Practice-led pedagogy for socio-technical transitions: A case study in systems thinking

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Abstract

Our paper attempts to make a case for systems thinking as a core component of a new foundational curriculum for design programs interested in socio-technical transitions and long-term systems-level change. Our case study of a systems thinking course offered to design undergraduates and non-design majors at Carnegie Mellon University highlights a vision of how the course fits into a 21st century design curriculum, how the present curriculum has been structured and the kinds of content and skills we believe design students should be equipped with, and shares insights gained over several iterations of the course on the outcomes of the course. By illustrating how design schools might combine teaching complex theoretical approaches and frameworks with research tools and studio exercises and projects, we aim to make an argument for how thinking in systems and complexity at the freshman level prepares first-year students for fourth-order thinking throughout their undergraduate experience and subsequently, their careers.

Introduction

At the turn of the 20th century, the founders of the Bauhaus laid the foundations of a pedagogical approach and core curriculum that could train a new kind of designer, one that could deal with a rapidly changing world where mass production had radically transformed human life, with a focus on the production of ever more complex socio-technical environments and systems (Gropius, 1919). Within the German model of 'total design', as Mark Wigley termed it in his review of the Bauhaus' legacy and impact on architecture and design education, this production of the socio-technical milieus that we encounter in everyday life was meant to be a totalizing one: on the one hand, both in taking *"over a space, subjecting every detail, every surface, to an over-arching vision"* (Wigley, 1998), while at the same time creating a new understanding that everything and every-where needed to be designed, that *"architecture is understood to be everywhere"*, thereby subjecting the totality of materially mediated experience to the unity of a singular design system.

As Wigley argues, the Bauhaus, its guiding philosophy and vision, and its program of education, were all reactions towards the rapid industrialization during the 19th and early 20th centuries and the growing influence of ever more complex technological infrastructures that were beginning, with decolonization and subsequently globalization, to entrench themselves as the foundations of social life in newly independent countries and regimes around the world. Towards the end of his essay, Wigley (1998) exposes how the Bauhaus' chief breakthrough was in realizing that in fact, *all* design is totalizing: the very (modern) view that the world can be changed and human life shaped and

molded via technical mediation is in itself a totalizing perspective. Gropius, Van Der Rohe, and their colleagues understood that for design and architecture to not only remain relevant but pivotal to this rapidly transforming world, new kinds of designers would need to be educated and sent out to seed this new vision across the world, and so *"Not only are objects designed, mass-produced, and disseminated; the designer himself or herself is designed as a product, to be manufactured and distributed. The Bauhaus produced designers and exported them around the world."* (Ibid)

Over the course of the 20th and 21st century, as our technological infrastructures have grown even more complex, no longer merely mechanical or tangible but virtual and intangible, and entirely inextricable from both the 'natural' environment, as well as from socio-cultural human lifeworlds, we now live in a reality where *"the artificial, and not nature, is the horizon, medium and prime condition of human (and not only human) existence."* (Dilnot, 2016). It therefore is imperative, according to Clive Dilnot, that we pay attention to both the terms on which we create our artificial environments and the quality of those environments, as well as in designing our way through the systems we have already created in the past and that continue to persist into the present, and so it therefore becomes imperative that we argue the need to develop a different kind of designer through a different kind of curriculum: designers that can analyze, understand and intervene in the complexities of intricate, 'wicked' problems spanning across domains of human experience and practice (Rittel, 1973).

An argument for a transformation of design education for the 21st century in order to grapple with precisely this kind of wicked complexity was advanced by Richard Buchanan in *Design Research and the New Learning* (2001), where he argued for design research as the element that transformed discipline-specific knowledge into materialized total design, in the sense that design research integrated cross-disciplinary knowledge from the humanities, social sciences, and artificial and natural sciences and directed those new, synthetic understandings of the complexity of reality into the informing of technologies and technological infrastructures at every level of scale, from interactions to products to services to systems. Buchanan, then the head of the School of Design at Carnegie Mellon University (CMU), had already made significant attempts to establish a curriculum that ran from the undergraduate to masters and then doctoral level, by integrating design studies seminars that sought to give design students exposure to different epistemic frames from various disciplines, as well as the widening of the purview of courses to deal with design at varying levels of scale.

Further changes to the curriculum at CMU were made under a values-driven curriculum developed under the rubric of transition design under Terry Irwin's leadership of the School of Design over the 2010s, with the curriculum reorienting itself around a dedication to imagining and materializing more sustainable and just futures for our present societies, and learning how to design interventions to help transition societies into more sustainable forms (Irwin, Kossoff & Tonkinwise, 2015). As part of the purview of the new transition design curriculum, teaching systems thinking to design students is a key part of preparing them to be designers that can engage in fourth-order thinking (Buchanan, 1992; Smith, 1996). The integration of systems thinking was a key part of the vision for the transition design framework as part of introducing students to theories of systemic change and new methods and tools in designing systemic transitions (Irwin, 2015).

This paper attempts to make a case for precisely this kind of pedagogy and its embeddedness in the development of the core foundational undergraduate curriculum at CMU, incorporating a holistic understanding of present natural, social and artificial systems in order to come up with designed

interventions which answer to the complexities of the problems they are trying to solve and account for the long-term effects at different scales of their solutions. Our case study focuses on a semester-long systems thinking class taught to Freshmen students at CMU as part of their mandatory design studies education. Employing the synergies between students at various levels in the same program, the Freshmen were taught by the doctoral students at CMU (the authors of this paper), who are themselves undertaking research in Transition Design and incorporating systems thinking into their own practice. This paper covers the things that we have learned over five years of experimenting with and refining this curriculum into the form it stands in today. We hope that this paper will give other teachers trying to incorporate systems thinking into their design studios some useful insights, and encourage more to try and push to integrate it into their curricula and courses.

Course structure

The course structure attempts to establish how various theoretical and methodological approaches, as well as practical tools, could better inform and derive in new forms of design praxis within the classroom, helping shape expertise in dealing with the difficulties of designing socio-technical transitions. Through an iterative intergenerational process, taken forward by doctoral students, to seamlessly weave theory, research, and practice, the course has been designed through a survey of the history of systems thinking as a discipline, exposing students to thinking about systems from the diverse perspectives given by cybernetics, Living Systems Theory (Maturana & Varela, 1984; Capra & Luisi, 2014), wicked problems (Rittel & Webber, 1973) and Soft Systems Methodology (Checkland & Poulter, 2010). The format of the course allows for students to learn of the legacy of systems thinkers and how work in this field has transformed society, while drawing inspiration from leading systems thinkers as they develop their own perspectives. Throughout the semester, students gain not only new tools, but new perspectives: in thinking across scales and through the various dimensions of modern human life, the roles technologies play in shaping our perspectives and agency within systems, and in considering the ethical and political implications of their interventions. Hence, the course has come to be structured in a modular form divided into two instances.

The first module defined under the guidelines of *Intrapersonal*, *Interpersonal* and *Institutional*, aims to take students from the micro to the meso. It focuses on familiarizing students, through the learning of different theoretical frameworks, case studies and in-class exercises as well as two projects, with the essentials of how various systems –social, technical, political, financial, etc. work in the United States.

For the first project students work individually, mapping the relationship they have to their environment as filtered through 5 lens of analysis of their choosing. For the purposes of the assignment, we define a lens is a framework or window for interpreting and assessing a specific system (financial, technical, ecological, cultural, etc.). Students can choose to collect objects or artifacts related to a practice, custom, tradition or ritual through a lens - building upon each lens of analysis. The goal is to demonstrate the complexity of multiple systems through our interaction with them by layering various lenses of interpretation. They are expected to demonstrate an ability to bound a system for analysis, embed an individual within multiple systems and clearly communicate the complexity of multiple overlapping and interconnected systems. This first assignment strives to get at the very nature of the systems that affect the self directly by encouraging students to make a systematic collection of objects, as a Cabinet of Wonders. By not

restricting the students creatively, the interpretation have been visual as well as 3D or audiovisual explorations that will be discussed in the last part of this paper.

Communities of practice emerge as we seek to connect with like-minded individuals who share similar interests and are driven by similar motivations. We rely on other actors (human & non-human) to help us make sense of the world as evidenced through our daily practices. Daily practices are an important area of study for designers as they make visual the socio-technical relationships that structure our everyday lives. This is the basis for the second project of the first module, which building from understanding the self as a system, connects into a larger meso space in which communities and institutions emerge.

Communities are shaped through systems of interaction as facilitated through communication (verbal & non-verbal), shared assets, social practices and cultural relationships. Working in groups of four, students work to collectively negotiate and define what a community is and use design research methods to better understand how and why a specific community organizes to fulfill their own needs. Highlighting a specific community group (school department, church group, non-profit etc.) students develop a system map which illustrates hierarchy and relationships that exist and which structure a selected community group. Students will attempt to identify community assets and local knowledge present within a specific group of people and work to understand how a community and its stakeholders develop a consensus of understanding around shared values.

The second module is defined by the *Ideological* and *Interventional* parameters, and so moving into the macro scale. This second part of the course focuses on familiarizing students, through the learning of wicked problems (Rittel & Webber, 1973), Checkland's Soft Systems Methodology (2010) and Donella Meadows' Leverage Points (1999). This part of the course entails a larger third project (in complexity and time) in which students are expected to be able to determine designerly intervention points within the larger scope of a wicked problem of their choice.
Mapping provides an exploration of the system, communicates understanding, and allows for the identification of knowledge gaps, intervention points, and insights. Shifting perception towards thinking more systematically involves developing the ability to look up and down systems levels and see the interconnections among issues and consequences related to large-scale, socio-technical problems.

In groups of five to seven, students work to visualize interconnections and interdependencies related to large-scale, socio-technical problems which are impacting Pittsburgh and Western Pennsylvania. Some of the topics that have been studied in the past are: racial discrimination/profiling, isolation of elderly people, waste management, rising adolescent depression/suicide Rate, the declining population of pollinators and opioid addiction.

In mapping complexity, teams explore ways of representing a selected large-scale issue at different systems levels, distinguishing root causes from consequences and begin to speculate on where the greatest 'leverage points for change' (Meadows, 1999) are within the system (where can interventions be situated that will help resolve many issues simultaneously). Each team's challenge is to find compelling ways to visualize problems and their interconnections at multiple levels of scale which is an important step in building consensus within large, multidisciplinary teams and coordinating productive action. It is also expected for every team to specify at least one intervention point and a broad future resolution for it, while considering its inbound and outbound impact. Interventions are not prototyped due to the time constraints of it being a semester long class.

Pedagogical approach

Concrete tools and methods are provided to students, incorporating a series of in-class exercises and projects that allow them to put each of the approaches covered to work. Lectures, case-studies and class exercises expose students to different ways of framing and analyzing systems. Learning goals intend for students to inspect and describe patterns within specific systems in order to understand them, as well as create compelling narratives and artifacts that communicate their findings and support propositions of design interventions using Meadows' leverage points scale (1999).

In order to move from the first module into the second one seamlessly, the praxis approach to the class is implemented each week. The class meets twice per week which means that once per week students are exposed to theoretical content usually delivered as a traditional instructure-led lecture, and the second time the group convenes they put what they learned to practice through a series of exercises. Students are progressively introduced to the art of mapping, moving from mapping basic positive and negative feedback loops when introduced to first-order cybernetics, to mapping a conversation when second-order cybernetics is presented. For this, Professor of Practice at the Human-Computer Interaction Institute at CMU, Paul Pangaro, is invited to deliver a lecture and workshop. Students model with him fundamental human interactions, like conversations, as systems.

This structure is followed in the second part of the course. It is then that a Futures component is brought into the classroom by the School of Design's Associate Professor Stuart Candy. Through the use of a *STEEP* –Social, Technological, Economic, Ecological, Political– analysis, students learn to organize and the information researched and place it on their mess map in a coherent and visually appealing way. Rich Pictures (Checkland and Scholes, 1990) and Giga Maps (Sevaldson, 2017) become a source of inspiration and the final deliverable of the project. Stuart Candy also introduces students to a *Three Horizons* structure (Curry & Hodgson, 2008) in order for them to address their intervention points in a more holistic and futures oriented way. They are encouraged to not only propose a present intervention but to speculate possibilities in the short and long future, as well as needs, challenges and opportunities in transitional moments they consider pivotal. The ethical implications and accountability of stakeholders is also taken into account in this part of the project.

Image 1. Students starting to mess map their chosen wicked problem.

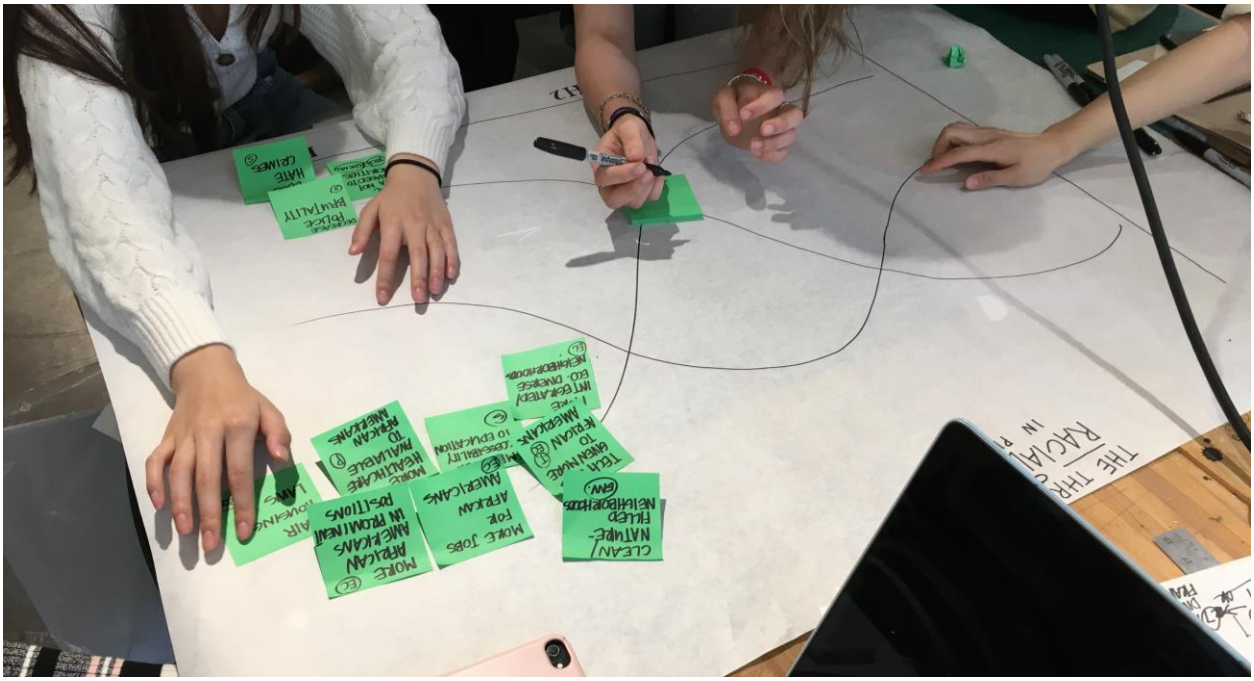

Image 2. Students undertaking a Three Horizons mapping exercise for their third and final project

As the projects become more complex and robust, and students move from mapping feedback loops to actually modelling socio-technical issues, the relational aspect of teamwork becomes fundamental. Collaboration, decision making and building consensus at such an early stage of the undergraduate degree can be daunting for many students, which is why it is tackled as a learning objective and prototyped within the classroom. The experience of mapping, understanding and taking a stance to intervene a wicked problem is taken into account from a meta perspective, in which each team is also a system that needs to work cohesively for the results to be productive and coherent for all. Team charters are included in the design process, in which students are encouraged to make communal decisions on where they want to take the project, how much time they want to invest in it and, in correspondence to the grading rubric, decide on the grade they are aiming towards while recognizing each other's strengths and areas of opportunity for practical and analytical skills improvement.

Iterations of the course

Finally, a significant part of the course lies in students connecting what they've learned in Systems to their chosen majors and tracks of study. Student reflections in past years have demonstrated that a nuanced understanding of complexity and design intervention within systems is of significant value in their future design endeavours.

Reflections have also changed over the years to reflect the changing nature of the syllabus - when the doctoral students first started teaching it in 2016, the course was designed to be more like a seminar, a survey of the literature and various approaches in systems and complexity theory in a roughly chronological manner, with shorter exercises that focused on a few key methods: for example, basic first-order cybernetic models, mess mapping, backcasting, and developing rich pictures using a soft-systems approach. Over the years, we've reduced the amount of theory and the number of approaches we cover, since some of these are now being covered in subsequent courses that students take in following years, and retooled the course to focus less on lectures and passive listening and more on hands-on exercises that take up the bulk of class time and discussions that encourage active learning and participation.

For the undergraduate students taking the course, almost all of whom hail from the School of Design, the course helps them build the essential vocabulary for the other studios and seminars they will take in subsequent years. Over successive years, students have reported that the value of the course becomes apparent when they begin to deal with projects in studios in junior and senior year that involve dealing with disparate sets of stakeholders and trying to understand complex social phenomenon, and especially with the undergraduate thesis in their final year. Over the years, as the course has been successively refined and become more hands-on, students have come to value the course on its own terms and have said that it is crucial for the way it frames their thinking about what design is in their first year.

It must be noted that the Systems course works as well as it does, in our view, because of its close integration with redesigned courses across the curricula. In their sophomore and junior years, undergraduate students take advanced studios in design for social behavior, and the environments, industrial and communication design studios gradually expand their purview from teaching design systems to (re)designing systems; similarly, the design studies seminars build on the approach to dealing with complexity in the systems course by introducing students to critical theory and cultural studies in order to make sense of social and cultural phenomenon, and to theories and frameworks in persuasion, as well as futuring and foresight analysis.

As for non-design majors taking the course, their insights have demonstrated that a design approach to complexity allows them to create clearer mental models to share information with peers and collaborators, and to pursue new avenues of applicability within their specialization. These end of semester reflections showcase how the Systems course helped students in other courses regardless of whether they were design or non-design majors.

Student work and final reflections

As part of the course, a Systems booklet was put together. This editorial material was a student-led project. Ten students from the course created the content, graphics and editorial design of the booklet that was later on presented at RSD8 as a complementary part of this paper. The booklet showcases the work done by students in each one of the three projects undertaken throughout the two modules. It also puts together the main theoretical frameworks revised in class and a glossary of key words, terms and tools. The booklet, produced and supported by the School of Design at CMU, has become a referential material for other courses and students in the program. The Systems course has come across as the space to train students with new skills to process the overlaps between theory and applied practice.

Image 3. The Systems booklet showcased at RSD8.

In parallel to this paper, five out of seven working teams at the Freshmen level submitted a poster for presentation and were accepted to RSD8. Their work portrayed some of the already mentioned wicked problems analyzed and mapped during the second part of the course's module. The following posters were presented at the conference at IIT in Chicago in October 2019:

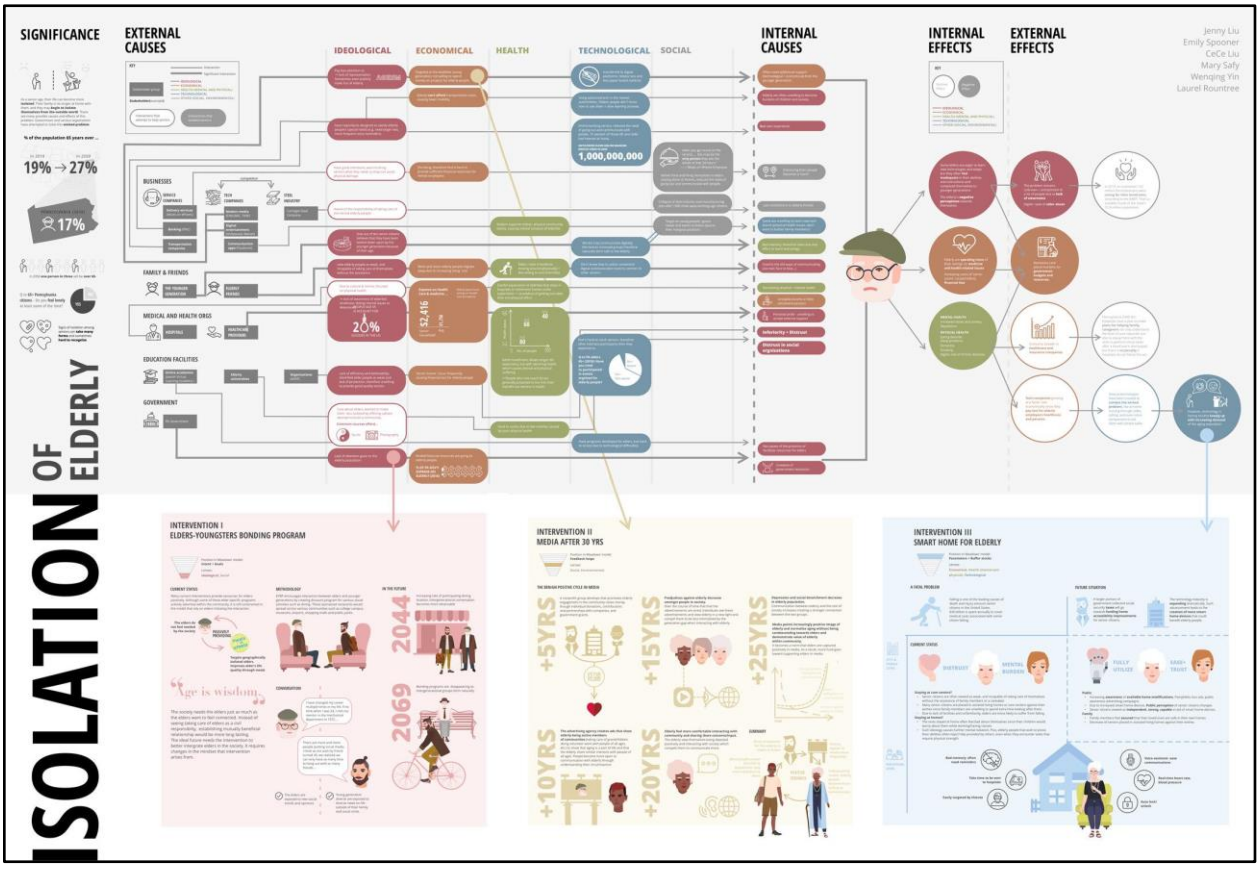

Image 4. ***Isolation of the Elderly*** **by CMU undergraduate students Jenny Liu, Emily Spooner, CeCe Liu, Mary Safy, Wenqing Yin, Laurel Roundtree**

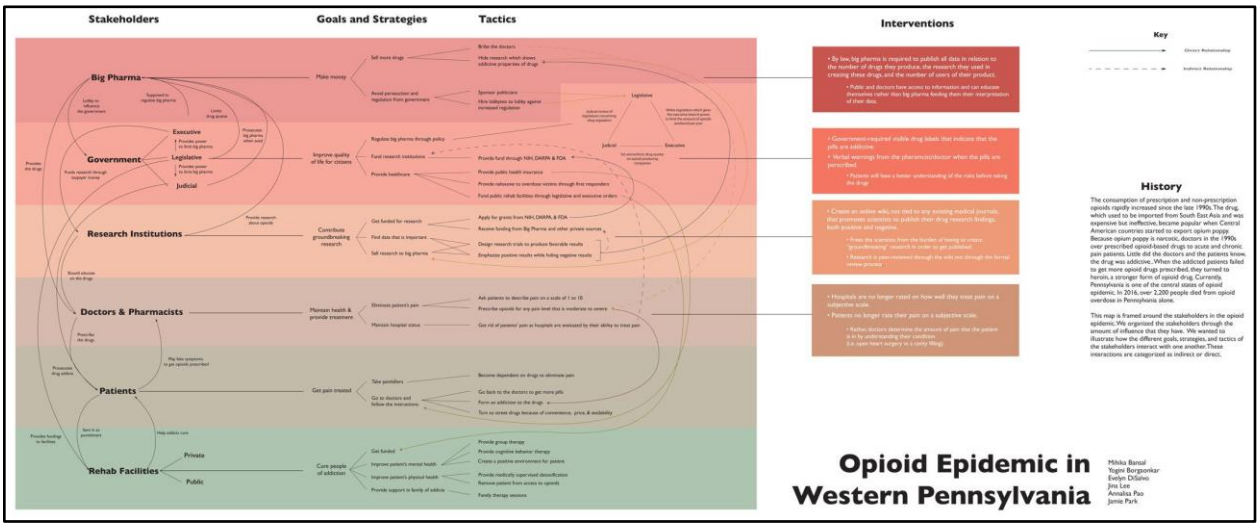

Image 5. ***The Opioid Crisis*** **by CMU undergraduate students Mihika Bansal, Yogini Borgaonkar, Evelyn DiSalvo, Jina Lee, Annalisa Pao, Jamie Park**

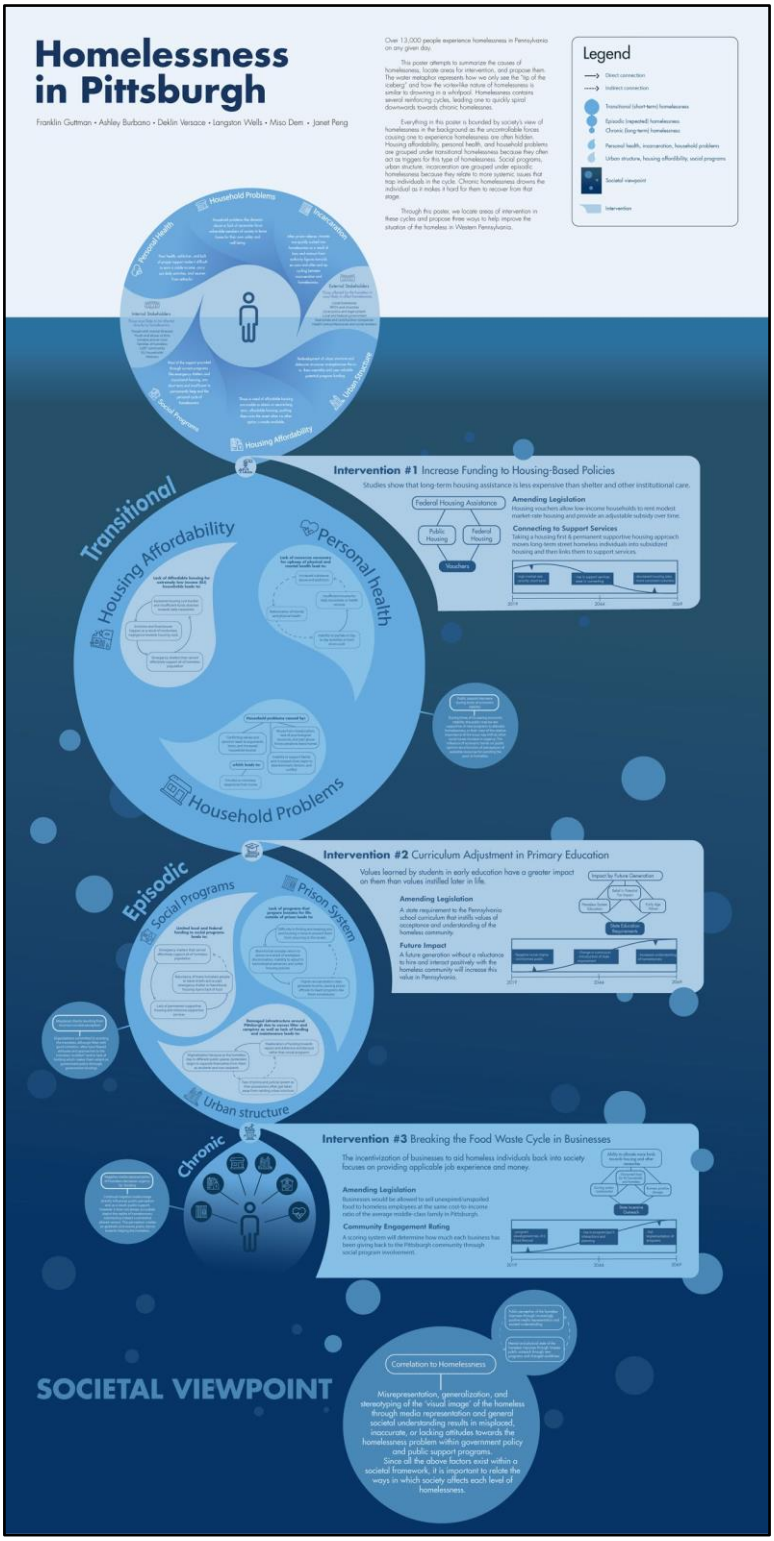

Image 6. *Homelessness in Pittsburgh* by CMU undergraduate students Franklin Guttman, Ashley Burbano, Deklin Versace, Langston Wells, Miso Demko and Janet Peng

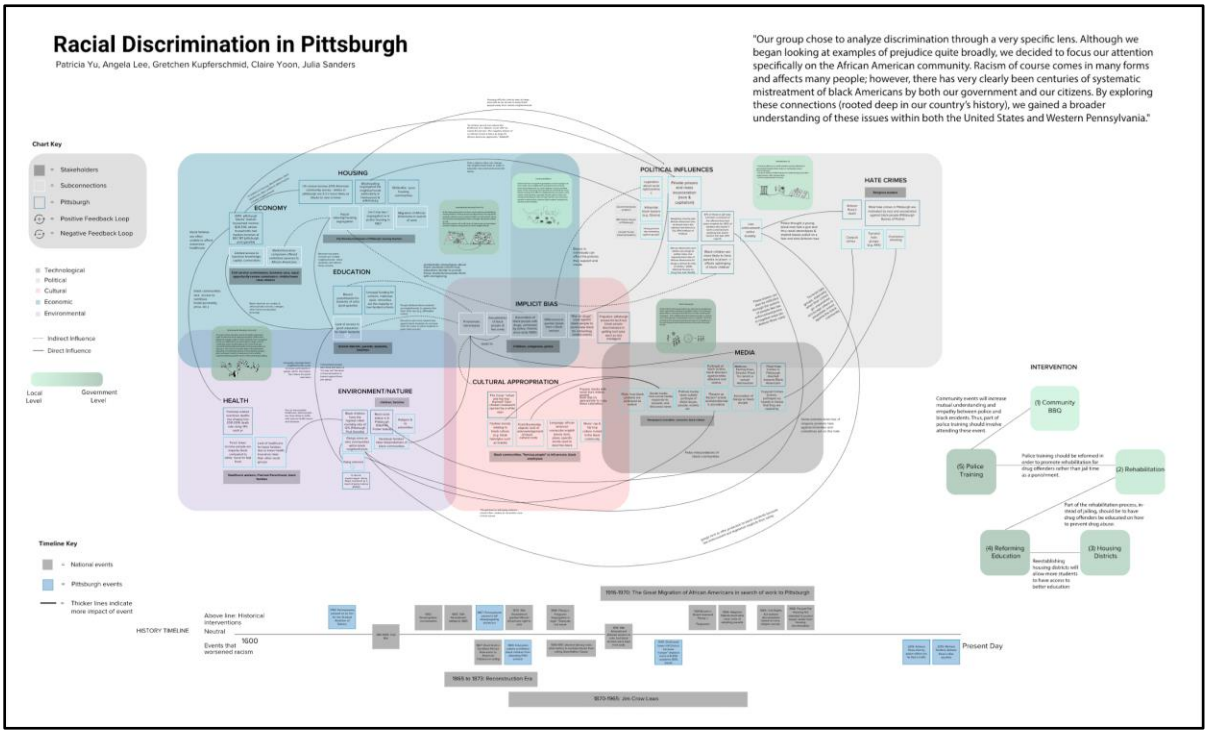

Image 7. ***Racial discrimination in Pittsburgh*** **by CMU undergraduate students Patricia Yu, Angela Lee, Gretchen Kupferschmid, Claire Yoon and Julia Sanders**

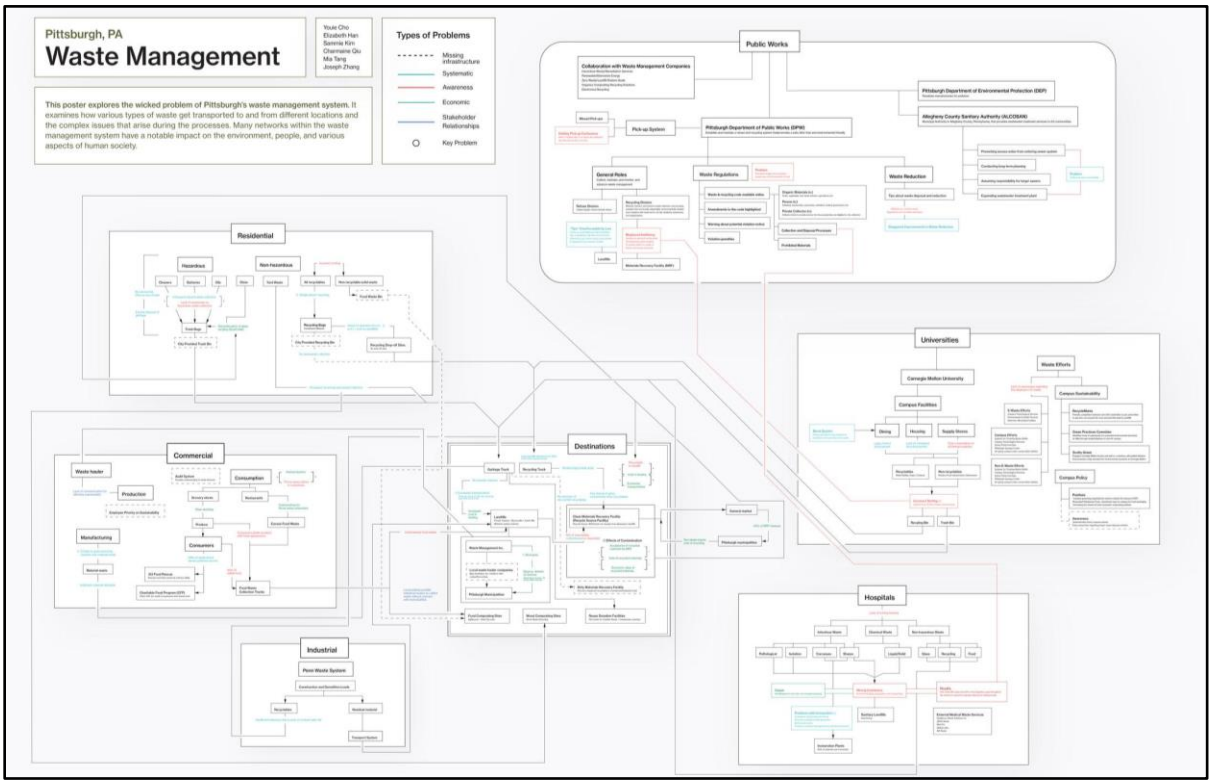

Image 8. ***Waste Management*** **in Pittsburgh by CMU undergraduate students Youie Cho, Elizabeth Han, Sammie Kim, Charmaine Qiu, Mia Tang, Joseph Zhang**

Finally, through a reflective short essay students are asked to make connections between their other courses, their learning throughout the semester in the Systems class and their track selection for the following years (a choice they need to make between visual communication, products and environments). Students generally spoke on how the relationship between the Systems course and their other academic undertakings had become palpable. One student referenced clearly this:

> *All in all, I was extremely happy with how Systems went and I found it very satisfying to see this sort of thinking starting to tie into our projects across all of our classes, showing how applicable it is across disciplines.*

Others reflected on the artificial examinations of systems, which can be boiled down to the materiality of the products designed:

> *This class has definitely helped me to see how product design can have a greater impact on a system when properly researched and considered, without discounting the physicality and formal characteristics of a product, which are factors that have always interested me.*

Particular attention was also paid to the political considerations of design and its permeability in socio-technical interactions (the student also makes reference to an array of lecture series carried out throughout each semester at CMU's School of Design):

> *This idea of using design for social change seemed to be a trend in all of the design lectures I attended. I was especially interested in the lecture by Bryan Boyer who talked about how he used the design of a new building to change governmental policy. I also was very intrigued by Mahmoud Keshavarz's idea of 'design politics' and how you can understand politics through the design of an object as well as how you can understand design through a political lense. I've always been interested in politics and after exploring systems thinking and attending these design lecture I would be interested to learn more about applying design principles to public services and policy.*

This final reflection taps upon the potential of design to connect with other disciplines and larger discourses that go beyond the historical visual and material characteristics of the field.

The Systems course has become a form for students to explore newer terrains of design practice and be able to connect diverse areas of knowledge from an early stage in their educational career. This holistic approach to pedagogy and design education has been fundamental for the course but also for the authors of the paper. In order to undertake the titanic challenges of the 21st Century education it is imperative for design education to shift, and this case study shows how a scaffolded praxis based approach can develop multi-leveled soft and hard skills for young commencing design students.

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