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Systemic Design for Second-Order Effects

A Case Study in Sustainability

Abstract

Second-order effects are changes within a system that are the result of changes made somewhere else in the system (the first-order effects). Second-order effects can occur at different spatial, temporal, or organizational scales from the original interventions, and are difficult to control. Some organizational theorists suggest that careful management of feedback processes can facilitate controlled change from one organizational configuration to another. Recognizing that skill in managing feedback processes is a core competency of design suggests that design skills are potentially useful tools in achieving organizational change. This paper describes a case study in which a co-design methodology was used to control the second-order effects resulting from a classroom intervention to create organizational change. This approach is then theorized as the Instigator Systems approach.

Keywords: systemic design, sustainability, Instigator Systems, case studies

Introduction

Creating change within an organization can be difficult. Even when an organization recognizes the need for change at all levels, introducing new processes, creating new relationships, and letting go of ingrained ways of thinking can pose a challenge. There are always inertial forces, some intentional, some unintentional, that resist change and attempt to pull the organization back into its previous equilibrium state. These forces can be beneficial if stability is deemed to aid in the overall survival and success of the organization. However, if the surrounding environment is radically different from the one in which the organization emerged, reversion toward the previous steady-state can end up destroying that organization, despite the best of intentions.

It is difficult to know whether effort should be put into maintaining a current configuration or into adaptation. Skilful managers, visionary leaders, and, increasingly, designers are often called upon to make this determination, and case studies of these success stories abound in the literature alongside stories of failed visions and inflexible organizations that could not adapt to or prepare for change. In *The Design Way* (Stolterman & Nelson, 2012), the authors identify 'desiderata-driven' change as characteristic of design, but only one of five 'triggers of change'. The other kinds of change –, management-, problem-, vision- and crisis-driven change – are less human-centred and more in line with the systems approaches found within the organizational and management literature (Gemmill & Smith, 1985; Leifer, 1989). Regardless of what drives it, in the 21st century change and adaptation are unavoidable. But how much change is enough to adapt to a dynamic environment and what role can design play in accomplishing this change?

There is a fundamental tension in the organizational management literature regarding whether transformations from one equilibrium state to another can be viewed as 'evolutionary' or 'revolutionary'. Both conceivably result in a new organizational configuration capable of meeting the demands placed on it by its environment, and both use the same mechanisms of self-organization. The difference lies in how much the restructured organization resembles its former self. There are no easy metrics for determining the right quantity or quality of organizational change. The literature frequently uses the language of 'radical transformation' to describe structural changes to an organization that result in new configurations, and the case studies presented are typically of entire business firms that reorganize to respond to the challenges of a changing business environment. Yet, one of the fundamental precepts of systems theory is that the patterns of organization that emerge from the interactions of subsystems are independent of scale. One example, from the popular book *Emergence* (Johnson, 2002), explains how an historic map of the city of Berlin bears a striking resemblance to the organization of the human brain, demonstrating that similar patterns emerge at vastly different scales and from the interactions of very different components.

Radical transformation itself can exist at multiple scales. The question we attempt to answer here is: can a subsystem of an organization (a department or division for example) undergo radical transformation, an evolutionary change, without substantially reorganizing the larger organization that contains it? This is an important consideration for design research as well. As Stolterman and Nelson (2012) also point out, in order for desiderata-driven change to be effective the right context and environment needs to exist. They define this context as 'a design crucible' or 'container, which defines the limits and possibilities of design activity'. Although those authors advocate for creating such a design culture in all organizations, this is not the current situation. What if the container, the design culture, exists on a smaller scale, perhaps, only in one small unit within a larger organization? Can we still effectively create intentional change?

The benefits of this kind of *radical change at manageable scale* are numerous. First, it is far easier to radically alter a subsystem than to alter an entire organization. The smaller scale of subsystems means less energy is required to change them. Yet, because systems rely on their subsystems to generate their overall character and configuration through emergence, smaller efforts by fewer personnel have the potential for amplified higher-scale impacts. Change at the subsystem level is attainable by a few motivated individuals and their efforts can have lasting influence through well-managed second-order effects. A second benefit of working in smaller scale subsystems is that changes are less likely to be noticed and counteracted, as they often do not have substantial implications for other subsystems. Although the fact that subsystems are connected to each other is a necessary criterion for emergence, subsystems frequently maintain a great deal of independence to manage their own components. Academic divisions, like the ones we examine below, share students and goals, and may interact through interdepartmental committees and obey common rules, but are otherwise autonomous. Attempts at radical change can leverage this autonomy to experiment with new approaches. Experimenting in one subsystem within an organization does not mean that others are impacted as radically, or at all, and any benefits resulting from that experiment may benefit other subsystems as well if the change helps alleviate pressures that are more widely felt. A final benefit of radical change at manageable scale is that it allows an organization to potentially outperform others by achieving the benefits of stability and adaptability simultaneously. Stability is maintained by making only minimal changes, which are largely constrained to the subsystem level. This helps to preserve the current configuration. Contrastingly those same changes are a form of adaptation that provides a way of relieving internal and external pressures while still meeting changing environmental demands.

At the heart of this idea is a modular and multiscale perspective – that large scale institutions can be conceived of as collections of relatively independent subsystems whose interfaces to other subsystems are tightly specified, while their internal dynamics are largely isolated from the functioning whole. This is, of course, just one way of modelling an organization, at the subsystem scale. It is equally valid to conceive of an organization at the scale of individuals, each obeying his or her own rules to create collective action, or any number of other models. Some organizations lend themselves to different conceptions more readily. The purpose here is not to advocate for one model or another (circumstances differ), but to show how framing a system in this way was productively employed in one particular scenario. One implication of the modular and multiscale view that we exploited in our work is that it affords the possibility to reorganize a subsystem while keeping other components of the larger organization unchanged and even unaware that adaptation is happening.

What follows is a case study that describes how we were able to achieve a modest structural change: the creation of new communication channels for the exchange of information between campus planners and municipal water authorities. While such a change was in keeping with institutional goals of both our university and the municipality at the highest levels, these goals lacked many of the organizational structures needed to achieve them. This is quite typical of large organizations with long histories. We were able to help achieve these organizational goals by creating new connections between campus planners and municipal water authorities as second-order effects resulting from our use of a co-design process integrated into a new design course called Sustainability: Theory and Practice. By involving students, faculty, campus planners and city engineers in a semester-long design exercise focused on green infrastructure (GI), we were able to open the decision-making process to new sources of information and change the way this subsystem functioned. While it is too soon to tell if our changes themselves are sustainable in the long-term, we believe that this method of creating institutional change – which we refer to as the instigator systems model – is a viable strategy in many contexts. We therefore offer some suggestions for those who wish to initiate their own instigator system.

Background

Dissipative structures arise through thermodynamic processes. Citing the work of Ilya Prigogine, Nobel Laureate and originator of the idea of *dissipative structures*, the organizational behaviourists MacIntosh and MacLean (MacIntosh & MacLean, 1999) offer a description that is worth quoting at length:

> Rather than viewing the world as essentially static, with equilibrium only occasionally disturbed, Prigogine regards the world as dynamic and characterized by systems in which normal Newtonian laws may apply, but only in a minority of situations. That is to say that whilst such systems can exist in equilibrium, change and transformation are associated with non-equilibrium conditions, which are subject to a different set of laws. The evolution of non-equilibrium systems is influenced by a combination of a complex network of nonlinear system relationships and random developments, which combine to create new system configurations in a way which is largely indeterminate. In extreme cases, the system can be so far from equilibrium that the structure breaks down and the system becomes chaotic. In such circumstances, the operation of simple rules in conjunction with nonlinear processes (i.e., the action of positive feedback on small and possibly random events) can give rise to the emergence of new, qualitatively different, structures. Since Prigogine's work focused on phenomena such as phase transitions in matter, his work is characterized by descriptions of systems moving progressively further from equilibrium to the point where a 'descent into chaos' ensues and the system structures are broken down. At this point the system becomes open to its environment, importing energy and exporting entropy (a measure of disorder) as a new structure takes shape in accordance with the operations of a set of simple order-generating rules. Since, in physics, heat is the most entropic form of energy, the system is said to be dissipative, in that the entropy exportation is characterized by heat loss. The system is thus termed a 'dissipative structure'.

As a physical scientist, Prigogine is intent on describing and understanding the physical world. A tenet of the systems view of the world however is the notion that physical, biological and social phenomena obey the same laws of organization (De Landa, 1997, for example). In keeping with this idea, Prigogine's model of dissipative structures has since been applied to social phenomena at various levels of organization (scales). MacIntosh and MacLean (1999) offer one such example, along with an extension of the dissipative structures idea, that adds an element of human intentionality missing from Prigogine's purely physical description of self-organization. In their view, conscious management of the transformational process, in other words—design, is able to move the organization towards a more favourable stable equilibrium state. The idea is based on the notion that all systems undergoing change reach a 'bifurcation point' where they can move into one equilibrium state, or another, and assumes that social organizations have the addition of human agency and technological tools that can be deployed to influence the change process toward a desired equilibrium state. Their framework, referred to as 'conditioned emergence', fits the definition of design as 'the creation of intentional change' given by Nelson and Stolterman (2012) and has much in common with the notions of desiderata-driven and management-driven design. It involves three steps:

1. Conditioning – The organization identifies 'deep structures' that are present in the current archetype and have guided its historical trajectory. These are often core values, business principles, etc. which are re-evaluated to create a new set of rules to govern and manage the behaviour of the organization in the future. Some of the old deep structures may be kept or modified and new ones are formulated.

2. Creating non-equilibrium – A crisis, either naturally occurring or precipitated forces the organization into chaos, creating entropy within the system and opening the organization up to import energy from the environment.

3. Managing the feedback process – Managers look for small signals consistent with the effects of the new deep structures and attempts to amplify these signals (positive or reinforcing feedback), while at the same time trying to damp out the influence of the old deep structures that are tending to pull the organization back into its previous equilibrium state (negative or balancing feedback).

The idea behind conditioned emergence is that the processes of self-organization that bring the institution to its new stable configuration, although still dependent on initial conditions like any other complex system, are not strictly the result of random interactions of system components. Rather, a manager or designer can intentionally shepherd the transformation process to bring about the most favourable result through skilled manipulation of the feedback processes inherent in self-organization. Moreover, these activities, while still goal-directed, are not pre-planned, but instead require the ability to perceive and direct feedback processes, as is done in iterative design methodologies.

MacIntosh and MacLean (1999), however, are extrapolating from earlier work, by Jantsch (1975), as well as by Leifer (1989) and Gemmill and Smith (1985). While they offer the additional three-step summary outlined above, an earlier characterization of the dissipative structuring process given by Gemmill & Smith provides a useful way of thinking about the overall process which helps generalize MacIntosh and MacLean's more operationalized view. The operational view becomes more important when we discuss intersections with design below, but understanding the overall process is helpful up front.

1. *Disequilibrium conditions* – Extreme turbulence, either internal, external or both, creates the initial conditions in which change becomes possible.

2. *Symmetry breaking* – The system's self-replicating or usual autopoietic functioning has become ineffective or has purposely been suppressed in order that new possibilities may emerge.

3. *Experimentation* – Through the experimentation process, the system creates new possible configurations around which it can eventually reformulate. The system that is best able to transform is one in which such experimentation and retention of variants are encouraged, rather than discouraged, dampened, and discharged.

4. *Reformulation processes* – In this formative process, new configurations are tested within the new environmental constraints and with respect to the system's previous level of development. For this to take place, the system must be highly resonant, both internally and externally, to both its subsystem alignments and its alignments with the contingencies of the environment. The presence of this resonance and the ability of the system to move as a whole into the configurations it experiments with makes successful transformation more probable.

Our Project

One of the hallmarks of complex systems is their 'multileveledness' (Boyatzis, 2006), the fact that they can be described at multiple levels of abstraction or multiple "scales". For example, a glass of water can be described by detailing the movements of the individual water molecules in the glass – a molecular-scale description. That same system can also be described using the emergent collective variables of temperature and pressure that describe the aggregate interactions of all the water molecules. This second view is often referred to as a 'macro-scale description'. Likewise, complex social systems can also be described at multiple levels of organization. Our project was an experiment at multiple scales; the topmost scale, which we refer to as the *institutional scale*, an intermediate scale at the level of departments, divisions, and working teams within the institution (the *departmental scale*), and a *classroom scale* that describes the individual interactions of students and instructors in the context of our course.

This experiment had goals at every scale, and it was vital that we articulated the different scales, our goals at each scale, and the activities we would engage in to achieve those goals. Moreover, it was equally vital that we re-evaluate those goals and methods at key points during the project. Our goal at the classroom scale was to implement an innovative pedagogical approach that created a better match between classroom instruction and professional activities. At the institutional scale, we wanted to help the university and the local municipality realize mutual goals around sustainability and community engagement, which had been agreed to in a series of high-level memoranda. At the departmental scale, we wanted to create an inter-institutional working group to facilitate the implementation of sustainable green infrastructure (GI) on the campus, to provide a continued source of learning opportunities and professional development for students, and to establish new relationships that could be used to plan and execute future joint ventures. The creation and maintenance of these new relationships at the departmental scale through new communication channels were the main dissipative structures we sought to create and sustain. As information flowed through these channels, across institutions at the departmental level, new opportunities and constraints flowed down to students in the classroom, and new requests and information flowed up to administers. Effectively these were new pathways for energy-entropy exchange, around which the system could self-organize.

At the institutional scale, we wanted to create new connections between Georgetown University in Washington, DC and the District of Columbia Water and Sewer Authority to help both institutions advance their sustainability efforts in the short term and create tighter coupling (better information flow, defining mutual goals, etc.) in the long-term. Georgetown University has made many commitments regarding sustainability and community relations. These commitments were the result of an examination of the institutions core values, which were re-evaluated in the context of global climate change, and these 'deep structures' formed the basis for the university's goals. The District of Columbia Water and Sewer Authority (DC Water), and particularly one group within DC Water called the Clean Rivers Project, has also made commitments around reengineering stormwater management in the District by using GI wherever feasible. The deep structures involved here were simply DC Water's mandate to supply clean water to city residents and to satisfy environmental regulation. However, there were also emerging disequilibrium conditions described below that created the opportunity for collaboration and change.

The Clean Rivers Project focuses on alleviating the problems caused by Combined Sewer Overflows (CSOs). Remnants of pre-industrial development in Washington DC, CSOs are large drainage pipes that drain both stormwater and sewage. In normal conditions the city's drainage system funnels the combined sewage/stormwater to treatment facilities where it is purified and released back into the ecosystem. However, during large rain events this system cannot process all the water and the combined sewage/stormwater overflows into the region's waterways—untreated—through the CSOs. While large-scale engineering solutions are being enacted as the normal course of action for large municipalities, symmetry-breaking has come in the form of many voices within DC Water and among the city's eco-conscious residents fighting for the inclusion of GI as an option for long-term stormwater management. GI has additional benefits associated with the triple-bottom-line of environment, economics and social equity, including reduced costs and added maintenance jobs, increased greenspace and educational opportunities, to name a few. Large parts of the university campus happen to be located within the boundaries of two major CSOs, suggesting that GI on the Georgetown campus would help meet both the goals of DC Water and the university. However, no mechanisms were in place for decision-makers in either institution to even know about each other's plans or to coordinate their activities.

Our project sought to create information channels that allowed for a reconfiguration of the GU–DC Water system to achieve its sustainability goals. While institutional-scale goals are set at the top level, the responsibility to operationalize these goals falls on other entities in the organization. Specifically, the DC Clean Rivers Project is the group within DC Water tasked with the planning and implementation of GI within CSO boundaries, while GU Facilities is responsible for all planning on campus, which includes coordination of sustainability efforts. Through our project, we hoped to create stronger connections, which increased the flow of information between these departmental-scale entities through conversations about priorities and a shared stake in student success. We tried to design the emergence of these connections through a co-design process aimed at creating a dissipative structure at the departmental scale that could help both institutions achieve sustainable structural change in the form of a new equilibrium between the two groups.

Our co-design methodology was centred on stakeholder meetings between the student teams, the DC Water facilitators and Facilities personnel, in which students gave presentations on their ongoing work to members of the Facilities team. This is where second-order effects where recognized and harnessed. As the students reported on their projects, the Facilities team was able to see and hear what students perceived as important goals and priorities for campus planning. They were able to interact with their counterparts from the DC Water team to learn more about that organization's goals and priorities and why their facilitators urged the students to include certain GI elements in their designs. Likewise, the DC Water team learned about campus planning priorities in the same context and were able to calibrate their feedback to students during subsequent classroom exercises. While the common goal of these meetings was ostensibly to help the students advance their design work, the two groups were also informally synchronizing their efforts. The student project was a low-stakes endeavour with all stakeholders genuinely wanting to promote the education of the students and see their project succeed. As such, any negotiation was focused on how the student project could be successfully designed and implemented, rather than all parties trying to get a favourable outcome for themselves, as is often the case. This context was essential for establishing a good working relationship. There were real constraints placed on the project but there was also real effort to find ways to work around these constraints for the sake of the students. The result of focusing on student work was that both DC Water and GU Facilities were effectively negotiating the project without consciously doing so. As we altered the direct intervention in the classroom based on feedback from stakeholder meetings students were directly affecting the conversation between the higher-scale divisions in both organizations.

The stakeholder meetings also furthered the professionalization of the students as they practised using the technical vocabulary they were learning in class to openly discuss the details of their project. Moreover, it gave the students a deeper understanding of how decisions are made within the university, which was a shock to most. Initially, students were reluctant to accept the ways that issues such as fiscal cycles, resource allocations and competing priorities within the university needed to be factored into their designs. However, by the end of the course, they had extensive experience in those matters, and developed a more innate understanding of how external factors might force design changes over the course of a project. They learned a lot about designing in the context of a large organization that operates on institutional timescales that could not have been learned from the short-term course projects they were used to.

Many second-order effects emerged from the stakeholder meetings in tangible ways. When the students asked to see surveys of campus drainpipes, to identify areas for intervention, it was found that university records and municipal records did not agree; subsequently, a joint survey was implemented by DC Water and GU Facilities to identify current drainage patterns and stormwater infrastructure in an effort to integrate and align the two archives. This was a second-order effect that we could not have anticipated or designed for when the project began, but we could quickly recognize it and direct it toward a productive collaboration. In another example, a plan to implement a small green roof demonstration site on the main university library incorporating the students' design was integrated into the Campus Sustainability Plan (to be approved in 2017). While a welcome outcome, this was not our intention when we planned the course, it simply emerged as a 'target of opportunity' when it was discovered, during a stakeholder meeting, that the 5th floor of the library was scheduled for renovation.

Our project also had goals at the classroom scale where we made our first-order interventions. We tried to create a unique combination of instructional approaches that would give students both solid theoretical grounding and practical experience in sustainability and design. Two instructors with overlapping but distinct expertise team-taught the course. We invited the outside experts from DC Water to assist in classroom activities and instructional design. During course planning DC Water was given opportunities to comment on each iteration of the syllabus (3 total), and their changes were incorporated into the content, exercises and assessments. During the semester, they were invited to facilitate discussion on topics such as the water cycle and water treatment, led two site walks around campus to determine suitable locations for interventions, and facilitated three design charrettes. The official course instructors, on the other hand, presented and discussed topics on the theory and practice of sustainability, and led more general design and educational exercises such as creating landscape plans and presentation slides, as well as visual and written communication. This combination gave the course a feeling of professionalization, as students were taught streamlined versions of the design process professionals used in their daily practice, while also maintaining an educational atmosphere in which learning and improvement were stressed. We used a lecture+studio model for teaching, in which students were given short explanations and demonstrations of activities that they were then asked to replicate in the context of their project. These became progressively more focused, based on feedback they received after each stakeholder meeting, until we converged on final designs. We also entered an external design competition, the Campus RainWorks Challenge administered by the US. Environmental Protection Agency (and received an Honourable Mention in our category), to provide external accountability and structure that helped students stay engaged. The deliverable for the competition were two 90cm x 120cm design boards and a ten-page project description that also served as the final deliverables for the course. The students created the design boards in teams of four and each student contributed an individual section to the project narrative.

Theoretical Implications for Systemic Design

It is the historical consistency and continuity of higher education institutions that mark them as what Jantsch (1975) calls ‘equilibrium institutions’. Turbulence from the outside or inside of these institutions gets absorbed and adapted to, while the whole institutional structure remains largely unchanged. For example, new departments such as media and communications are created in place of journalism to account for the changing landscape of information dissemination. These are evolutionary changes rather than revolutionary ones. Making these kinds of adaptations has allowed the university to continue with basically the same structure for generations. Still, the fast pace of technological change and the increasing magnitude of social, economic, and environmental stresses have left many contemporary observers wondering if the same strategies are capable of sustaining universities into the future.

No one working in higher education will be shocked to hear that disequilibrium conditions exist. The growth in for-profit colleges and universities, the availability of ‘open’ courseware and internet-enabled distance learning, the soaring costs of attending colleges and the debt burdens they create for students and governments, are only a few of the pressures being faced by institutions of higher learning around the world. While educational institutions may be able to adapt to these new pressures and maintain a steady-state equilibrium, it is also apparent that some symmetry breaking is occurring. Smaller universities are struggling to survive in this new environment, and many are citing financial difficulties as a symptom that the usual self-sustaining equilibrium processes are breaking down. The move toward MOOCs (massive online open courses) in traditional universities can be seen, in this context, as an attempt to open the system up and export entropy and import energy, creating a dissipative structure. In our own institution we have begun the experimentation stage. New initiatives such as the Designing the Futures of the University and Initiative on Technology-Enhanced Learning are deliberately suppressing the autopoietic processes of the university to allow faculty and departments to explore new structures for research and teaching, like the course we developed.

Our course was able to flourish in this atmosphere of open and encouraged experimentation, which allowed us to attach a number of unique features to this project. Having instructors situated in both academic and administrative units added an important dimension to this project. Facilities planners and the Director of Sustainability interacted directly with students, creating an opportunity to practice co-design in a way that contrasts with how much university planning is typically done. Additionally, having one of the instructors embedded in the facilities office facilitated communication and ready exchange of information and allowed for timely feedback and advance planning. These all presented opportunities for us to manage the feedback processes that are important to the conditioned emergence model presented by MacIntosh and MacLean (1999), but the key element was the implementation of the three monthly stakeholder meetings. As stated previously, these were student-led, with the stated purpose of getting feedback on the students' projects and helping the instructors re-align the course goals. Between meetings students iterated on their designs under the guidance of the instructors and facilitators who, in addition to supplying technical expertise to improve the accuracy and presentation of the work, would ensure that students were actively addressing the feedback from previous sessions to better meet the needs of the facilities team. Students then presented the current iterations of their designs and explained their reasoning behind their design decisions. They received additional feedback about the feasibility of their project and its relation to ongoing planning at the university. Although this feedback was directed at students it also provided crucial information to the DC Water team about campus infrastructure priorities, upcoming plans and initiatives, and communicated subtle signals about how far the university was willing to go to meet specific goals. These stakeholder engagement briefings, with the low-stakes 'sacrificial' student work as the context created an additional channel for information to flow between organizations (at the departmental scale) that we hoped would help both organizations self-organize during the reformulation phase to create a sustained connection.

After each meeting the instructors and DC Water debriefed in an effort to adapt the first-order interventions at the classroom level to better align the project with university priorities for the next iteration. For example, during one stakeholder meeting facilities personnel, concerned with foot traffic, suggested that students incorporate a design that 'regraded' (changed the elevation) one area to alter the drainage pattern. However, doing so would move stormwater into an even more overburdened CSO, effectively solving one problem by making another worse. The ensuing discussion helped DC Water and Facilities more clearly articulate their needs and constraints, and we added a lecture that focused on permeable pavement so that students could address the foot traffic and drainage issues simultaneously in their next iteration.

An additional and unforeseen educational benefit of these briefings was that they allowed students to see how decisions are made at an institutional scale, and helped them understand the complexities and indirect effects their design decisions might have. Giving students a look behind the curtain of institutional processes helped them grasp and design for the system as a whole. They saw firsthand how a design decision driven purely by engineering and aesthetic concerns could become subject to constraints from other priorities introduced during the planning process. For example, students first proposed replacing a flowerbed with a 'bioswale' employing local plants to naturally clean and purify water in one area, only to find out that a commitment to an external donor demanded that a specific breed of tulip be planted in that area. Seeing that a deeper understanding of organizational politics was going to be an important takeaway for students, we invited a guest speaker and devoted half of one class to organizational behaviour.

The work of Argyris and Schön (1989) is considered foundational in the complexity management literature. Schön's notion of reflective practice (1983) is also considered an important foundation in the literature on design. Designers, particularly those who explicitly use an iterative process, rely on the management of feedback loops. As the instructors and managers for our course, we were also implicitly designers of the larger dissipative structure we hoped to create within our institution, and managers of the second-order effects we created. This required constant reflection and action cycles on our part. We frequently discussed the current state of the project in relation to our multi-scale goals and made adjustments to keep things moving smoothly toward those goals despite many setbacks, including the conflicting priorities of stakeholders and the disillusionment of students faced with working as part of large organization for the first time. We managed not only classroom activities, but institutional politics as well, and the outcomes, although still in flux, appear to be favourable. Most importantly, we were able to recognize when our classroom interventions were creating second-order effects in the ongoing conversation between GU Facilities and DC Water, and we learned to revise our classroom interventions to help move that conversation in the direction we wanted it to go, toward convergence on mutually agreed goals and processes.

Our reflection has enabled us to identify two unique contributions of this work. First is the notion of a using a design process to create a dissipative structure at the subsystem level, which we refer to as *radical change at manageable scale.* Formally, the purpose of this dissipative structure is to maintain energy-entropy exchange with the environment, hopefully in an on-going and sustainable way; informally, it is embodied in the tighter coupling between DC Water at GU Facilities. Second, we introduce the idea of an *instigator system*. The instigator system refers to a system created specifically with the intention of altering another system at a higher or parallel scale through second-order effects. In this case the instigator system, our course, was the vehicle for creating the higher-scale and longer-lasting dissipative structure at the departmental scale.

We define an instigator subsystem as having two characteristics:

1. It exists for a finite amount of time that is shorter than the lifespan of the system it attempts to change
2. It acts upon subsystems of which they are not a part through second-order effects.

Creating and shepherding an instigator system is an act of creating intentional change, an act of design. Specifically, it requires the in-situ management of first-order and second-order feedback loops to move a system toward convergence at a new equilibrium state. However, it doesn’t end there. The changes initiated by instigator systems are likely to be unstable themselves, with forces working against them to pull the larger system back to its former equilibrium. Maintaining these changes is likely to require additional energy and sustained effort but, if this energy is able to reorganize some components of the larger system and eventually results in a self-sustaining dissipative structure, the effort is not wasted. In fact, it has the potential to multiply its impact over institutional time-scales long after it itself dissipates.

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