Technical University of Munich

School of Computation, Information and Technology

Informatics

Master's Thesis in Management and Innovation

Integrating Social and Ecological Sustainability in Software Product Development

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Integration sozialer und ökologischer Nachhaltigkeit in die Softwareproduktentwicklung

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I confirm that this Master's thesis is my own work and I have documented all sources and material used.

Munich, 30.09.2025 BSc Monika Zielińska

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In preparing this thesis, I used several AI tools to support different stages of the research and writing process. Their use was limited to assistive functions, all substantive content decisions were made by me.

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- **Grammar and style correction**: I used ChatGPT to improve sentence structure, clarity, and overall writing quality across all chapters of the thesis.
- **Translation and language enhancement**: I used DeepL and ChatGPT to refine fluency and accuracy in English throughout the thesis.
- **Developing content and expanding ideas**: I used ChatGPT to brainstorm and elaborate on ideas, especially during the framework ideation stage.
- **Literature discovery and synthesis**: I used ChatGPT and Elicit to identify relevant research and summarize academic papers.

Review and Responsibility All AI-generated or AI-assisted content was thoroughly reviewed, edited, and verified by me to ensure accuracy, coherence, and alignment with the academic objectives of this work.

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List of Abbreviations

AI	Artificial Intelligence
CSD	Conscious Service Design
DT	Design Thinking
HCD	Human-Centered Design
HCI	Human-Computer Interactions
ICT	Information and Communications Technology
ISC	Inclusive Segment Cards
N/A	Not Applicable
RQ	Research Question
SD	Service Design
SE	Software Engineering
SJM	Systemic Journey Map
TUM	Technical University of Munich
UI	User Interface
UN	United Nations
UX	User Experience

Abstract

Software plays a dual role in sustainability: it can drive responsible innovation while also contributing to ecological and social challenges. Yet, sustainability remains only marginally embedded in software engineering education and practice.

This thesis investigates how sustainability can be integrated into a project-based learning environment through Conscious Service Design methods—the Systemic Journey Map and Inclusive Segment Cards. The study explores how students understand sustainability, how they perceive the value of these methods, and what challenges arise in applying them.

A qualitative, intervention-based study analyzed project artefacts, surveys, and student feedback. Findings show that students engaged most readily with individual and social dimensions of sustainability, while ecological reasoning was less developed. The methods were valued for raising awareness and fostering reflection. Although students expressed a strong sense of responsibility for sustainability, many lacked the confidence and capability to translate this responsibility into concrete design choices.

To address these challenges, the thesis introduces the Software 5.0 Framework, which refines existing methods, adds new ones, and integrates educational content with ready-to-use templates and an accompanying documentation website. The framework provides practical guidance for sustainability-oriented software engineering and offers a transferable approach for embedding responsibility into both software product development and higher education curricula.

Zusammenfassung

Software spielt eine doppelte Rolle in der Nachhaltigkeit: Sie kann verantwortungsvolle Innovationen fördern, trägt jedoch zugleich zu ökologischen und sozialen Herausforderungen bei. Dennoch ist Nachhaltigkeit bislang nur unzureichend in der Softwaretechnik-Ausbildung und -Praxis verankert.

Diese Arbeit untersucht, wie Nachhaltigkeit in eine projektbasierte Lernumgebung integriert werden kann, am Beispiel von Methoden des Conscious Service Design — der Systemic Journey Map und der Inclusive Segment Cards. Ziel der Studie ist es, zu analysieren, wie Studierende Nachhaltigkeit verstehen, welchen Wert sie den Methoden beimessen und welche Herausforderungen bei der Anwendung auftreten.

Eine qualitative, interventionsbasierte Studie analysierte Projektartefakte, Umfragen und studentisches Feedback. Die Ergebnisse zeigen, dass Studierende vor allem individuelle und soziale Dimensionen der Nachhaltigkeit berücksichtigten, während ökologische Überlegungen weniger stark ausgeprägt waren. Die Methoden wurden für ihre Bewusstseinsbildung und Reflexionsförderung geschätzt. Obwohl die Studierenden ein starkes Verantwortungsbewusstsein für Nachhaltigkeit äußerten, fehlte ihnen häufig das Vertrauen und die Fähigkeit, diese Verantwortung in konkrete Designentscheidungen umzusetzen.

Zur Bewältigung dieser Herausforderungen entwickelt die Arbeit das Software-5.0-Framework, das bestehende Methoden verfeinert, neue ergänzt und mit didaktischen Inhalten, anwendungsfertigen Vorlagen sowie einer begleitenden Dokumentations-Website verbindet. Das Framework bietet praxisorientierte Leitlinien für eine nachhaltigkeitsorientierte Softwaretechnik und stellt einen übertragbaren Ansatz dar, um Verantwortung sowohl in die Softwareproduktentwicklung als auch in die Hochschullehre einzubetten.

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1 Introduction

Over the past two decades, sustainability[1] has evolved from a specialised concern into a guiding principle for policy, industry, and innovation [AAS23, CÁG22]. It now extends beyond environmental stewardship to include social responsibility, ethical governance, and equitable economic participation. These dimensions shape national and international agendas, corporate strategies, and technological roadmaps [CÁG22].

This development is visible in the shift from *Industry 4.0*, centred on automation and efficiency, to *Industry 5.0*[2], which promotes technology that is human-centred and sustainability-oriented [ALG23]. While originating in manufacturing, Industry 5.0 increasingly informs technology-intensive sectors, including Software Engineering (**SE**), where it creates opportunities and challenges [Anb23].

Software plays a central role in this context. It no longer supports only specific applications but increasingly shapes processes, products, and services across domains. A prominent example is digital transformation, which denotes a broad organisational evolution that relies heavily on software and emerging technologies [DSE20, Lem23]. McKinsey & Company estimate that about 90% of organisations are pursuing digital transformation[3], underlining the transformative reach of software.

Given this pervasive role, software has considerable potential to advance sustainability — both by improving its own practices and by enabling sustainability in other domains [CÁG22]. Exploring this dual role is essential for realising the vision of Industry 5.0, where technology aligns with human-centric and sustainability-oriented goals.

[1] The term **sustainability** has multiple interpretations [Mor+25]. In this work, it is used as an umbrella term; **sustainable development** denotes policy and societal outcomes, while **sustainable innovation** refers to technology-driven change.

[2] European Commission. (2021). **Industry 5.0**. European Commission. Retrieved August 31, 2025, from ec.europa.eu.

[3] McKinsey & Company. (2024). **What is digital transformation?** McKinsey & Company. Retrieved August 13, 2025, from mckinsey.com.

1.1 Problem

Sustainability is increasingly recognised as a dimension of **SE**, yet its practical integration remains limited and fragmented [Chi+16, KMM19, Rib+24]. In academia, the topic has been explored through diverse conceptual lenses; in industry, by contrast, it has received comparatively less sustained attention [Nom+22].

This limited uptake in industry creates a strong incentive for change. Many organisations, aligned with the United Nations (**UN**) Sustainable Development Goals, are increasingly prioritising sustainability in their strategies [AlH25, Hel+24]. However, their efforts are constrained by a shortage of professionals who can translate broad sustainability principles into actionable and measurable software requirements while combining technical expertise with sustainability competencies [Hel+24].

Empirical studies further report that while 91% of practitioners acknowledge sustainability's importance, many remain unaware of existing methods and lack clarity on how to integrate sustainability into daily development practices [Nom+22, WMP25]. Moreover, the topic is frequently narrowed to energy efficiency, leaving other sustainability dimensions underexplored. These include long-term maintainability, inclusive and accessible design, social equity, and economic impacts [Ata+24, Nom+22].

These challenges underscore the crucial role of higher education in closing the skills gap. Yet sustainability remains insufficiently embedded in **SE** curricula, where teaching often centres on energy efficiency and neglects broader dimensions due to limited awareness, resources, and teaching materials [Tor+17]. Strengthening curricula with explicit learning outcomes, systematic coverage of multiple sustainability dimensions, and practice-oriented activities would better equip graduates to implement sustainability in **SE** practice.

2 Motivation

The shortfalls outlined above present risks but also open opportunities for systemic change. Momentum around sustainability is increasing across multiple domains.

Organisations are embedding sustainability into their operations [Hel+24], regulators and investors demand accountability [KI24], and younger generations actively seek to contribute to sustainable development [Tor+17]. This convergence of industry demand and youth motivation generates a pressing need for higher education to prepare graduates with sustainability competencies.

Universities act not only as institutions for preparing skilled professionals but also as catalysts for sustainability transitions [KV22]. Computing and education have been described as "two disciplines with high leverage for change" [Pet+24]. Embedding sustainability as a core competency in **SE** curricula enables graduates to minimise environmental harm and design systems that foster societal[4] transformation [Mor+25]. With these competencies, graduates can transfer sustainability principles into their workplaces, influence organisational practices, and shape industry standards.

The urgency of this transition is evident across environmental and social dimensions. Environmentally, the Information and Communications Technology (**ICT**) sector accounts for approximately 2% of global greenhouse gas emissions and up to 9% of global electricity use [DFS25]. Sustainable practices in software design can reduce energy consumption by up to 25% [PFL16], delivering ecological and economic benefits. Socially, values of equality, diversity, human rights, and fairness are increasingly critical, particularly in Artificial Intelligence (**AI**), where risks such as bias and exclusion are well documented [MBC24].

Policy drivers further reinforce this imperative. The EU Corporate Sustainability Reporting Directive requires transparent carbon accounting and responsible digital practices [KI24]. Market dynamics add an additional layer of pressure: firms with strong environmental, social, and governance performance achieve competitive advantage and resilience in global markets [RY24]. Training graduates

[4] In this thesis, **societal** refers to system-level or structural changes, while **social** refers to individual and community-level dimensions.

with sustainability competencies therefore not only supports compliance but also enables innovation and long-term value creation.

Embedding sustainability into **SE** education generates benefits at multiple levels. For students, the integration of these competencies enhances employability, aligns with personal values, and prepares them for interdisciplinary roles. For industry, it develops professionals capable of creating solutions consistent with sustainability strategies, thereby enabling competitiveness and regulatory alignment. For society and the planet, it reduces environmental impact, improves resource efficiency, and supports equity, inclusivity, and well-being.

Preparing **SE** graduates with sustainability competencies is no longer optional. It is a prerequisite for responsible innovation. By aligning education with industry requirements, societal expectations, and planetary limits, higher education can equip future professionals to lead the software sector's contribution to sustainability transitions.

2.1 Research Gap and Objectives

As discussed in Chapter 4, research in Software Engineering (**SE**) and Human-Computer Interactions (**HCI**) has produced multiple frameworks and methods for sustainability. However, these resources remain fragmented, abstract, and difficult to apply in practice. Their lack of integration restricts adoption in real-world contexts, particularly in education, where students and educators require clear, practical, and accessible tools. While environmental sustainability has received increasing attention in development workflows, social sustainability—including inclusivity, well-being, and societal impact—remains insufficiently embedded. In **SE** education, sustainability is rarely integrated into project-based courses, and educators lack systematic approaches for teaching it effectively.

This thesis addresses these gaps by consolidating and adapting existing resources into a coherent educational framework that makes sustainability-oriented design both teachable and actionable, with explicit attention to environmental and social dimensions. Building on the principle of design as an enabler for sustainability, the study applies Conscious Service Design (**CSD**) methodologies to support students in embedding sustainability directly into **SE** projects. Specifically, it investigates the integration of **CSD** methods into the iPraktikum course (Chapter 5) as a means of fostering sustainability-oriented thinking in **SE** education and advancing sustainable software product development. Informed by the Karlskrona Manifesto for Sustainability Design [Bec+15], the research emphasizes the design phase as a strategic entry point, where fundamental decisions about product direction, user experience, and long-term vision are established, thereby bridging the gap between theory and practice.

The overarching aim is to develop a practical sustainability-oriented framework that enables students and future professionals to embed sustainability considerations systematically into software products. To achieve this aim, the study pursues five objectives, each linked to a corresponding research question (**RQ**).

2.1.1 Analyze students' conceptualization of sustainability

The first objective examines how students conceptualize sustainability when using **CSD** methods in the course context. This involves analyzing how they define, interpret, and prioritize sustainability dimensions — environmental, social, and individual — during the design phase of their projects. Artefacts such as the Systemic Journey Map (**SJM**), the Inclusive Segment Cards (**ISC**), workshop reflections, and responses to the Impact Questionnaire provide the basis for this analysis. The goal is to understand how sustainability reasoning emerges in practice and how **CSD** methods support students' perspectives.

RQ1. How do students conceptualize sustainability in the design phase of software, particularly when using **CSD** methods in project-based learning?

2.1.2 Evaluate students' views on CSD usability and value

The second objective builds on RQ1 by exploring students' perceptions of the usability, relevance, and value of **CSD** methods. This includes assessing how accessible and practical the tools appeared, how well they integrated into project workflows, and whether students regarded them as beneficial for learning and professional practice. Data derive from survey responses, open-ended feedback, and workshop reflections. The analysis highlights both usability concerns and the extent to which students perceive sustainability as a meaningful design consideration.

> **RQ2.** How do students perceive the usability and value of the **CSD** methods during software design in project-based learning?

2.1.3 Identify barriers in CSD methods and course integration

The third objective extends the analysis by identifying barriers that hinder students when applying sustainability in practice. These may include incomplete tool use, insufficient clarity in instructions, or challenges linked to course timing and workload. The study combines artefact analysis, student feedback, and project observations to triangulate insights. This process highlights where methods and course design fall short in enabling sustainability-oriented thinking and provides a foundation for improvements.

> **RQ3.** What limitations and gaps emerge in both the **CSD** tools and the course design that hinder the integration of sustainability into projects?

2.1.4 Recommend improvements to methods and course design

The fourth objective builds on RQ1–RQ3 by identifying improvements to both the **CSD** toolkit and the course structure that could enhance students' ability to apply sustainability in the design phase of **SE**. Potential improvements may address usability, workflow integration, or explicit support for systemic and long-term thinking. These refinements draw on both sustainable **SE** literature and empirical insights from student experiences to strengthen the effectiveness of **CSD** methods and course structures.

RQ4. What improvements to the **CSD** methods and to the course structure could enhance students' ability to apply sustainability in the design phase?

2.1.5 Develop a sustainability-oriented design framework

The final objective synthesises the findings into a refined and transferable sustainability-oriented design framework, hereafter referred to as the *Software 5.0 Framework*. This framework integrates improved **CSD** methods with course-level adaptations, embedding sustainability systematically within education. The goal is to deliver a framework that balances pedagogical effectiveness with professional applicability. It should foster systemic sustainability thinking while remaining practical for students and educators.

RQ5. How can the **CSD** toolkit and course integration be refined into a coherent sustainability-oriented design framework that is transferable to educational contexts?

2.2 Thesis Outline

The remainder of this thesis is structured as follows. Chapter 1 introduces the motivation, research problem, and objectives. Chapter 2 provides background on sustainability in software engineering, Conscious Service Design, and project-based learning. Chapter 3 reviews related work and highlights the research gap. Chapter 4 describes the research context of the iPraktikum course. Chapter 5 outlines the methodology. Chapter 6 presents the results, and Chapter 7 discusses the findings in relation to the research questions. Chapter 8 synthesises the results into a sustainability-oriented design framework. Chapter 9 concludes with contributions, limitations, and directions for future research.

3 Background

This chapter establishes the conceptual and methodological background of the thesis. It introduces the foundations that situate the study within both academic and professional contexts. The chapter highlights how sustainability is addressed in Software Engineering (**SE**), outlines Human-Centered Design (**HCD**) approaches relevant to software development, presents the Conscious Service Design (**CSD**) framework, and describes the role of real-client **SE** projects in education.

The first section discusses sustainability in **SE**, including its dimensions and implications for software development practices. The second section introduces human-centred design principles and their relevance for sustainability-oriented **SE**. The third section presents the **CSD** framework as a structured approach to embedding sustainability in design processes. The fourth section examines project-based learning with real clients, which provides the educational context for this study.

Together, these elements provide the necessary foundation for understanding the research context. They frame how sustainability is conceptualised in this thesis and establish the theoretical basis for the analysis presented in later chapters.

3.1 Sustainability in Software Engineering

A widely cited definition of *sustainability* originates from the **UN** Brundtland Commission[5]. It defines sustainable development as “development that meets the needs of the present without compromising the ability of future generations to meet their own needs” [Wor87].

In software engineering (**SE**), sustainability was initially understood as the *capacity to endure*, that is, the ability of a system to function reliably over time [Lag19]. This perspective emphasised technical longevity. Recent work reframes sustainability as a multidimensional construct that spans environmental, social, economic, technical, and individual concerns.

[5] The Brundtland Commission, formerly the World Commission on Environment and Development, was a sub-organization of the United Nations (UN) that aimed to unite countries in pursuit of sustainable development.

The Karlskrona Manifesto broadens the conventional three-pillar model—economic, environmental, and social[6]—by adding *technical* and *individual* dimensions [Bec+15]. Together, the five interdependent perspectives are defined as follows:

- **Environmental**: long-term effects of human activity on ecosystems, such as climate change, biodiversity loss, and resource depletion.
- **Social**: equity, inclusion, institutional trust, and ethical use of technology.
- **Economic**: value creation, capital investment, and long-term financial viability.
- **Technical**: maintainability, adaptability, and resilience of systems.
- **Individual**: well-being, autonomy, and skill development of those affected by software.

The Manifesto also distinguishes three orders of impact: *first-order* (direct operational effects), *second-order* (behaviour or practice changes enabled by software), and *third-order* (long-term systemic shifts) [Bec+15].

Building on this foundation, McGuire et al. reconceptualise sustainability as both *multisystemic* and *stratified*, emerging from interactions among ecological, social, technical, psychological, and economic systems and manifesting across scales from individuals to global ecosystems [McG+23]. Their framework consolidates the individual and social dimensions into a broader social domain and distinguishes between the sustainability of *products* and *processes*, emphasising the need to evaluate both software artefacts and the practices through which they are developed.

3.2 Design and Software Engineering

Embedding sustainability in **SE** requires careful attention to the role of **design**. Design decisions not only define the technical structure of a system but also shape long-term social, economic, and environmental consequences [Bec+15]. Yet, design remains a complex concept with no universally accepted definition. Erlhoff and

[6] The three-pillar model is often attributed to the Brundtland Report, Agenda 21, and the 2002 World Summit, though none provides an explicit theoretical basis [PMR19].

Marshall describe it as the intentional creation or shaping of something, while stressing that its meaning varies across contexts [EM08].

From a **SE** perspective, design is a central activity in which ideas are transformed into structured, implementable requirements and solutions. According to the SWEBOK Guide[7] [Was24], software design can be viewed both as a life cycle activity and as a transformative process. As a life cycle activity, it analyses requirements to define a system's external characteristics and internal structure. This process typically progresses through three stages: architectural design, high-level or external-facing design, and detailed or internal-facing design.

Design can also be framed as a problem-solving process, in which goals, constraints, and alternatives are systematically explored to generate feasible solutions [Par+22]. As a transformative process, software design converts customer and stakeholder needs into implementable specifications that guide development [Was24]. These perspectives show that software design is both an engineering practice and a creative activity, requiring systematic reasoning and creative exploration.

Within this problem-solving perspective, methodologies such as **Design Thinking (DT)**[8] and **Service Design (SD)**[9] have gained prominence [Par+22]. These approaches share substantial conceptual and practical overlap, with distinctions most evident in educational contexts [TM20]. In this thesis, they are treated collectively as Human-Centered Design (**HCD**) methodologies, reflecting their shared iterative, collaborative, and user-focused orientation.

HCD methodologies place users at the centre of development, emphasising creativity, empathy, and the integration of divergent and convergent thinking to

[7] **SWEBOK Guide** — Software Engineering Body of Knowledge, published by the IEEE Computer Society.

[8] **Design Thinking** — a human-centred approach that integrates people's needs, technological possibilities, and business requirements [TM20].

[9] **Service Design** — an interdisciplinary approach to creating or improving services, often focused on user experience and organisational processes [TM20].

address complex challenges and so-called **"wicked problems"**[10]. They are particularly valuable in the early stages of development, supporting requirements engineering through interviews, observation, and prototyping. They also help shape product vision through iterative ideation and testing [DP19]. Their principles align with Agile and Scrum practices, which emphasise adaptability, simplicity, and rapid delivery. While Agile provides process flexibility, HCD methodologies offer structured approaches for framing problems and generating solutions. Together, they enable multidisciplinary collaboration that balances user expectations with technical feasibility and business viability [DP19].

3.3 Conscious Service Design

While Human-Centered Design (**HCD**) methodologies provide a strong foundation for user-centred innovation, they often overlook systemic environmental and social impacts [BTG22, TRB17].

Conscious Service Design (**CSD**) extends traditional **SD** by explicitly integrating societal and ecological considerations into the design process[11]. Its guiding philosophy is to create products and services that meet user needs while contributing to ecological health, social equity, and systemic resilience. In doing so, **CSD** challenges conventional assumptions, encourages critical reflection, and amplifies marginalised perspectives in decision-making [Fri23].

The **CSD** framework is structured around three interconnected layers of impact—**environmental reaction, societal reaction, and individual interaction**—addressed through an iterative cycle of exploring, ideating, validating, and planning.

[10] **Wicked problems** — issues that resist straightforward solutions because they involve interdependent or conflicting factors. In **SE**, this often refers to trade-offs where solving one problem creates another [EM08].

[11] Conscious Service Design Methodologies, DieProduktMacher GmbH, Munich, 2024. Available at: https://www.dpm.digital/conscious-methodologies

3.3.1 Conscious Digital Product Principles

CSD defines a **conscious digital product** (Figure 1) as one that integrates sustainability and responsibility into its design and operation. This is articulated through five dimensions:

- **Address systemic problems**: tackle root causes rather than symptoms.
- **Focus on the long term**: prioritise durability, adaptability, and resilience.
- **Promote sustainable behaviour**: reduce ecological and social harm.
- **Ensure transparency**: make processes and decisions understandable to stakeholders.
- **Guarantee inclusion**: ensure accessibility across diverse contexts and backgrounds.

Beyond its conceptual framing, **CSD** offers practical tools such as the Impact-Driven Business Model Canvas, Eco-Social Proposition Canvas, and Critical Reflection Cards. This thesis focuses on two methods applied in the iPraktikum course: **Systemic Journey Map** (**SJM**) and **Inclusive Segment Cards** (**ISC**).

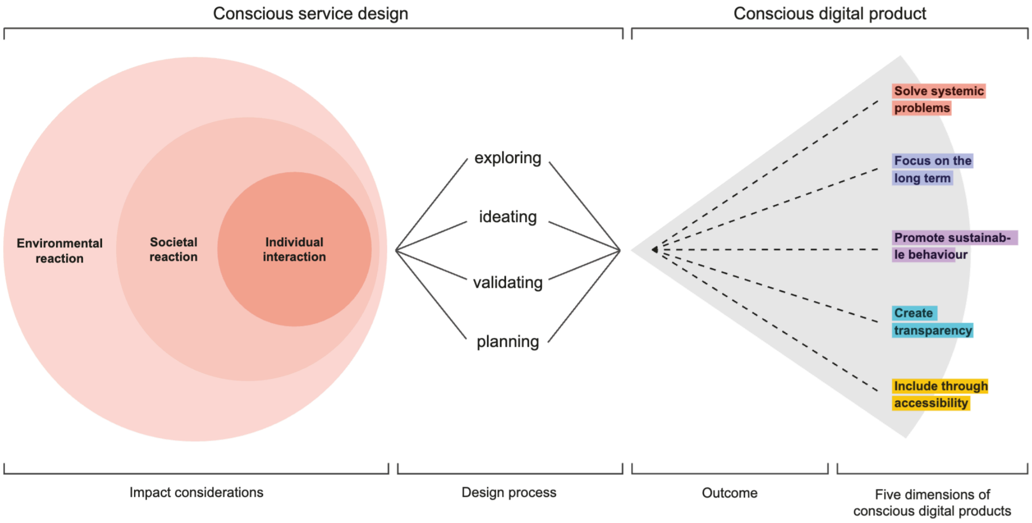


Figure 1: The **CSD** framework: layers of impact and design process

3.3.2 Systemic Journey Map

SJM visualises the experiences, needs, and impacts of stakeholders across the lifecycle of a product or service. Unlike conventional journey maps, which primarily capture user interactions and pain points, the **SJM** integrates environmental and social dimensions. Each stage considers both functional and systemic impacts (Table 1).

Element	**Description**
Phases	Distinct stages of user interaction with the product
Core activities	Primary user actions in each phase
Goals	Objectives or aspirations driving engagement
Jobs	Specific tasks users aim to accomplish
Gains	Desired positive outcomes
Pains	Challenges or negative experiences
Data	Evidence supporting assumptions
Touchpoints	Interfaces for user engagement
Environmental impact	Ecological effects
Social impact	Societal effects
Other	Additional contextual notes

Table 1: Key elements of the **SJM** tool

By linking micro-level interactions (e.g., completing a task) with macro-level consequences (e.g., ecological or social impacts), the **SJM** helps identify leverage points where design interventions can address user needs and systemic challenges simultaneously.

For the purposes of the iPraktikum, the tool was adjusted to exclude data touchpoints and other sections. The template used in this study is provided in Appendix A.

3.3.3 Inclusive Segment Cards

ISC ensure that diverse perspectives, needs, and constraints are systematically included in the design process. This method integrates societal and environmental considerations, exposes biases, and highlights opportunities for equitable outcomes. It follows five steps:

- **Segment demographics**: define criteria (e.g., age, abilities, background) using research data, avoiding assumptions.

- **User stories and use cases**: link stories and cases explicitly to societal and environmental aspects.
- **Needs, pains, and gains**: capture user needs, barriers, and positive experiences.
- **Competition and value drivers**: analyse comparable products and align drivers with sustainability principles.
- **Privilege wheel**: assess advantages and disadvantages across segments, exposing the influence of design choices.

For the purposes of the iPraktikum, the tool was adjusted to exclude competition and value drivers. The template used in this study is provided in Appendix B.

3.4 Real-Client Software Engineering Projects

Real-client Software Engineering (**SE**) projects provide a valuable environment by combining authentic requirements, stakeholder engagement, and the complexities of professional practice. In these projects, students collaborate with external stakeholders from industry or other organisations to design, develop, and deliver software that addresses genuine needs.

Bruegge et al. describe the "6Rs": engage a real external client with a real problem, use real data, form a real team, and operate under a real deadline within the academic term [BKA15]. This structure requires students to apply technical knowledge while developing competencies in communication, teamwork, and negotiation. Real-client projects vary in scope and scale, ranging from single-project to multiproject, multicustomer, and global **SE** courses [BKA15].

Two tailored process models manage this complexity. *Rugby* combines Scrum with the Unified Process[12], adapted for part-time student developers. The model emphasises structured weekly meetings, continuous integration, and continuous delivery of executable prototypes for ongoing client feedback [BKA15]. *Tornado*

[12] **Unified Process** — an iterative and incremental software development framework in which a system is developed in iterations. Each iteration includes feedback and adaptation, allowing progressive refinement and expansion of the system over time.

supports scenario-based design[13], moving from visionary to design to demo scenarios. The model promotes informal artefacts—such as sketches, storyboards, and low-fidelity prototypes—as early communication tools before teams transition to formal models (e.g., the Unified Modeling Language) [BKW12]. Both models rely on release management, with multiple internal and external releases—from an initial “empty release” to the final Customer Acceptance Test—supported by continuous delivery pipelines that enable rapid deployment and integrated feedback [BKA15, BKW12].

Building on these approaches, evaluations show that combining real clients with Agile methods such as Rugby and Tornado enhances both technical skills (e.g., architecture, usability, configuration management) and non-technical skills (e.g., client communication, teamwork, presentation) [BKA15]. Universities offer such courses not only as capstone experiences but also earlier in the curriculum, which gives students timely exposure to professional practice.

In sum, real-client **SE** courses combine authentic stakeholder interaction with iterative, feedback-driven processes, which provides a suitable context for embedding sustainability-oriented design practices explored in this thesis.

4 Related Work

This chapter reviews existing literature on sustainability in **SE** and related disciplines to situate this thesis within the academic and professional discourse. The review is structured around four areas: (1) conceptual frameworks and methodologies for designing software for sustainability, (2) industry practices addressing environmental and social dimensions, (3) the integration of sustainability in **SE** education, and (4) the role of human-centred design methodologies in fostering sustainability competencies in higher education.

[13] **Scenario-based design** — a user-centred design approach where the anticipated use of a future system is described through narrative scenarios early in development. These narratives focus on how people will use the system to achieve goals and guide design decisions without relying on formal task models.

4.1 Designing Software for Sustainability

Section 3.2 established the definition of **design** in software development and outlined how **HCD** methods are applied within **SE**. Building on this foundation, the present section reviews the landscape of **practical resources** that support sustainability-oriented design.

Although principally associated with ecology, sustainability has become a significant area of research across multiple subfields of computing, including **SE** and **HCI**[14]. These communities have addressed sustainability challenges from their respective perspectives, yet a lack of shared understanding persists regarding the fundamental concepts of sustainability and their relationship to software systems[14]. This study considers sustainability from two perspectives: **HCI**, which emphasises human-centred design, user experience, and interaction contexts; and **SE**, which primarily addresses the technical and methodological dimensions of software systems.

In **SE research**, several sustainability-oriented **frameworks**, **methods**, and **tools** have been proposed. The Karlskrona Manifesto articulates fundamental principles for sustainable software design [Bec+15]. Building on these principles, the Sustainability Awareness Framework supports engineers in anticipating the short-, medium-, and long-term effects of IT systems during development [Bet+24], while the Sustainability Assessment Framework provides models for identifying and evaluating sustainability requirements in projects [Con+20]. Other contributions, such as the Software Sustainability Design Catalogue, offer structured guidelines for embedding sustainability into design processes [OSP18]. Broader lifecycle approaches — including Green Software Engineering and Sustainable Software Development — integrate sustainability principles across software development stages [Ata+24]. In addition, practice-oriented methods, such as

[14] Venters, C. C., Becker, C., Betz, S., Chitchyan, R., Duboc, L., Easterbrook, S., Penzenstadler, B., Rodriguez-Navas, G., & Seyff, N. (2015, July). Mind the gap: Bridging the sustainable software systems research divide. In Proceedings of the UK Workshop on Sustainable HCI (UK-SHCI). Lincoln, UK.

sustainability-oriented decision maps, help architects scope quality requirements along sustainability dimensions and balance trade-offs in design choices [Lag19].

In **HCI and design research**, the focus has been on how interaction design influences user behaviour and broader socio-technical systems. Early work on Sustainable Interaction Design targeted reductions in energy consumption and e-waste [Ble07]. Subsequent studies extended this focus, exploring eco-feedback mechanisms, persuasive design strategies, and more-than-human perspectives that include ecosystems, future generations, and non-human actors as stakeholders [Ros+24, BTG22, SKZ23]. Complementary design artefacts—such as Sustainability Design Cards [HR17] and non-human personas [NN25]—adapt established **UX** practices to explicitly integrate sustainability considerations. **SE** and **HCI** represent complementary perspectives: **SE** emphasises system-level frameworks and technical methods, while **HCI** foregrounds user values, behaviours, and socio-ecological dimensions.

Alongside academic work, **industry initiatives** have sought to support the adoption of sustainability-oriented design in practice. The Sustainable **UX** Network[15] curates toolkits, principles, templates, and case studies that embed sustainability into digital product design. Similarly, the W3C Web Sustainability Guidelines[16] provide structured principles and practices for creating more sustainable web applications.

Despite the breadth of resources now available, challenges persist in translating these ideas into practice. Many frameworks and methods remain underutilised in industry [Fal+20]. Practitioners also report difficulties in applying them, particularly when sustainability impacts are difficult to quantify or when trade-offs span technical, environmental, and social domains [Fal+20]. As a result, much of the existing work remains fragmented and inconsistently applied.

[15] **Sustainable UX Network** — a non-profit global community initiative (https://sustainableuxnetwork.com) that provides resources, events, an academy, and a podcast to advance sustainability in UX and design.

[16] **W3C Web Sustainability Guidelines** — W3C Sustainable Web Design Community Group Report. Available at: https://w3c.github.io/sustainableweb-wsg/.

In summary, research and practice have produced a wide range of sustainability-oriented frameworks, methods, and tools across **SE**, **HCI**, and industry initiatives. Yet these contributions remain fragmented and unevenly adopted in practice. This situation underscores the need for approaches that consolidate and adapt existing resources in ways that make them more actionable, particularly in educational contexts where future practitioners develop their competencies.

4.2 Sustainability in Software Development

Design establishes the foundations for sustainability, but it is during **software development** that these principles are put into practice. Yet, as in other phases of the lifecycle, an imbalance is evident: environmental sustainability has been more systematically integrated into development workflows than social sustainability [Kha+20, Rib+24, Tri+24].

4.2.1 Environmental Dimension

Environmental sustainability has received sustained attention in software development. Research has examined how design patterns, code smells, and refactorings influence energy consumption, although results vary considerably across contexts [CÓ25]. Established practices include optimising algorithms and data structures [WMP25], modularising compute-intensive components for scalability, and deploying workloads on low-PUE data centres or energy-efficient hardware [Pot+24].

Much of a system's environmental footprint is determined early in the lifecycle, which motivates development practices to adopt a **shift-left mindset**[17]. This approach embeds sustainability requirements directly into architecture and code, promotes the use of resource-aware algorithms, and leverages life-cycle assessment tools to anticipate environmental impacts before deployment.

These concerns also extend into the operational pipeline. **Green DevOps** and **GreenOps** practices integrate sustainability into CI/CD pipelines and cloud operations, while **green requirements engineering** and **energy-aware test-**

[17] **Shift-left mindset** — moving sustainability considerations earlier in the lifecycle, embedding them into design, architecture, and development phases rather than addressing them only at later testing or operational stages [Pot+24].

ing aim to ensure that efficiency gains do not create new sustainability trade-offs [Ata+24]. Agile and DevOps teams have likewise begun embedding sustainability checkpoints into sprints [Dic+13], introducing non-functional requirements such as energy budgets and digital well-being metrics, and aligning development workflows with organisational sustainability objectives [Pot+24].

While environmental sustainability is increasingly embedded in development workflows, the social dimension follows a different trajectory.

4.2.2 Social Dimension

The **social dimension** of sustainability is integrated less consistently into software development practices. Concerns such as developer well-being, trust, psychological safety, inclusivity, and broader societal impact are increasingly recognised [AA25], yet they are often addressed informally rather than through structured methods. Practices such as distributed leadership and decentralised decision-making have been associated with stronger team resilience and inclusiveness, but they remain exceptions rather than established practice [AA25]. Compared to environmental efforts, social sustainability is seldom incorporated into formalised development workflows [Tri+24].

Empirical research further shows that current SE practice remains limited in scope. Gross [GMO25] finds that practitioners interpret sustainability mainly in technical terms, with limited awareness of its economic or individual aspects. Other studies confirm this trend, showing that while practitioners value technical and economic sustainability, they devote little attention to social aspects [BGS22, Hel+24, Oye+21].

This persistent gap between conceptual frameworks and industry practice underscores the challenge of embedding a holistic view of sustainability in SE. Practitioners tend to prioritise technical and economic concerns, while the social dimension — and to a lesser extent the environmental dimension — remain underexplored in practice. This thesis therefore focuses on these two dimensions and investigates how they can be integrated more effectively into software design.

4.3 Sustainability in Software Engineering Education

Although demand for sustainability-aware graduates is steadily increasing, sustainability remains marginal in most **SE** curricula. The *ACM Software Engineering 2014 guidelines*[18] mention sustainability only once [Ard+15], whereas the more recent CS 2023 guidelines contain 62 references [Mor+25]. This development signals progress but also illustrates the slow and uneven adoption of sustainability across computing education.

Several reviews confirm this gap. A systematic review of 89 studies found that integration efforts remain **immature**, typically limited to isolated modules or case studies rather than embedded across full programs [Pet+24]. Sustainability is often reduced to environmental aspects such as energy efficiency or green IT, while social dimensions such as equity and inclusion receive comparatively little attention [Mor+25, Tor+17]. This narrow focus reinforces the imbalance already visible in research and practice.

Different strategies have been explored for embedding sustainability into **SE** education. Early initiatives relied on interactive seminars and sensitisation activities to raise awareness among students [PB12, PF11]. Subsequent work integrated sustainability into existing courses, such as a master's-level **SE** course designed to foster competences for developing resource-efficient cyber-physical systems while also addressing social dimensions [PSP18]. Other approaches include course redesigns that weave sustainability into software design methodologies[19] , and comprehensive blueprints for teaching **SE** for sustainability that combine conceptual grounding with **SE** practice [Pen+18].

Persistent barriers continue to limit progress. Instructors often lack awareness and training, suitable teaching resources remain scarce, and redesigning curricula requires substantial effort [Tor+17]. Professional norms and industry practices

[18] The **ACM Software Engineering 2014 Guidelines** are curriculum recommendations for undergraduate **SE** degree programs, developed by the ACM and the IEEE Computer Society.

[19] Guéhéneuc, Y.-G., Rousse, N., & Voisard, L. (2025). Bringing sustainability and software design together: A transformational co-design journey. Centre for Teaching and Learning, Concordia University. Available at: https://www.concordia.ca (Accessed: 1 September 2025).

that tend to downplay sustainability further weaken the reinforcement of these competencies in educational settings [Chi+16]. Consequently, sustainability education in **SE** continues to lag behind both industry expectations and the societal demand for sustainable digital technologies.

This thesis positions itself within this gap. Its contribution is to advance sustainability education in **SE** in ways that align with current industry trends. By drawing on design approaches as a guiding methodology and providing structured tools, the thesis aims to make sustainability-oriented design more accessible, actionable, and teachable in **SE** curricula.

4.4 Design as an Enabler of Sustainability in Education

HCD methodologies — including **DT** and **SD** — offer promising avenues for embedding sustainability into higher education. Their iterative, collaborative, and empathy-driven processes are particularly well suited to addressing the "wicked" problems of sustainability that span environmental, social, and economic dimensions.

Within the broader field of **Education for Sustainability**, **HCD** methodologies have been shown to cultivate creativity, systems thinking, futures thinking, and collaborative action [Buh+19, Hua+20]. Recent contributions emphasise that design-based learning can foster challenge-centred and participatory approaches to sustainability, while highlighting the need for new pedagogical interventions to support the development of sustainability competencies [Ard+25]. To strengthen the alignment between design methods and sustainability goals, some educators propose extending the traditional evaluation triad of **desirability, feasibility, and viability** with a fourth dimension: **sustainability**[20]. This addition underscores the importance of integrating environmental and social concerns directly into design evaluation and decision-making processes.

[20] Jussila, J. & Seppänen, L. (2023). Design Thinking Meets Agile Development in Design Factory Project. HAMK Unlimited Journal. Available at: https://urn.fi/URN:NBN:fi-fe2023052447458.

Case studies illustrate both opportunities and challenges in applying **HCD** methodologies to sustainability education. At Häme University of Applied Sciences, **SE** students collaborated with industry partners by combining **HCD** methodologies with Agile methods. Environmental and social impacts were explicitly considered, yet feasibility and viability proved easier to operationalise than sustainability criteria, revealing the need for more structured pedagogical support[20]. At the Berlin School of Economics and Law, a **SD** module tasked students with organisational sustainability challenges, producing actionable proposals that enhanced systems thinking and problem-solving capacities [BMA22].

These examples demonstrate the potential of design-led, project-based learning to bridge theory and practice in sustainability education. This thesis builds on these insights by leveraging the benefits of design for sustainability education, with a specific focus on the **SE** context. It adapts and applies **HCD** methodologies as pedagogical instruments, equipping students with concrete methods and a structured toolkit for integrating sustainability principles into their development practices. In this way, design becomes not only a vehicle for innovation but also a critical enabler of sustainability education in **SE**.

5 Research Context: iPraktikum

This research took place in the **iPraktikum** course at Technical University of Munich (**TUM**), a project-based **SE** environment with industry collaboration. The course applies the multicustomer model introduced in Section 3.4 and serves as the practical foundation for this thesis. Student teams work with external clients to deliver functioning software within one semester. Its client-driven, Agile structure mirrors industry conditions and provides a controlled setting for investigating how sustainability-oriented design practices integrate into established software development workflows.

5.1 Course Structure

The instructors organise the course into two phases. The **Introduction Phase** spans one week and provides training in Agile methods, **UX/UI** design, software architecture, and deployment. This gives all participants a shared foundation.

The **Project Phase** extends over twelve weeks. It begins with a kickoff, followed by **Sprint 0**, during which teams establish cohesion, align with client goals, and produce a project trailer. Development continues in Sprints 1–4 and includes two milestones. The first milestone, the **Design Review**, provides a mid-course evaluation with structured feedback. The second milestone, the **Client Acceptance Test**, concludes the course with a demonstration of a product that reflects refined client requirements.

5.2 Workflows

Instructors assign each team two members per **workflow**. These members act as knowledge mediators and ensure that expertise transfers across the team.

- **Architecture** — Requirements modelling, Analysis Object Model creation, subsystem decomposition, and iterative reviews.
- **Deployment** — Continuous delivery pipelines, integration, release management, GitLab configuration, CI/CD setup, and version control troubleshooting.
- **UI/UX** — Human-centred design, usability principles, sustainability, and prototyping. Activities included the **SJM**, **ISC**, and user research through interviews and shadowing. This workflow served as the main integration point for **CSD** in this study.

5.3 Team Structure and Roles

Teams consist of 5–7 developers supported by one coach and one project leader. Team composition balances preferences, international diversity, gender representation, and prior experience.

- **Coach** — Facilitates team processes, monitors progress, and supports backlog quality without holding decision-making authority.

- **Project Leader** — Maintains the product backlog, collaborates with the client on architectural decisions, prioritises tasks, and ensures alignment between deliverables and client needs.

5.4 Projects

Each team worked on one project proposed by an external client. The projects addressed different domains and demonstrated how methods can be applied across both commercial and societal contexts.

Team	**Project Description**
Team 1	Immersive VR/AR showroom for car designers, enabling real-time setup, visualisation, and interaction with 3D models.
Team 2	AR supermarket guide with grocery lists, maps, and live navigation.
Team 3	Mixed Reality tool for visualising and adjusting energy installations on 3D property models.
Team 4	Secure mobile app digitising towing forms, capturing on-site data and photos to replace paperwork.
Team 5	AR sales tool for dealerships allowing real-time interaction with car features via hand gestures.
Team 6	AR/mobile app for emergency response, enabling live video, audio, and location sharing to improve coordination.
Team 7	VR/AR factory safety system detecting hazards (heat, noise, vibration) with real-time alerts.
Team 8	AI chatbot guiding prospective students to suitable study programmes and assisting with applications.

Table 2: Projects developed in the 2025 edition of iPraktikum.

These projects formed the basis for the students' semester-long development work. They served as practical testbeds for applying **SE** principles in collaboration with real clients.

6 Research Methodology

This study adopted a qualitative, intervention-based case study design. The single case — the **iPraktikum** course contained multiple units of analysis, including individual students, project teams, and project artefacts. This design enabled an in-depth investigation of how sustainability-oriented design can be embedded in an industry-simulated software environment that mirrors professional practice.

6.1 Thesis Interventions

Targeted interventions introduced sustainability-oriented design and Conscious Service Design (**CSD**) methods into student projects. These were implemented at two key points in the course: the **Introduction Phase** and the **UI/UX workflow** in the Project Phase, which served as the primary integration channel for this research.

6.1.1 Introduction Phase

A dedicated workshop introduced user-centred and sustainability-oriented design principles. Students developed a concept for a software application, separate from their official project, and assessed its potential impacts at three levels: individual, societal, and environmental. The workshop also introduced the Systemic Journey Map (SJM) and provided training in both low- and high-fidelity prototyping. This phase established a foundation for the later integration of sustainability in project work.

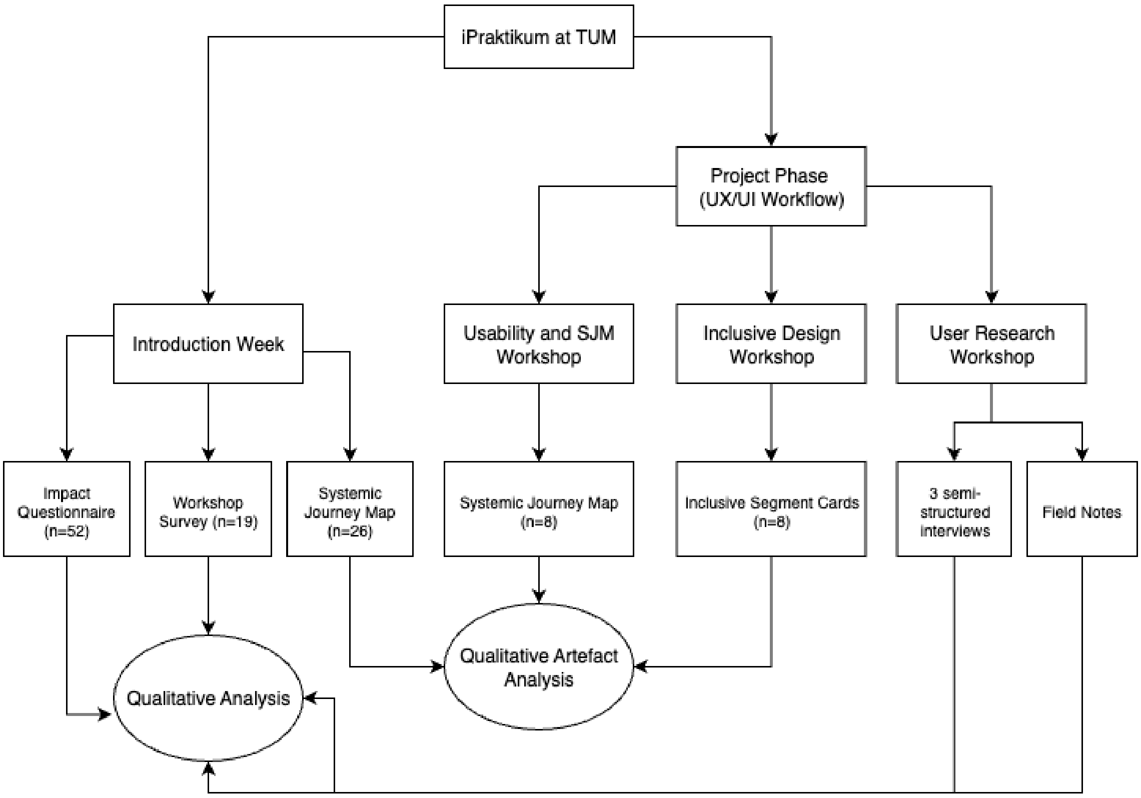

iPraktikum at TUM
Project Phase (UX/UI Workflow)
Introduction Week
Usability and SJM Workshop
Inclusive Design Workshop
User Research Workshop
Impact Questionnaire (n=52)
Workshop Survey (n=19)
Systemic Journey Map (n=26)
Systemic Journey Map (n=8)
Inclusive Segment Cards (n=8)
3 semi-structured interviews
Field Notes
Qualitative Analysis
Qualitative Artefact Analysis

Figure 2: Overall study design with case context, units of analysis, and intervention phases

6.1.2 Project Phase

The Project Phase embedded sustainability into the ongoing project workflow. UI/UX workflow incorporated constructive sustainability design principles through three structured sessions.

The first session, the **Usability and Systemic Journey Map Workshop**, introduced Jakob Nielsen's usability heuristics, demonstrated prototyping techniques, and guided teams in applying the Systemic Journey Map (**SJM**)[21] to their projects. The second session, the **Inclusive Design Workshop**, introduced the Inclusive Segment Cards (**ISC**) method[21] to encourage attention to diverse user groups, equity, and accessibility. The third session, the **User Research Workshop**, provided training in user shadowing techniques.

[21] Templates customised for the course are provided in Appendix A and Appendix B.

6.2 Data Collection

Multiple qualitative and mixed-method data sources were collected to evaluate the interventions and to examine student engagement with sustainability thinking throughout the course (Table 3). The primary data consists of workshop artefacts, complemented by a survey designed and administered by the workflow instructor, who granted permission to include the results in this study. Additional sources include field notes from student use of the **ISC** method and three interviews conducted during the User Research Workshop.

Source	**Description**	**Phase**	**Type**
Impact Questionnaire	52 written reflections on individual, social, and environmental impacts	Introduction	Qualitative
Systemic Journey Map	26 maps from Introduction and 8 team maps from Project Phase	Introduction, Project	Artefact
Workshop Survey	19 responses on workshop experience and learning outcomes	Introduction	Mixed
Inclusive Scenario Cards	8 cards documenting inclusivity and accessibility considerations	Project	Artefact
Student Feedback	Field notes from workshop discussions on **ISC**, unstructured student feedback, and interviews with three students	Project	Qualitative

Table 3: Overview of data sources, their description, intervention phase, and type

Together, these sources provided complementary perspectives on how sustainability principles were understood and applied, ranging from individual reflections to group artefacts and process-level observations.

6.3 Data Analysis

Analysis proceeded in three stages. First, all data were anonymised and systematically reviewed. Second, a hybrid coding approach was applied: predefined sustainability dimensions (individual, societal, environmental) guided deductive coding, while inductive coding captured emergent themes. Third, findings from each data source were compared and triangulated to identify patterns, divergences, and complementary insights across individual and team levels. Table 4 provides an overview of the analysis approaches applied to each data source.

By combining deductive and inductive strategies across multiple sources, the analysis enhanced reliability and provided a more nuanced understanding of how students engaged with sustainability in their projects.

Data Source	**Analytical Approach**
Impact Questionnaire	Framework-guided coding across the **Individual**, **Societal**, and **Environmental** dimensions. Quantitative coverage and combination analysis, complemented by keyword frequency analysis to examine how students conceptualised sustainability impacts.
Systemic Journey Map	Inductive coding to identify recurring environmental and social themes. Classification of impacts using the Karlskrona Manifesto framework (**first-order**, **second-order**, **third-order**), with assessment of completeness, thematic breadth, and distribution across impact orders.
Workshop Survey	Descriptive statistics of Likert-type items to assess perceptions of responsibility, confidence, and the usefulness of the **Systemic Journey Map**. Inductive coding of open responses to identify themes in learning interests, positive aspects, and suggested improvements.
Inclusive Scenario Cards	Privilege coding of user segments across demographic dimensions using a structured privilege scale. Descriptive analysis of user roles, needs, pains, and gains, with attention to social and environmental value links. Privilege Wheel analysis to map distributional patterns across categories, complemented by thematic synthesis of student feedback from workshop field notes.
Interviews	Semi-structured interviews with three **UI/UX** workflow participants. Thematic coding to identify recurring patterns in sustainability engagement, including challenges with environ-

Data Source	Analytical Approach
	mental framing, stronger emphasis on social and individual dimensions, process and motivation factors, and preferences for individualised feedback. Used as triangulation evidence alongside artefact and survey data.

Table 4: Overview of analysis approaches for different types of collected data.

7 Results

This chapter presents the empirical results of the study, organised by the different data sources and interventions introduced in the course. The analysis follows the structure of the research design: beginning with the **Impact Questionnaire** and **Systemic Journey Maps** created in the Introduction Phase, followed by the **Workshop Survey**, the project-phase **Systemic Journey Maps**, and the **Inclusive Segment Cards**. The chapter concludes with insights from student interviews and feedback collected during the UI/UX workflow.

Each subsection reports the findings specific to its data source, supported by tables and figures where appropriate. While the results are presented per instrument, a synthesis across sources is provided at the end of the chapter to highlight converging patterns, divergences, and complementary insights.

7.1 Introduction Phase — Impact Questionnaire

Students generated initial application ideas in a guided ideation exercise. Immediately after the exercise, they completed a short questionnaire describing potential positive impacts across three predefined sustainability dimensions: **Individual**, **Societal**, and **Environmental**. The section reports descriptive coverage and a keyword-based reading of how students articulated these impacts.

7.1.1 Coverage Analysis

The workshop yielded 52 student responses. The first stage assessed whether each response addressed the three sustainability dimensions to establish a baseline before the detailed content analysis.

The analysis identified 47 responses (90.4%) referring to the **Individual** dimension, 34 responses (65.4%) mentioning the **Societal** dimension, and 17 responses (32.7%) referring to the **Environmental** dimension. These values indicate a pronounced emphasis on individual-level considerations relative to collective and ecological perspectives.

Dimension	**Count**	**Percentage**
Individual	47	90.4%
Societal	34	65.4%
Environmental	17	32.7%

Table 5: Coverage of sustainability dimensions across (N = 52) responses. Percentages are calculated relative to all responses.

The overlap analysis quantified how frequently students combined dimensions within a single response. The combination **Individual** + **Societal** occurred in 21 responses (40.4%). Twelve responses (23.1%) covered all three dimensions, and 10 responses (19.2%) referred exclusively to the **Individual** dimension. Figure Figure 3 summarizes these patterns.

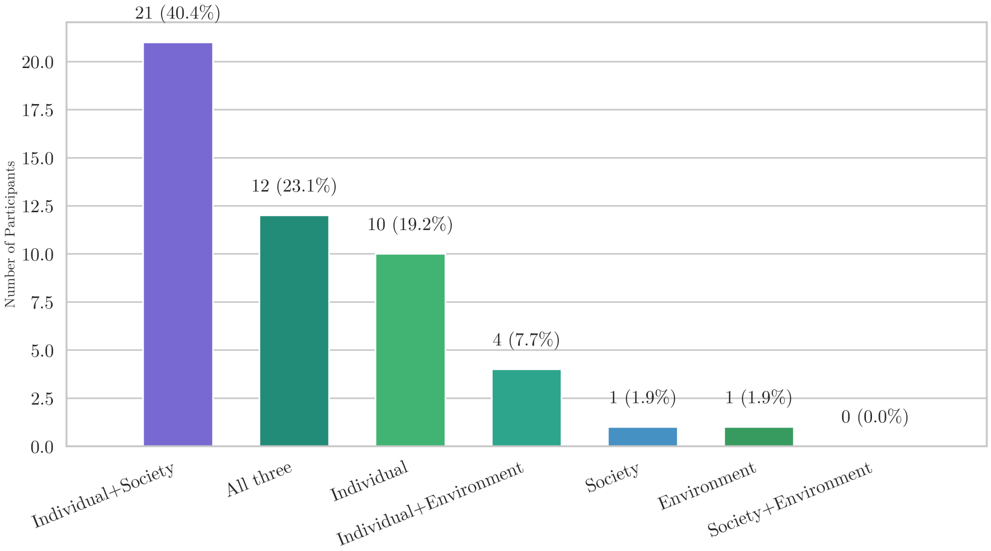


Figure 3: Combinations of sustainability dimensions across $N = 52$ responses. Most frequent were Individual + Societal (40.4%), Individual - only (19.2%), and all three dimensions (23.1%).

7.1.2 Keyword Analysis

The keyword analysis examined how students articulated impacts within each dimension. The procedure removed stopwords to focus on substantive vocabulary and aggregated term frequencies per dimension.

Frequent terms included **users**, **helps**, and **individuals**, along with vocabulary associated with convenience and efficiency (**time**, **easy**, **easier**, **track**, **making**, **make**). Health-related expressions appeared prominently (**healthy**, **mental**, **wellbeing**, **better**, **positive**, **reduces**), as did finance-related terms (e.g., **financial**). This distribution indicates that many students framed individual impacts through the lenses of everyday efficiency, health management, and personal finance.

Prominent terms included **promotes**, **people**, and **users**, alongside economic vocabulary such as **financial**, **markets**, and **economic**. Collective perspectives appeared through **society**, **impact**, **cultural**, and **culture**. Community-related expressions (**encourages**, **shared**, **community**, **social**, **values**) and notions of responsibility and awareness (**responsible**, **awareness**) were also salient. These terms indicate that students linked societal impacts to community well-being, cultural context, and economic participation.

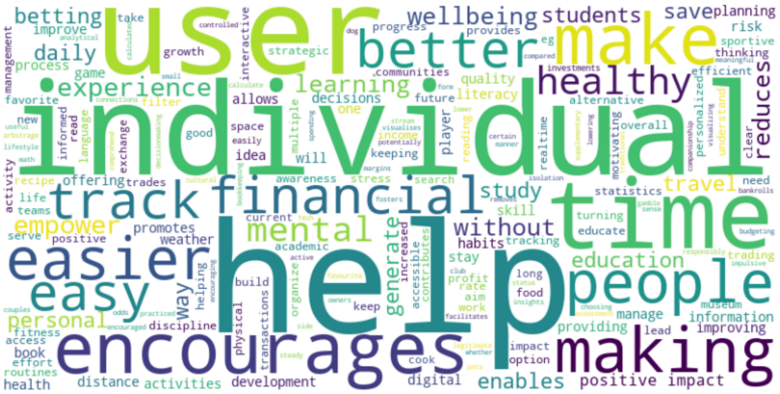


Figure 4: Keyword distribution for Individual responses. Highlighted terms show themes of well-being, efficiency, and finance.

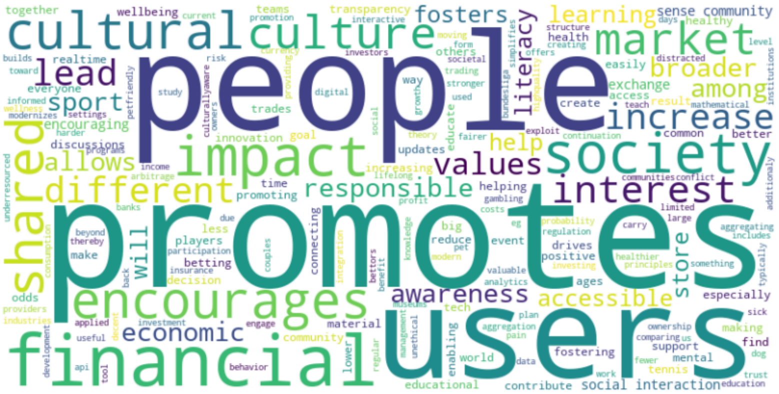


Figure 5: Keyword distribution for Societal responses. Highlighted terms show themes of community well-being and economic participation. Word sizes indicate relative frequency.

Frequent terms included **reduces**, **paper**, and **waste**. Many responses contrasted **physical** and **printed materials** with **digital** or **digitizing** alternatives, signaling a resource-saving orientation. Additional terms such as **sustainable**, **environmentally**, and **plants** reflected ecological concerns, while **supports**, **encourages**, **helping**, **local**, and **promoting** suggested proactive measures.

These observations show that students commonly framed environmental impacts as reductions in material use and waste through digitization.

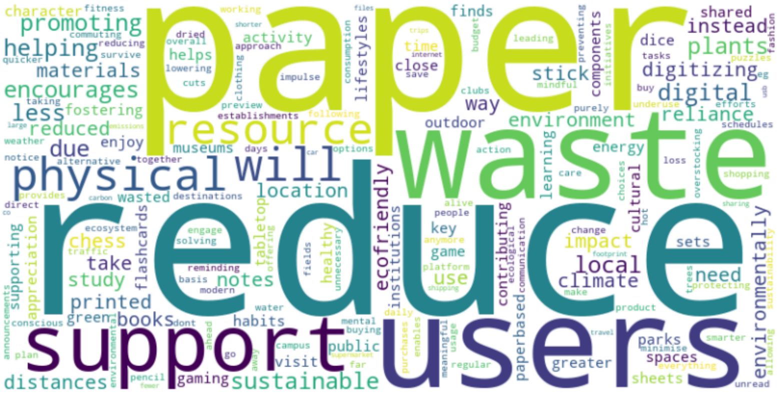


Figure 6: Keyword distribution for Environmental responses. Highlighted terms show themes of resource reduction and substitution of physical materials with digital solutions.

7.2 Introduction Phase — Systemic Journey Maps

Students created **Systemic Journey Map** (SJM) to anticipate potential social and environmental effects of their proposed applications. I applied an inductive coding procedure to the **SJM** entries. Coders grouped semantically similar statements into themes without imposing a prior taxonomy. This approach produced a grounded summary of what students documented and enabled the later aggregation of environmental and social themes.

After thematic coding, I assigned each entry to one of three impact orders from the Karlskrona Manifesto: **first-order** (direct operational effects), **second-order** (behaviour or practice changes enabled by software), and **third-order** (long-term systemic shifts).

7.2.1 Completeness Analysis

A considerable share of student entries was incomplete or irrelevant (**N/A**) at this early stage, and several responses explicitly stated **No impact** (Table Table 6). After filtering, the analytic corpus comprised 33 Environmental entries and 48 Social entries.

Dimension	**Total**	**Blank**	**N/A**	**No impact**
Environmental	164	111	10	10
Social	164	104	9	3

Table 6: Completeness of **SJM** entries in the Introduction Phase. After filtering blanks, Not Applicable (**N/A**), and No impact cases, 33 Environmental and 48 Social entries remained for analysis.

7.2.2 Thematic Analysis

Within the **Environmental** dimension, entries were predominantly concrete and operational, clustering around resource efficiency (Table 7). Students most frequently mentioned paper waste reduction (13 entries), followed by energy use and efficiency (11), travel behaviour change (6), and other resource-related topics (3). Within the **Social** dimension (Table 8), entries most often addressed community building (15), health and well-being (12), behavioural awareness (9), financial awareness (6), cultural engagement (5), and accessibility and inclusion (1) .

Environmental Theme	Frequency
Paper waste reduction	13
Energy use and efficiency	11
Travel behaviour change	6
Other resource efficiencies	3

Table 7: Most frequent environmental themes in SJM entries.

Social Theme	Frequency
Community building	15
Health and well-being	12
Behavioural awareness	9
Financial awareness	6
Cultural engagement	5
Accessibility and inclusion	1

Table 8: Most frequent social themes in SJM entries.

7.2.3 Impact Orders Coding

Second-order impacts dominated across both dimensions, accounting for about three-quarters of all coded entries (61 of 81). Within the Environmental entries, second-order effects represented two-thirds of cases (22 of 33), while Social entries showed an even stronger pattern (39 of 48, 81%). First-order effects were less frequent, and third-order references were rare (Table Table 9).

Dimension	First-order	Second-order	Third-order
Environmental	9	22	2
Social	3	39	6

Table 9: Distribution of impact orders across SJM entries. Second-order effects dominated, with fewer first-order cases and only a small subset of third-order systemic shifts.

7.3 Introduction Phase — Survey Results

To evaluate the Introduction Phase, the workshop instructor administered a voluntary survey to collect feedback on learning outcomes and the SJM activity. The survey instrument was designed by the instructor, and I obtained permission to use it for analysis in this thesis.

The questionnaire comprised 14 items combining Likert-type ratings and open-ended prompts (see Appendix F for details of the survey design). This section presents results related to responsibility, perceptions of the SJM, and suggestions for improvement. Findings are reported in two parts: a synthesis of closed-ended (Likert-type) items and an analysis of open-ended responses.

A total of 19 valid responses were collected. The majority identified as men (68%), while women accounted for 26%, and one participant selected "don't know." In terms of age, most respondents (68%) were between 21 and 25 years old, followed by 21% in the 26–30 range, and a single respondent (5%) in the 16–20 category.

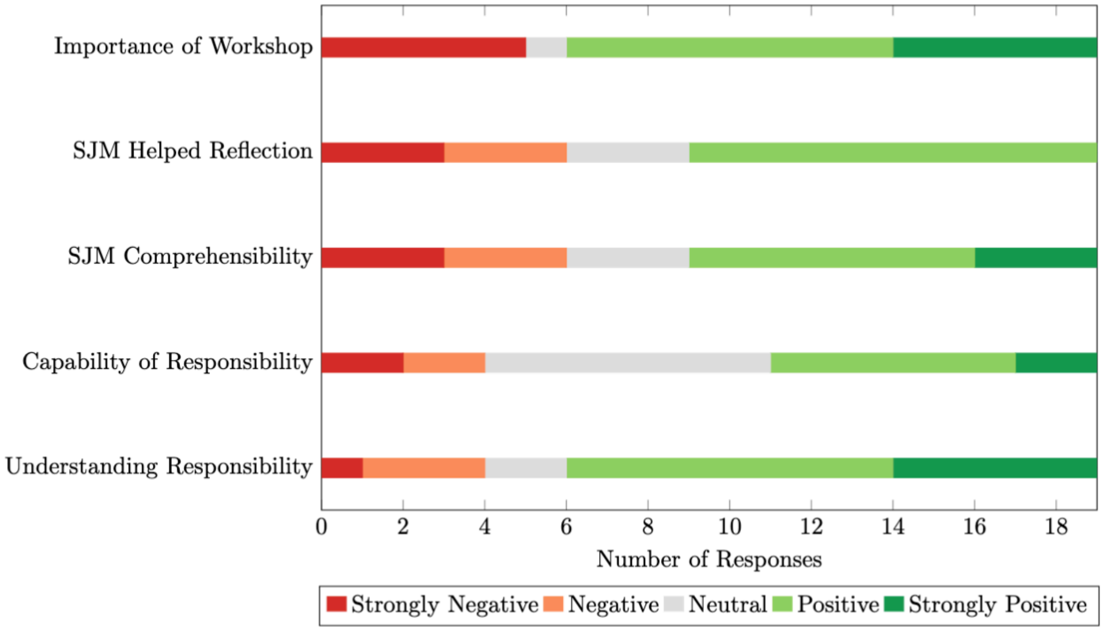


Figure 7: Survey overview for selected items related to responsibility and the SJM.

7.3.1 Likert-type Items

Responses to the closed-ended items revealed consistent patterns. Most students rated the workshop as important, though a minority expressed disagreement. Perceptions of the SJM were overall positive. Comprehensibility received the strongest endorsement, with most students evaluating the method as clear and easy to follow. By contrast, fewer respondents considered the SJM strongly helpful for reflection, indicating a weaker endorsement of this dimension.

Responsibility-related items revealed a distinction between **understanding responsibility** and **capability of responsibility**. The former was rated positively by most respondents, with many strongly positive scores. The latter attracted more neutral responses and fewer strongly positive ratings. This suggests that the workshop was more effective in strengthening awareness and understanding of responsibility than in building confidence to act responsibly.

7.3.2 Open-ended Items

Two prompts complemented the quantitative results with qualitative insights.

- Learning interests: Respondents most frequently mentioned **prototyping** and **responsible digital product development**, followed by societal impacts of digital products. Environmental impacts and specific methods such as the SJM appeared less often, suggesting stronger demand for practical design skills and ethics-oriented content.
- Positive aspects and suggestions: Students highlighted prototyping activities as helpful for developing ideas and valued the interactive format, opportunities for active participation, and the connection between sustainability concepts and real-world applications. Several noted that the SJM supported broader reflection on app impacts. Suggestions included increasing interactivity, providing clearer guidance on the SJM, including case studies of mature applications, and allocating more time for exercises. A small number of respondents indicated that no changes were necessary.

7.4 Project Phase — Systemic Journey Maps

During the Project Phase, students again created SJM to anticipate potential environmental and social consequences within the user journeys. This activity followed the same procedure as in the Introduction Phase: (1) coding entries inductively into themes and (2) classifying them into impact orders. Using the same tool and coding approach ensured comparability across phases and enabled tracing how student reasoning evolved over time.

7.4.1 Completeness Analysis

Compared to the Introduction Phase, completeness improved substantially. Fewer entries were blank or marked as N/A, which reflects both the progression of the course and the higher stakes of official deliverables (Table 10). After filtering, the analytic corpus comprised 25 Environmental entries and 30 Social entries.

Dimension	Total	Blank	N/A	No impact
Environmental	42	14	3	0
Social	42	8	4	0

Table 10: Completeness of SJM entries in the Project Phase. After filtering blanks and irrelevant cases, 25 Environmental and 30 Social entries remained for analysis.

7.4.2 Thematic Analysis

Within the **Environmental** dimension, entries again clustered around operational concerns, with a strong focus on energy use (7), resource efficiency (6), paper waste reduction (6), and travel behaviour change (5). Efficiency was mentioned once, and safety culture appeared once (Table 11). These themes partly overlap with the Introduction Phase but show a stronger emphasis on energy.

Within the **Social** dimension, the most frequent themes were community building (8) and trust and community (7). Other themes included safety culture (5), education access and equity (3), health and well-being (2), behavioural awareness (2), digital equity (2), and community engagement (noted as part of broader trust and participation). Compared to the Introduction Phase, the Project Phase entries framed responsibility more often in terms of collective values and equity (Table 12).

Environmental Theme	Frequency
Energy use	7
Resource efficiency	7
Paper waste reduction	6
Travel behaviour change	5

Table 11: Most frequent environmental themes in SJM Project Phase entries. Common topics included energy and resource efficiency, paper waste, and travel behaviour.

Social Theme	Frequency
Community building	8
Trust & community	7
Safety culture	5
Education access & equity	3
Health & well-being	2
Behavioural awareness	2
Digital equity	2
Efficiency	1

Table 12: Most frequent social themes in SJM Project Phase entries. Common topics included community building, trust, safety, education, health, and equity.

7.4.3 Impact Orders Coding

As in the Introduction Phase, second-order impacts dominated across both dimensions, but the distribution displayed notable shifts (Table 13). Environmental entries included more first-order references (8) than before, suggesting greater attention to immediate operational effects. Social entries, by contrast, showed a marked rise in third-order references (20), which indicates that students increasingly recognised long-term systemic changes enabled by digital products.

Dimension	First-order	Second-order	Third-order
Environmental	8	15	2
Social	0	10	20

Table 13: Distribution of impact orders in **SJM** Project Phase entries. Second-order effects dominated, with more first-order Environmental impacts and more third-order Social impacts than before.

7.5 Project Phase - Inclusive Segment Cards

This section synthesises artefacts created with the Inclusive Segment Cards (**ISC**), including user segments, roles, needs, pains, gains, user stories, use cases, and the Privilege Wheel[22]. The results are reported across four components: user segments, user groups and use cases, privilege wheel data, and student feedback.

7.5.1 User Segments

User segments were analysed across six demographic dimensions: **age**, **ethnicity**, **gender & sex**, **physical/mental ability**, **social background**, and **financial safety**. Students completed a template that emphasised evidence rather than assumptions and instructed them to avoid stereotyping. Each entry was consolidated and coded on a privilege scale:

- Privileged (1) — groups associated with social, economic, or cultural advantage.
- Mixed/Marginalised (0.5) — partially inclusive or ambiguous diversity.
- Marginalised (0) — groups facing structural disadvantage.

[22] The wheel of power and privilege is a reflective activity to map and explore issues of power and privilege in an intersectional way. It can be conducted individually as a self-awareness tool or in a group to highlight how different people might benefit from or be marginalised by systems in society. https://www.icvanetwork.org/resource/wheel-of-power-and-privilege/

- Not Specified (−1) — blank or undefined entries.

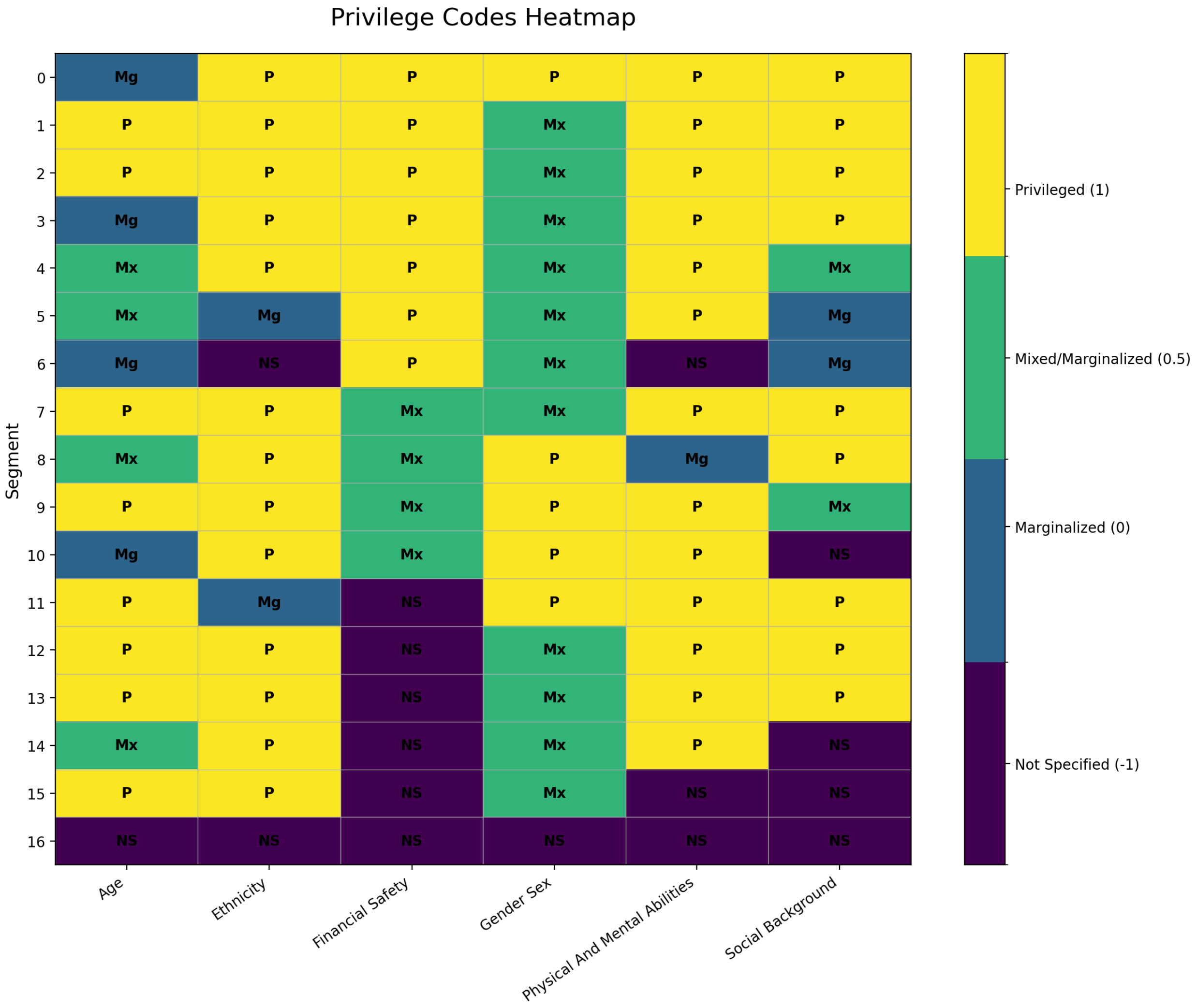
The distribution patterns (Figure 1) showed clustering toward **Privileged** categories. Entries coded as **Mixed/Marginalised** often described generic “diverse” groups, while **Not Specified** entries represented missing or uncollected data. Explicitly **Marginalised** segments appeared only infrequently.

7.5.2 User Groups, Stories, and Use Cases

The analysis of user group roles, needs, pains, and gains revealed recurring categories across multiple domains. Roles extended beyond **end users** to include design and prototyping, customer experience, management, retail operations and analytics, safety and training, education, support, and civic services.

Identified pains clustered around four main categories: **Data Integration & Visibility**, **Time & Efficiency**, **Usability & Simplicity**, and **Collaboration & Alignment**. Reported gains mirrored these themes, with an additional emphasis on **Visualisation & Immersion**.

Analysis of user stories and use cases showed that impacts most frequently aligned with **social value**, particularly in relation to Accessibility & Inclusion, Safety & Risk Reduction, Digital Literacy & Skills, and Transparency & Accountability. **Environmental value** was primarily described as efficiency-related co-benefits such as reduced travel, less printing, and material savings. References to rebound effects and trade-offs appeared occasionally but were less systematically discussed.



Segment	Age	Ethnicity	Financial Safety	Gender Sex	Physical And Mental Abilities	Social Background
0	Mg	P	P	P	P	P
1	P	P	P	Mx	P	P
2	P	P	P	Mx	P	P
3	Mg	P	P	Mx	P	P
4	Mx	P	P	Mx	P	Mx
5	Mx	Mg	P	Mx	P	Mg
6	Mg	NS	P	Mx	NS	Mg
7	P	P	Mx	Mx	P	P
8	Mx	P	Mx	P	Mg	P
9	P	P	Mx	P	P	Mx
10	Mg	P	Mx	P	P	NS
11	P	Mg	NS	P	P	P
12	P	P	NS	Mx	P	P
13	P	P	NS	Mx	P	P
14	Mx	P	NS	Mx	P	NS
15	P	P	NS	Mx	NS	NS
16	NS	NS	NS	NS	NS	NS

Figure 8: Privilege coding across user segment dimensions.

7.5.3 Privilege Wheel

The Privilege Wheel dataset (n=149) produced distributions across multiple demographic dimensions. Privilege appeared most often in **Age**, **Education**, **Ability**, and **Race**. Greater diversity was observed in **Gender & Sex** and **Color**. By contrast, **Class** and **Language** included higher proportions of marginalised categories.

Dimension	Not Specified	Marginalised	Mixed/Marginalised	Privileged
Age	22.2%	11.1%	0.0%	66.7%
Education	16.7%	16.7%	0.0%	66.7%

Dimension	**Not Specified**	**Marginalised**	**Mixed/Marginalised**	**Privileged**
Ability	33.3%	5.6%	0.0%	61.1%
Race	38.9%	5.6%	0.0%	55.6%
Neurotypicalism	44.4%	5.6%	0.0%	50.0%
Status	41.2%	11.8%	0.0%	47.1%
Ethnicity	35.3%	17.6%	0.0%	47.1%
Gender & Sex	27.8%	16.7%	16.7%	38.9%
Color	50.0%	5.6%	5.6%	38.9%
Class	27.8%	33.3%	5.6%	33.3%
Language	27.8%	38.9%	0.0%	33.3%
Sexuality	66.7%	0.0%	0.0%	33.3%
Religion	70.6%	5.9%	0.0%	23.5%
Body Type	77.8%	0.0%	0.0%	22.2%

Table 14: Privilege distribution per dimension across Inclusive Segment Cards. The table reports percentages of Not Specified, Marginalised, Mixed/Marginalised, and Privileged codes.

7.5.4 Student Feedback

Field notes from the **UX/UI** workshop on 4 June 2025 documented several challenges (Appendix C). Client use cases often directed teams toward privileged user segments, such as wealthy homeowners. Data scarcity led students to adopt "self-as-user" perspectives or to employ generic categories such as "for everyone."

Students frequently accepted platform constraints, such as Vision Pro's incompatibility with blind users, without further critique. Heterogeneous contexts, including multiple factories or diverse customer groups, encouraged broad and assumptive entries that did not differentiate between distinct user needs.

7.6 Project Phase - Supplementary Insights from Interviews

To complement the artefact and survey data, three semi-structured interviews were conducted with students participating in the **UX/UI** workflow (Appendix D). These interviews provided additional perspectives on how students experienced the integration of sustainability into their projects.

Students reported difficulties in defining environmental aspects. They described challenges in identifying concrete environmental impacts when client requirements allowed little scope for software-level improvements. Reported examples included reliance on servers without renewable energy and platform-specific limitations, such as those associated with Vision Pro. In many cases, environmental considerations were reduced to operational efficiency, most often expressed in terms of paper savings.

By contrast, students articulated social and individual dimensions of sustainability more readily. These aspects were frequently framed around inclusivity and user needs, often summarised in broad terms such as designing “for people.” Accessibility and usability emerged as recurring points of reference and were mentioned more often than systemic or long-term considerations.

Process-related factors also shaped how students addressed sustainability. Templates provided structure and ensured that sustainability was considered; however, some participants described them as repetitive or restrictive. Team motivation further influenced the depth of engagement, with students participating in the **UX/UI** workflow reporting stronger commitment than those in other groups.

The interviews also highlighted preferences regarding feedback formats. Individualised feedback was perceived as more useful than group presentations. Several students stated that personalised comments supported their learning more effectively than general feedback delivered in larger settings.

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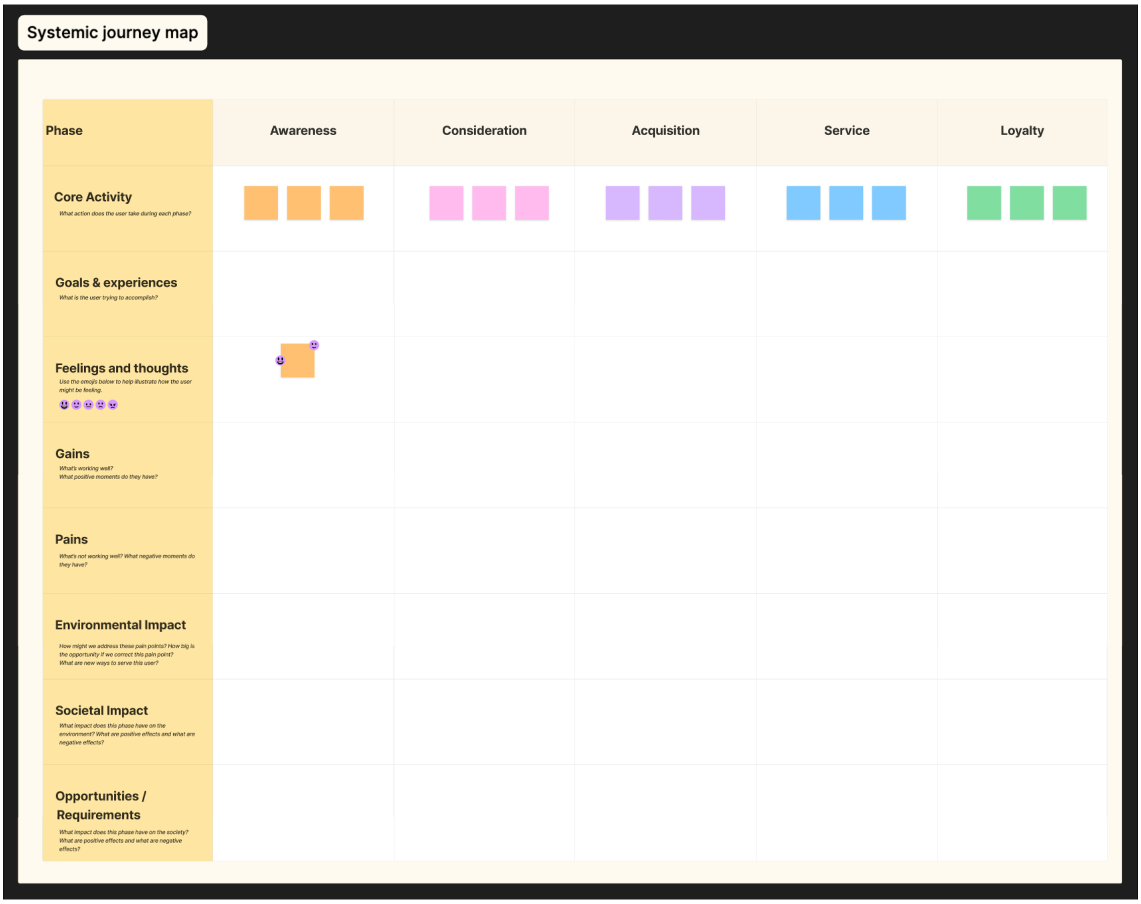
Appendix A

Systemic Journey Map Template for iPraktikum

This study adapts the original SJM template to streamline collaboration. Instructor removed the “Jobs”, “Touchpoints”, “Data”, and “Other” fields to reduce cognitive load and keep participants focused on core journey elements. “Goals” and “Experiences” were merged into a single prompt and added a “Feelings and thoughts” row to encourage empathetic reflection on user experiences (Figure 9).



Systemic journey map

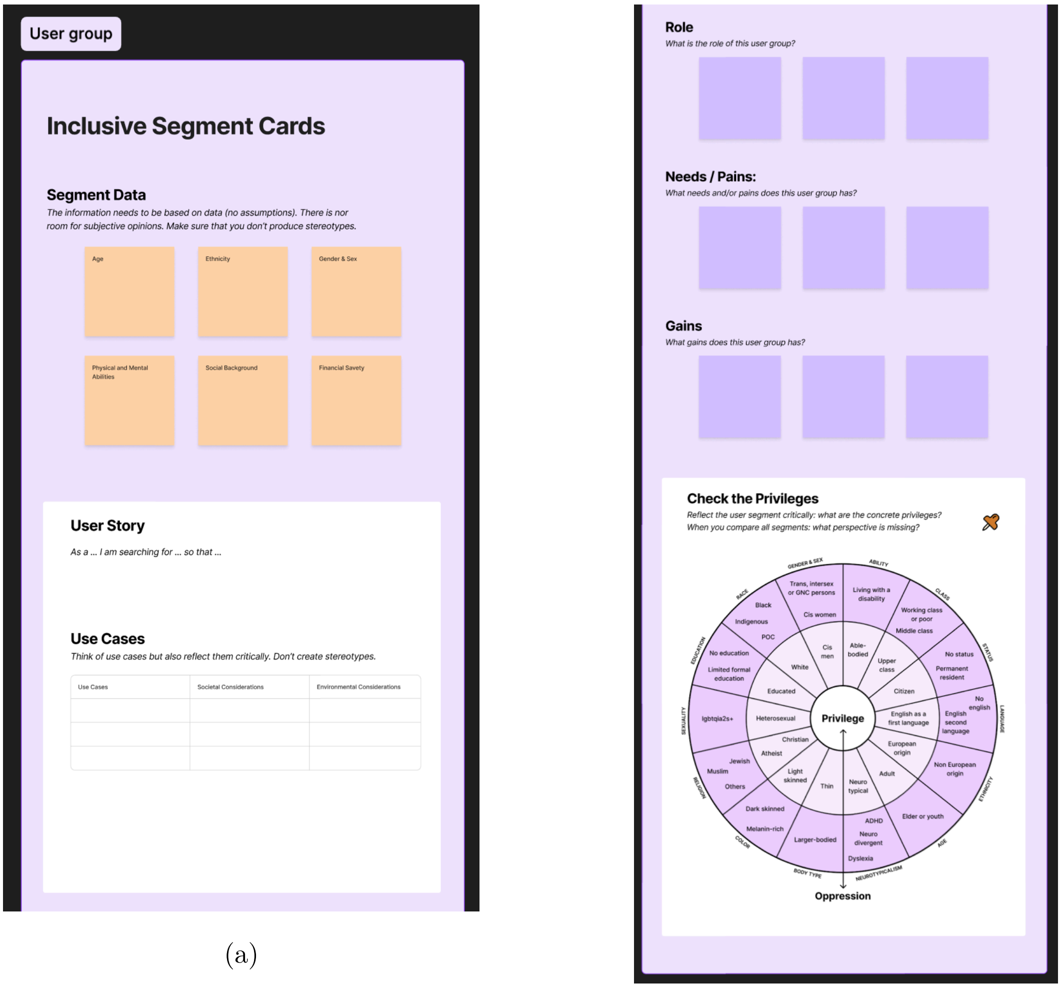
Phase	Awareness	Consideration	Acquisition	Service	Loyalty
Core Activity *What action does the user take during each phase?*					
Goals & experiences *What is the user trying to accomplish?*					
Feelings and thoughts *Use the emojis below to help illustrate how the user might be feeling.* 😃 🙂 😐 🙁 😠					
Gains *What’s working well?* *What positive moments do they have?*					
Pains *What’s not working well? What negative moments do they have?*					
Environmental Impact *How might we address these pain points? How big is the opportunity if we correct this pain point?* *What are new ways to serve this user?*					
Societal Impact *What impact does this phase have on the environment? What are positive effects and what are negative effects?*					
Opportunities / Requirements *What impact does this phase have on the society?* *What are positive effects and what are negative effects?*					

Figure 9: Systemic Journey Map template adapted for iPraktikum.

Appendix B

Inclusive Segment Card Template for iPraktikum

This study adapts the original **ISC** template to streamline its use in collaborative settings. Instructor removed non-essential fields such as “Value Drivers”, “Competition Recently Used”, and “Research Impact” to reduce cognitive load. Template was applied during second workshop. Each team first recorded demographic and contextual segment data, then described concrete user stories and mapped them to use cases. Teams reflected on roles, needs, pains, and gains before discussing the privilege wheel.



User group

Inclusive Segment Cards

Segment Data

The information needs to be based on data (no assumptions). There is nor room for subjective opinions. Make sure that you don't produce stereotypes.

Age

Ethnicity

Gender & Sex

Physical and Mental Abilities

Social Background

Financial Savety

User Story

As a ... I am searching for ... so that ...

Use Cases

Think of use cases but also reflect them critically. Don't create stereotypes.

Use Cases	Societal Considerations	Environmental Considerations

(a)

Role

What is the role of this user group?

Needs / Pains:

What needs and/or pains does this user group has?

Gains

What gains does this user group has?

Check the Privileges

Reflect the user segment critically: what are the concrete privileges?
When you compare all segments: what perspective is missing?

(b)

Figure 10: Inclusive Segment Card template adapted for iPraktikum.

Appendix C

Group Feedback on Inclusive Segment Cards

The following notes were collected during a feedback session in the third **UX/ UI** workshop. In this session, students shared their experiences with the methods, discussed challenges they faced, and reflected on accessibility, sustainability, and design considerations in their projects.

Team 1

- Limited user information available. App design considered **independent of demographic differences** (male/female, short/tall). In cases of missing user group data, design became **generalised**.

Team 2

- Identified **three distinct customer groups**. Faced challenges in obtaining data for some groups. Relied on **assumptions** when data was unavailable.

Team 3

- Focused on one specific user group: **wealthy homeowners** (a privileged segment). Unable to identify other user groups due to the narrow use case.
- Accessibility limitation: **Vision Pro** cannot be used by blind people, demonstrating technology-based exclusion.
- Team made a **conscious decision** to restrict scope.
- Relied on themselves as representative users ("putting yourself as the user").
- Raised the question of whether design should differ for **men and women**.

Team 6

- Intended for **general use ("everyone")**, therefore avoided specifying detailed user groups.
- Recognised that **excluded groups** (e.g., blind users) could have been considered.

Team 7

- No direct user data available. Faced difficulties in identifying groups due to the presence of **different factories** with varied contexts.

Appendix D

Interviews with Students

The following notes were collected the third **UX/UI** workshop while talking to students.

Team 1

- Design and development phases were both considered important. Planning phase also highlighted as important.
- Environmental and social requirements were difficult to define, as customers were very direct in specifying what they wanted. Requirements were highly specific to the use case and the client.
- Example: environmental sustainability was difficult to address because BMW used its own servers, leaving no room for software-level improvements.
- Accessibility was limited by **Apple Vision Pro**

Team 7

- Planning phase was considered helpful. Motivation of the team influenced the outcome: participants who joined the **UX/UI** workflow were more engaged and focused.
- Templates made the process structured, but also repetitive and at times frustrating (e.g., applying feedback repeatedly rather than following flexible guidelines).
- Client requirements were often changing; e.g., requests for customisation without providing sufficient data.
- Environmental aspects were reduced mainly to **saving trees** and **reducing paper**. Social aspects were easier to address, since the product was "for people."

Team 6

- Difficulties in defining environmental aspects. Only those engaged in the **UX/UI** workflow considered sustainability dimensions.
- Students felt **individual feedback** was more useful than group presentations.
- Development phase progressed faster than design.

Appendix E

Software 5.0 Toolkit

Interview Guidelines

Purpose

Interview Guidelines support students in approaching clients and conducting requirements elicitation. They extend conventional interview practice by embedding prompts for sustainability. The guidelines structure semi-structured interviews so that ecological and social concerns appear alongside functional requirements. This integration ensures that sustainability becomes part of stakeholder conversations without dominating other priorities.

Theoretical foundation

Interviews are established techniques in requirements elicitation. They enable requirements engineers to gather information from stakeholders with different perspectives [NE00]. Semi-structured interviews are particularly effective because they combine predefined questions with the flexibility to follow unexpected insights. In **SE**, interviews are commonly used to prepare requirement specifications [Ali+18]. They also support researchers and practitioners in developing a comprehensive understanding of stakeholder practices and system use [Woo97]. The quality of elicited requirements, however, depends on the questions asked and the interviewer's guidance [SW11].

The Interview Guidelines build on this foundation by embedding prompts for sustainability into semi-structured interviews. Research in sustainable **SE** highlights the importance of considering ecological and social concerns at the beginning of the development lifecycle rather than treating them as secondary issues [Bec+15, Rib+24]. The guidelines translate this perspective into practice by ensuring that sustainability concerns become a standard element of stakeholder discussions.

Derivation from study

The development of the Interview Guidelines responds directly to challenges observed in the study. Student reasoning showed an awareness–action gap: participants expressed confidence in understanding responsibility yet struggled to act on it. Sustainability considerations often lacked holistic integration, as students addressed individual and social dimensions but rarely ecological or systemic ones. Project briefs constrained the scope of sustainability by privileging user-centred and short-term concerns.

Embedding explicit sustainability prompts into interviews addresses these challenges. By triggering conversations about ecological and systemic effects, the guidelines encourage students and clients to reflect beyond immediate functional needs. Prompts create space for discussing underrepresented dimensions and help counter biases introduced by project briefs. In this way, the guidelines transform findings from the study into practical scaffolds that broaden the scope of requirements elicitation.

Input

Project context and scope, Selection of interviewees, Prepared interview guide with sustainability prompts

Processing

Students conduct semi-structured interviews, capture stakeholder narratives, and identify sustainability-related insights. These insights are analysed together with functional and non-functional requirements. The process ensures that sustainability is included in the requirements specification.

Output

The output consists of consolidated insights into stakeholder needs, values, and expectations that relate to sustainability. These insights expand requirements documentation and strengthen systemic perspectives for later design phases.

When to use

The Interview Guidelines are most useful in the early stages of a project, when teams prepare and conduct client interviews. They can also be revisited when updating requirements to ensure that sustainability remains visible across project phases.

Stakeholder Ecosystem

Purpose

The Stakeholder Ecosystem provides a structured approach for identifying human and non-human actors in software projects. It extends analysis beyond immediate users by explicitly including institutions, communities, and environmental entities. This perspective highlights interdependencies, links projects to broader societal and ecological systems, and integrates sustainability considerations from the beginning of the development process.

Theoretical foundation

Stakeholder mapping is a central practice in SE, where stakeholders are individuals or organizations who are affected by, or can influence, a system. Sharp et al. describe stakeholders as both direct users and those who indirectly shape requirements [SFG99]. Requirements engineering literature emphasizes systematic stakeholder identification, prioritization, and selection as key activities that guide elicitation and negotiation [GW07]. The Stakeholder Ecosystem builds on these foundations and expands the notion of legitimate actors to include institutions, communities, and environmental entities, which supports a systemic view of software development and embeds sustainability into early decision making.

Derivation from study

The Stakeholder Ecosystem emerged in response to patterns observed in the study. Students tended to centre individual users and usability while paying limited attention to systemic and ecological aspects. Inclusive Segment Cards prompted reflection on social groups, yet they reinforced narrow role-based thinking that overlooked institutions, communities, and environmental entities. Systemic Journey Maps broadened reasoning but demanded a maturity of perspective that many students did not reach without targeted scaffolding.

The Stakeholder Ecosystem addresses these barriers with a lightweight method that widens the scope of stakeholder identification. It introduces layered categories of direct, indirect, and extended actors to make interdependencies visible and to surface stakeholders who are usually absent from early discussions. The method integrates ecological reasoning by placing environmental entities alongside human actors and counters structural biases by recognizing institutions and communities as actors with influence and needs. This approach responds to the study's findings by countering user-centric dominance, extending ecological reasoning beyond operational concerns, and fostering systemic integration in requirements work.

Input

Provide a concise project brief and contextual description. State initial assumptions about users, institutions, communities, and environmental factors that may influence or be affected by the project. These inputs ground the first iteration of the ecosystem and guide subsequent evidence gathering through interviews and desk research.

Processing

Follow a layered "onion" model that structures actors by proximity and influence:

Project: Place the name of the application, system, or research project in the central circle.

Direct actors: List entities that directly use or interact with the project.

Indirect actors: Add entities that influence or are affected by the project without direct interaction.

Extended actors: Include entities with long-term exposure or deferred impacts who may not have a direct voice in the project.

Output

The result is a stakeholder ecosystem diagram that positions users, institutions, communities, and environmental actors across three layers of influence. The diagram makes interdependencies visible and foregrounds sustainability-relevant impacts. Teams use the artifact to plan interviews, guide systemic reflection, and support sustainability-aware requirements elicitation in later phases.

When to use?

Apply the method at project initiation to guide interviewee selection and broaden the scope of inquiry. Revisit the ecosystem after interviews to incorporate newly identified actors and refine relationships. Use the artifact before systemic design tools, such as a Systemic Journey Map, where it serves as a concise entry point for multi-actor reasoning.

Template

Template available in Figma: Stakeholder Ecosystem Template

[Miq24] - there is nice tool that can be used

Inclusive Personas

Purpose

Inclusive Personas support equitable and sustainability-aware software development by foregrounding diverse user perspectives. Traditional personas risk reinforcing stereotypes and privileging assumptions about “typical” users [PHM19]. Inclusive Personas emphasise systemic inclusion, privilege awareness, and the identification of marginalised groups so that design decisions consider accessibility, equity, and long-term social sustainability.

The method refines the Inclusive Segment Cards from the CSD framework. The refinement strengthens privilege analysis, separates user stories and use cases, and deliberately excludes environmental considerations to keep the tool focused on social sustainability.

Theoretical foundation

Personas are established techniques in Human-Computer Interactions (**HCI**) and requirements engineering that synthesise user research into archetypes guiding design decisions and maintaining user focus throughout development [BBA18]. Alan Cooper introduced the concept of personas in **The Inmates are Running the Asylum** as a way to describe fictitious users that represent stakeholder needs [CS99]. Teams use personas as communicative artefacts that coordinate perspectives across disciplines. Conventional personas often reinforce stereotypes and reduce users to simplified categories, which narrows attention to usability and efficiency at the expense of equity and sustainability [PHM19].

Inclusive Personas refine the Inclusive Segment Cards from the **CSD** framework by strengthening privilege analysis and emphasising social sustainability [Fri23].

Derivation from study

The refinement emerged from limitations observed when students applied the **ISC** method. Student descriptions concentrated on privileged groups such as young, educated, and able-bodied users. Marginalised perspectives appeared rarely. These patterns indicated a bias in segment selection and a lack of early attention to systemic barriers. Project constraints reinforced this tendency, as client briefs directed teams toward privileged use cases and user groups.

Reasoning in student artefacts focused on individual and social aspects. Usability, inclusivity, and collaboration dominated design arguments, while ecological reasoning remained narrowly operational. Students referred to paper savings or reduced travel and rarely connected design choices to upstream or downstream environmental effects. Combining user stories and personas into a single artefact reinforced this efficiency-centred focus and obscured systemic effects.

The Inclusive Personas method responds by separating user stories from personas, moving privilege analysis to the start of persona creation, and introducing a structured reflection step that surfaces missing voices and blind spots. These refinements create space for marginalised perspectives and counteract the influence of project constraints on user selection.

Input

The method requires identified primary users, demographic and contextual information, indicators of privilege and barriers, and evidence-based needs, pains, and gains.

Processing

The creation of Inclusive Personas follows a concise template that supports traceable decisions and systemic attention:

1. **Data**: Document demographic and contextual information based on research evidence; leave fields blank where data is not reliable.
2. **Privilege and barriers**: Apply a privilege wheel or checklist to assess advantages (e.g., citizenship, education) and disadvantages (e.g., disability, low income).
3. **Role**: Define the persona's relation to the system or product in one precise sentence.
4. **Needs and pains**: Identify goals and challenges grounded in data from interviews, observation, or surveys.
5. **Gains**: State expected benefits and aspirations such as inclusion, financial stability, or community belonging.
6. **Reflection**: Compare personas to identify missing voices, systemic blind spots, and risks of stereotyping; record explicit follow-up actions.

Output

The output consists of a set of Inclusive Personas that articulate diverse user perspectives, reveal systemic barriers and privileges. These personas guide design discussions, support comparison of alternatives, and protect against overlooking marginalised groups.

When to use

Use Inclusive Personas at the beginning of design processes to expand the scope of user research and avoid exclusionary assumptions. Revisit the personas during requirements elicitation, prototyping, and evaluation to validate priorities against diverse needs and to assess inclusivity, accessibility, and sustainability.

Template

Template available in Figma: Inclusive Persona Template

Systemic Journey Map

Purpose

The Systemic Journey Map facilitates reflection on how software affects individuals, society, and the environment across different stages of the user journey. By grounding the analysis in one chosen user group, the method helps **SE** students and practitioners move beyond functional requirements toward multi-level sustainability implications and systemic interconnections. It refines the Systemic Journey Map from the **CSD** framework to address challenges observed in student projects and adapt the method to educational and **SE** contexts.

Theoretical foundation

Journey mapping is an established approach in design and software development for analysing and optimising user experiences across lifecycle stages, touchpoints, and emotional states [Can+23]. When combined with personas, journey maps support requirements elicitation by clarifying user needs, fostering collaboration, and integrating stakeholder knowledge. In agile processes, journey mapping strengthens usability and contributes to project success [Kus+23].

The Systemic Journey Map extends this foundation by embedding sustainability reasoning. The method situates user actions within broader societal and environmental systems, highlighting direct and indirect impacts. This systemic orientation draws on sustainability research that distinguishes between first-order operational effects, second-order enabling effects, and third-order systemic effects

[Bec+15]. By linking everyday user journeys to systemic impacts, the tool supports reflection that reaches beyond immediate usability concerns.

Derivation from study

The refinement of the Systemic Journey Map responds to recurring limitations in student projects. Artefacts and interviews showed that reasoning concentrated on individual and social aspects, while ecological reflections remained narrow and operational. Systemic entries demonstrated that second-order effects dominated reflections, while first-order operational impacts and especially third-order systemic effects appeared infrequently. Early artefacts contained incomplete entries, suggesting that students found it difficult to apply the method without clearer scaffolding. Survey responses indicated that students considered the tool understandable but did not consistently find it helpful for deeper reflection. These patterns highlighted a need for targeted prompts, explicit examples, and clearer terminology.

The refined Systemic Journey Map addresses these challenges by simplifying the naming of phases, providing placeholders that guide completion, and integrating concise educational content adn more examples on sustainability dimensions.

Input

The method requires the selection of one user group and a shared understanding of the system to be analysed.

Processing

The creation of a Systemic Journey Map follows a structured sequence. First, the phases of the persona's user journey are defined. For each phase, user actions, goals, pains, and gains are documented. Societal and environmental impacts are then annotated, guided by scaffolding materials and prompts that link to the sustainability dimensions.

Output

The output is a visual journey map that highlights sustainability impacts at multiple levels and makes systemic interconnections explicit. It provides a tangible artefact for reflecting on design choices, broadening sustainability perspectives, and generating insights that can later inform requirements.

When to use?

The Systemic Journey Map is most effective in early-stage design and reflection phases, when systemic implications should be surfaced without requiring quantitative analysis. It can also be revisited during prototyping and evaluation to reassess systemic effects.

Template

Template available in Figma: Systemic Journey Map Template

Conscious Requirements

Purpose

The Conscious Requirements tool helps students consolidate insights from earlier research activities into a structured set of user stories and use cases. While the requirements themselves do not have to be explicitly about sustainability, the tool incorporates reflection prompts that encourage students to consider environmental, social, and inclusivity aspects alongside functional and non-functional needs. This ensures that earlier reflections are not lost and that sustainability has an opportunity to inform design decisions.

Theoretical foundation

User stories and use cases are established practices for capturing requirements in both agile and traditional development processes. User stories frame needs from the perspective of specific roles and have become a standard artefact in agile contexts [Coh04].

These techniques are effective for translating user needs into actionable requirements, but they rarely incorporate sustainability. Research in sustainable **SE** highlights the importance of considering environmental and social concerns in early stages of development rather than adding them later [Bec+15]. Reflection prompts embedded in requirements elicitation can address this gap by linking functional and non-functional needs with sustainability considerations. Conscious Requirements extend established practices by adding this reflective layer.

Derivation from study

The refinement responds to limitations observed in the empirical study. Students engaged with sustainability through tools such as the Inclusive Segment Cards and the Systemic Journey Map, but these insights often disappeared once projects progressed to requirements and prototyping. Sustainability considerations rarely carried over into backlogs or final deliverables, which limited their influence on design outcomes. This confirmed the barrier of poor transfer from reflection tools to final outputs.

The Conscious Requirements tool addresses these challenge by requiring teams to revisit earlier artefacts when drafting user stories and use cases. Reflection prompts guide students to ask whether a requirement has environmental implications, disadvantages specific user groups, or affects long-term resilience. In this way, the method links design reflections to requirements documentation and sustains sustainability reasoning across project phases.

Input

- Research outputs
- Functional and non-functional requirements identified so far
- Project goals and constraints

Processing

1. **Collect**: Summarise relevant insights from earlier research.
2. **Translate**: Write user stories and use cases that capture identified needs and opportunities. Example: “As a teacher, I want the grading tool to work offline so I can use it without constant internet access.”
3. **Reflect**: Apply prompts that ask whether requirements have environmental implications, disadvantage specific user groups, or affect long-term system resilience.
4. **Revise**: Adjust or extend requirements based on reflection insights.

Output

A set of user stories and use cases annotated with reflection notes. These requirements consolidate previous research findings and encourage consideration of sustainability dimensions before moving into prototyping and testing.

When to use?

Conscious Requirements are applied after early research and reflection tools have been completed, but before prototyping. They provide a bridge between qualitative insights and development activities.

Template

Template available in Figma: Conscious Requirements Template

Prototyping

Purpose

Prototyping enables students to translate requirements into tangible artefacts such as sketches, wireframes, and interactive models. While the primary goal remains testing usability and functionality, this tool introduces scaffolding to ensure that inclusivity and ecological considerations are not overlooked. Rather than making sustainability the central theme, the approach encourages students to infuse small but meaningful adjustments—such as energy-efficient interface choices or inclusive design practices—into their prototypes.

Theoretical foundation

Prototyping is a central practice in **HCI** and **SE**. It enables design teams to externalise ideas, test assumptions, and gather feedback before implementation [LST08]. Low-fidelity sketches and wireframes provide quick, inexpensive ways to explore alternatives and identify usability issues. High-fidelity prototypes support more realistic testing of functionality and interaction flows, bridging the gap between design concepts and implementation.

Prototyping guidelines in this toolkit follow industry practices while adding targeted advice on sustainable and inclusive design. References to energy-efficient user interfaces, accessible colour palettes, and inclusive interaction patterns provide practical entry points for students to integrate sustainability into prototyping without losing focus on usability [Kio+24].

Derivation from study

Prototyping was not directly analysed in the empirical investigation. However, survey responses showed that students were strongly interested in prototyping and in responsible digital product development. At the same time, earlier findings indicated that sustainability reflections often disappeared once projects moved toward implementation.

The Prototyping guidelines were therefore introduced to connect this student interest with sustainability-oriented design. By embedding light scaffolding and reference materials on sustainable and inclusive user interface practices, the tool supports students in carrying forward reflections from earlier methods into prototypes. This ensures that ecological and social considerations remain visible at the stage where students are most motivated to test and refine their ideas.

Input

- User stories and use cases
- Reflection notes and annotated sustainability insights

Processing

1. Create low-fidelity sketches or wireframes based on requirements.
2. Translate into high-fidelity prototypes or interactive mock-ups.
3. Integrate sustainability and inclusivity considerations.

Output

Prototypes that visualise functionality, usability, and design flows, while making inclusivity and ecological considerations visible and testable. These artefacts provide a concrete basis for stakeholder feedback and iterative refinement.

When to use?

Apply during **develop phases** once requirements are documented.

User Testing

Purpose

Testing validates whether prototypes and implemented features meet user needs, usability standards, and functional goals. In this framework, Testing is introduced not as a new sustainability-specific tool but as a structured bundle of established practices. The tool equips students with three of the most widely used testing approaches—usability testing, heuristic evaluation, and acceptance testing—and extends them with sustainability prompts.

Theoretical foundation

Testing is a core activity in **SE** and **HCI**. Usability testing involves observing representative users as they interact with a system to identify problems and assess task performance rubin2008handbook. Heuristic evaluation applies expert-based inspection using recognised principles such as Nielsen's heuristics nielsen1994usability. Acceptance testing verifies that implemented features meet user stories, use cases, and agreed functional goals pressman2010software.

Traditional testing focuses on functionality and usability. Extending established testing approaches with reflection prompts on inclusivity and environmental effects makes it possible to combine rigorous validation with sustainability-oriented learning.

Derivation from study

Testing was not directly analysed in the empirical investigation. The Testing guidelines respond by equipping students with three established testing practices, extended with sustainability prompts. Reflection questions ask, for example, whether the design excludes or disadvantages any group or whether specific features introduce unnecessary resource costs. In this way, the tool sustains ecological and social reasoning in the validation phase while familiarising students with standard industry practices.

Input

- Prototypes or implemented features

- User stories and use cases
- Earlier reflections

Processing

1. Select and apply one or more classical testing methods (usability testing, heuristic evaluation, acceptance testing).
2. Involve a diverse group of participants where possible to surface inclusivity gaps.
3. Use sustainability reflection prompts such as:
   - Does the design exclude or disadvantage any group?
   - Could any design choice introduce unnecessary resource or energy costs?
   - How resilient is the design to long-term use?
4. Summarise findings for refinement in subsequent iterations.

Output

Validation results that combine usability and functional outcomes with reflections on inclusivity and ecological considerations. These results help maintain continuity with earlier research without overburdening the testing phase.

When to use?

Testing should be conducted in **validation and review phases** such as Sprint Reviews, Design Reviews, and Client Acceptance Tests. It provides continuity with earlier tools while familiarising students with classical evaluation practices.

Limitations

The tool was not examined empirically in this study. Its impact depends on whether students and facilitators adopt the sustainability prompts during testing. There is a risk that inclusivity and ecological aspects remain superficial if they are not actively integrated into evaluation.

Appendix F

Survey Design

This appendix documents the survey instrument used in the Introduction Phase workshop. Another researcher designed the survey, and Survio was the tool to host the survey during the session. The instrument comprised seven sections with a mix of Likert-scale, multiple-choice, single-choice, and open-ended items to capture both structured judgments and reflective comments. Participation was voluntary and anonymous. In total, 19 students completed the survey. Table table 15 provides a structured overview of all items, their formats, and the available scales or options.

No.	Question	Format	Scale/Options
1.1	What gender do you identify with?	Single choice	Man, Woman, Non-binary, Don't know
1.2	Which age group do you belong to?	Single choice	16–20, 21–25, 26–30, 31+
2.1	I found the atmosphere of the workshop to be...	Multiple choice	Inspiring, Stress-free, Informal, Other
2.2	The workshop was well organised.	Likert scale	−2 (disagree) to +2 (agree)
2.3	The content structure of the workshop is understandable.	Likert scale	−2 to +2
2.4	The duration of the workshop was...	Likert scale	−2 (too short) to +2 (too long)
2.5	The duration of the exercises was...	Likert scale	−2 (too short) to +2 (too long)
3.1	I actively participated in the workshop.	Likert scale	−2 to +2
3.2	I learned a lot from the workshop.	Likert scale	−2 to +2

No.	Question	Format	Scale/Options
4.1	I consider the priority of the workshop content to be…	Likert scale	-2 (not important) to $+2$ (very important)
4.2	The workshop helped me develop my own understanding of responsibility.	Likert scale	-2 to $+2$
4.3	I now feel capable of handling this responsibility.	Likert scale	-2 to $+2$
4.4	I would be particularly interested in learning more about…	Multiple choice	Responsible digital product development, Environmental impact, Societal impact, Prototyping, Systemic Journey Map, None
5.1	The instructor conveys the content clearly.	Likert scale	-2 to $+2$
5.2	The instructor's feedback was helpful.	Likert scale	-2 to $+2$
5.3	The Systemic Journey Map was comprehensible to me.	Likert scale	-2 to $+2$
5.4	The Systemic Journey Map helped me reflect on the impact of my app idea.	Likert scale	-2 to $+2$
6.1	What did you find particularly good about the workshop?	Open text	Free response
6.2	Do you have any specific suggestions for improvement?	Open text	Free response
6.3	I think it is important that the workshop is part of the course every semester.	Likert scale	-2 (disagree) to $+2$ (agree)
7.1	Is there anything else you would like to share?	Open text	Free response

table 15: Overview of the survey instrument used in the Introduction Phase workshop. The table lists each item, the response format, and the associated scale or options.

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