Ethical navigation in the development of healthcare digital applications: a case study of the DC4DM Learning Lab on Madeira Island

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Abstract

The digitization of industry sectors is revolutionizing business practices, enhancing efficiency, agility, and data-driven decision-making. However, healthcare professionals face barriers such as insufficient computer literacy, cybersecurity concerns, and ethical considerations, which hinder the adoption of innovative technologies. Interdisciplinary initiatives like the *Digital Creativity for developing Digital Maturity future skills* (DC4DM) project aim to equip future Digital Maturity Enablers to support healthcare professionals with creative and strategic digital solutions, allowing healthcare systems and organizations to transform and achieve maturity. The paper presents an empirical study to critically reflect on the importance of including specific considerations and attitudes toward ethics while designing future digital applications for the healthcare sector. Despite the limitations of the proposed study, the paper aims to provoke a wider debate on how higher education curricula should align with real-world needs while connecting with Small and Medium Enterprises (SMEs) in search of innovative ideas towards digital transformation. The paper presents the knowledge exchange which occurred between a specialized health solutions startup, *Musiquence Technology* (*MT*) and an international and multidisciplinary team of students (*Sensitiva* project team) while developing possible future digital healthcare applications through the DC4DM methodology at the very first DC4DM Learning Lab (DC4DM LLab1). Then it reports the results from a later conversation that occurred between *Musiquence Technology* Startup and *Sensitiva* project team in February 2024. While trying to understand the value of involving real SMEs within the creative process of intensive design and learning experiences, such as the DC4DM LLab1, this empirical study aims to highlight how the connection with real world challenges and organizations could effectively instill a strong sense of ethical responsibility among young digital technology experts and businesses.

Keywords: Design Education; Digital Health Technologies; Digital Transformation in Healthcare; Ethics; Future.

1. Introduction

Digital transformation has become a major interest for small and medium-scale enterprises (SMEs) as it would allow them to pursue innovative and competitive solutions to respond both to internal needs and market conditions. For example, through digitalization companies can 1) substitute manual and repetitive labor using technologies such as artificial intelligence and robotics (Ayoko, 2021), 2) access real-time metrics on the overall performance of their business (Holopainen et al., 2021), and 3) achieve economic, social, and political improvements among many other advantages (Sabbagh et al., 2012). Many business models evolved to enhance their operations, efficiency, and competitiveness through the digitalization of their operations. Just to mention, the use of digital platforms for online marketing, e-commerce and social media purposes enables SMEs to reach out to wider audiences and the global market. Improved customer relationship management (CRM) systems help in providing personalized and efficient customer service (Matt et al., 2023). Finally, some digital tools can help in optimizing the supply chain by providing real-time visibility, reducing lead times, and enhancing overall efficiency (Matt et al., 2023).

While businesses and organizations transition towards complete digitalization, the need to update and enhance workforce skills accordingly becomes crucial. Particularly in the case of SMEs, high is the demand for digitally mature professionals (Vezzani et al. 2023, Bruno & Canina, 2019; *The Future of Jobs Report 2020*, n.d.). These individuals own Digital Creative Abilities (Vezzani et al. 2023, Bruno & Canina, 2019; Canina & Bruno, 2021) and can demonstrate technological knowledge and skills in robotics, artificial intelligence, Internet of Things, Augmented Reality (Sousa & Wilks, 2018), including, among others, digital hard skills such as programming, digital marketing, and others (Bernhard & Russmann, 2023).

As in all sectors, the advancements in digital applications and systems are transforming the healthcare industry on different levels. Specifically to this sector then, it is urgent to shift business models to encourage a universal approach to digital healthcare, combining patient empowerment, purposeful use of digital technologies, and data-driven care for improved outcomes (Kraus et al., 2021).

When analyzing more specific cases in the healthcare field, healthcare professionals (HP) are required to develop digital competencies to use them responsibly in the context of patient care. To ensure a smooth transition among healthcare professionals to the new era of digitalization, Konttila et al. recommend that healthcare organizations focus on cultivating a supportive social environment within the workplace. The authors emphasize that fostering a positive atmosphere is crucial, as the successful adoption of new technologies depends heavily on both organizational and collegial support (Konttila et al., 2019).

Another aspect to take into consideration in this constantly evolving scenario is that as digital health technologies (DHT) continue to mature, public concerns regarding ethical issues have become increasingly prominent. These ethical and legal concerns encompass a range of issues, including patient data breaches and the potential for the dehumanization of patient-doctor relationships, patient autonomy and empowerment, and other issues (Cordeiro, 2021). Also, inflated publicity regarding DHT's alleged benefits for improving mental health can be misleading (Torous & Roberts, 2017). These concerns have led to heightened resistance towards the development and usage of DHT, both within healthcare organizations and among private users (Torous & Roberts, 2017).

Upon examining the far-reaching implications of digitalization across multiple industry sectors for SMEs, numerous scholars argue for a necessary shift in the educational paradigm (Halverson & Collins, 2009). Collaboration between technology leaders and educators is encouraged to harness learning technologies effectively. A societal shift in thinking is required for political changes to make new educational resources accessible to all (Halverson & Collins, 2009).

Efforts towards achieving a necessary shift in the educational paradigm, including collaboration between technology leaders and educators, have been supported by initiatives such as the *DC4DM—Digital Creativity for Developing Digital Maturity Future Skills* project (www.dc4dm.eu). The DC4DM methodology aims to encourage an interdisciplinary and collaborative way of educating future professionals who will help SMEs become digitally mature (Vezzani et al., 2023).

This article focuses on the knowledge exchange which occurred between a specialized health solutions startup, *Musiquence Technology* (*MT*), and an international and multidisciplinary team of students (*Sensitiva* project team) while developing possible future digital healthcare applications for the very first DC4DM Learning Lab (DC4DM LLab1). This article presents an empirical study to critically reflect on the importance of including specific considerations and attitudes toward ethics while designing future digital applications for the healthcare sector. Despite the limitations of the proposed study, the paper aims to provoke a wider debate on how higher education curricula should align with real-world needs while connecting with Small and Medium Enterprises (SMEs) in search of innovative ideas towards digital transformation.

After contextualizing the study within the current digital technologies for healthcare scenario, the article provides an overview on both the type of learning conditions and type of knowledge exchange which occurred

between *MT* startup and *Sensitiva* project team and led to the development of *Sensitiva* at the DC4DM LLab1 (July 2022). The article then reflects on subsequent discussions between the parties in February 2024, examining how the DC4DM educational model and the direct interaction with a tech partner like MT influenced attitudes and critical considerations towards ethics in designing digital healthcare solutions like *Sensitiva*. Grounded in the insights provided by MT representatives and *Sensitiva* team members during and after the DC4DM LLab1, this empirical study aims to highlight areas that still need reinforcement within higher education curricula to better prepare future professionals for the complexities of the digital world. The article concludes by inviting educators, digital technology experts, and healthcare businesses to collaborate in fostering a strong sense of ethical responsibility among young professionals and organizations in the creative, tech, and business fields.

2. Digital Technologies in Healthcare and Health Services: Challenges, Risks, and Opportunities

While recognizing the needs and potential for digitizing health services, several studies found barriers that make HP reluctant to use digital tools in their clinical practice. For example, failing to recognize the impact of digital competence poses a potential threat to patient safety by increasing the likelihood of human errors, which can lead to ethical issues (Konttila et al., 2019).

For example, Pereira et al. performed a SWOT analysis of electronic health records at *Centro Hospitalar do Porto* (Pereira et al., 2013). The SWOT analysis tool is designed to help, for example, organizations and individuals identify and assess major internal and external factors that can impact goals and objectives. They identified that the lack of financial resources can affect the purchase of new IT resources. Additional ethical concerns associated with digitalization include safeguarding patient autonomy and ensuring transparency in algorithms (Konttila et al., 2019; Pereira et al., 2013). Also, automation is becoming a reality; with sophisticated technologies such as Artificial Intelligence (AI) and the Internet of Things (IoT), businesses can stay competitive, foster innovation, and enhance customer service. Such technologies may raise concerns regarding the privacy and security of sensitive information.

Nevertheless, some opportunities that can increase the adherence of digitized-based resources have been identified. Thanks to the adoption of digital technologies, health services can 1) rely on the use of digital files instead of traditional records on paper, certainly less efficient and environmentally friendly; 2) exploit the use of mobile applications to enhance remote access to other systems and data within them; 3) actively design and enhance existing security protocols; 4) seek government incentives to modernize equipment, among other strategic incentives (Pereira et al., 2013; Philips Future Health Index 2021, n.d.).

Recognizing the benefits of digital transformation holds significant potential for improving efficiency, accessibility, and overall quality of healthcare. A summary of the effects that digital technology can have in the healthcare sector can be seen in Table 1.

Table 1: A SWOT analysis concerning the impact of digital technology in the healthcare sector.

Strengths ▪ Cost effectiveness. ▪ Customization of user interface to the skill set of the user. ▪ Easy maintenance. ▪ Easy to expand.	**Weaknesses** ▪ Ethics and privacy concerns. ▪ Lack of system documentation. ▪ Lack of training of users. ▪ Lack of clinical evidence.
Opportunities ▪ Promoting environmentally friendly practices. ▪ Remote access of systems. ▪ Enhance security protocols. ▪ Governance assistance to modernize systems. ▪ Worldwide interest in digital healthcare transformation.	**Threats** ▪ Patient autonomy. ▪ Data Security. ▪ Economic constraints. ▪ Scarce talented IT personnel. ▪ One-size-fits-all approach. ▪ Low acceptance and adoption

Source: This table gathers different aspects identified through research by Konttila et al. (2019) and Pereira et al. (2013).

3. Preparing Digital Maturity Enablers to Navigate the Complexity of an Ever-Changing Technological Landscape. The DC4DM Methodology at Test During the LLab1 Funchal

The overview on DHT presented in the introduction seeks to highlight some of the current concerns and reluctance to adopt new digital applications in healthcare. Particular attention is given to the ethical and legal implications when adopting new digital tools and systems for healthcare services. However, in a digital landscape in constant transformation, individuals and organizations must develop new competencies and skills to navigate the complexity of the digital world.

Through the Erasmus+ funded project *DC4DM—Digital Creativity for developing Digital Maturity future skills,* a human-centered design model to educate Digital Maturity Enablers (DMEs) was developed and tested. DMEs are creative professionals who will be able to drive small and medium organizations toward their digital transformation and maturity. By possessing specific creative digital skills, they will be able to extract value from what the technological landscape offers and respond to human needs through the principles of ethics and sustainability (Vezzani et al., 2023).

The DC4DM educational model was implemented through practical application during three *Digital Maturity Learning Labs*, intensive design-led workshops characterized by cross-functional and interdisciplinary teamwork, a future thinking approach, and tech-driven SMEs or Start-Ups participation. The first *Digital Maturity Learning Lab* happened on Madeira Island in July 2022. LLab1 was titled “Feeding Madeira. Regenerative and Distributive Food Systems for Sustainable Island Futures” and aimed at challenging the participants to think about the island as a testbed for sustainable and potentially circular systems where digital technologies can enable the shift towards distributive and regenerative local food systems. The participants were invited to respond creatively to the general challenge through the lens of one of the following macro-themes: (1) Agrobiodiversity is our safety net; (2) Forest & Water as island lifeblood; (3) Pollinators our saviors; (4) Waste as opportunity. The LLab1 lasted 10 days and involved 36 master’s and undergraduate students from Politecnico di Milano (Italy), Télécom Saint-Etienne, Mines Saint-Etienne (France), and Universidade da Madeira (Portugal), with different study backgrounds in the areas of design, engineering, business and organic agriculture. Organized into six multidisciplinary and multicultural teams, the participants encountered numerous and various local stakeholders able to stimulate their understanding of the island’s challenges concerning sustainable development.

Six local start-ups were selected, each one assigned to one of the teams, to become part of this creative process towards Madeira's digital transformation (Vezzani, 2023). This paper focuses on the development of one specific project and future scenario within the macrotheme (3) *Pollinators our saviors*. Named *Sensitiva*, inspired by the plant that reacts quickly to external stimuli and is common in tropical regions, this project deserved peculiar attention. Compared with others developed during the LLab1, it is the product of a constant dialogue with a startup whose expertise is in healthcare applications. None of the other teams had the opportunity to receive such guidance along the design process, to reflect on ethics and other implications.

The Sensitiva project team was made of six students from three different European countries, ranging from second-year bachelor's to second-year master's programs. This international mix brought diverse perspectives and advanced insights, fostering innovative problem-solving. However, the variety in experience levels, methodologies, expectations, and cultural perspectives introduced significant communication and coordination challenges. Robust team dynamics and conflict resolution strategies were essential to fully harness the multidisciplinary expertise in interaction design, integrated design, graphic design, computer science engineering, and product design. This diversity enriched the project but also highlighted the need for effective collaboration mechanisms.

The collaborative workspace was designed to inspire creativity and innovation, equipped with tools for rapid prototyping and iterative testing. This environment promoted open idea-sharing and collective growth but also exposed disparities in familiarity with advanced tools and methodologies. Regular workshops and brainstorming sessions aimed to bridge these gaps, but their effectiveness varied, revealing the need for more tailored approaches to skill development. Critically evaluating these interventions is essential to ensure all team members can contribute effectively and address any gaps in technical proficiency.

Musiquence Technologies (MT) played a pivotal role in guiding the project. MT's continuous support and expert guidance provided invaluable insights into technological developments and ethical considerations specific to healthcare. They directed and supported the team's understanding of healthcare complexities, helping maintain a critical perspective on supporting vulnerable communities and assessing the ethical impact of the project. This collaboration was crucial in navigating regulatory landscapes and ensuring ethical alignment. However, the team's reliance on MT for ethical and practical validation exposed a potential gap in their ability to independently address these critical aspects. This dependency underscores the necessity for building internal capacity for ethical decision-making.

The ongoing dialogue with MT was crucial for identifying innovative solutions and aligning project objectives with ethical standards. MT's guidance, delivered through dynamic tutoring sessions during the project's development, helped navigate regulatory complexities and supported the team in maintaining a critical vision of the project's impact on vulnerable communities. This support highlighted the importance of ethical decision-making and provided a robust framework for assessing the project's ethical implications. However, the reliance on MT also indicated that the team had some gaps in their internal capacity for independently navigating these challenges, emphasizing the need for further enhancing their capabilities in these areas.

The Sensitiva project was characterized by an open-dialogue approach, where initial misunderstandings and conflicts were seen as opportunities for deeper engagement and learning. Triggers for these interactions included the team's varied expertise

3.1. Using the DC4DM Methodology to Develop Future Digital Scenarios and Applications in Healthcare. The *Sensitiva* Project

During LLab1, a multidisciplinary and international team of students developed the *Sensitiva* concept alongside the constant dialogue with the representatives of *Musiquence Technologies* (*MT*), a digital health startup specializing in creating digital interventions to enhance cognitive and physical well-being across various clinical populations. The purpose of such direct interaction between start-ups and students was to provide insights into current technological developments in the healthcare system. Also, *MT* was asked to showcase some of their

projects to help the students understand the enterprise mindset, needs, and future potential developments. The project's objective for *MT* was to investigate emerging technological trends that hold potential value (or lack thereof) in future healthcare scenarios. This will enable *MT* to gain a more comprehensive understanding of the most probable scenario to be embraced in the healthcare field.

Sensitiva envisions a future where patients are the central focus when utilizing DHT. By integrating advanced diagnostic and therapeutic technologies with human-centered design principles, *Sensitiva* aims to provide personalized care pathways that are adaptive to individual patient needs and contexts. The project employs a holistic approach to healthcare, wherein technology not only supports clinical decisions but also enhances patient autonomy and engagement in their health management.

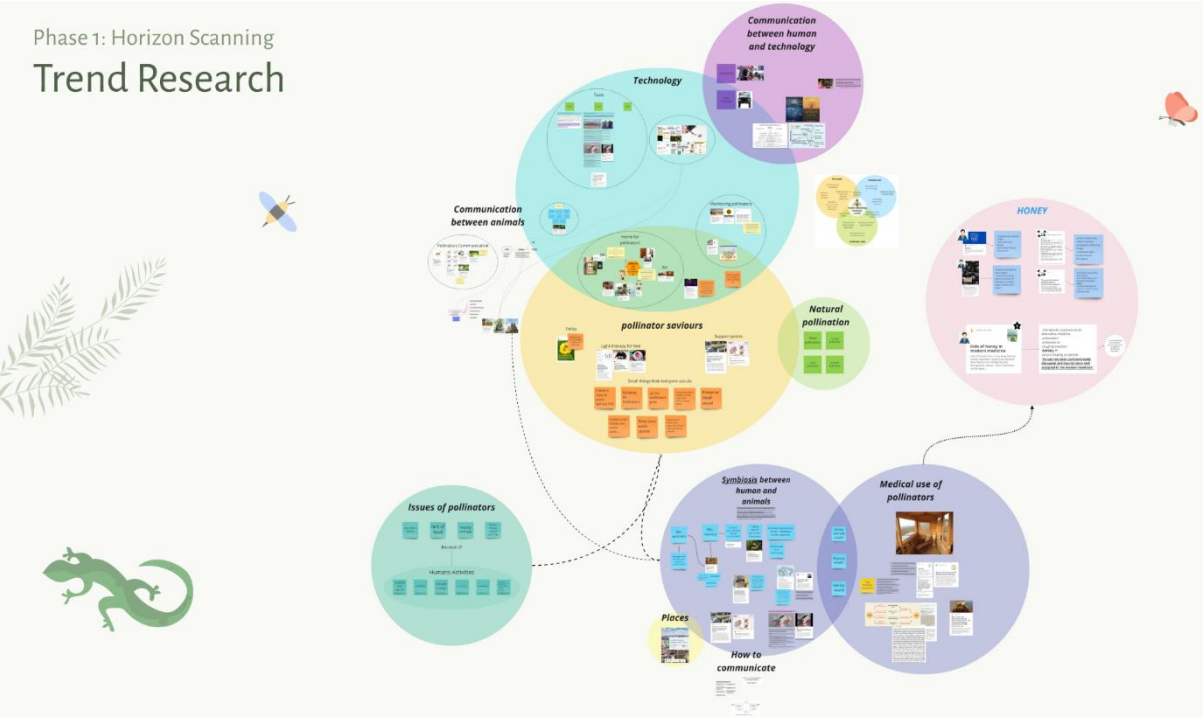
The development process of *Sensitiva* was structured through the DC4DM model, which aimed to facilitate the systematic exploration of the technological and ethical landscapes of healthcare innovations. This model ensured that the solutions proposed were not only technologically feasible but also socially acceptable and ethically viable.

Sensitiva adopts the approach and philosophy of "*Taking care of each other*" integrating advanced diagnostic and therapeutic technologies based on the symbiosis between humans and animals, with human-centered design principles. It offers personalized care pathways tailored to individual needs, positioned within a futuristic vision of 2032. Employing a holistic approach, the project aims to enhance patient autonomy and involvement in health management using advanced sensors and augmented reality, which amplify the perception of others' conditions. This vision focuses on how the needs of various entities will become central to mutual understanding and collaboration in creating a new, respectful equilibrium based on a biocentric approach, essential for facilitating shared survival and coexistence. The reflection extends to themes of pollinating insects and the question of how to care for local ecosystems. The *Sensitiva* project went through different iterations phases guided by the provided DC4DM toolkit (www.dc4dm.eu/model-and-tools).

3.1.1. Phase 1: Horizon Scanning

In the *Horizon Scanning* phase of this research project, the *Sensitiva* team delved into emerging trends and signals of change to anticipate transformations within the context of "Pollinators our saviors." Utilizing comprehensive research from academic and sector-specific sources, the team identified key actors and analyzed their social and environmental impacts (Figure 1). Special attention was given to pollinators, crucial for biodiversity and severely threatened by unsustainable agricultural practices and environmental changes, as observed in specific regions such as Madeira.

Figure 1: An exploratory mapping of research and brainstorming conducted during the Horizon Scanning phase, highlighting various emerging trends and signals of change. The diagram includes elements such as AI and robotic pollination technologies, human-animal communication interfaces, and the utilization of drones and robotized insects for pollination.

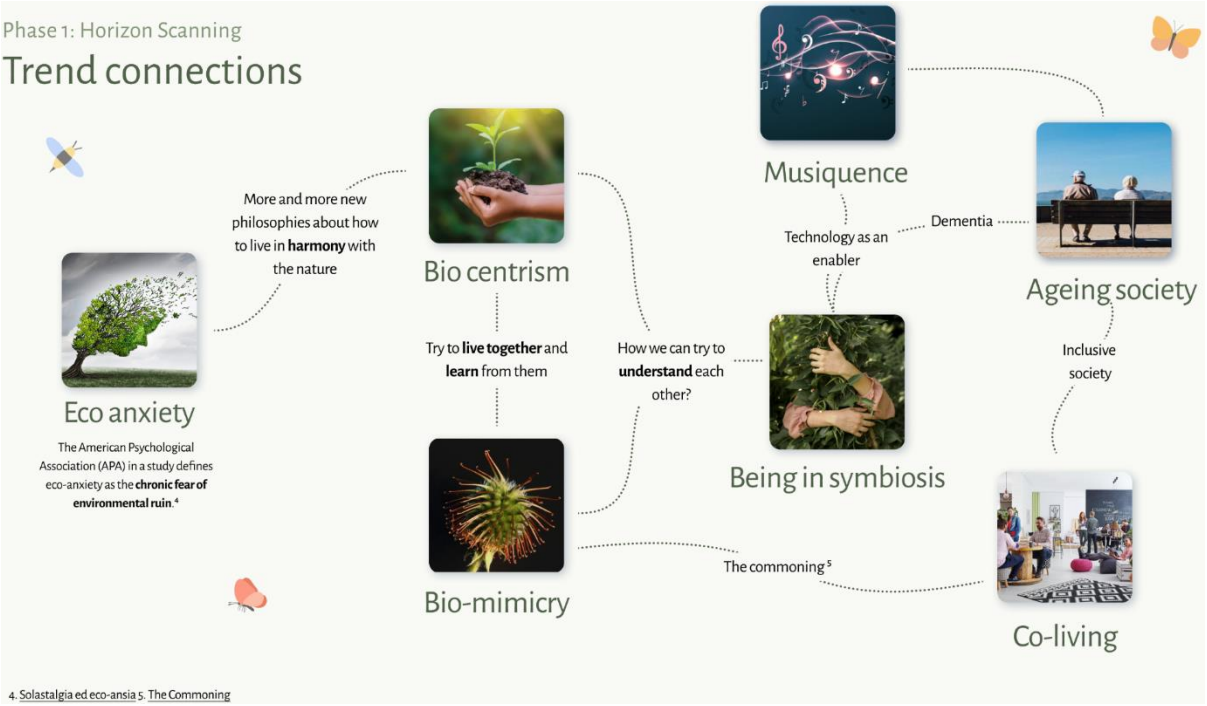


Source: *Sensitiva* project, Final Presentation, DC4DM Learning Lab 1, July 2022.

During this phase, the team members also addressed fundamental ethical issues such as consent and autonomy of non-human entities, biodiversity impact, data privacy and security, technological dependency, equity, access, and the long-term consequences of proposed interactions. The STEEP analysis (Social, Technological, Economic, Environmental, and Political analysis) facilitated an examination of various factors that could influence the project. This method helped the team incorporate considerations such as demographics, technological innovation, economic conditions, and environmental regulations. Key elements include advancements in empathetic robots, biocentric government policies, eco-anxiety, and symbiosis between humans and nature. The analysis highlights the interplay between societal values, technological innovations, environmental sustainability, economic factors, and political regulations, providing a comprehensive overview of the factors influencing future scenarios in digital healthcare design. Additionally, the diagram identifies regions at risk and emphasizes the importance of monitoring local pollinators to protect public health and economic well-being.

Among the emerging trends, the team identified biocentrism, human-animal symbiosis, biomimicry, eco-anxiety, societal aging, and innovative forms of cohabitation. They explored how advanced technologies, including optoelectronic and motion sensors, could facilitate a symbiotic relationship between humans and nature, enhancing life quality and reducing anxiety and depressive symptoms (Figure 2).

Figure 2: A visual representation of trend connections identified during the Horizon Scanning phase. This figure demonstrates the interplay between new philosophies on living harmoniously with nature, technological enablers, biocentrism, societal aging, and eco-anxiety. It underscores the significance of symbiotic relationships with nature, the communing approach, and the "Taking care of each other" philosophy.



Source: *Sensitiva* project, Final Presentation, DC4DM Learning Lab 1, July 2022.

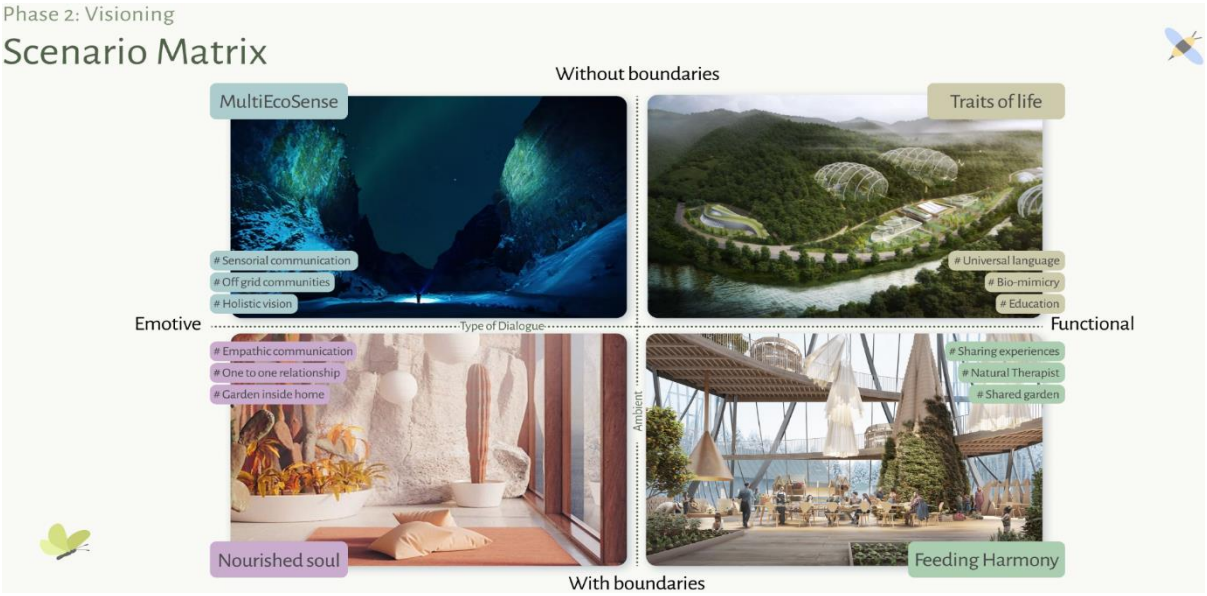
The domain mapping allowed for a visualization of the theme's complexity, organizing the collected data in a structure that aids in understanding the interactions among various trends. This approach provided the team with a profound understanding of the evolving dynamics of the external context, essential for the development of targeted strategies to promote an inclusive and sustainable society.

In conclusion, the Horizon Scanning phase was pivotal in laying the groundwork for future interventions, integrating ethical considerations at the core of the design process to ensure responsible and sustainable solutions. Collaboration with *MT* enabled a thorough analysis of technological advancements and their impact on future care environments, identifying macro themes such as approaches to personalized care and the integration of advanced diagnostic technologies.

3.1.2. Phase 2: Visioning

In the Visioning phase, the team transitioned from the initial insights gathered during the Horizon Scanning phase to a comprehensive formulation of potential future scenarios. This phase was characterized by the creation of a structured 2x2 Scenario Matrix, meticulously combining the critical uncertainties identified previously to forecast diverse but plausible future outcomes (Figure 3).

Figure 3. A scenario matrix developed during the Visioning phase, outlining various future scenarios such as MultiEcoSense and Traits of Life. This matrix explores sensorial communication, universal language, off-grid communities, and the balance between emotive and functional interactions. It emphasizes the role of education and holistic vision in creating an inclusive society.



Source: *Sensitiva* project, Final Presentation, DC4DM Learning Lab 1, July 2022.

These scenarios explored the complex interplay between technological advancement and ecological stewardship within the context of human and non-human interactions. The 2x2 Scenario Matrix facilitated the exploration of varied approaches to integrating humans and non-humans in ecological contexts (Figure 4). The scenarios envisioned included:

- MultiEcoSense: A world without boundaries, where advanced sensorial communications and holistic visions foster a deep, all-encompassing symbiosis across species. This scenario emphasizes non-verbal, emotive communication, allowing communities to thrive in off-grid, fully integrated ecosystems.
- Traits of Life: Also set in a boundaryless environment, focusing on the educational aspects of symbiosis. Using biomimicry and a universal language, this scenario fosters mutual learning and understanding across species.
- Nourished Soul: Shaped as an intimate, therapeutic experience within defined spaces, promoting mental well-being through empathetic, one-to-one relationships and shared residential gardens.
- Feeding Harmony: Illustrates a respectful, collaborative approach to food production within communal gardens, where multiple species work together to create sustainable food systems.

The team investigated the balance between emotionally driven and task-focused interactions (emotive vs. functional dialogue) and assessed the impact of spatial definitions on symbiotic relationships (with boundaries vs. without boundaries ambient).

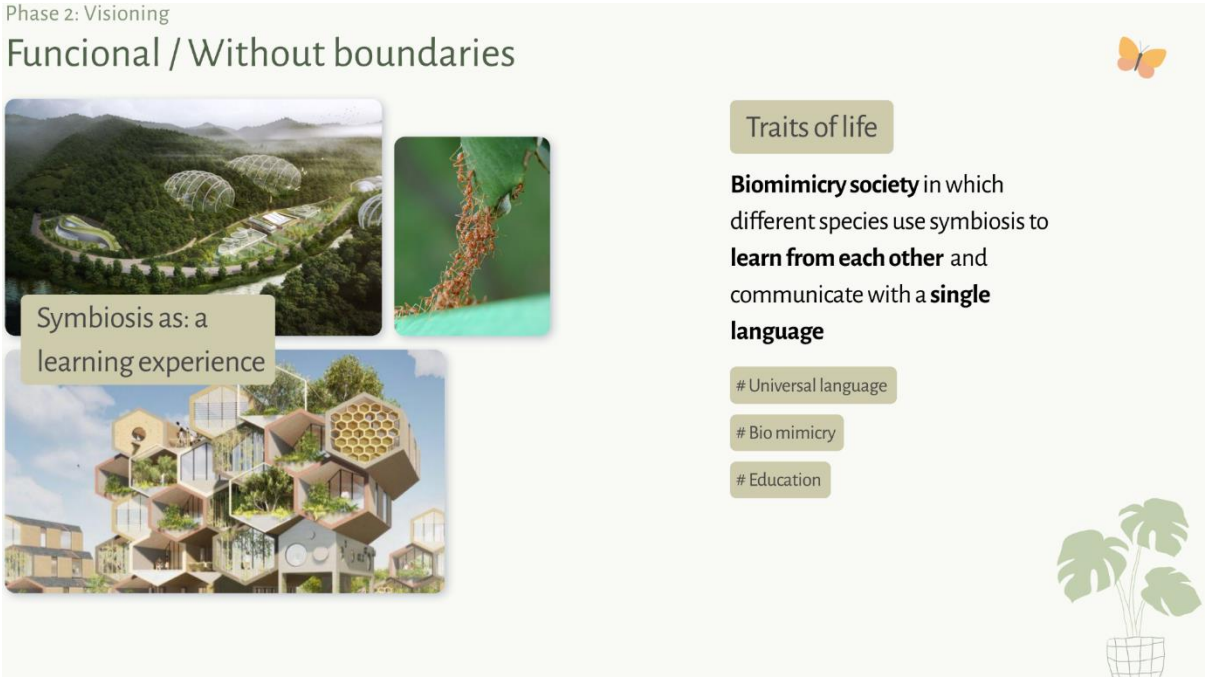
Throughout the Visioning phase, each scenario was critically evaluated for its ethical implications. The focus was on consent and autonomy of non-human entities, the impact on biodiversity, and the equitable distribution of technological benefits. This ethical scrutiny ensured that the proposed futures not only aligned with technological feasibility and ecological necessity but also adhered to principles of fairness and respect for all species involved.

To envision possible issues and impacts, hypothetical news articles from the future were created. These narratives illustrated how the scenarios might unfold in real-world settings, helping to foresee challenges such

as the overwork of pollinators in agricultural settings, societal shifts towards sustainable living, and technological innovations that enhance interspecies communication.

The scenarios were brought to life through detailed narrative descriptions, supported by visual aids such as diagrams and mood boards. These visual representations articulated the nuances of each scenario, making them accessible and comprehensible to stakeholders, thereby facilitating informed decision-making.

Figure 4: A conceptual illustration from the Visioning phase showing the exploration of functional and boundary-less environments. The image focuses on the Traits of Life scenario, highlighting symbiosis as a learning experience and the use of biomimicry for interspecies communication and cooperation. Key elements include universal language and biomimicry.



Source: *Sensitiva* project, Final Presentation, DC4DM Learning Lab 1, July 2022.

The Visioning phase was essential in mapping out the trajectory of the project's impact on future ecological and social systems. By carefully considering a range of dynamic interactions and potential outcomes, the team laid a robust foundation for subsequent project phases. This phase not only highlighted the project's commitment to sustainable and ethical practices but also underscored the potential for innovative solutions to enhance the cohabitation of humans and non-humans. As a result, the project is well-positioned to advocate for and implement strategies that promote a balanced, thriving ecosystem for future generations.

Throughout the process, collaboration *MT* was crucial. *MT* provided insights on the practical and ethical deployment of digital healthcare technologies, highlighting issues such as patient privacy, data security, and the ethical use of AI in healthcare. This partnership ensured that *Sensitiva* aligned with values promoting cognitive and physical well-being through ethical digital interventions, fostering innovative research paths for ethical digital healthcare solutions.

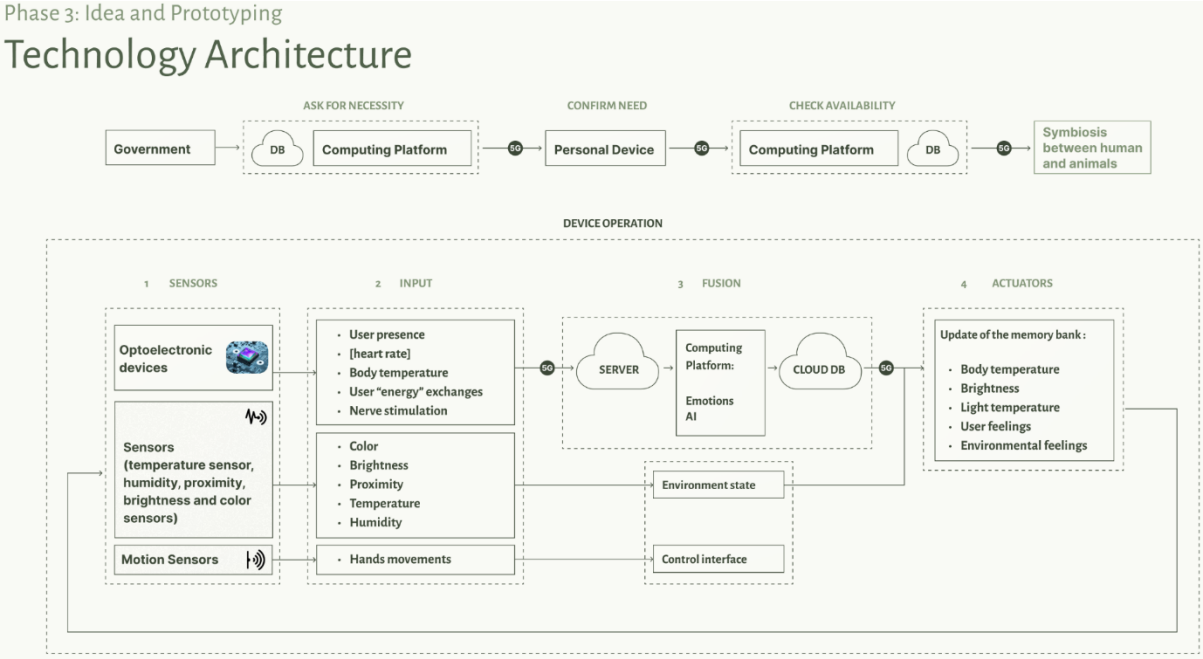
3.1.3. Phase 3: Idea and Prototyping

In the Idea and Prototyping phase, the team transformed the visionary concepts into tangible prototypes, focusing on the practical and ethical dimensions of technology use in ecological contexts (Figure 5). This phase was driven by a set of creative rules aimed at fostering innovation while ensuring clarity and feasibility.

The *Sensitiva* concept revolves around enhancing the autonomy and symbiotic experiences of both humans and non-humans. By employing advanced sensors and augmented reality, the project aims to amplify sensory

experiences, allowing individuals to perceive and understand the conditions and emotions of other species. This holistic approach is designed to improve the quality of life for all beings by fostering deeper mutual understanding and cooperation.

Figure 5: A schematic of the technology architecture developed during the Idea and Prototyping phase. This figure includes the framework of ASK FOR NECESSITY, CONFIRM NEED, CHECK AVAILABILITY, and illustrates the roles of government, databases, and computing platforms. It highlights the integration of 5G technology, personal devices, sensors, and optoelectronic devices to facilitate symbiosis between humans and animals.



Source: *Sensitiva* project, Final Presentation, DC4DM Learning Lab 1, July 2022.

The technological framework of *Sensitiva* integrates various advanced components to support seamless interaction and data sharing:

1. Sensors and Input Devices: Utilizes temperature, humidity, proximity, brightness, and color sensors to gather environmental data. Optoelectronic devices and motion sensors capture user presence and physical interactions, including heart rate and body temperature.
2. Computing Platform: The centralized computing platform processes the data collected from sensors, updating the memory bank, and facilitating real-time interaction. This platform supports the integration of AI to enhance user experiences and environmental feedback.
3. 5G and Cloud Infrastructure: Ensures high-speed data transmission and storage, allowing for real-time updates and access to the shared memory bank. The infrastructure supports a distributed network of personal devices and centralized databases.

The prototyping phase involved creating mockups and early prototypes to visualize and test the system. This iterative process was crucial for refining the concept and ensuring practical implementation:

- Brainstorming and Ideation: The team engaged in intensive brainstorming sessions, utilizing techniques like Build to Think to generate and refine ideas. Visual aids, sketches, and role-playing were used to explore various aspects of the concept.
- Early Prototypes: Initial prototypes were developed to test the feasibility of the technology. These included wearable devices with embedded sensors and augmented reality interfaces that allowed users to interact with the environment and other species.

The key functions of the *Sensitiva* system are designed to enhance the symbiotic relationship between humans and non-humans:

- Memories Bank: Collects and stores experiences from various species in a centralized database, enabling users to upload and relive memories. This fosters a deeper understanding and empathy across species.
- Augmented Reality: Uses AR to visualize environmental data and enhance sensory perceptions, making it easier for users to connect with and understand other species.
- Global Trends Visualization: Analyzes collected data to identify and visualize trends, providing insights into the effectiveness of ecological interventions and guiding future actions.

Throughout the prototyping phase, ethical considerations remained central. The team focused on ensuring consent and autonomy for all entities involved, protecting data privacy, and promoting equitable access to technological benefits. Hypothetical news articles from the future were created to envision potential challenges and impacts, such as overworking pollinators and societal shifts toward sustainable living.

An additional tool for the community was developed to facilitate broader engagement and support. This tool, exemplified by a wearable holographic interface, provides real-time data on environmental conditions and pollinator recovery rates, empowering users to contribute to and benefit from the shared ecological network (Figure 6).

The Idea and Prototyping phase of *Sensitiva* was pivotal in bringing visionary concepts to life. By integrating advanced technologies and adhering to ethical principles, the team created a robust framework for enhancing the symbiotic relationship between humans and non-humans. This phase not only demonstrated the practical feasibility of the project but also reinforced its commitment to fostering a balanced and thriving ecosystem for future generations.

Figure 6: An illustrative mockup of an additional tool for the community, developed during the Idea and Prototyping phase. The tool is based on the ©Cicret Bracelet concept and provides real-time data on environmental conditions and pollinator recovery rates. It aims to empower community engagement and support the shared ecological network.

Source: *Sensitiva* project, Final Presentation, DC4DM Learning Lab 1, July 2022.

The presence of *MT* throughout the *Sensitiva* design-thinking process allowed more attention and reflection on the ethical implications of the proposed ideas compared to all the other teams participating in the LLab1. The stress on ethics expressed by MT during the development of the *Sensitiva* digital application for healthcare reflected their interest and value as an enterprise; at the same time the belief that such understanding can lead to additional and innovative research interests.

Using the DC4DM methodology and the guidance by *MT*, the *Sensitiva* team members were encouraged to start with wide research on the current technological developments in healthcare, coupled with an exploration of ongoing technological trends. This initial research phase was crucial to establishing a foundation that not only highlighted existing solutions but also identified gaps and opportunities for innovation in the healthcare sector. By leveraging insights and resources from *MT*, the team was able to gain a deeper understanding of market dynamics and the regulatory environment, which are critical for designing applications intended for clinical use, even when envisioned in a speculative and visionary context.

4. Reflecting on Ethics When Designing Healthcare Digital Applications Through the Experience of DC4DM LLab1 and *Sensitiva* Project Development

The presented study utilized a three-phase research methodology to explore ethical integration in digital healthcare design. During the DC4DM Learning Lab phase (July 2022), data was collected by capturing real-time interactions and ethical discussions through direct observation and notes. In the Post-DC4DM Learning Lab phase (February 2024), semi-structured interviews aimed to provide insights regarding the impact of both the DC4DM learning methodology and interaction with a tech-partner.

Finally, the Reflective Recap (April 2024) aimed to analyze commonalities and contrasts by critically examining shared ethical challenges such as data privacy, the subject, and the complexities of interdisciplinary collaboration (Figure 7). This phase highlighted how varying professional backgrounds influenced problem-solving approaches and ethical considerations. The recap underscored the necessity for a cohesive ethical approach that accommodates diverse perspectives, revealing both the strengths and potential conflicts inherent in multidisciplinary teams. This critical reflection on the dynamic interplay between different disciplines provided deeper insights into how ethical dilemmas were navigated and resolved, ultimately emphasizing the importance of fostering an environment where diverse viewpoints can converge to enhance ethical decision-making in digital healthcare design. This structured approach underscored the critical role of interdisciplinary collaboration in ethical digital innovation.

Figure 7: Illustrates the methodology employed in the Sensitiva project, encompassing three distinct phases: the DC4DM Learning Lab phase (July 2022), the Post-DC4DM Learning Lab phase (February 2024), and the Reflective Recap (April 2024). It includes activities such as observations, data collection, and semi-structured interviews, aimed at providing a comprehensive understanding of the research's development and insights gained. The figure highlights key elements such as capturing real-time interactions, documenting decision-making processes, gathering in-depth reflections, and identifying recurring themes and contrasts in ethical challenges and interdisciplinary collaboration.

Source: Project Methodology Overview, created for the purpose of this paper.

During the DC4DM LLab1 (July 2022), *MT* representatives followed through each step of the *Sensitiva* project development. A constant and mutual learning exchange between the start-up and the students was in place. Almost two years after that creative interaction, MT representatives were invited to meet again with the *Sensitiva* team members to discuss and reflect on the design of digital applications for the healthcare sector through the example of *Sensitiva* and the lens of the DC4DM methodology.

One of the co-founders of *MT* ran individual conversations with each of the *Sensitiva* project team members. These took place online in February 2024 and were recorded with the consent of the participants. The recordings were stored safely, as their transcriptions were to be used for analysis.

The *Sensitiva* project team members, who then took part in the latest conversations with MT, were university students from different disciplinary and cultural backgrounds. For data collection, they will be identified as: [**ID01**] Designer, BA in Design, University of Madeira; [**ID02**] Engineer, BSc in Informatic Engineering, University of Madeira; [**ID03**] Designer, MSc in Digital and Interaction Design, Politecnico di Milano.

The three conversations with the *Sensitiva* team members were organized following the topics listed below.

1. *Ethical considerations to make during the design thinking process.* This topic focuses on understanding how ethical issues were identified, considered, and addressed throughout the design process. It examines the continuous integration of ethical thinking and the challenges faced. Team members were discussed about the following: 1) what the project was about, 2) if they always presented ethical questions during the design process, and 3) if there was anything that made them feel uncomfortable when dealing with ethical issues during the process.
2. *Use of tools and resources for ethical development.* This topic evaluates the effectiveness of specific tools and resources, such as the DC4DM toolkit, in fostering ethical awareness and resolving ethical dilemmas. Team members discussed: 1) what they found useful from the DC4DM toolkit in developing

their attention towards ethics, and 2) whether they found the tool useful in solving ethical dilemmas they encountered.

3. *Ethical sensitivity development through interactions with the Startup*. This topic explores how interactions with the startup influenced the development of ethical sensitivity, emphasizing the role of stakeholder engagement in shaping ethical perspectives. Team members were invited to reflect on what they found useful from their dialogue with the startup in developing their ethical sensitivity.
4. *Ethical insights and reflections on project presentation.* This topic reflects on the ethical insights gained during the project presentation phase and how these insights influenced perceptions of the project's impact. Team members discussed: 1) what ethical insights they gained throughout the entire experience of presenting the project, and 2) how these considerations shaped their perspective on the project's impact and implications.
5. Influence of LLab1 experience on ethical thinking. Lastly, this topic assesses the long-term impact of the LLab1 experience on participants' approach to ethical considerations in future projects. Team members were invited to reflect on whether the LLab1 experience and the development of their project influenced the way they think about ethical implications when designing new digital products.

The purpose of these later conversations was to explore not just the impact of the DC4DM methodology and LLab1 experience on both start-up and team members, but especially to reflect on what aspects and phases of the design thinking process should focus on ethical considerations and possible implications.

4.1. Results

Sensitiva project team members were encouraged by the Startup to seek a forward-thinking solution to address the ever-increasing needs of clinical populations worldwide, all the while considering the ethical considerations inherent in their proposal. The students researched macro themes exploring the influence of nature on human experience. Additionally, they delved into trend research, establishing connections between technology and nature. Following their research, the students envisioned a future where patients would relate to the nature of bee pollinators through a symbiotic relationship facilitated by sensory technology, including optoelectronic devices, motion sensors, and weather sensors.

Furthermore, it also allowed for a deeper human connection with their environment as this allowed the collection and authorized sharing of pleasant memories among individuals. The goal of such symbiosis was to help reduce anxiety and depression-like symptoms while increasing the quality of life of the patients.

During the follow-up conversations, when asked about *1) the ethical considerations during the design process,* team member ID01, reported that she, indeed, had that into consideration as "*(they) have always been very human people"* and that they *"never saw the pollinators as a machine".* She also commented that *"this empathy (was) always present"*. As for ID02, she replied that *"to be honest, we (did not) pay much attention to some points".* Participant ID03 said that multiple ethical considerations were identified as the project involved the role of humans in the biodiversity and pollinators as they *"are like another living being"* and that "*they're like in a bad situation (because of) humans*".

Regarding *2) usage of tools and resources for ethical development*, ID01 admitted that at the beginning she was confused about how to use these tools as she *"(was) not used to using these methodologies as (she) is from informatics, and not design*". Nevertheless, she found it useful during the design process as she was able to focus on "*(...) the points we had to focus on and those that were a little more irrelevant".* ID02 said that despite this tool being interesting, "*(they) were (...) focused on trying to understand how it really worked that this part was left a little aside*". As for ID03, found it to be useful as "*the toolkit provided (...) support (...) in framing ethics, ethical framework, and guidelines*".

As for *3) Ethical sensitivity development through interactions with the Startup,* team member ID01 said she found it useful to have a representative that provides insights regarding ethical practices within healthcare. Participant ID02 said that *"they focused on the project"* so that it can benefit *MT* in the future and that communication with

MT was *"facilitated very much by having 'our' startup"* present during the design process. As for ID03, it was a fruitful conversation in the sense that it led to a discussion about the importance of safeguarding user data—"*Understanding (...) habits and their personal information (,) their stories and their fragility is really (...) important consideration about the privacy, understanding, security, safety and also how we could (...) involve (...) those topic(s) in a critical way in our project.*"

For *4) Ethical insights and reflections on project presentation*, ID01 mentioned that ethical choices remained relatively consistent following the project presentation to other groups. However, they acknowledged the potential influence of the diverse multidisciplinary and cultural backgrounds within the groups on their ethical sensibility—*"(...) I don't think there was a drastic (ethical) change, but obviously there was a sensitivity there, especially if we go to a place with people from other countries, which is a different experience".* For ID02, she claimed that she gained more *"awareness"* regarding the "*pollinators (and) what they were going through and what could be done to reverse some situations".* As for ID03, presenting the project was useful as it allowed her to be more aware of the team's design decisions—"*you really have to think carefully about what you are designing (...), but also underscore the ethical responsibility to ensure that the human entities are not exploited or harmed.*"

Lastly, *5) Influence of Llab1 experience on ethical thinking,* ID01 said that she viewed ethical thinking as *"secondary"* but believes it should be a priority. ID02, she said that it had influenced her. She also mentioned that the tools provided during the Llab1 are useful—*"It helps a lot to see the innovations that are already happening and those that are not happening. This whole process helps a lot in creating new ideas and trying to reach a new point".* Finally, ID03 reported that she *"felt like (...) an extra person, like a sustainable management project, and (...) like the lab was really like an exposure to a different perspective.*"

These conceptual projects play a pivotal role in delivering innovative solutions and serving as a source of inspiration not only for professionals in the DHT industry but also for emerging companies that focus on developing DHT-related products. Consequently, through educational projects like DC4DM, we empower and help to remember both current and future DME personnel to create innovative, ethical, and human-centered technologies, thus enhancing trust between healthcare practitioners and patients.

Regarding *MT's* reflection on the Post-DC4DM LLab1 conversation, ethical considerations are crucial when developing digital health technologies as they ensure user trust and retention by addressing privacy, security, and fairness concerns: "Healthcare professionals become reluctant in using technologies if data protection is not safeguarded" Neglecting ethics in development can lead to significant consequences, including data breaches, loss of user trust, reduced user engagement, potential harm to patients, and legal liabilities. Ensuring ethical standards not only protects users but also enhances the credibility and sustainability of the technology. Another important aspect to have in mind in developing is user-experience: "Also, from an ethical point of view, technologies must be designed according to the user experience of healthcare professionals. Improper use of these technologies in clinical populations may lead to significant ethical issues."

5. Discussion

The ongoing digitization across various industry sectors is rapidly becoming a reality, profoundly impacting current business practices, and revolutionizing organizational operations. This transformation aims to enhance efficiency, agility, and responsiveness to evolving market needs. Digitized organizations benefit from streamlined operations and improved data-driven decision-making capabilities.

However, despite the identified strengths and opportunities, significant barriers impede healthcare professionals from fully leveraging technology in their daily practice. The SWOT analysis revealed prevalent obstacles in the literature, including insufficient computer literacy, cybersecurity concerns, and ethical considerations, which hinder the widespread adoption of innovative technologies despite their potential benefits. Therefore, a paradigm shift in education becomes essential.

Interdisciplinary educational initiatives like the DC4DM project are designed to foster collaborative and interdisciplinary approaches to educating future healthcare professionals. These initiatives aim to equip SMEs with the right skills and attitudes to achieve digital maturity, which means navigating and harnessing the potential of emerging technologies confidently and effectively.

The *Sensitiva* project exemplifies the critical interplay between design, engineering, and business disciplines. The collaboration between the *Sensitiva* team members, who brought diverse expertise in interaction design, computer science engineering, and integrated design, and *Musiquence Technologies (MT)* demonstrated the potential of interdisciplinary dialogue to foster innovative solutions. This integration facilitated a holistic approach to problem-solving, ensuring that technical feasibility, user experience, and business viability were all considered.

The design team contributed user-centered perspectives, ensuring that the solutions were intuitive and met user needs. The engineering team provided technical insights, addressing feasibility and implementation challenges. Meanwhile, the business-oriented members focused on market relevance and sustainability, ensuring that the solutions had viable business models.

This dynamic dialogue not only enriched the project outcomes but also highlighted the importance of effective communication and collaboration mechanisms. Regular workshops and brainstorming sessions enabled the seamless integration of these diverse perspectives, fostering a culture of continuous learning and innovation.

During the project, it became evident that bridging the gap between theoretical knowledge and practical application requires more than just technical skills. It demands an appreciation of the different perspectives each discipline brings and an ability to synthesize these insights into coherent and actionable strategies. This multidisciplinary approach is essential for developing robust, user-centered digital healthcare solutions that are both ethically responsible and commercially viable.

Following the DC4DM "Feeding Madeira" LLab1 in July 2022, the specialized health solutions startup *Musiquence Technologies*, and some of the *Sensitiva* project team re-met for further knowledge exchange and discussed the experience developing a healthcare application with DC4DM tools and how this experience influenced subsequent projects.

During a follow-up conversation, participant ID01 highlighted the importance of ethical considerations in the design process, emphasizing a human-centered approach and stating that they never viewed pollinators merely as machines. ID03 also highlighted significant ethical reflections, particularly concerning the role of humans in biodiversity and the plight of pollinators. In contrast, ID02 admitted that certain aspects were not given significant attention during their project.

Regarding the use of tools and resources for ethical development, ID01 initially struggled with using ethical development tools due to her informatics background but ultimately found them valuable for prioritizing key design aspects. ID02 prioritized understanding its functionality over addressing ethical considerations during the project. Conversely, ID03 found the toolkit beneficial for providing support in framing ethics and establishing an ethical framework and guidelines, indicating its value in structuring ethical considerations during the project.

As for ethical sensitivity development through interactions with the Startup, Participant ID01 valued having a representative from the startup who provided insights into ethical healthcare practices. ID02 highlighted that the presence of the Startup facilitated communication and focused efforts on the project's future benefits. ID03 found the interactions particularly fruitful, as they led to important discussions about safeguarding user data and incorporating considerations of privacy, security, and safety into the project. Overall, these interactions significantly contributed to the team's awareness and handling of ethical issues.

For the ethical insights and reflections on project presentation, after presenting the project to other groups, ID01 noted that ethical choices remained consistent, though they acknowledged the potential impact of diverse

backgrounds on their ethical sensibility, particularly in multicultural settings. ID02 expressed gaining awareness about the pollinators' experiences and how to address challenging situations, indicating a deeper understanding and empathy developed through the project. ID03 highlighted the importance of project presentations in promoting careful consideration of design decisions and ethical responsibilities towards human entities. This underscores the role of project presentations in reinforcing ethical values and principles within teams.

Finally, regarding the Influence of LLab1 experience on ethical thinking, participant ID01 acknowledged that while she initially viewed ethical thinking as secondary, she now considers it a priority. On the other hand, ID02 mentioned that her experience in LLab1 had a significant influence on her ethical thinking and found the tools provided valuable for understanding existing innovations and generating new ideas. ID03 describes feeling like an "extra person" and mentions exposure to a different perspective, particularly in the context of sustainable management projects.

Based on the participants' responses, it can be inferred that individuals with different academic backgrounds may have varying levels of comfort and effectiveness when using tools for ethical development in design projects. ID02, with an informatics background, initially faced challenges but ultimately benefited from the tools in focusing on essential design elements. On the other hand, ID01, while interested in the tools, may have prioritized technical understanding over ethical considerations during project implementation. This highlights the importance of integrating ethical considerations seamlessly into design processes, regardless of academic background, to ensure comprehensive and responsible project outcomes.

Regarding the reflection of *MT,* ethical considerations in developing digital health technologies are crucial for ensuring user trust and retention by addressing privacy, security, and fairness concerns. Neglecting these ethics can lead to data breaches, loss of trust, reduced engagement, patient harm, and legal liabilities. Upholding ethical standards not only protects users but also enhances the credibility and sustainability of these technologies. Additionally, designing technologies with the user experience of healthcare professionals in mind is essential to prevent improper use and associated ethical issues in clinical settings.

Another observation that we made is that we were not able to relate to some of the topics identified in the SWOT analysis. This highlights a gap between theoretical frameworks and practical applications. Nevertheless, the inability to integrate major key factors identified in the scientific literature regarding SWOT analysis into their discussions highlights a significant gap, suggesting a disconnection between their academic training and the practical realities they face.

Conclusion

The ongoing digitization in various industries, especially healthcare, offers significant benefits like enhanced efficiency and data-driven decision-making. However, barriers such as insufficient computer and digital literacy, cybersecurity concerns, and ethical considerations impede the full adoption of these technologies. Insights from the DC4DM LLab1 reveal that while *Sensitiva* project team members struggled initially with integrating ethical aspects of the DC4DM methods, they ultimately recognized the importance of considering ethics within a design process. This highlights the need for higher education programs to better align theoretical frameworks with practical applications, ensuring that all participants can effectively and responsibly address ethical issues.

Incorporating ethical considerations into the development of digital health technologies is not just beneficial but essential for maintaining user trust and ensuring responsible innovation. Educational initiatives like DC4DM are essential for preparing healthcare professionals to navigate these challenges, fostering an ethically aware and competent workforce capable of leveraging the full potential of digital advancements in healthcare.

By addressing these aspects, a comprehensive understanding emerges of how the conditions and quality of dialogue influenced the development of the Sensitiva project. The involvement of students from three different disciplinary and cultural backgrounds brought a rich diversity of approaches and perspectives, which greatly enhanced the project despite the challenges. Multidisciplinary teams can drive innovation but require effective

coordination and conflict resolution strategies to harness their full potential. Tailored interventions are necessary to bridge skill gaps in collaborative environments, ensuring all team members can contribute effectively.

While external expertise, such as that provided by MT, is invaluable, it is crucial to build internal capacity for ethical decision-making. This balance ensures that teams can innovate responsibly and independently. Engaging with a diverse range of stakeholders enriches project outcomes, but it requires careful integration of different perspectives. Understanding these elements helps educators, practitioners, and organizations better prepare for and navigate the complexities of digital transformation in healthcare.

These insights emphasize the importance of ethical considerations, internal capacity building, and effective stakeholder engagement in developing digital healthcare applications. Learning from the Sensitiva project can inform future projects, fostering innovation while maintaining a strong ethical foundation, ultimately contributing to more effective and responsible digital transformation in healthcare.

Future research steps should expand the scope to include a greater number and variety of projects to validate and extend these findings. Additionally, developing and testing educational curricula that better prepare future professionals to tackle ethical issues in digital transformation is imperative. By addressing these limitations and enhancing the ethical dimension of digital healthcare education, we can bridge the gap between theoretical knowledge and practical application, ultimately fostering a more ethical and effective digital healthcare landscape.

Limitations and Future Steps

While this study provides valuable insights, it is not without limitations. The limited scope of projects and the specific context of the DC4DM LLab1 may restrict the generalizability of the findings. Future research must address these gaps by focusing on larger sample sizes and a more diverse range of projects to validate and expand upon these results. Furthermore, the long-term impact of integrating ethical considerations into digital healthcare design education remains underexplored and warrants further investigation.

Future work should prioritize broadening the scope of the study to encompass a wider variety of projects. This would enhance the robustness of the findings and uncover specific ethical challenges and their resolutions within digital healthcare design. Additionally, there is a pressing need to develop and rigorously test educational curricula that better prepare future professionals to tackle ethical issues inherent in digital transformation.

Incorporating ethical considerations into the development of digital health technologies is not merely beneficial; it is imperative for maintaining user trust and ensuring responsible innovation. Educational initiatives like the DC4DM project are pivotal in this regard, as they equip healthcare professionals with the ethical awareness and competencies necessary to navigate the complexities of digital advancements. By fostering a workforce that is both technologically adept and ethically grounded, we can ensure that the evolution of healthcare technology serves the best interests of society.

Without a concerted effort to address these limitations and enhance the ethical dimension of digital healthcare education, the potential for innovation may be compromised by the very issues it seeks to solve. Thus, future research and educational reforms must align to bridge the gap between theoretical knowledge and practical application, ultimately fostering a more ethical and effective digital healthcare landscape.

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Ethical Statement

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