effectively. The participant also expresses the desire to know the extent of their sustainability improvements in order to further motivate and refine their design choices.

#### **4.1.10 Participant 10**

The participant admitted that he had not received much education on sustainable digital design during his studies.

*"I won't say I'm educated on the topic, because I'm not but I've heard and I know there's like..."*

They expressed that they do not prioritize reducing his carbon footprint emissions at the moment, citing other issues as more important in his life. However, they recognized the importance of sustainability in the context of HCI, emphasizing that it is an area that can be addressed before it becomes a major problem. The participant mentioned the need for education and awareness regarding the harmful effects of digital design on the environment, particularly the energy consumption of servers and blockchain mining.

When asked about challenges in implementing sustainable HCI practices, the participant did not see any significant challenges, suggesting that it is a straightforward process if educators and professors are knowledgeable about it and can educate students effectively.

*"The challenges? I don't really see any challenges. As of right now. I think it's quite straightforward. I guess, I don't know as much about the topic and how it's supposed to be making it more sustainable. But it's just a matter of a professor or someone knowing about it and educating students, I don't think it's an issue at all."*

Regarding their own experience with sustainable HCI, the participant mentioned optimizing image sizes and efficient coding to reduce computing power. They also



believed that sustainable HCI could contribute significantly to reducing the carbon footprint of digital technologies, emphasizing the importance of making it a trend.

They recognized the role of designers in promoting sustainable HCI practices, noting that designers often set trends and influence consumer behavior. The participant mentioned that making sustainable design trendy would encourage designers and companies to prioritize it. They highlighted low-resolution images and efficient code as examples of sustainable HCI practices they were aware of. When introduced to the concept of eco-feedback technology, the participant recalled seeing similar features on websites, where users are provided with information about their environmental impact. They believed that the main challenge in integrating eco-feedback technology lies in making it desirable to companies and clients.

*“I feel like if companies don't want it, like if there's no desire for it, as a designer you can't really implement stuff that your client doesn't want. So I think that would be the main issue. As the designer you can't really take the liberties to do stuff, especially as a small scale designer. Like a freelancer, you have to stick to their brief, you can't really go outside of it. But if you're an AD or like a big executive making decisions, I think there's less issues.”*

Regarding the impact of eco-feedback technology on the design process, they believed it would not have a significant impact but might add an additional step or artifacts to the design. They emphasized the need for education and knowledge for designers to integrate eco-feedback technology effectively.

#### **4.1.11 Participant 11**

When asked about sustainable HCI, the participant admits to having limited knowledge and defines it as designing something that is more sustainable.

*“What does it mean? I don't really know. Designing something that is more sustainable?”*

They acknowledge the importance of reducing carbon footprint emissions but admit that he hasn't given much thought to it in digital design. They believe that lack of knowledge and education might be the reason for not implementing sustainable practices.

*“I think maybe in that case, like the main challenge is that people don't know enough about it and maybe the teachers don't know enough about it to care or to educate because they aren't up to speed with it. So maybe this generation thing as well.”*

The participant recognizes the potential impact of optimizing websites and reducing unnecessary clicks as ways to reduce the carbon footprint. They suggest that education and awareness can encourage people to design more optimally. The participant believes that if everyone starts designing environmentally responsible designs, it could make a significant difference in reducing the carbon footprint. Designers, according to the participant, have a responsibility to promote sustainable HCI practices and need knowledge as a key resource.

*“I think like in terms of all knowledge, if you know something, I think it's your is your duty to encourage people to do that also, if you think that is good. So I think if you know about it, just spread the word. I think it's like, yeah, designers have a responsibility here.”*

The participant mentions optimizing picture files and reducing website complexity as examples of sustainable practices. The interview introduces the concept of eco-feedback technology, which provides individuals with information about their environmental impact. The participant expresses concerns about the responsibility being shifted to users instead of designers and the challenge of incorporating such technology into design software widely.

*“I mean, the difficult thing then is to incorporate that stuff to be a general practice that is used all over because there's like a lot of design software that you use and you design stuff, right? So if, if that should be viable, it should be like a practice that it's like used all over. I don't know – Figma or WordPress, Adobe Suites. Without any plugins or stuff like that. So it's just like a thing that is used, I think.”*

They believe that eco-feedback technology may limit creative freedom but acknowledges its potential to provide new perspectives and improve eco-friendliness.

*“If there are limits, the little amount of freedom you have can be frustrating for designers. If you have an idea, then the ecosystem tells you that ‘No, that's not a good thing to do’. You always take away some of the creative freedom.”*

The participant suggests a software that can evaluate sustainability and testing websites for improvement as an additional resource or support needed for integrating eco-feedback technology. They emphasize the importance of tangible metrics and clear contexts to understand the impact of sustainable design.

#### **4.1.12 Participant 12**

Participant 12 admits to having limited knowledge about sustainable HCI. They acknowledge attending a focus group on low-impact web design but don't have much understanding of the concept. When asked about reducing carbon footprint emissions,

they mention basic actions like turning off lights but admit not giving it much thought. They haven't considered the digital aspects of reducing their carbon footprint either.

*“Not much. I have to be honest. I did have a focus group the other day about low impact web design. But I don't know much about that either, so.”*

Participant 12 lacks knowledge about how digital designs impact the environment or the harmful effects they may have. They also reveal that they haven't received any education on sustainable digital design throughout their studies. When asked about challenges in implementing sustainable HCI practices, they repeatedly respond with "I don't know." They speculate that sustainability might not be extensively taught because it's a relatively new topic. This participant has no notable experience. However, they acknowledge the important role of designers in promoting sustainable HCI practices, emphasizing the need to make users aware of their actions. They believe that designers require a significant amount of data and resources to integrate sustainability into their work and make people aware.

When asked about examples of sustainable HCI practices or technologies, Participant 12 mentions the concept of servers shutting down when inactive and being reactivated later. Moving on to the theory of eco-feedback technology, they admit to being unfamiliar with it. However, they suggest that a challenge in integrating eco-feedback technology into design practice is making it subtle and not overwhelming for users. They believe that the use of eco-feedback technology will become natural in the long run and might impact the design process. They also mention the need for additional resources, such as data points and user testing, to effectively integrate eco-technology into design practice.

#### **4.1.13 Participant 13**

The participant initially had no knowledge of sustainable HCI but learned about its focus on reducing harm to the environment, rather than considering the consumer's perspective. The interviewee expressed their efforts to reduce their carbon footprint, including being vegetarian and compressing images for websites. They highlighted the importance of considering sustainability due to the growing size of the internet and the significant emissions and energy consumption associated with digital design. The participant mentioned receiving some education on sustainable digital design but felt that it was not emphasized enough. They suggested a dedicated section or lecture on the topic

*“ So we we do get the access to it and it gets mentioned. But I think there should be a bigger phrasing on it, maybe have a dedicated section or lecture or whatever it is to that.”*

Regarding personal experience, the participant mentioned learning to optimize image sizes and reduce loading times for websites. They also discussed the role of designers in promoting sustainable practices and the challenges of balancing aesthetic trends with sustainability. They stated that they don't think implementing sustainability should be a challenge.

*“ I wouldn't say it is a challenge. I'm not sure why it's not being. I don't feel like there was a really big focus on it. As I said, it's more of a side sense and oh, be good people and be ethical. But I think it could be more of a focus on why it actually really matters and why everybody profits of it. As I said, like loading time, like it all kind of comes together and I wouldn't say it a challenge. Just do it.”*

They had not encountered designers who prioritize sustainability, as it is often considered an additional aspect rather than a primary focus. When asked about needed resources or support, the interviewee mentioned the importance of measuring energy consumption and having tools to identify specific problems in design. The concept of eco-feedback technology was introduced. The interviewee expressed interest in this technology and did not see immediate challenges in integrating it into design practice.

#### **4.1.14 Participant 14**

When asked about their understanding of sustainable HCI, the participant associates it with their personal relationship with computers and social media. When asked about their efforts to reduce their carbon footprint, the participant mentions recycling, conserving energy, and using public transportation, but admits to not making any efforts on the digital side. When asked about the harmfulness of digital design to the environment, they admit to having limited knowledge and not receiving specific education on sustainable digital design. They see challenges in implementing sustainable HCI practices in education due to limited time in courses. Moving to their own experience with sustainable HCI, the participant mentions considering code length to optimize loading times but not necessarily due to sustainability concerns.

*“I don't really have experience with thinking much about how sustainable something is, more than maybe trying to reduce the code length or something. I think about that sometimes. For example, if I have a lot of JavaScript code that's not really used, I*

*could delete it rather than make it load that code that's not needed or something.”*

They believe designers play a crucial role in promoting sustainable HCI practices, though it may not be their sole responsibility. They emphasize the need for more information and education to integrate sustainability into design work.

*“I think it needs to be taught out. So more information. I think that's the primary reason that I don't think about it because people didn't teach me and no one's talking about it.”*

The participant admits to being unaware of specific sustainable HCI practices and is unfamiliar with eco-feedback technology. The interviewer explains the concept of eco-feedback, and the participant sees the challenges of time consumption but doesn't mention other limitations. They suggest that designers may initially resist integrating eco-feedback technology due to additional work and inconvenience. They reiterate the need for education and resources to support designers in incorporating eco-feedback technology. Overall, the interview highlights the participant's limited knowledge and awareness of sustainable HCI and the importance of education and resources to bridge this gap.

## **4.2 Themes**

After the data has been analyzed using thematic analysis and three themes emerged: Lack of Knowledge, Resource Needs, and Concerns About the Design Process.

### **4.2.1 Theme 1: Lack of Knowledge**

Based on the data we have collected, a “lack of knowledge” also emerged when we interviewed students about their understanding of sustainable HCI and it is their biggest challenge in implementing sustainability in their designs. Participant 3 said,

*“The challenge I would face is probably the lack of knowledge because I don't know enough about it to be able to follow set guidelines and act sustainable online”.*

Additionally, when they were asked what they know about the harmfulness their digital designs cause, most students said they don't know much. They only know that it is somehow harmful and has an environmental impact, but not how or why.

The students implied that one factor that contributes to their lack of knowledge about sustainable HCI is a lack of emphasis on the topic in formal education. They reported a lack of dedicated courses or modules that address the environmental impact of digital technologies and how to lessen it. This absence of curriculum integration results in a limited understanding of sustainable HCI among students. Almost all the students reported that their education has not focused on sustainability in terms of the

digital world and that they have not received training in sustainable design practices. They followed that by saying that one of the reasons they do not practice sustainable digital design is that they simply are not educated on the topic.

## **4.2.2 Theme 2: Resource Needs**

This theme emerged after several students highlighted the need for specific resources in order to implement sustainability into their designs. These resources were categorized into three main types: knowledge, tools, and support.

### *4.2.2.1 Knowledge*

This traces back to the first theme “Lack of knowledge” as knowledge could be seen as a resource that's needed to integrate sustainability. Most students stated the need for resources to help them develop this knowledge. Several participants mentioned that they would benefit from more information about sustainable design principles and practices, as well as case studies and examples of successful sustainable HCI projects. Participant 3 noted that *"there's so much information out there, it can be overwhelming. It would be helpful to have a curated list of resources that are specific to sustainable HCI."*

### *4.2.2.2 Tools*

In addition to knowledge, students also expressed a need for tools and resources to help them design sustainable HCI. A common request was for software and design tools that integrate sustainable design principles and provide feedback on your environmental behaviors and the impact of design choices while designing. When asked, “What resources or support do you think designers need in order to integrate sustainability into their work?” Participant 4 replied:

*“Maybe a nice Figma plugin? So when you do wireframes they can tell you what you just made here is energy consuming, and then you're going to be like, okay, I'm going to delete this feature and then make it more sustainable or something like that.”*

Additionally, when eco-feedback technology was mentioned during the interview, students mentioned that such a tool or carbon footprint calculator would help them assess the sustainability of their designs. Participant 6 mentioned *“100%, yes. If I see how my good practices help reduce the number across time. I think that would really make a difference and it would help me be more aware of how I can make a better impact”* when they were asked whether finding out how much carbon footprint they emit will help them design more sustainably.

### *4.2.2.3 Support*

Finally, students identified the need for support and guidance in order to design sustainable HCI. This included mentorship from experienced designers or sustainability experts, as well as access to networks and communities of practice where they can learn from others and share their own experiences. After being asked “From the designers you've come in contact with, do you think they tried promoting it?” referring to sustainable design, participant 3 replied *"I'm thinking back, like in my internship as well. Like, it was never really talked about by my mentors, um, in a way of how to design more sustainable."* This shows how big of a role and an impact mentors have in promoting sustainability since they have a big say in their workplace. Students reported a lack of experienced professionals or mentors who could provide guidance and support in incorporating sustainable practices into their designs. This lack of mentorship further contributes to their limited knowledge and hampers their ability to engage in sustainable design.

Overall, these findings suggest that students require a range of resources in order to design sustainable HCI. These include knowledge about sustainable design principles, tools and software that support sustainable design practices, and support and guidance from experienced designers and sustainability experts. By addressing these resource needs, it may be possible to bridge the gap in young people's knowledge about sustainable HCI and support them in designing more sustainable technologies.

### **4.2.3 Theme 3: Concerns About the Design Process**

In addition to the lack of knowledge and resources, students also expressed concerns about the design process when it comes to sustainable HCI. The main concern that appeared is that designing sustainably can be time-consuming and that adding an extra step to the design process can be frustrating at first. Participants were asked what challenges they see in implementing sustainable human-computer interaction practices, and some of their responses included:

*"I think it will take me a bit longer maybe as well. Just because I have like another factor to focus on as well. So obviously it's going to take me longer."* - Participant 9,

*"I think like the actual workflow, it's like something else, like just another component to take into account when doing design work. I see a problem, not a problem, but a challenge of working with other stakeholders or with a client because it's something that you like. It's another reason that you have to probably motivate when doing design work for a third party. It's like, Yeah, I'm doing this because I'm following sustainable design practices. It's probably yet another reason that you have to motivate when doing design work."* - Participant 6.

Another concern that occurred is not knowing exactly how something needs to be changed in the design if it is stated to not be sustainable. The majority of the interviewees who raised this issue noted that while it is helpful to learn how sustainable the design they are creating is, it is still unclear what could be a more sustainable option. This lack of clarity can make the process of designing sustainably feel even more overwhelming.

Furthermore, some participants expressed concern that designing sustainably would lead to reduced creative freedom and that all designs could begin to look the same. Participant 11 explained,

*"If there are limits, the little amount of freedom you have can be frustrating for designers. If you have an idea, then the ecosystem tells you that 'No, that's not a good thing to do'. You always take away some of the creative freedom."*

These issues emphasize the significance of finding methods to include sustainability in the design process that does not limit creativity or add unnecessary delays. Addressing these concerns will be critical to encouraging more young designers to prioritize sustainability in their work.

## **5 Discussion**

In this chapter, the researchers discuss the results and findings from the interviews as well as the method used and what challenges were faced.

### **5.1 Result discussion**

This study explored, identified, and analyzed the gaps in students' understanding regarding the theory of sustainable HCI design, in order to help design educators and policymakers develop effective strategies to enhance students' knowledge and awareness of sustainable design practices in the digital realm. Moreover, this study investigated the resources young designers need, in order to integrate sustainability into their design processes. This links to the theory of the Digital Carbon Footprint, as identifying the mentioned resources helps with reducing the digital carbon footprint by identifying the key challenges designers face in implementing sustainable design practices and exploring effective solutions to overcome these challenges.

The first research question for this study was "How can young designers be incentivized to learn more about sustainable HCI?".

That could be achieved through a combination of training programs, mentorship opportunities, workshops, and recognition for sustainable design achievements. Lack



of knowledge was a common theme that emerged from the data (*Theme 1*), indicating that young designers may be interested in learning more about the SID frameworks, but may not have the necessary knowledge or skills to do so. Providing training programs and mentorship opportunities can help to address this gap in knowledge and provide young designers with the tools they need to integrate sustainability into their design processes. This proves that educators have a big role in contributing to helping the environment and reducing the digital carbon footprint. Recognition for sustainable design achievements can also incentivize young designers to learn more about sustainable HCI by providing them with a sense of accomplishment and recognition for their efforts.

With this comes the following research question “What resources do young designers need to integrate sustainability into their design process?”

Young designers need access to a range of resources in order to integrate sustainability into their design process. The data gathered during this research contributed to identifying the resources that could be beneficial for young designers. Resource needs were a common theme that emerged from the data (*Theme 2*), indicating that young designers may face barriers to sustainable design due to limited access to tools, knowledge, guidelines, and support from mentors/leaders/educators as well as peers. To address this, young designers may need access to sustainable tools for designing, such as plugins in design softwares. Furthermore, implementing a relevant theoretical framework, such as eco-feedback technology, provides young designers with feedback on potential sustainable/unsustainable practices while designing. The theory of eco-feedback technology supports the notion that providing designers with access to such resources can incentivize their learning and adoption of sustainable HCI practices. Other than the fact that these tools uncover unsustainable practices, they can also serve as a source of motivation for designers as they witness the positive impact of environmentally-conscious designs. Collaboration with experts in sustainability can also provide young designers with the guidance, support, and drive they need to integrate sustainability into their design process.

## **5.2 Method discussion**

The qualitative method used for this study involved semi-structured interviews with 14 students from the Jönköping region. The study set out to discover where young people's knowledge of sustainable HCI is lacking and what tools they would require to create sustainable HCI.

The capability of this approach to compile comprehensive and rich data on the experiences and viewpoints of the participants was one of its advantages. We were

able to learn more and have an in-depth understanding of participants' perspectives and experiences with sustainable HCI because of the semi-structured format's flexibility in asking. Additionally, the use of interviews allowed for a more individualized strategy, establishing a secure environment for the participants to express their thoughts.

However, one of the weaknesses of this method was our limited resources such as time and access to a broader target group. This limits the generalizability of the findings and could have also restricted our ability to explore certain areas in more depth. A greater sample size or additional techniques, such as surveys or focus groups, might have given a more thorough knowledge of the research objectives and helped with the validity of this research. We could have obtained more in-depth information on the research subject if we had had access to more resources.

The method was effective in revealing what resources young designers require to include sustainability in their design process, which helped to answer the research questions. In terms of validity and reliability, the use of semi-structured interviews allowed for the participants' perspectives to be accurately captured.

Overall, the chosen method had both strengths and weaknesses. While the small sample size and lack of time and resources may limit the generalizability and depth of the findings, the use of semi-structured interviews allowed for a personalized and in-depth exploration of the participants' experiences and perspectives.

## **6 Conclusions and further research**

In this chapter, a conclusion for the study is given with implications and further research recommendations. We mention what implications this study has practically and scientifically. Moreover, we give recommendations of what to improve, and what could have been done better for future research.

### **6.1 Conclusions**

In conclusion, this study sought to explore the gap in young people's knowledge about sustainable human-computer interaction (HCI) and the resources they need for designing sustainable HCI. Through qualitative research involving 14 semi-structured interviews with informatics students in the area of Jönköping, we identified three themes: Lack of Knowledge, Resource Needs, and Concerns About the Design Process. The findings showed that young designers have a limited understanding of sustainable HCI, which highlights the need for education on the topic. The aim of the study was to provide insights and recommendations to digital designers, design educators, and policymakers on how to adopt sustainable digital design practices that minimize the environmental impact of digital products and services. With our research, we wanted to contribute to the development and awareness of sustainable digital design practices by figuring out what challenges young people face by integrating sustainability, as well as what resources they need.

Moreover, the research highlights the importance of sustainable digital design, as data processing from web applications contributes significantly to carbon emissions. Therefore, it is imperative to integrate sustainability into the design process to make a positive impact on the environment and promote responsible technology use.

The implications of this study are significant as it provides insights into the knowledge gap among young designers regarding sustainable HCI and highlights the need for education on the topic. Furthermore, the study provides a foundation for future research in the area of sustainable digital design and HCI. Overall, this study contributes to the larger problem statement of how to incentivize young designers to learn more about sustainable HCI and what resources they need to integrate sustainability into their design process which includes education, design tools, feedback technology, and support.

#### **6.1.1 Practical implications**

The practical implications of the findings from this research on sustainable HCI could be significant for the industry, public sector, and society as a whole. By identifying the resources that young designers need for designing sustainable HCI and highlighting the gap in their knowledge about sustainable HCI, this research may

encourage companies, organizations, and governments to invest in training and education programs for young designers to promote sustainable design practices. This, in turn, may lead to the development of more environmentally friendly products and services, which can benefit society and the planet as a whole. Additionally, the findings from this research may help to raise awareness about the importance of sustainable design practices and encourage designers to take a more proactive role in addressing the environmental challenges facing our world today. Overall, the practical implications of this research could be far-reaching and contribute to a more sustainable and environmentally conscious future.

### **6.1.2 Scientific implication**

The scientific implications of the findings from this research on the topic of sustainable HCI could be significant for the scientific community. By shedding light on the gap in young designers' knowledge about sustainable HCI and identifying the resources they need for designing sustainable HCI, this research may inspire further studies to investigate the factors that inhibit or facilitate sustainable design practices among young designers. Additionally, this research may contribute to the development of effective strategies for incentivizing young designers to learn more about sustainable HCI and promote sustainable design practices in the field. Ultimately, the scientific community may benefit from this research by gaining a deeper understanding of how to bridge the gap in knowledge and resources to promote sustainable HCI practices among the younger generation of designers.

## **6.2 Further research**

Based on the results and conclusions of this study, there are several potential avenues for further research. One area for future research could be to investigate the effectiveness of different types of training programs and mentorship opportunities in incentivizing young designers to learn more about sustainable HCI. This could involve conducting experimental studies where different training programs are compared to determine which ones are most effective in improving young designers' knowledge and skills in sustainable design practices.

Another area for future research could be to explore the potential of new technologies and tools for supporting sustainable HCI design. This could involve developing and testing new eco-feedback technologies, carbon footprint calculators, and other tools to help young designers integrate sustainability into their design process. Additionally, research could be conducted to identify the key challenges that designers face in using these tools and technologies and to explore effective solutions for overcoming these challenges.

Finally, further research could be conducted to explore the role of collaboration and interdisciplinary approaches in promoting sustainable HCI design. This could involve investigating the benefits of collaboration between designers, sustainability experts, and other stakeholders in the design process. Additionally, research could be conducted to identify the key barriers to collaboration and to explore strategies for overcoming these barriers.

Overall, there are many potential avenues for further research based on the results and conclusions of this study. By building on this research, we can continue to develop effective strategies for promoting sustainable HCI design and reducing the carbon footprint of digital technologies.

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## **8 Appendixes**

### **8.1 Interview Guide**

We are going to be conducting semi-structured interviews with 10-15 informatics students. To avoid any bias, we will not inform the participants of the interview's topic in advance to prevent them from researching it beforehand since we're exploring the gap in their knowledge. However, at the beginning of the interview, we will provide the participants a short overview of our topic and the aim. By conducting the interviews in this manner, we hope to obtain unbiased and candid responses from the participants, which will aid us in identifying the gaps in their knowledge and the areas that need to be emphasized in sustainable HCI education. We aim to conduct these interviews in a respectful and ethical manner, ensuring that the participants' privacy and rights are protected at all times. We will use a language that is familiar to our participants and us the interviewers. Therefore, we will be using English during all our interviews.

#### **Setting and Context**

The interviews will be individual, with only one of the interviewers present. It will take place at school properties, where we will book a private room to ensure privacy and no distractions. If that is not possible for some participants we'll do it over the Zoom meeting, but it will be the very last option. The Interviews will be recorded and transcribed with the participants' consent, for the interviewers to go back to them to check if they have missed any information and to make sure nothing is left out.

After we have provided an overview of our topic we will start with a few warm-up questions to get familiar with the environment and allow them to get more comfortable before we start with the real questions. We will also ask whether they want to be anonymous or if they do not mind having their name stated as well as if they approve of them being audio recorded

## **Questions:**

### *Part 1*

1. What does the term "sustainable HCI" mean to you?
  - a) If the interviewee's definition or understanding of sustainable HCI does not match ours we provide them with the definition we are working with in our research to make sure we are on the same page.
2. How much effort do you put into reducing your carbon footprint emissions?
  - a) How important do you consider it for you?
  - b) How come you do not put much thought into it?
3. In your opinion, why is sustainability important in the context of HCI?
4. What do you know about the harmfulness of digital design to the environment?
5. Have you received any education on sustainable digital design throughout your studies?
6. What are the challenges you see in implementing sustainable HCI practices in education or industry?

### *Part 2*

1. Can you describe your own experience with using or designing for sustainable HCI?
2. How do you think sustainable HCI can contribute to reducing the carbon footprint of digital technologies?
3. What role do you think designers play in promoting sustainable HCI practices?
4. What resources or support do you think designers need in order to integrate sustainability into their work?
5. In your opinion, what are ways to integrate sustainable HCI?
6. Can you describe some examples of sustainable HCI practices or technologies that you are aware of if any?

### ***Eco-feedback Technology***

1. Have you heard of eco-feedback technology before?
  - a) If so, can you describe what it is and how it works?
  - b) If not, Eco-feedback focuses on providing users with feedback about their energy usage and other resource consumption, in order to promote more sustainable behavior

*In between these questions we will give the participants a paper with an overview of eco-feedback technology so they can clearly understand what it is before we move on to the next questions.*

2. What are some challenges or limitations you see in integrating eco-feedback technology in design practice?
3. How might the use of eco-feedback technology impact the design process itself?
4. What additional resources or support do you think designers need in order to integrate eco-feedback technology into their design practice?