Article

Design for Social Innovation: A Systemic Design Approach in Creative Higher Education toward Sustainability

Fanke Peng *, Benjamin Altieri , Todd Hutchinson, Anthony J. Harris and Daniel McLean

UniSA Creative, University of South Australia, Adelaide, SA 5000, Australia; benjamin.altieri@unisa.edu.au (B.A.); huttm001@mymail.unisa.edu.au (T.H.); haraj037@mymail.unisa.edu.au (A.J.H.); dan.mclean@unisa.edu.au (D.M.)
* Correspondence: fanke.peng@unisa.edu.au

Abstract: The role and responsibilities of our creative Higher Education are evolving in our ever-changing society. Systemic design thinking equips our design students with the means to promote sustainable development objectives via engagement, community building and discourse. This study reflects on interdisciplinary resource recovery projects for the City of Adelaide (CoA) during a final-year systemic design course in the Product Design programme at the University of South Australia. Since 2015, the core design team has collaborated with external partners outside of HE sectors, including NGOs, local councils, the Australian Capital Territory (ACT) government and the South Australia (SA) government, to promote social innovation towards sustainability. Systemic design is one of the core courses of the Bachelor of Design, Product Design programme within the faculty of Creative, University of South Australia. In this course, system thinking combined with project-based learning (PBL) was adapted and illustrated to demonstrate good systemic design practice for social innovation. This study was focussed on how we can collaborate on a variety of interdisciplinary projects to contribute to the realisation of the United Nations' (UN) Sustainable Development Goals (SDGs) from a human-centred systemic design perspective.

Keywords: Sustainable Development Goals (SDGs); sustainability; resource recovery; systemic design; creative higher education (HE); design for social innovation; project-based learning (PBL)

1. Introduction

Today, social innovation is concerned with encouraging people to engage proactively in initiatives for the benefit of society. Such activity involves engagement, interaction and bringing people together to change the world for the better [1]. "Social innovation has many challenges in practice due to the complexity of stakeholders and ecological systems involved in the framework of value co-creation" [2]. The same challenges apply to teaching and promoting design for articulating social innovation in creative Higher Education (HE).

Design for social innovation is a developing discipline; it is an emergent area of design study, research and practice that challenges existing socio-economic and political paradigms while complementing established and developing sub-disciplines of design for service and transition design [3]. Manzini argued that "design for social innovation is everything that expert Design (designers) can do to activate, sustain, and orient processes of social change toward sustainability" [4]. Design thinking has been promoted as a powerful practice for aligning organised action with social goals, including social innovation [5], business management and education [6].

Creative disciplines and programmes taught at the higher education level in Australia and internationally have a crucial role to play in creating positive social impact and sustainable transformation in society [3,4,7]. Many are interested in the role of social innovation as a driver of sustainable development and approach the subject from the discussion of conceptual aspects and its evolution [8,9]. Some Australian universities, such as the University of Canberra and Monash University, have embedded the United Nations' 17 Sustainable

Development Goals (SDGs) into their research profiles to identify the expertise within their academic and research capacities to work towards sustainable social innovation. However, the objectives of the SDGs are "highly complex since it requires profound structural changes capable of transforming existing social paradigms" [8].

Jones [10] reviewed design models and principles in the domains of systems theory and design thinking and proposed that the recent formulation of systemic design draws on the maturity of these long-held precedents toward an integrated systems-oriented design practice [11–13].

Systemic design is distinguished from service or experience design in terms of scale, social complexity and integration. Systemic design is concerned with higher order systems that encompass multiple subsystems. By integrating systems thinking and its methods, systemic design brings human-centred design to complex, multi-stakeholder service systems such as those found in industrial networks, transportation, medicine and healthcare. It adapts from known design competencies—form and process reasoning, social and generative research methods and sketching and visualization practices—to describe, map, propose and reconfigure complex services and systems [10].

Compared to service or user experience (UX) design, systemic design as a discipline or design framework in creative HE has not been well established. In the last two decades, the transition and value toward systemic design have been discussed and documented in various design papers, including the mapping design process to challenge complexity [14] and the four orders of design [15]. However, "there is a surprising paucity of literature in systems-oriented design theory and few published cases that define a systems-orientation to design" [10]. This article intends to explore whether human-centred systemic design principles combined with problem-based learning (PBL) could be embedded into a design course to encourage students to design for positive social innovation.

As part of an ongoing dedication to align its creative programmes with the needs of society, the University of South Australia's (UniSA) Product Design discipline is currently investigating new approaches towards teaching design for social innovation. Like many creative HE offerings in Australia, the Bachelor of Design (Product Design) at UniSA is a three-year programme designed to equip students with the skills needed to design and create products that people use every day. Across these three years, students are taught fundamental design skills to consider the human factors, usability, aesthetics, manufacturing technologies, materials and environmental sustainability of their designs, and yet in the current programme, little attention is afforded to the implications of design in a wider, long-term context.

In this article, the core research team will discuss how they recently adopted and piloted a framework designed by the Design Council in 2021 to instill systemic design principles into a product design course. The authors will provide evidence to contribute to this design discourse and offer a design pedagogy for educators and professionals to adopt that combines a design thinking process with PBL and human-centred system thinking toward social innovation.

The systemic design projects included as a case study in this paper recount and reflect on the teachings, methods and tools introduced to students in their PBL and support their adoption of systemic design thinking when applied to a real-world problem. The context of the case study is focussed on how we, design educators, students and practitioners, can collaborate with local government and other key stakeholders on various interdisciplinary projects to improve our current resource recovery systems. The opportunities and challenges of combining human-centred system thinking and PBL as an instructional framework for learning and teaching will also be revealed through the case study, discussion and reflection.

Four Orders of Design and Systemic Design

Towards this effort, designers have the position and ability to contribute along a spectrum of change that ranges from existing paradigms, where design is practiced primarily within the commercial marketplace. A radically new paradigm sees design as

central to creating change and innovation in domains inclusive of social and environmental issues. Kimbell argued that designers (and those engaged in design processes) have a new role as cultural interpreters within contemporary capitalism, acting as "the glue holding multidisciplinary teams together" [16].

In essence, social innovation can be undertaken as a co-design process where designers work as facilitators and catalysts within multidisciplinary and transdisciplinary teams. Solutions strive to benefit multiple stakeholders and empower communities to act in the public, private and voluntary sectors, striving for alternative economic models and significant positive social change.

To articulate this, Buchanan introduced four orders of design, which scaffold the responses that designers can take in responding to a problem across four levels [17,18]. As the designer analyses the context through each level, the degree of complexity and perspective needed increases, as is demonstrated in Figure 1.
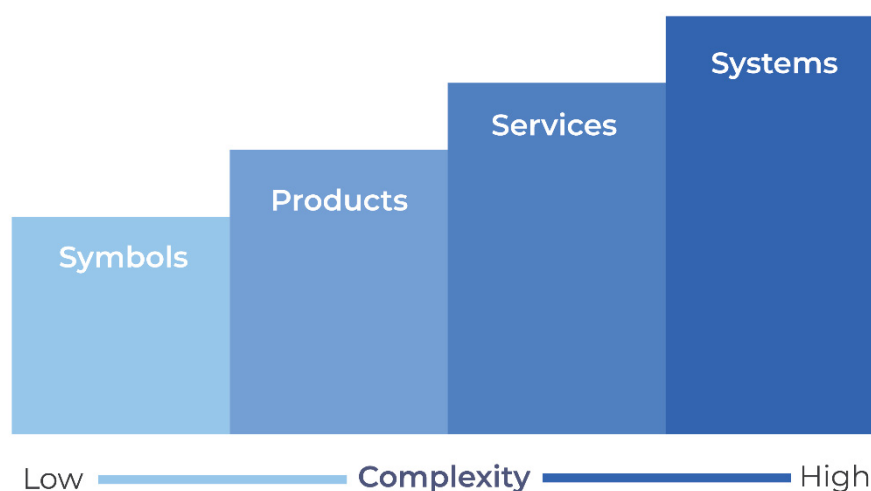

Figure 1. Based on Buchanan's four orders of design, illustrating the role of design according to the complexity of the problem or challenge [15].

To summarise, the first order involves problems of communication—the symbols, signs and other information-based artefacts that can be created or exist within the problem space. The second order involves the construction of products in response to problems. The third order involves problems of actions within activities and services, and the fourth order involves problems of integration in new or existing organisational and social systems [15].

To elaborate on the four orders of design's degree of complexity, Jones and Van Patter suggested four distinct types of design: Design 1.0, traditional design thinking; Design 2.0, product design thinking; Design 3.0, service design thinking; and Design 4.0, social transformation design thinking [14]. There is a "need to connect service design with digital innovation, social innovation, social change or policy making, opening up novel realms of investigation and raising questions that need our attention" [2]. For our purposes, we will be focussing on how product designers, who traditionally operate in the realms of Design 2.0 and 3.0, which are concerned with the first and second orders, can engage in Design 4.0 to enhance their design process and improve the development of solutions to be more informed, targeted and innovative.

Additionally, design-driven social innovation is different from design practice in the first and second orders, because it focusses not only on creating new products or services but also on adoption and diffusion [19]. Within the design discipline, the role of design is evolving from the first generation of design to the fourth generation. Unlike previous generations of design methods, "the fourth generation has not accepted a leading systems theory influence. Rather, design studies today tend to follow an ambiguous version of complexity theory, rendered without citations or methodological influence" [10]. Designers for social innovation look for emergent possibilities within problem contexts instead of

imposing pre-planned and fully resolved solutions upon a situation. This way of designing must be informed by a deep understanding of local eco-systems and culture [20].

2. Research Design: A Systemic Design Approach

Systemic design thinking methods help students to see the structures that underlie complex situations. At a high level, system thinking helps practitioners to see the connections and interactions between people and artefacts in a system. At the same time, a human psychology lens is needed to understand what motivates people to act because understanding motivations is essential to influencing behaviours through design. As the roles and responsibilities of designers change, understanding and applying systemic design principles, methods and theory are becoming increasingly valuable in design, as problems continue to increase in complexity [10].

To test the effectiveness of this approach to systemic design research and practice, this framework, which adapts systems thinking and design thinking, combined with project-based learning (PBL), was embedded and delivered as one of the core courses of the final year of the Product Design programme at UniSA. As a third-year course, students will build upon the design skills learned during the first two years of the Product Design programme and expand on students' knowledge in design research, usability, human factors and user experience. In this course, students build upon their skills, methods and knowledge of human-centred design (HCD) and systems thinking, in addition to new insight and teaching acquired through the course syllabus, to develop design outputs for a systemic design project—a context that students previously have not addressed in their studies.

When designing something, such as a product or service, designers need to make a series of decisions that shape the experience for the user. Designers will consider the nature of the product in terms of form, material, technologies, etc., as well as consider the usability of using a product, interface, system or service. Insights into usability, human factors and user experience can come from qualitative design research methods. Human-centred design (HCD) techniques allow designers to observe, participate, analyse and understand the design problem space and identify where design opportunities exist.

Since 2018, final-year product design students at the University of South Australia have participated in a 13-week PBL studio course in which they undertake a systemic design project in partnership with a client or industry partner. Students are encouraged to choose subjects/topics within the project context about which they are passionate about and contribute to realising the objectives of the SDGs.

To support embedding systemic design into a course structure, the research team has employed PBL, a student-centred pedagogy in which students are focussed on problem solving, critical thinking, collaboration and reflection within real-world practices [21,22], to scaffold and contextualise the theory and provide students with an authentic, hands-on experience. A key benefit of PBL empowers students to realise that their contributions to the community and our ecosystem can make a tangible difference [23]. This course exposes students to another type of thinking and design process, which looks beyond a product designed for manufacture to a design response that considers the users, contexts, logistics and environments in which a design will impact.

Teaching Framework

There are many established design approaches in this field that are referenced as effective interpretations by both practitioners and academics. However, most are created for a disembodied and ahistorical design thinking and are focussed on the process itself (see Table 1). "Traditional design history, until the most recent generation of design approaches, presented design as a planning process, oriented to industrial design, where analytical problem definition preceded solution" [10].

Table 1. Comparison of selected design thinking models that articulate the design process.

Selected Models	Stages in the Process
Stanford University d.school [24]	Empathise, Define, Ideate, Prototype and Test
IDEO [25]	Discover, Interpretation, Ideation, Experimentations and Evolution
Design Council Double Diamond model [26]	Discover, Define, Develop and Deliver
Design Council [27]	Explore, Reframe, Create and Catalyse

In formulating a systemic design framework that can be effectively utilised in our teaching environment, the core research team draws from several design approaches and frameworks from leading consultancy and creative higher education institutions (HEIs), which include Stanford University d.school [24], IDEO [25] and the UK-based Design Council [26,27]. Comparing these models, both the d.school and IDEO's design thinking models [24,25] have five steps. Although the name of each step is different, the core concept of each step is similar.

As human-centred designers, empathy (Empathise, Discover, Explore) is at the centre of the initial step, which in all models is described as an integral mechanism to establish a deep understanding of the people, context and challenges that occupy the problem space of interest, which later leads to defining the focus of the design process (define, interpretation, reframe) and generating creative and innovative responses to the identified problem (ideation, develop, create, and later prototype-test, experimentation-evolution, catalyse). From comparing each framework as listed in Table 1 and from experiences with each approach shared by the authors, no one model works in its entirety when followed in an educational environment. As such, parts of each model are readily adapted to suit both the needs of the students and the learning objectives of the course. To provide an example of this process, both the d.school and IDEO have an extensive library of methods, tools and case studies from which we draw from in the application of our teaching framework, with specific examples described in the case study and Appendix A.

Central to our teaching framework is the Design Council's colloquially known "Double Diamond" model (see Figure 2), which was recently updated by the organisation in 2021 to accommodate a systemic design approach to "help designers work more sustainably and systemically" [27]. The previous iteration of the Double Diamond (2015) has been embedded into the Product Design pedagogy; thus, transitioning to the new model was a natural fit, as the previous incarnation has proven successful. In addition to rephrasing the stages of the design process, the model also introduced six principles (see Table 2) and four core roles (system thinker, designer and maker, leader and storyteller, and connector and convener) to support designers with employing the system design thinking process in their practice [27].

Table 2. Descriptions of the six principles of systemic design [27].

| Principles	Description
People- and planet-centred	Focussing on the shared benefits of all living things
Zooming in and out	From the micro to macro, from root cause to hopeful vision, from the present to the future, from the personal to the wider system
Testing and growing ideas	Making things to see how they work and help more things emerge
Inclusive and welcoming difference	Creating safe, shared spaces and language to bring in multiple and marginalised perspectives
Collaborating and connecting	Seeing a project as one element in a wider movement for change
Circular and regenerative	Focus on existing assets—physical and social—and how we can re-use, nurture and grow these
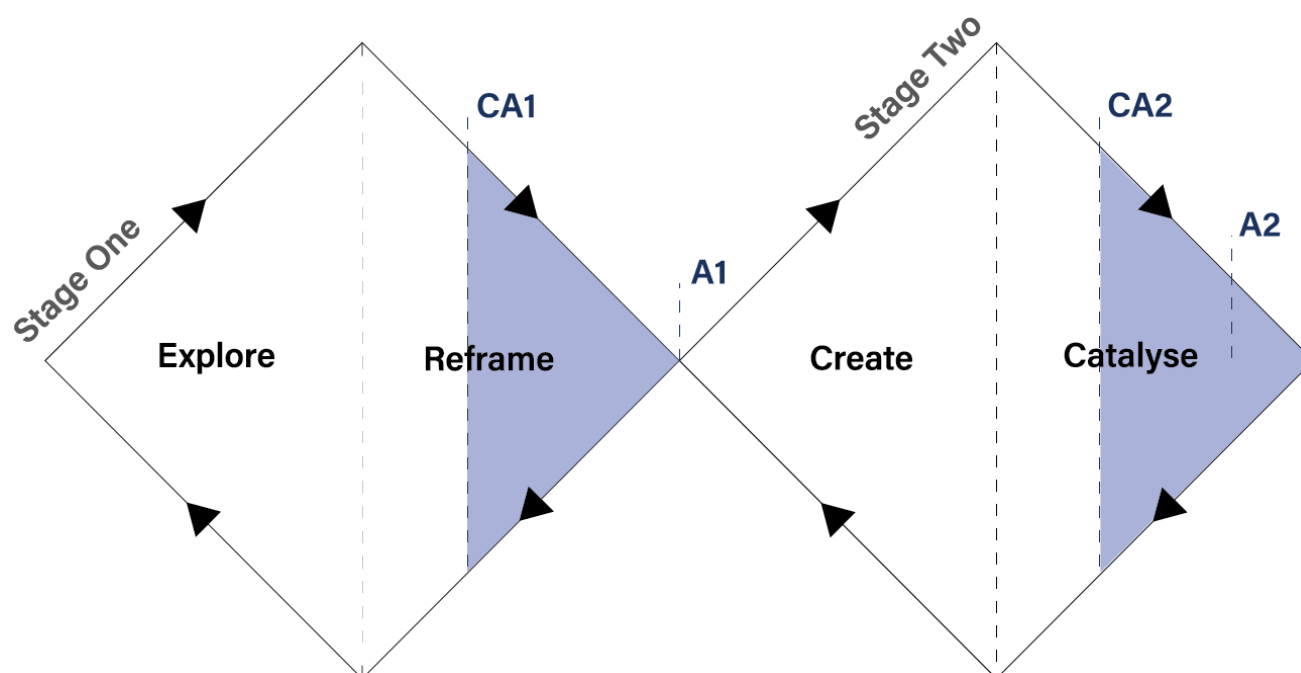
Figure 2. Systemic design model based on the Design Council diagram [27], with key course assessment points. There are many design methods within each step to achieve the design principles and goals. Students' final assessment (A2) occurs before the end of the catalyse phase, as implementing the proposed design is outside the scope of higher education. For a detailed demonstration on how to adopt and implement these design methods, see Section 3: Practical Case Study.

Within the systemic design approach, students are encouraged to use human-centred design (HCD) methods, including observation, analogous and precedent analysis and behavioural mapping, to understand the problem space, which in the case of this article is concerned with resource recovery from waste systems and the potential users (their thoughts, motivations and interactions) with the system. Students can draw from HCD methods outlined in the IDEO Field Guide to Human-Centred Design (Design Kit) [28], as well as others they have undertaken in their studies prior to this course, to inform their explorations. Through observations and analysis of the insights distilled from the process, the students uncover opportunities and identify criteria they will need to address in their design.

Taking inspiration from the previously mentioned HEIs, to embed these objectives into PBL, three relevant SDGs to the topic of the course (Goal 3: Ensure healthy lives and promote wellbeing for all at all ages, Goal 11: Sustainable Cities and Communities and Goal 12: Responsible Product and Consumption) were formally introduced and embedded, to recognise their value to the project context while allowing the students some agency to interpret them into design criteria relevant to waste management and resource recovery.

In delivering the project within the course, the project has been divided into two stages, with two corresponding assessments per stage (see Figure 2). The first stage is where students explore and reframe the problem through a dynamic research process. At the end of their research phase, the students present their findings and their individual design criteria in the form of a presentation (CA1) and research report (A1). As part of this documentation, students frame and reframe their design challenge repeatedly to refine the scope and objectives of their design as they uncover new information and receive feedback from teaching staff and key stakeholders.

Stage two then takes the learnings and criteria of stage one to "create" and "catalyse". Initial ideation begins during this first part of the research (when design opportunities begin to emerge) and is then focussed on more intensely in stage two as students develop ideas, prototype and test their design responses with users, circulating through each stage until reaching a suitable outcome. At the end of the create phase, the students share their

development process for feedback (CA2), before finalising their design for presentation to the client, key stakeholders and peers (A2).

3. Practical Case Study: Increasing Resource Recovery in Multi-Unit Dwellings in the City of Adelaide (CoA)

To illustrate and reflect on the effectiveness of this teaching framework, a case study of a recent systemic design for resource recovery project in multi-unit dwellings (MUDs), which applied this approach as part of the 13-week Systemic Design course, has been included. Echoing the approach outlined in Figure 2, the case study describes both stages of the design process, recounting the process and learnings as they occurred. Extracts from projects developed by the 23 participating students have been included as examples of some of the methods employed, followed by a comprehensive discussion, which includes the use of the six principles (see Table 2) as a demonstration of reflective practice.

3.1. Stage One: Explore and Discover

To facilitate the requirements of PBL, the core research team collaborated with the City of Adelaide to offer a realistic design project experience, which some students may not have previously experienced in their studies up to this point. The City of Adelaide (CoA) aims to explore how the council could improve its resource recovery in multi-unit dwellings (MUDs) as part of its more comprehensive Resource Recovery Strategy and Action Plan (2020–2028) [29,30]. At the beginning of the project, the students were introduced to the course structure and teaching team, followed by the subject and topic of the project and later representatives from the CoA, who were key stakeholders and contributors. As part of this briefing, students received a written brief, which also introduced SDGs 3, 11 and 12 and two CoA documents which collectively outlined the background and context of the problem the students were to address.

Upholding the integrity of PBL, students were given the freedom to undertake their own self-directed research phase, selecting appropriate research methods to develop insight into the waste system and identify problems or criteria for which their design could address. According to the brief, the proposed design must include the development of a physical product/s and interface and represent a clear and detailed understanding of the current waste system as a whole. The students were given the first four weeks of the course to undertake this research, either working individually or in collaboration with their peers.

To guide their initial inquiry, students frame the challenge as they currently understand it using the "Frame Your Design Challenge" tool from the IDEO Field Guide to Human-Centred Design (Design Kit) [28]. This tool assists designers with assessing the problem they are trying to solve to articulate the problem as a question that their design would eventually answer. Some of the initial questions posed by the students included: (1) "How might we make it easier to use recycling and green waste, encourage ownership of this within Multi-Unit Dwellings in the city of Adelaide"? and (2) "How might improvements in domestic systems in the MUDs reduce food waste to landfill, and resident's negative impact on the environment?"

Once determined, students then engaged in both primary and secondary research methods. They were encouraged to utilise secondary research that examined literature, precedents and resources to inform their awareness of the context. They also undertook approved primary methods—site visits of MUDs and observations (see Figure 3) and informal interviews and systems mapping—to delve deeper into the motivations and behaviours of people in this system. The students were invited on an arranged field trip to collect primary data and reinforce how the current system operates. Students selected at least three human-centred inspiration methods from the IDEO Design Kit or another source to inform their initial inquiry. These methods are suitable for gaining insight into the system and its users and begin the iterative process of explore, discover, reframe, explore again.
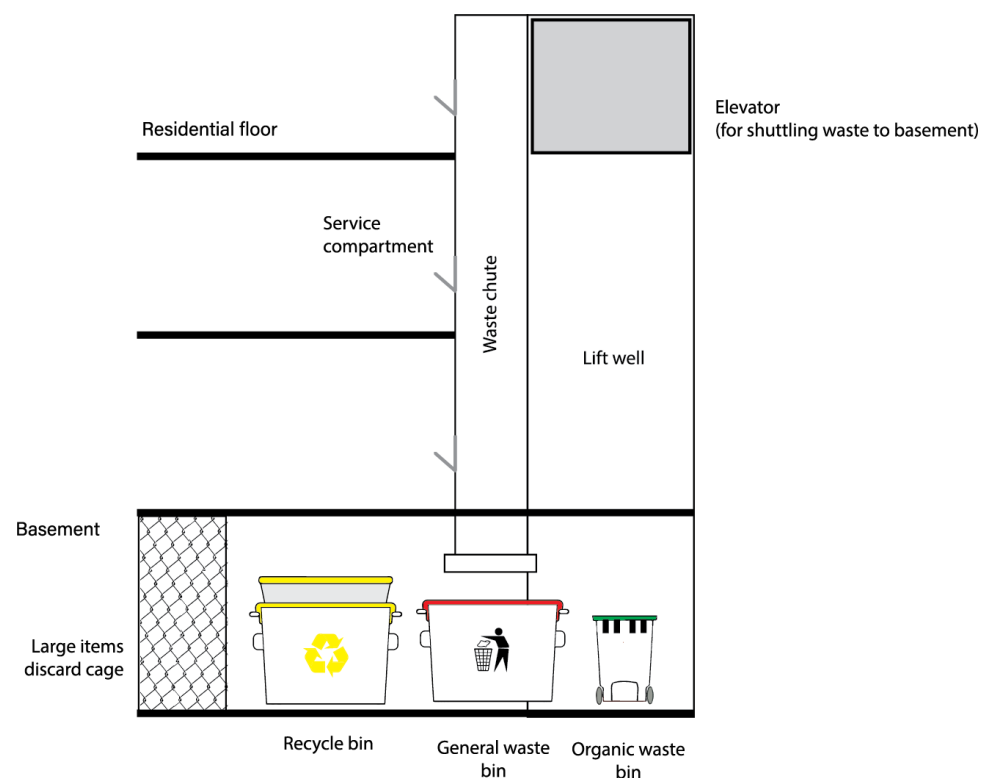
Figure 3. Example of a typical waste system within a local MUD [31].

During this time, the resource recovery manager from the CoA delivered a guest symposium to introduce the context of a MUD and their accompanying waste systems. The early briefing helped the students understand the current system in detail and acquainted students with the project's priorities, how the current system functions to produce a circular economy and the CoA's challenges. The students also received several guest presentations from an expert in resource recovery, waste management and the circular economy and participated in a series of workshops that covered areas of the design process including information gathering and research techniques, methods for structuring their research inquiry and tools for interpreting their findings into design criteria.

One activity, which all students completed towards the end of the research phase, introduced d.school's "mapping the problem space" tool [32], which helps designers to both organise research findings into key areas and highlight gaps in knowledge that need to be investigated further (see Table 3). This activity enabled students to recognise and appreciate the interconnected nature of the wicked problem and target their focus into an area that will have the greatest impact.

Table 3. Example of mapping the problem space of waste and resource recovery in the City of Adelaide, utilising the "mapping the problem space" tool from the Stanford University d.school [32].

Category	Descriptor	Student Thoughts & Considerations
Implications	What societal trends/phenomena do you see? Who is part of these trends and what is causing them?	• Migration of persons from suburban areas to city council area. • Greater use of Multi Unit Dwellings. Suggested greater travel globally long term, not necessarily English as a language, no longer local ownership. Increasing Isolation in society. • General consensus—on trend to consumerism.

Table 3. *Cont.*

Category	Descriptor	Student Thoughts & Considerations
Systems	What systems are you working within/against? Type of systems: Support systems/Educational systems, Government, ingrained in society.	• Differing approaches to waste, no consolidated view. • Private versus Public views, aka some MUDS use private waste systems. • The existing waste management approach of CoA.
Experiences	What are the current experiences/services? Good/bad? Problems/opportunities?	• No Accountability. • Lacking space, distance to travel, confusion of waste. • Smelly green waste. • Confusing messaging. • What is someone's place in the world.
Products	What are the physical/digital products that are part of the current experience/system?	• Green Bags, Caddies, Waste Chutes, Green Bins, Red Bins and Yellow Bins. • Laminated cards. • Share waste web platforms, "Recycle Mate" scanning app, existing council web platforms.
Innovative approaches	Do you know of any innovative approaches being used in this space/to address this problem? What about in other areas/industries?	• Dehydrators, Open Vent Caddies, Mobile apps to assist in identification. • RFID technologies, Scanning, Tracking and Tracing.
Data	What types of data will you need to understand the problem or support your approach to the solution?	• Kerbside serviced households each producing on average 650 kg of waste p.a [29]. • Target to reduce waste generation by 5% per capita. • Target 75% of residential waste diverted from landfill [30]. • 43% of the red waste bin was food scraps, garden organics and compostable material. • Kerbside-serviced residents diverted approximately 54% of material from landfill [29].

3.2. Reframe

The "reframe" phase of the project begins when students start to identify and focus on possible solutions and where design interventions may occur. The framed question, established earlier in the process, is re-examined to reflect new thinking, which begins to converge on possible outcomes. Students select and utilise further HCD methods to guide this examination before repeating the "Frame your design challenge" exercise to focus the scope of the project, acknowledging new opportunities and refining the approach they will take through the remainder of the project. This use of divergent thinking and convergent thinking enables a more holistic exploration of the problem at hand before homing in to address a specific problem. During the research process, there is a constant iteration of the framing question and objectives, especially as design opportunities are discovered.

It is at this stage in the project that students formalised their progress and delivered a presentation (CA1). Each student described the methods and findings from their research phase and presented their reframed design question, along with opportunities to explore in the upcoming ideation phase, and then received feedback from both teaching staff and key stakeholders to improve their communication before submitting their research reports (A1). Continuing from the earlier examples, the reframed design questions became (1) "How might we make the invisible visible to users and the community of the waste systems in MUDs"? and (2) "How might systemic design/improvements in waste systems in the MUDs reduce food waste to landfill and increase resource recovery in the city of Adelaide"?

In their reports, many students organised their findings using different pro forma strategies to compare findings (see Table A1) as well as developed systems maps that indicated the scale and complexity of the current waste system and then highlighting their new focus or expanding the scope of what aspect of the system their future design might address (see Figures A1 and A2).

3.3. Stage Two: Create and Ideate

Upon conclusion of the first stage of the project, students were asked to generate some initial concepts and ideas informed by their research findings and design criteria. At this stage of the project, the students make iterations on those concepts, or generate new concepts, and create prototypes that are suitable for user testing.

Following the completion and presentation of their research findings in A1, the students entered the next stage of the design process, create, in which they translate their research into informed ideas that address their design question. However, before launching into this process, the students participated in a peer review exercise in which they were paired up and asked to swap reports and provide feedback. The students were instructed to consider two perspectives in their critique: (1) From the perspective of a designer, does the report effectively communicate the process undertaken by the author of the report, clearly summarising the key findings applicable to their identified design question? (2) From the perspective of the client, does the report provide them with confidence to proceed in the project? At the end of the exercise, the students were asked to share the feedback they had received and discuss how they would address the feedback in stage two of the project and its outcomes. Feedback included opportunities to improve the presentation of the report, advice for how to improve the structure and clarity of the research findings and suggestions for alternative design opportunities not yet considered.

In addition to developing a physical product, which the students already have experience developing from their prior studies, the students are also required to design an interface as either a standalone product or as a companion to their physical product. Together, both artefacts were to address their design question and criteria defined in stage one.

The students then spent several weeks developing their ideas, iterating and refining how they work and the impact they could have on/in the system. Figure 4 represents this process of creating prototypes, testing them with users, synthesising and refining their ideas into new prototypes as quickly as possible. This method of prototyping and refining seeks to gain insight into the users' experience of the conceptual product and begins the iterative process of create, ideate, catalyse, create again. Undertaking this process in a rapid timeframe allows designers to overcome barriers and challenges without investing significant resources, which will follow when approaching the next stage of the process. During this stage, the students are also advised to not be concerned if completely new concepts arise, as this is inherently part of the reason to engage in this process.

To support students to develop their ideas and abilities to prototype, a rapid prototyping workshop was held midway to facilitate the exploration of their ideas' form and function. Using any variety of found materials, which included cardboard, wool, paper, tape, glue and an assortment of other objects and materials, the students were instructed to prepare a prototype of a product or an interface that could demonstrate part of or all of an idea they were currently working on. After 45 min, the students then demonstrated their prototypes to their peers and received feedback on how each could improve. Many of the students reported enjoying this exercise for not only strengthening their proposed product ideas but also for further expressing how systems thinking can be utilised in practice.

Leading from this workshop, the students were given the remaining week to continue their ideation and prototyping, in which the students could seek one-on-one consultations with teaching staff to receive feedback.
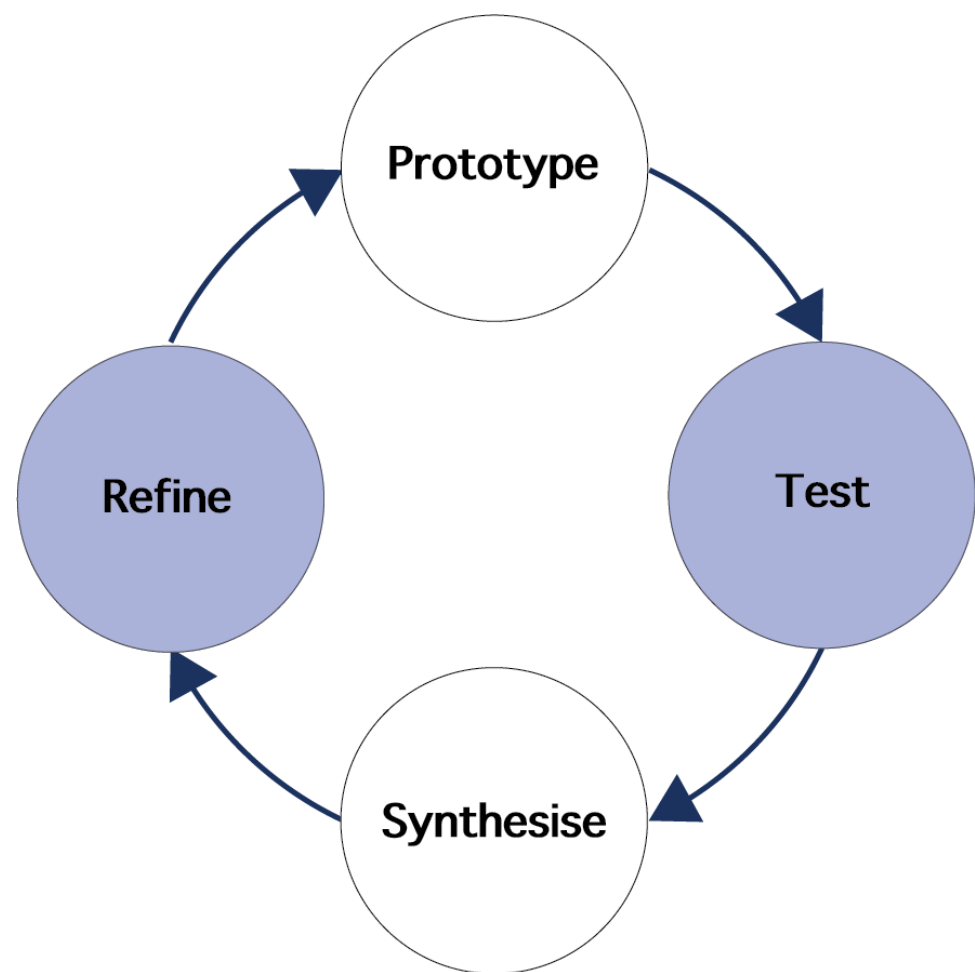
Figure 4. The prototyping and usability testing cycle. Students are encouraged to repeat the process quickly, fail early and make and test as many improvements as possible in the time frame.

In the same style as CA1, to conclude the creation phase, the students present their latest prototypes and project progress as part of CA2, highlighting the development of their ideas through prototyping and sharing how user feedback has shaped the development of their final concept. For time management reasons, this presentation focussed predominantly on the physical products; however, some students also used this time to present an update on the development of their interface.

3.4. Catalyse

In conclusion of their create stage and the overall development of their projects, the students prepare and present their final prototypes for their product and interface designs to their peers and stakeholders through the medium of a video presentation. This format is utilised in other product design courses and in this course for two reasons: to allow students to develop skills in a broad range of areas, adding videography, editing and visual effects capabilities that complement their other product design skills, and to allow all students to present their outcomes in a succinct manner.

The catalyse stage in practice often involves the finalisation of the design process for implementation. However, such an outcome is difficult or impossible to facilitate in an educational environment. Therefore, for our purposes, this stage still acts as a deadline for the project to conclude and allows the outcome/s to be assessed as if it were to be hypothetically implemented, and this stage can also serve as a catalyst for students to continue to pursue their outcomes and the topics they are passionate about beyond the scope of this course.

As depicted in Figure 5, 27 standalone products were proposed in response to the CoA's challenge of improving resource recovery in MUDs, across several aspects and contexts within the waste system. As is shown, a large quantity of concepts is focussed within the household, targeting three priority areas: 1. reducing the creation of waste, 2. improving the recovery of reusable resources from the current waste stream and finally 3. improving the storage of waste in the household to increase the success of areas 1 and 2. Additionally, several products also engaged surrounding areas including the shared spaces within an MUD, the hallways and recreational spaces, and addressed challenges unique to particular MUDs such as student housing. Finally, four concepts also presented opportunities outside of an MUD building to engage the local community and wider council area in the conversation and engagement in better waste management practices.
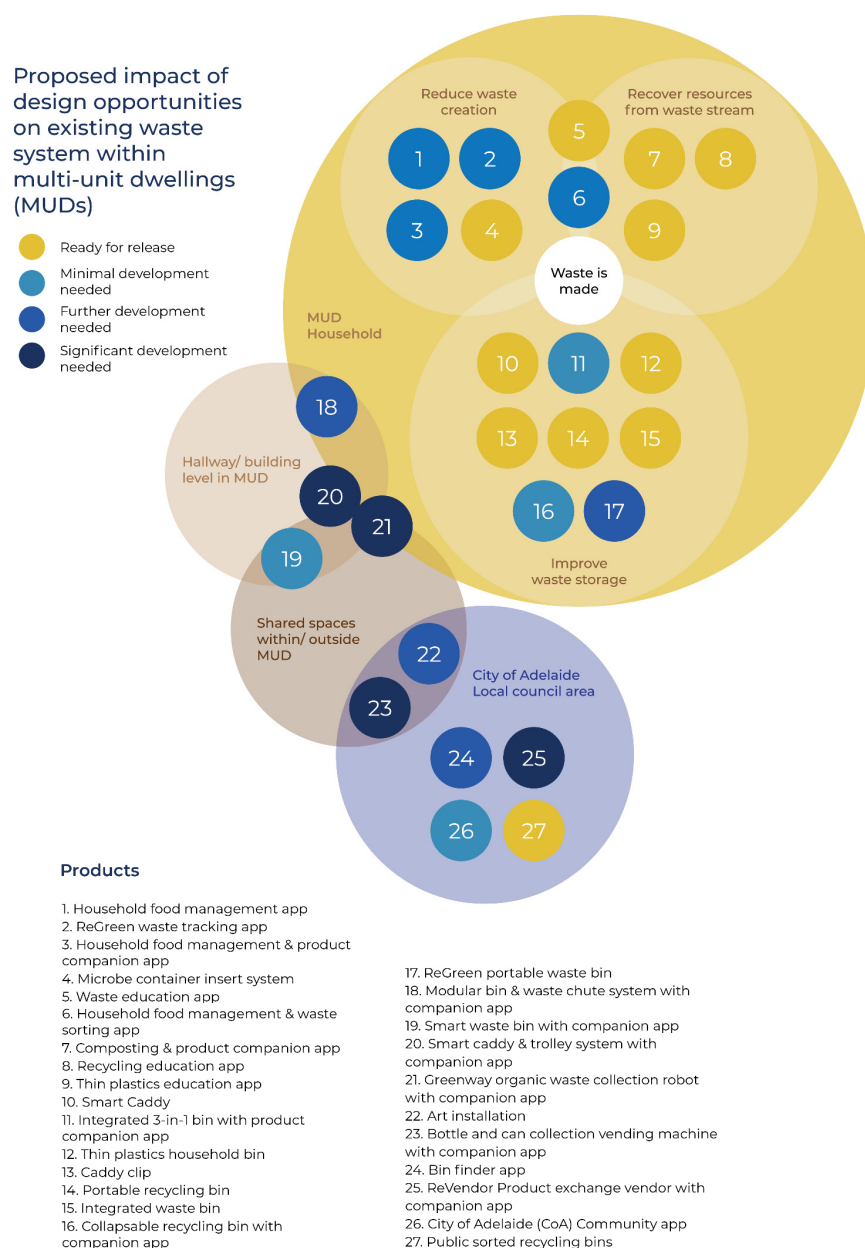
Proposed impact of design opportunities on existing waste system within multi-unit dwellings (MUDs)

- Ready for release
- Minimal development needed
- Further development needed
- Significant development needed

Products

1. Household food management app
2. ReGreen waste tracking app
3. Household food management & product companion app
4. Microbe container insert system
5. Waste education app
6. Household food management & waste sorting app
7. Composting & product companion app
8. Recycling education app
9. Thin plastics education app
10. Smart Caddy
11. Integrated 3-in-1 bin with product companion app
12. Thin plastics household bin
13. Caddy clip
14. Portable recycling bin
15. Integrated waste bin
16. Collapsable recycling bin with companion app
17. ReGreen portable waste bin
18. Modular bin & waste chute system with companion app
19. Smart waste bin with companion app
20. Smart caddy & trolley system with companion app
21. Greenway organic waste collection robot with companion app
22. Art installation
23. Bottle and can collection vending machine with companion app
24. Bin finder app
25. ReVendor Product exchange vendor with companion app
26. City of Adelaide (CoA) Community app
27. Public sorted recycling bins

Figure 5. Mapping the potential impact points of each proposed design opportunity within the existing MUD waste system within the City of Adelaide (CoA). Based on the students' proposals and professional insight, each idea is also categorised based on if the concept in its current form is "ready for release" or requires additional development across a scale of "minimal" to "significant".

Collectively, the concepts proposed reflect the need for solutions to this wicked problem to be multi-faceted and target many areas of the waste system for resource recovery. The products and interfaces range in impact, with some concepts exploring how products within the existing system could be retrofitted to improve their usability or functionality, such as a caddy clip to make storing existing caddies easier in the home. Other concepts incorporated newer technologies, such as a green waste collection robot that comes to your door or microbe RFID chips that notify users when their food is expiring, to improve people's engagement with better waste practices. Several students proposed applications that explored how education about sorting waste and reusing products can improve behaviour and resource recovery.

Many of the proposals would suit supporting the circular economies emerging in South Australia, diverting more waste from landfill into resource recovery, while some reduce waste in the first place and focus on product exchanges to reduce waste. Most have a focus on improving the user experience and some incentivise the proper use of the system. The products addressed multiple aspects of the design problem by proposing methods for implementation ranging from the City of Adelaide or council-led initiatives to retail products and applications to corporate services and initiatives and building development and management initiatives.

4. Discussion

Design thinking and systemic design principles share a standard orientation to the desired learning outcomes of complex "wicked" problems, affecting highly leveraged, well-reasoned and preferred changes in situations of concern [10]. As demonstrated in the case study, design thinking prefers an action-first generative bias (toward action on intended outcomes, using iterative, successive approximations with highly differentiated artefacts) [10].

As introduced in the research design, the six principles of systemic design are intended to enable effective intervention at the systemic scale of application. Therefore, we also use them as a reflective tool for students to ensure their system thinking and designs are as holistic as possible, which promotes the understanding of complex problem situations independently of interventions or solutions. These principles have also been used in this discussion to reflect on the effectiveness of this teaching approach and on the students' response as interpreted from their design work.

4.1. People- and Planet-Centred

The outcomes proposed in the case study aimed to benefit both the environment and people engaged in the system, improving the current waste system to recover organic waste in general waste streams and improving the usability for people in MUDs predominantly. Towards this principle, many students demonstrated this consideration in their design criteria and later in their prototypes as they explored models of usability, communication and encouragement of users to improve users' engagement in the waste system.

A fourth generation of design perspective encouraged the participatory viewpoint of interdisciplinary projects: "design, when everyone designs" [4]. The key difference between the traditional design thinking and system thinking is that the stakeholders are the designers in the innovation of social systems [33]. During the projects, the stakeholders in design practices are observed and engaged by design students. We recommend an integration of viewpoints through different design methods, including empathy mapping, interviews and peers observing peers.

Students built upon their existing HCD skills to engage a broad cross section of the community to further understand the systems and problems. In this process, most students would have benefited from a greater access to residents and stakeholders, which was limited due to timing and access difficulties.

4.2. Zooming In and Out

This project considers both the potential local impacts and global environmental impacts. Throughout the research undertaken, the students discovered a series of local implications of the existing system and reviewed exemplars to see what has been accomplished in other cities and countries. As is essential to human-centred design, the focus is on the user experience within homes, analysing how the systems that support the user's actions deliver the service provided.

As discussed in the fourth generation of design, we are dealing with wicked problems; with so much interconnection, it is impossible to develop an effective solution from one lens. Recording, noting and examining observations and details throughout this process enabled comparisons to be drawn and the role of individual components understood in more detail. By taking a broader view, the relationships of the individual components could be understood and inferred.

Many students presented a good understanding of the micro issue within the local system that their design would address; however, some struggled to draw connections with a greater vision: how their ideas could be built upon over time to address a macro issue, such as reducing waste produced or drawing greater parallels with the SDGs. Next time, part of the systems mapping activity/workshop could emphasise these connections.

4.3. Testing and Growing Ideas

The research phase of the project was undertaken to explore and reframe the design challenge. This was conducted through an understanding of the components and their interplay, with constant testing and reframing of ideas and the objectives. An iterative approach and a variety of lenses (both divergent and convergent) enabled the consideration of possibilities, of what could be, rather than be overwhelmed by the magnitude of the project. Stage two focusses on prototyping ideas for user testing, developing new products or services and a graphical user interface to improve one or several key aspects of the current user experience and system. Each student created prototypes, tested them and synthesised and refined their ideas several times in iteration to progress their concepts.

The groundwork for enabling the students to grow and iterate on their ideas was set and evidenced by how their research informed their initial design ideas. Stage two of the project included workshops and activities to support students to expand on their initial ideas to further idea generation and to consider how these ideas can perform when measuring their potential impact against the resource investment needed to implement the idea.

4.4. Inclusive and Welcoming Difference

Collectively, a diverse array of insight was garnered by the students, with many investigating not just MUDs in the CoA area but also neighbouring residential and commercial locations: investigating not just how the journey of waste in those areas is similar or different but also identifying economic, social and environmental factors which influence the way things operate and peoples' motivations.

Many students also drew from international contexts, citing case studies, government policy and technological innovations in several countries to understand the differences between these groups and welcome the opportunities that this presented in their approaches to waste management. When developing empathy with users and ideas, user's abilities, physical attributes, language and emotions are all included to ensure the designs are accommodating for different people and to inspire new or inclusive ways to achieve goals.

4.5. Collaborating and Connecting

Since the project is dedicated to contributing to the United Nations SDGs, students developed an understanding of how this project fits into the wider movement towards a sustainable future. The services involved in this system are already making headway in effecting positive changes in how food waste is disposed of and recovered as a resource. Based on the responses developed in the project, one of the key outcomes of this project is

to better connect the users of the system with existing and emerging services. Encouraging collaboration across the system and leveraging technology and other catalysts for design interventions will enable better outcomes, with many small improvements more likely to make a big difference in tackling this issue.

4.6. Circular and Regenerative

The solution and intervention are intended to be created in such a way that will harness existing mechanisms where possible, adopting them and adding adjuncts where necessary. Finding out the size and scope of the system that students are attempting to design for, it becomes clearer that they are not able to feasibly redesign the entire system in 13 weeks. Effecting just part of the system is possible here and the reframing of the problem helps students to focus on areas where interventions can make an impact. There is so much excellent work and thought that had occurred already in the system we are attempting to affect, and there is already a sunk cost in terms of effort and resources that should be used.

The current waste system already produces a circular economy with green waste collected being reprocessed into compost and returned to local soil in agricultural operations. Student proposals that focus on improving part of the waste system to increase its overall proper use will contribute to that circular economy. At the end of the first stage of the project, very few students had articulated ideas that could be considered circular. Reflecting on this, it is not to say that what students had produced at this stage in the project was ill-considered but rather reflects the difficulty in articulating something inclusive of every positive and sustainable criterion from research insight alone. In response to this, our approach to ideation and prototyping in stage two focusses on this principle, as the students take tangible actions in refining their designs. From iterations of feedback and refinement, many students successfully pivoted their concepts (even quite late in stage 2) and delivered something that could be seen as circular, either increasing potential resource recovery, reducing waste in the first place or encouraging better waste management.

Most concepts delivered, successfully, seek to positively change behaviour and the user experience of the system. The regenerative component of this principle was not covered in sufficient detail in the teaching framework due to the context of the urban setting of MUDs and circular waste system in place and will be an aspect addressed in future iterations.

4.7. Course Impact for Social Innovation

The product design course described here is the result of the core research team developing a teaching framework through many iterations beginning in 2018. At its core is the PBL approach to a systemic design project in partnership with a client or industry partner. The course has had a demonstrable impact on both the external partners involved and the students who participate in the course.

For the 2018 and 2019 iterations of the course, the research team worked with Meals on Wheels SA (MoW). MoW is a not-for-profit organisation that supports members of the community to live independently by delivering nutritious meals and providing regular social contact to maintain health and wellbeing for their customers. The organisation is heavily staffed with volunteers who prepare and deliver meals and provide social contact to their customers, many of whom are elderly or suffering from other conditions, which limits their ability to leave their home and prepare food for themselves. By following the systemic design process, students were able to identify areas where the MoW could improve. Students created a diverse array of design solutions to the opportunities identified in the MoW system. Students were able to have an impact in diverse areas including kitchen layouts, food preparation, user experience aspects throughout the system and in making use of digital tools to improve the efficiency and effectiveness of the operation.

The 2021 iteration of the course involved the research team and students working with Australian residential aged care provider ACH Group. ACH Group has sites in South Australia and Victoria, Australia, offering a range of services including residential care, retirement living, home care and National Disability Insurance Scheme (NDIS) services.

The course focussed on ACH Group's residential care sites that offer permanent aged care accommodation. ACH Group states that residential care should be a safe and secure place to continue to live well and invited the research team and students to investigate where the current system could be improved. The research team created the overarching theme of "Communication, Connection and Wellbeing". Students investigated the current system and identified dining, exercise, social activities, special events, garden activities and personal space as areas where the most impact could be made. The student team created design proposals in response to the established areas of impact. Many of the proposals resonated with ACH Group, and there is development work ongoing with one of the student proposals.

> "The research phase took some of the students outside of their comfort zone, having to engage with stakeholders and environments that they have not or would not normally be associated with" (participating student).

In each iteration of the course, the core research team observed and received feedback from some students who initially struggled to feel comfortable working within the systematic design framework where they are working on complex "wicked" problems and where much of the scaffolding that has supported other courses earlier in the product design programme is removed. Evidence from programme alumni that have been interviewed indicates the systemic design course has had some of the biggest impact on their career when they entered professional practice or further study.

5. Conclusions

Through the CoA resource recovery projects, we acknowledge that the human-centred systemic design approach encourages a shared systems-level understanding of resource recovery and sustainability among stakeholders throughout the projects and evokes a holistic view. The integrated systemic design framework with six principles and four vital roles has helped inform and make interventions fit into an extensive system and has highlighted inadequate or underperforming service delivery and ineffective community-based monitoring strategies.

Since social innovations and transformation through systemic design take place in a highly complex social paradigm, the mapping of the problem space and stakeholders' lived experiences assisted in identifying that there are many interconnected and unknown elements. The problem is not necessarily one thing or another, rather a series of interconnected elements.

A more systemic design approach with the fourth generation of design methods and principles is needed in creative HE to motivate our students and academics to contribute to transforming existing social paradigms. This study looks to explore how such an approach can be effectively taught in creative HE, and while some of the designs presented by students at the conclusion of the project point positively to having environmental and social impact, the intention of this paper and our conclusions are not focussed on the outcomes themselves but the engagement of product design students in this process.

More opportunities exist in this domain to investigate and evaluate the impact of this approach in creative HE. Future studies could collect more empirical evidence to measure the degree of engagement that students have with these principles in the first instance and a more longitudinal study into the use of these practices across the next semester of study and into the students' careers could also prove insightful.

More academic discourse around systems-oriented design would also be recommended, particularly in the exploration of other pedagogy frameworks, which could adapt industry practices for educational environments to maintain the authenticity of the process. Through this collaboration, CoA was very receptive to the concepts presented by the students and is actively exploring pathways to further develop several of the presented ideas, alongside new areas and opportunities made aware to CoA by the students' analysis and visualisation of the waste system.

Appendix A

Table A1. The table is an example of a pro forma used for multi-site observations; the student observed and role-played some of the waste management processes, noting the physical and interconnected environment. In immersing themselves, they reflected on the original design question at hand, questioning, iterating and considering possibilities. This helped to reframe the question considering what was learnt.

Site	CBD MUD 1	CBD MUD 2	CBD MUD 3	CBD MUD 4	MUD Suburban	Suburban Home 1	Suburban Home 2	Suburban Home 3
No. of Bedrooms	3	2	3	-	1	3	4	2
TYPE	APARTMENT	APARTMENT	APARTMENT	APARTMENT	UNIT	HOUSE	HOUSE	HOUSE
Time in lift (Sec)	80	122	67	0	0	0	0	0
Private waste disposal	NO	NO	NO	NO	YES	YES	YES	YES
No. of floors	34	17	13	-	GROUND	GROUND	GROUND	GROUND
Number of access pass swipes (to get into appt.)	4	3	3	-	1	1	1	1
Bins under bench	1	1	1	-	1	SEPARATE	4	SEPARATE
BENCH SPACE	MEDIUM	SMALL	LARGE	-	TINY	MEDIUM	LARGE	MEDIUM
Waste disposal infrastructure	2 CHUTES SYSTEM-RED/RECYCLABLE	1 CHUTE + SMALL PLASTIC BIN (RECYCLABLE)	2 CHUTES SYSTEM-RED/RECYCLABLE	1 CHUTE	2 BINS RED/RECYCLABLE BIN	3 BIN SYSTEM	3 BIN SYSTEM (4 BINS)	3 BIN SYSTEM
Waste chute location	IN UNLOCKED CUPBOARD (10M)	IN UNLOCKED CUPBOARD (20M)	IN HALLWAY (30 M)	-	IN CARPORT (7M)	CARPORT (25M)	CARPORT 20M)	REAR GARDEN (7M)
Green bin location	GROUND	BASEMENT	BASEMENT	BASEMENT	NO	CARPORT	CARPORT	REAR GARDEN
Entry	GROUND	GROUND	GROUND	GROUND	GROUND	GROUND	GROUND	GROUND
Vehicle access	-	BASEMENT	1ST FLOOR	BASEMENT	OUTSIDE	DRIVEWAY	-	-
Surrounding greenery	NO	NO	NO	YES	NO	YES	YES	YES
Hard waste	N/A/YES	N/A/YES	N/A/YES	CAGE/YES	YES	YES	YES	YES
Can see greenery when cooking	NO	NO	NO	MAYBE	NO	YES	YES	YES
Garden	2 × 20 M	1 x 30 MM	1 x 100M	? 20 M	8 M	350M	700 M	350M

Table A1. *Cont.*

Site	CBD MUD 1	CBD MUD 2	CBD MUD 3	CBD MUD 4	MUD Suburban	Suburban Home 1	Suburban Home 2	Suburban Home 3
Balcony garden	NOT VISIBLE (NEW BUILD)	YES	NOT VISIBLE	YES	NO	N/A	N/A	N/A
Waste community notices	NOT VISIBLE	VISIBLE	NOT VISIBLE	VISIBLE	N/A	N/A	N/A	N/A
Situation	URBAN/CITY/NO GREEN	URBAN CITY/STREET TREES ONLY	URBAN CITY/SMALL STREET TREES	ADJACENT PARK	SUBURBS/NO TREES/FAKE GRASS	SUBURBS/ GREEN	SUBURBS/ GREEN	SUBURBS/ GREEN
Occupancy	ELITE/OWNED	RENTAL/OWNED	RENTAL/OWNED	-	RENTAL	OWNED	OWNED	OWNED

Appendix B

Figure A1. Example of a simplified domestic system map analysing resource flow through the household. Images used from Emojipedia [34].
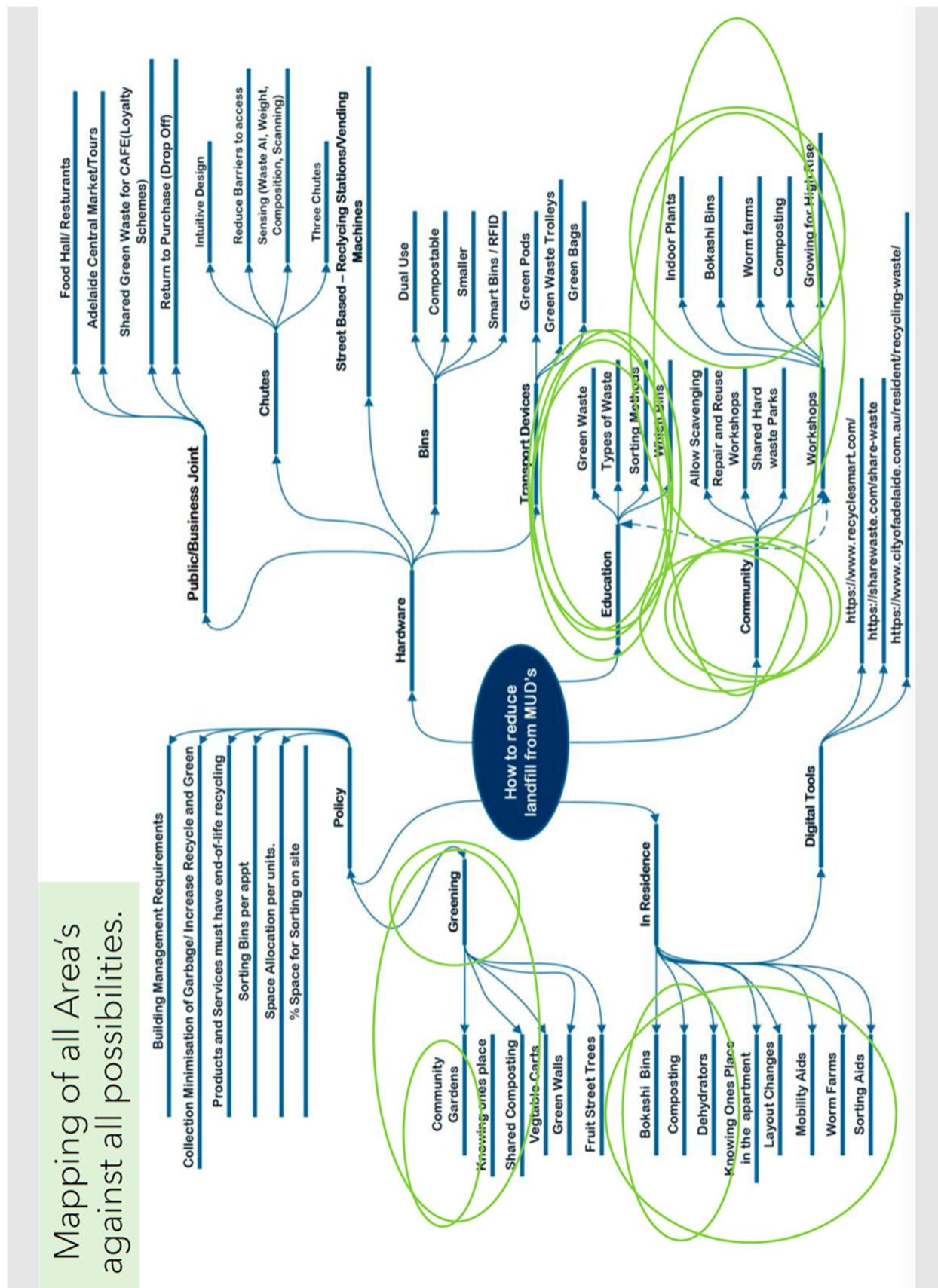
Figure A2. Example of a mapping exercise, visualising the complexities of the system. The green circles highlight priority areas of this system that can be targeted through design.

References

1. Peng, F.; Chow, L.; Tran, N. Service design thinking for social good. *Fusion* **2020**, *18*, 71–82.
2. Sangiorgi, D. Transformative Services and Transformation Design. *Int. J. Des.* **2011**, *5*, 2.
3. Transition Design. 2015. Available online: https://design.cmu.edu/sites/default/files/Transition_Design_Monograph_final.pdf (accessed on 21 November 2020).
4. Manzini, E. Design for social innovation. In *Design, When Everybody Designs: An Introduction to Design for Social Innovation*, 1st ed.; Friedman, K., Stolterma, E., Eds.; MIT Press: Cambridge, MA, USA, 2015; pp. 55–74.
5. Brown, T.; Wyatt, J. Design thinking for social innovation. *Stanf. Soc. Innov. Rev.* **2010**, *8*, 31–35. [CrossRef]
6. Dunne, D.; Martin, R. Design thinking and how it will change management education: An interview and discussion. *Acad. Manag. Learn. Educ.* **2006**, *5*, 512–523. [CrossRef]
7. Dunne, A.; Raby, F. *Speculative Everything: Design, Fiction and Social Dreaming*; MIT Press: Cambridge, MA, USA, 2013.
8. Puente, C.; Eugenia-Fabra, M.; Mason, C.; Puente-Rueda, C.; Sáenz-Nuño, M.A.; Viñuales, R. Role of the Universities as Drivers of Social Innovation. *Sustainability* **2021**, *13*, 13727. [CrossRef]
9. Raghu, G.; Karnoe, P. *Path Dependence and Creation*; Psychology Press: Hove, UK, 2013.
10. Jones, P.H. Systemic Design Principles for Complex Social Systems. In *Social Systems and Design*, 1st ed.; Metcalf, G.S., Ed.; Springer: Tokyo, Japan, 2014; pp. 91–128. [CrossRef]
11. Nelson, H.G.; Stolterman, E. *The Design Way: Intentional Change in An Unpredictable World*, 2nd ed.; MIT Press: Cambridge, MA, USA, 2012.
12. Sevaldson, B. Gigamapping: Visualization for complexity and systems thinking in design. In Proceedings of the Nordes 2011: Nordic Design Research Conference, Helsinki, Finland, 29 May 2011.
13. Cross, N. Designerly ways of knowing: Design discipline versus design science. *Des. Issues* **2001**, *17*, 49–55. [CrossRef]
14. Jones, P.H.; VanPatter, G.K. Understanding Design 1, 2, 3, 4: The rise of visual sensemaking. *NextD J.* **2009**, 1–12.
15. What Do We Mean by Design? Available online: https://www.nesta.org.uk/blog/what-do-we-mean-by-design/ (accessed on 12 May 2022).
16. Kimbell, L. Rethinking Design Thinking: Part, I. *Des. Cult.* **2011**, *3*, 285–306. [CrossRef]
17. Buchanan, R. Wicked Problems in Design Thinking. *Des. Issues* **1992**, *8*, 5–21. [CrossRef]
18. Buchanan, R. Design Research and the New Learning. *Des. Issues* **2001**, *17*, 3–23. [CrossRef]
19. McKeown, M. *The Truth about Innovation*, 1st ed.; Prentice Hall: Upper Saddle River, NJ, USA, 2008.
20. Small, Local, Open and Connected: Resilient Systems and Sustainable Qualities, Design Observer. Available online: https://designobserver.com/feature/small-local-open-and-connected-resilient-systems-and-sustainable-qualities/37670 (accessed on 2 May 2022).
21. Kokotsaki, D.; Menzies, V.; Wiggins, A. Project-based learning: A review of the literature. *Improv. Sch.* **2016**, *19*, 267–277. [CrossRef]
22. Savery, J.R. Overview of Problem-based Learning: Definitions and Distinctions. *Interdiscip. J. Probl.-Based Learn.* **2006**, *1*, 9–20. [CrossRef]
23. Design Thinking and PBL. Available online: https://www.edutopia.org/blog/design-thinking-and-pbl-beth-holland (accessed on 14 May 2022).
24. The Bootcamp Bootleg. Available online: https://static1.squarespace.com/static/57c6b79629687fde090a0fdd/t/58890239db29d6cc6c3338f7/1485374014340/METHODCARDS-v3-slim.pdf (accessed on 20 June 2016).
25. Byars, M. Myerson, Jeremy. IDEO—Masters of invention. (London: Laurence King, 2001). *Graphis* **2001**, *57*, 103.
26. The Design Process: What is the Double Diamond? *2015.* Available online: http://www.designcouncil.org.uk/news-opinion/design-process-what-double-diamond (accessed on 10 June 2016).
27. Beyond Net Zero: A Systemic Design Approach. Available online: https://www.designcouncil.org.uk/resources/guide/beyond-net-zero-systemic-design-approach (accessed on 3 May 2022).
28. The Field Guide to Human-Centered Design (Design Kit). Available online: https://d1r3w4d5z5a88i.cloudfront.net/assets/guide/Field%20Guide%20to%20Human-Centered%20Design_IDEOorg_English-0f60d33bce6b870e7d80f9cc1642c8e7.pdf (accessed on 14 May 2022).
29. City of Adelaide Resource Recovery Strategy 2020–2028. Available online: https://d31atr86jnqrq2.cloudfront.net/docs/strategy-waste-resource-recovery-2020-2028.pdf?mtime=20201223145927&focal=none (accessed on 14 May 2022).
30. City of Adelaide Resource Recovery Action Plan 2020–2028. Available online: https://d31atr86jnqrq2.cloudfront.net/docs/action-plan-resource-recovery-2020-2028.pdf?mtime=20201223143059&focal=none (accessed on 14 May 2022).
31. Zero Waste SA and Integrated Design Commission Report for State Waste Management Guidance for Medium Density, High Density and Multi-Unit Developments in Metropolitan Adelaide: A New Approach for Municipal Waste—Delivering the Strategy June 2012. Available online: https://www.greenindustries.sa.gov.au/documents/MUDs%20consultation%20report.pdf?downloadable=1 (accessed on 19 March 2022).
32. Map The Problem Space. Available online: https://drive.google.com/file/d/1thk9DZdn26oEjd9aWZawkMny8byWoZ63/view (accessed on 14 May 2022).
33. Pourdehnad, J.; Wexler, E.R.; Wilson, D.V. Systems & Design Thinking: A Conceptual Framework for Their Integration. In Proceedings of the 55th Annual Meeting of the ISSS, Hull, UK, 17–22 July 2011.
34. OpenMoji 12.2. Available online: https://emojipedia.org/openmoji/12.2/ (accessed on 29 March 2020).