Using Systems Thinking to Improve Interdisciplinary Learning Outcomes:

Reflections on a Pilot Study in Land Economics

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Abstract

Systems thinking is a tool that can be used by faculty to facilitate the exercise of integration while promoting critical thinking in the classroom, which is hypothesized to improve student learning. This paper describes a pilot study undertaken in 2003 in an undergraduate economics course. The paper reflects on the experiences incorporating the use of systems thinking to improve interdisciplinary learning from both the learner and teacher perspective.

Introduction

Many of us teaching are passionate about helping our students to cultivate an integrated view of the world so that they are able to identify linkages between themselves and the world around them, and among various elements of their community and personal lives. This notion frequently appears in university and college mission statements, in general education principles, and in many of our courses in both content and pedagogy. We aspire to teach students critical thinking and other higher order thinking skills so that they can improve their understanding of the world in which they live. Systems thinking is one such tool that can be used to facilitate this exercise of integration while promoting critical thinking in our classrooms, and thus improve student learning. This paper reflects on a pilot study incorporating the use of systems thinking to improve interdisciplinary learning in an undergraduate economics course.

Systems Thinking

What is Systems Thinking?[1]

[1] Useful general references on systems thinking include Sterman (2000), Richmond (1993, 2000) and Anderson & Johnson (1997).

Systems theory, which identifies and analyzes the linkages among various elements in a system, has been an important area of study for decades. One intellectual thread of systems theory is the field of systems thinking, which is a methodology for understanding and managing complex feedback systems, such as ones at work in business and other social systems (Forrester). An early systems model, made famous in 1972 in *Limits to Growth* (Meadows et al), emphasized the linkages between the economy and the environment; other models examine urban areas, product development, global climate change, and terrorism as systems (Sterman). Understanding the interworkings of a system is useful because it improves understanding of the outcomes of the system (why, despite diligent road-building, do we have so much traffic congestion?), and this knowledge can help those of us who see ourselves as agents of change to make better, more informed decisions about policy options, or future outcomes (do we need to widen our roads? Or will the problem solve itself when the hockey games are moved to the new stadium across town? And what would be the secondary effects of widening the roads?). While systems thinking covers much ground – Richmond (2000) describes the seven types of systems thinking as dynamic, systems-as-cause, forest, operational, closed-loop, quantitative, and scientific – the systems thinking approach as addressed in this paper centers on building theories for the causal feedback structure of a system (e.g., how does the price of timber influence the number of trees that are harvested, and how, in turn, does the harvest rate influence price?) and using the feedback theory to develop insights about the behavior over time of the system, towards the goal of improving system performance.

The primary tools of systems thinking include system mapping – stock/flow and/or causal loop diagrams – and experimentation with formal mathematical models. Much of the work of systems thinkers has been done in the quantitative fields of engineering, operations management, computer science and environmental science departments. However, the model conceptualization and experimentation (as opposed to mathematical model-building) tools of systems thinking are gaining increased attention in less quantitative applications. For example, the tools of systems thinking have been applied to Hamlet (Hopkins 1992), Alice in Wonderland (Horiuchi 2002) and to understanding the chain of events in disaster management that led to the successes and failures of emergency workers on September 11, 2001.

It is important for systems thinkers, and those learning about systems thinking, to understand that systems is plural; that is, systems theory does not presume that there is one grand system to be studied. Systems thinking is a heuristic, a tool of analysis that encourages discovery rather than a predictor of behavior. Systems thinkers thus do not produce deterministic models, but rather models that facilitate an understanding of the interworkings of systems that can help us to visualize what behavior is occurring within the system.

Figure 1 provides a causal loop diagram which illustrates this point. Specifically, this causal loop diagram depicts how population affects the amount of driving in a region, which impacts air quality (negatively), which then has a negative impact on word of mouth which tempers the attractiveness of the region, in-migration and population growth. This type of off-setting relationship is said to be a 'balancing loop,' and is labeled with a B (for balancing). In contrast, there are other factors that serve to reinforce the trend simultaneously; these are labeled with an R (for reinforcing) in the causal loop diagram. As population grows, positive word of mouth can also grow as people rave about the region to their friends and relatives; this can lead to an increase in the attractiveness to immigration and a corresponding increase in immigration, which reinforces the population growth trend.

Insert Figure 1 here

Previous Approaches to the Incorporation of Systems Thinking in the Classroom

There have been several reports of attempts to teach systems thinking in a formalized manner in both high school and college classrooms. In the late 1980s the Educational Testing Service conducted a multi-year study, the Systems Thinking and Curriculum Innovation (STACI) project, which examined the effects of using systems thinking to teach science and history content and general problem solving skills in high school classrooms (Mandinach et al 1988). Results suggest that teachers faced a learning curve when it comes to teaching systems content, and that there were qualitative but not quantitative differences in student learning in the courses. The systems students approached problems differently than students in traditional classes, but did not perform better in the courses than students in the traditional (non-systems) courses. Although students did note that they could use the tools of systems thinking to solve problems in their other classes, any spillover impact was not measured.

In the higher education setting, Felder and Soloman report on their experience teaching an interdisciplinary freshman course, “The Systems Approach to the Universe,” at North Carolina State University. Their perception was that a single three-credit course was inadequate for freshmen to adopt the formal abstract reasoning they envisioned teaching within the general systems approach, so they modified their course to reflect an emphasis on critical questioning and evaluation. Kahne (1980) offers the suggestion that all university students could benefit from being introduced to systems thinking, and provides an outline for the teaching of a two semester sequence. Bierema (2003) provides a conceptual framework for how systems thinking could be used to modify learning in medical contexts so they are more practice-based. In our study, we incorporate systems thinking into an existing course taken primarily by upper level college students.

The Pilot Study

Description of the Course and Motivation for the Project

Land Economics: The Study of Land and People (ECON 245) is an elective sophomore level course in Economics taught with an interdisciplinary focus that draws students from many majors. Historically, enrollment in Land Econ has consisted primarily of students from outside of Economics including Management, Environmental Studies, and Literature & Language, and because of its occasional offering, frequently enrolls upper division students. The course content is, as the sub-title implies, at its core about a system that links humans and a particular natural resource, land. Course readings are drawn from history, environmental studies, economics, policy and planning studies. While each offering of the course is unique, we have studied land use planning, the links between government land policy and environmental quality, and the incidence of famine, among others. A primary objective of the course is for students to understand how people, institutions, and land influence each other.

The course has historically relied on the extensive use of case studies to make linkages across disciplines. While this has been successful in some ways, the use of case studies depends largely on discussion in order to make linkages and improve student learning of the content. Not all students are auditory learners, and some students appear to have struggled to make the links in their own minds when the only 'tool' to make linkages is class discussion and related writing assignments. We hypothesized that using systems thinking to analyze land economics issues could provide a specific set of strategies for students to use which would increase the analytical rigor of our discussion of land systems. In addition, it could provide visual as well as auditory tools for students to use, in the form of causal diagrams. For example, in a land use planning case, instead of merely discussing the links between developers, policy makers, residents, and the environment, using systems theory we can model the specific relationships between these actors, map the causal linkages and direction of linkages, and thus improve our understanding of how policy affects the environment.

In the semester when this pilot study took place, the course enrolled 27 students. Most students were Environmental Studies majors (n=16) and all were upper division students. The course has a prerequisite of Principles of Microeconomics or Macroeconomics, so all students had at least one semester of exposure to economics before enrolling in the course. Several students were in their last semester at UNCA when they took the course (n=8), which may have impacted their abilities and interests in the course content and pedagogy. The course met once a week during the evening for two and a half hours in order to allow for more uninterrupted interaction with the material.

Objectives of the Pilot Study

This project had several goals for both students and faculty. The primary learning objectives for students were twofold: (1) the acquisition of a set of systems thinking tools, more specifically, causal loop and stock/flow diagramming, which students could take with them to their other courses in order to improve their learning outcomes across the curriculum, and indeed, as part of their lives; and (2) an increased understanding of the complex relationship between the actors in land economics (individual property owners, local, state, and federal government, commercial entities, and other institutions). In addition, the primary objectives for faculty were: (1) to learn an effective manner in which to teach systems thinking; (2) to gauge whether a more diverse pedagogy improves student comprehension of the course material, and (3) to investigate if systems thinking could help improve interdisciplinary learning outcomes.

Description of the Project: Course Modifications Used to Accommodate Systems Thinking in the Course

This project purposefully injected systems thinking into an existing course with the aim of improving student experiences and learning outcomes. In order to ensure student understanding of the tools of systems thinking, and to provide students with the opportunity to use systems thinking repeatedly, the course structure and content was modified in several ways. First, a collaborating instructor, Jones, was added to assist in teaching the course that Mathews had previously taught individually. Second, a unit introducing students to the idea of systems thinking was added to the course. Third, the way in which case studies are discussed changed to reflect this content and pedagogical innovation. Fourth, the course project was changed to reflect the desire that students learn and use systems thinking to help their understanding of regional land issues.

While Mathews, the regular course instructor, considers herself an interdisciplinarian at heart, and is learning systems skills incrementally, she did not have the ability to effectively *teach* systems thinking prior to this pilot study. Thus, the most significant change to the course in the pilot test was the addition of an instructor who could provide students with the appropriate background in systems thinking, and who could simultaneously teach Mathews how to teach systems thinking. Drew Jones is an expert in systems thinking from the Sustainability Institute who regularly teaches systems thinking to lay audiences. Jones and Mathews co-taught the course so that (1) Mathews could learn from Jones' methods of teaching systems thinking, and (2) students could benefit from learning the tools of systems theory from an expert in the field (Jones). An additional benefit was that learning in ECON 245 was multi-directional, which invigorated the classroom dynamics.

The course content outline was modified to include a unit on systems thinking. This included an introduction to the basic tools of systems thinking, presentation of case studies, experimentation with a systems thinking computer simulation, and opportunities for students to 'practice' with causal mapping and the like. Altogether the systems content contributed four weeks of class during a 16 week term, or roughly 25% of the content. Because we wanted students to understand some basic land economic principles before being introduced to systems thinking, the systems content began about a month into the course. The presentation of the systems content was done exclusively by Jones, and was integrated throughout the remaining months of the course. The first week's session covered an introduction to systems thinking and causal mapping, while the second session introduced stock and flow mapping and included discussion of a local case where systems thinking has been used to understand land use change (Carlson et al 2003). The third systems session focused on the case of human extinction on Easter Island (Diamond 1995) and included experimentation with a computer model of the system. The fourth systems session was focused on student project debriefing. Each group presented their model of local land use change, and other students and the instructors provided questions and comments on the draft projects.

A third significant change to the course was notable in the case study discussion. Case studies were used to introduce content both before and during the systems sessions. The first cases that were discussed by the class had accompanying questions that were provided to the students with the case and were used to guide the discussion. During the two systems cases, there were no accompanying discussion questions but rather Jones used verbal questioning to guide students through the process of thinking about what was happening in the case using a system dynamics framework. In other words, the first few cases the class discussed followed a fairly traditional case study discussion format, while the cases being used to examine the dynamics of a system did not.

Due to the fact that the course objectives had been modified to include the desire that students learn and use systems thinking to understand land issues, the course project was significantly altered from previous years where research papers or service learning were typical options. The course project was designed by Mathews and Jones collaboratively to provide students an experience using systems thinking as a way to analyze an issue and develop recommendations for improving system performance, and to help students develop insights into the dynamics of growth in a rural/urban context. Teams of three to four students were asked to examine growth trends over time in the local area, and then sketch several potential futures for local growth. Each team was to select a desired future and appropriate time horizon, then present a theory of systemic structure that explains local growth trends using causal mapping. Groups were asked to perform "policy tests" and explain how the policy impacted the dynamics of growth in the region, then select a recommended policy for achieving their desired future. Each group presented a draft of their project to debrief their status to date and gain feedback on their causal mapping, policy tests, and the like; the final project output included a class presentation and a written report.

Student Perceptions

Student Reflections on Systems

We asked students directly in an end-of-class reflection exercise several questions about the use of systems thinking in Land Economics. The first item asked if they thought that their learning of land economics was helped (or hindered) by the use of systems thinking, and invited them to provide specific examples of how this helped/hindered their learning of the content. An overwhelming majority of the class who completed the evaluation, 21 of 23 students, indicated that the use of systems thinking in the course (in general) helped improve their understanding of land economics. According to one student, *The use of systems thinking significantly enhanced my understanding of land economics. There are many different factors involved in land use and land policy that must be recognized in order to have a basic understanding. While all of these various factors were addressed without systems thinking, systems thinking helps by placing them in a more comprehensive picture.* Another student appeared to suggest that the visualization of causal mapping helped her when she said,*…it was a more clear way to explain the cause and effect of things without having to write it all out into words, you can clearly see what factors affect others*. Another student indicated, *the use of systems thinking dramatically improved and shaped my understanding of the economics of land and the connections that we have to land.* Some of the reflections also suggest some spillover effects: *For me, the use of systems thinking in this course not only helped me understand land economics, but also helped me understand many of the other subjects that I was learning about in other courses, such as mathematics and environmental science.*

Not surprisingly, the same majority of students (n=21) recommended that future offerings of Land Economics include a systems thinking component. Most of these were strong recommendations, such as *YES! YES! YES!*; *I feel like the course would not be as complete* *without the systems thinking component*; and, *YES! In fact, most UNCA classes should integrate some component of systems thinking into their course material*. Of the two students who did not recommend it be included in future offerings—the same students who indicated it neither helped nor hindered their understanding of land economics—one confessed to being indifferent as to whether it would make sense in the class. She indicated that she began to get turned off the day that the course introduced simulation modeling, and instead suggested that a separate course in systems be taught which would cover case studies from all of the liberal arts. The other student said, *I think that the other kids in the class benefited from systems thinking and I think it is applicable to this class…(but) I personally feel like I would have enjoyed and understood this class more if systems thinking was not a part of it.* This student self-identified a problem comprehending the systems material, noting specifically the jargon and causal mapping, which led her to this conclusion.

Student Reflections on Course Projects

We also asked students to reflect on whether the group project helped their understanding of land economics, and the same patterns emerged as with the first two items: most students felt the project improved their understanding of land economics. (21 of 23, or 91.3%) *The group project helped in my understanding of land economics by exemplifying how difficult it is as policy-makers to agree upon and implement effective policies. It is extremely hard to find an effective point of leverage that is ethical, that everyone can agree upon, that is politically feasible, that does not have unintended negative side-effects, etc…I think all policy makers should be trained in systems thinking as a prerequisite to their jobs.* Some student comments focused on the active components of the exercise*: This group project did help me understand* *land economics, because it was a "hands on" experience. Instead of just learning from case studies or other experiences, we were able to create our own solutions to a problem and see how land economics played into it.* When asked what specifically they learned as a result of the group project, one student replied, "it's *hard* to be a policy maker". This was particularly revealing to the instructors since it summed up the fact that the student understood the many challenges that a policy maker faces when designing a policy instrument.

Faculty Observations

Did Students Understand and Use Systems Thinking?

While we didn't have the luxury of a control group to evaluate student learning outcomes in this course, we did use multiple modes of observation collectively to gauge student learning of the systems thinking content. First, we evaluated student understanding of the tools of systems thinking through their responses on exams and their participation in class. Most students appeared able to identify and use the jargon, tools, and methods of systems thinking. They showed proficiency in reading and (in small teams) in creating their own causal loop and stock/flow diagrams. At least two students appeared to struggle with the basic elements; these students self-identified in their end of class reflections as having difficulty acquiring the basic knowledge required to fruitfully use all of the elements of systems thinking. Interestingly, because of the group nature of the final projects, and the fact that the individual exam questions specifically related to their projects or other applications of the tools of systems thinking, the students' perceived discomfort with this material did not necessarily translate into lower course grades for them. Both of the students who perceived difficulty acquiring the tools of systems thinkers were female, which raises the question of whether or not this is evidence of a gendered resistance to the content. However, given that most students in this course, 17 of 27, were women it is difficult to conclude from this experiment that this is so. Further research is necessary to determine more methodically which learners may face more difficulty in learning systems material.

Did Systems Thinking Appear to Promote Higher Order Thinking?

Bloom's taxonomy describes the hierarchy of cognitive processes, from knowledge, comprehension, application, and analysis to synthesis and evaluation (1956). The higher order activities of analysis, synthesis, and evaluation are believed to be promoted by systems thinking, and we were interested in gauging whether students were engaging in these activities. Thus we also gauged the level of classroom discussion in terms of whether we heard and saw evidence of higher order thinking, and looked for evidence of higher order thinking woven into class projects and questions on exams. As Jones was new to the course, we relied on Mathews' observations most heavily for these elements. Mathews had a benchmark from previous years of a 'typical' level of higher order thinking that was demonstrated in the class; in addition, Mathews had instructed several of the students in previous semesters and thus had some prior knowledge of many students' individual levels of higher order thinking ability.

Generally speaking, Mathews' perception was that while connections between actors and cause-effect relationships have always been important learning elements in the course, this year's offering appeared to yield more complex, intertwined—i.e., *realistic*—understandings of land-people-place systems. For example, many students could readily identify multiple possible sources of outcomes in addition to those that had been previously offered in the class through readings. During the final group presentations, students were <u>*synthesizing*</u>: they were demonstrating their knowledge of connections between seemingly unrelated policies, identifying multiple effects as a result of forcing themselves to think through problems, and thinking more globally/comprehensively than in previous semesters. In addition, their observations tended to be more dynamic than in previous offerings of the course; students were regularly identifying and using trends over time to help explain phenomenon, which ultimately helped them to identify and demonstrate trends in the effects of their policies.

The process of not only articulating but also conceptually depicting directional cause-effect flows between actors and outcomes appeared to help students with this task: *By using the loop diagrams we were able to see flaws in our policies that we otherwise probably wouldn't have seen. Specifically, we needed to draw out loop diagrams in order to see how policies were feeding the population.* Another group reported, *in systems thinking, we learned how one action leads to a separate action and can be traced through a system to find the resulting actions…these methods require one to step back and critically look at what they are doing. System thinking is a type of formal introspection for the policy maker*. A third group stated their understanding and *evaluation* this way:

> We felt that systems thinking is a tool that everyone should have access to and everyone should learn. Most important, we enjoyed the ability to tangibly, visually create a model of a seemingly non-tangible systemic structure. This allowed us to find gaps and uncover bad logic in our understanding of these structures as well as manipulate data. We saw that slightly changing one variable could, like a set of dominoes, affect all parts of the system dramatically. This tool allowed us to clarify our assumptions and beliefs, as well as make realistic changes to the system. Our world moves fast and systems thinking allowed us to understand it and break down the complexities within which we live.

Overall, it appeared as if students were able to use the tools of systems thinking in a way that enhanced their ability to think critically about land-people-place systems, which promoted higher order thinking in the class both during discussions, in written reports, and on exams.

General Observations: What We Like about Using Systems Thinking in Our Classroom

Students overall seemed to enjoy playing the role of policy maker (as noted in their comments above). From the perspective of the teacher, it was important for us that students be able to "play policy maker" in order to allow them to experience the joys and pitfalls of the real world. One of the objectives that Mathews has in all of her courses is to improve students' economic literacy; one way to do this is to allow students the opportunity to see how the discipline can be used in real-life situations. Systems thinking provided a framework for students to see how economics fits in with land use change in western North Carolina. Students were able to see the failure or success of their theories about what was driving land use change in the region and what could modify the amount of land use change; it allowed them to see economic theory come to life by allowing them to see the options available and test the outcomes of different responses.

Because of this real-life orientation, students also had the opportunity in their class project to see that their ideas are sometimes morally problematic. Several individual students and groups of students identified important challenges with ethics during their projects. *Ethics was our largest hurdle when dealing with our project. It seems that every positive action we wanted to take had negative repercussions. It seemed that every action had the potential to be unjust and unfair for some community members.* While courses frequently deal with the distributional effects of policy, the tools of systems thinking require that students identify and name the affected parties and the ways in which they are affected, which can make the distributional consequences of policy actions more visible to students.

Many college students hold the notion that research is about supporting one's beliefs, rather than asking questions. One of the components of systems thinking that we favor is that it encourages us to *test* our beliefs to evaluate whether or not they lead to the outcomes that we desire. Systems thinking teaches students to ask questions—to put policies on an idea list before modeling them—rather than picking (policy) answers that they like, which is a temptation that some students (and policy makers?) can't resist. This process of thinking before doing is extremely helpful for students when they are understanding the *how* and *why* of decision processes. By encouraging us to first choose the policy outcome that we think we wish to see realized (*What do we want to see happen? Reduce air pollution)* and then requiring us to answer this question about each policy option—*Can the model support our expected behavior, or will it lead us to an outcome opposite of that which we intend?*—systems thinking helps us to build confidence (or lack thereof) in our theories. This type of iterative critical thinking appears to be an excellent way to develop students' critical thinking skills, and emphasize the notion of inquiry.

Another related feature that we find advantageous about systems thinking is its continuous learning orientation. There is not one correct answer to a systems question, but rather an opportunity to improve our understanding of the dynamics of the system. This, in turn, implies that our understanding of the system can only improve with additional effort to understand the system. While not as neat and tidy as many students would like, this continuous learning orientation is a useful skill for the real world. In addition, it conveniently fits what colleges and universities profess to aim to teach students.

An appealing feature of the systems thinking framework is that it builds bridges across disciplines. You can't build a model of a system of land use with merely economics, for example. Thus systems thinking can be used as a tool for improving the understanding of how content areas/disciplines are linked, and has the potential to be a link for academic divisions as well (humanities, social science, natural science and math). Real life problems are interdisciplinary, thus systems thinking is a tool that can be used to help students prepare for understanding issues that they will deal with once they leave the cocoon of our campuses.

For all of the reasons above, learning and using systems thinking is empowering to students. They are asked, indeed *required*, to identify the outcomes they desire to see in the world, hypothesize ideas about how to achieve those outcomes, test them, and refine them. The student voice is particularly strong, which is challenging to some students who have not yet become comfortable with the notion of being responsible for their own learning. Since many of the seniors in this class clearly were engaged students who possessed a thirst for knowledge which they had individually identified and were actively pursuing, they were able to be invigorated by the opportunities that this course provided them to direct their learning. The combination of inquiry-based methods and self-directed learning potential that is characteristic of systems thinking may explain why not all high school students or college freshmen may be able to take advantage of the opportunities that systems thinking provides in the same way that junior and senior level students are able.

Lessons Learned: Reflections on the Pilot Study

First, we learned about *how* students *learn* systems thinking, which has implications for how systems thinking is taught to students. As we know, students have different abilities to visualize data and concepts; some of the students in our class (though a distinct minority) were aching for more math and computer modeling of systems to help improve their understanding. Somewhat predictably, these students tended to be economics majors and/or had a significant background in math or computer science. Mathews had anticipated (correctly) that most of the students who would enroll in the course would not fall into these categories, and thus had decided with Jones early on that the modeling component in this course would be minimized. However, it is clear that additional modeling would have benefited some students and would likely be important for courses which are predominated by more mathematically trained, quantitatively-oriented, and/or scientifically rigorous students.

A second message about how students learn systems thinking deals with the time it takes to acquire and hone systems thinking skills. The course project was started in October, but in retrospect it is clear that students would have benefited from an earlier start time so that they could engage in additional rounds of feedback and the ability to incorporate concepts as they learned them. As it was, students were able to present one draft of their project and get feedback on it, but there was not adequate time for a significant overhaul of a project. All groups could have benefited from another iteration in which to thoughtfully examine their hypotheses, check them against real-world data, and refine their ideas.

One strategy that we invoked and will continue to utilize in these settings is to require that each group be composed of students from different majors. In our class, most students were environmental studies majors while a minority were from economics, political science, or interdisciplinary studies. We required that each group contain at least one student who was not a major in environmental studies. We found that this was an excellent way to get groups of diverse strength and perspective, which ultimately, we believe, improved each group's ability to evaluate the region's growth dynamics.

From a curricular perspective, we also learned many things. Since learning to be a systems thinker is not natural for many of us, it may be useful in some settings to consider a two-course sequence such as that suggested by Kahne (1980). An introductory course could have as its aim to help students acquire the basic tools of systems thinking, along the lines of the Feder and Soloman (1988) course, while a second more intense course could be a semester-long opportunity to apply systems skills to a student's topic of choice. This could function as an upper-division undergraduate research seminar, either in the major or in the general education context as a capstone experience. A common theme in all of the published studies to date suggests that learning how to become a systems thinker is a gradual process. Thus it seems to naturally follow that repeated exposure to systems thinking will be necessary for a meaningful impact on students' ability to make connections between issues and events in their personal and professional lives, as well as other courses. Many of the students in our pilot study concur with this idea. While it may be a function of the somewhat retrospective view at one's undergraduate education—which many of our students could do, since they were soon graduating—eleven of 24 students indicated they thought that a separate course in systems thinking would be ideal.

As with any team-teaching endeavor, there are additional costs involved for faculty. Readings and assignments have to be decided upon, then coordinated, and regular communication is essential. In this class, the arrangement was somewhat unique in that Jones was essentially responsible for four weeks of the class instructional material but none of the grading or day-to-day communication with students (though he regularly worked with students on their projects). Mathews was the only one responsible for assigning course grades so no additional time was necessary for coordination of grading activities. However, this approach clearly had its downsides. One student reported that she "felt as if I was taking two separate classes" due to the discrete teaching styles and content in the course. While this did not appear to be a universally held view, future efforts will benefit from greater integration of content and style so that both faculty and students have a greater sense of integration within the course operation itself.

Future Directions/Other Applications/Implications

As noted above, systems thinking tends to build bridges across disciplinary lines. While we personally find this appealing, it is also appealing to those working in interdisciplinary studies, integrated studies, and general education since it could be a tool for improving student understanding of the limits of and links among individual disciplines. Our campus recently completed a review of our general education curriculum and has adopted a new model for students around the notion of clustering courses by topic. This is an exciting prospect, but it also comes with challenges about how to best yoke the content from our traditional disciplinary based courses. Systems thinking offers one tool that may facilitate the bridging and integrating that must occur if this new framework is to serve students well. Student comments seem to support this notion: *systems thinking is crucial in integrating any number of disciplines together* <u>*and*</u> *applying them to the real world. A systems thinker will look beyond his/her discipline, assumptions, and knowledge and search for a holistic view of whatever is at hand.* Another student noted, *systems thinking is not only valuable in the academic setting but in the personal setting as well. By understanding yourself and how your "personal" system works, you can better understand how the world around you operates. It's not the behavior, but the motives behind the behavior that are important—systems thinking helps you discover that.* A third student said, *as time continues to pass, the world we live in gets increasingly more complex. If today's students are to be tomorrow's policymakers, problem solvers, educators, etc then we must empower them to possess a set of skills that enables them to think about and analyze* *complex systems. They may then be able to more effectively and efficiently create solutions to the complex issues that we are increasingly faced with—systems thinking should be implemented into all majors like writing and speaking proficiencies.*

Future research on the teaching of systems thinking will benefit from a deliberate monitoring and critical examination of the potential and type of student resistance to the use of systems thinking in college classrooms. In our pilot study, only two of 23 students expressed resistance. However, there is potential for resistance based on differences in learning styles, as well as student preferences for learning outcomes with more certain processes and outcomes than systems thinking provides. While we perceive the heuristic nature of systems thinking to be a real benefit to student learning, there may be resistance by students because they may perceive that learning about systems is "more work" than learning more concrete concepts because there is no set right or wrong answer. This can yield uncertainty for students because it is an unfamiliar pedagogy, one that requires a significant level of abstract thinking about big picture issues. In addition, students may also be concerned about how these less certain outcomes will be translated into grades, especially if they are accustomed to being evaluated on outputs as opposed to process. Additional research is needed to determine what types of resistance may be encountered when teaching systems thinking, and if they are significantly impacting student learning outcomes.

Conclusion

Our pilot study on teaching systems thinking to economics students in order to integrate course content across disciplines and teach higher order thinking skills was, by many criteria, a success. Students enjoyed being able to learn how to get their heads around the dynamic interworkings of systems while faculty reveled in the higher order thinking that students demonstrated in class discussions and course projects. While this could be a random experience—the luck of the draw with the dynamic interaction of the particular group of students—our sense is that there is something to be acknowledged about the excitement that both teachers and students felt about the course.

For faculty interested in fostering a learning of integration in their classrooms, systems thinking is a pedagogical option which has tools and methods to foster integration *built in* as part of the field of inquiry. However, since most academics are trained in one discipline, our desire to teach and use the tools of systems thinking to improve student learning in our courses is complicated by the fact that most of us have been trained to *not* use a systems view. Richmond (1993) points to an additional problem that arises: systems thinking requires a learning-directed educational process, which is not yet standard in our higher education system.

Future research on the use of systems thinking in higher education classrooms should address the potential for student resistance to the tools of systems thinking, and whether or not it is feasible to measure any learning improvement from the adoption of systems thinking. Other questions that the pilot study raised include, is the use of systems thinking advantaging visual learners to the disadvantage of students with more auditory learning preferences? Would this experiment have worked as well in a Women's Studies class? We will be interested in learning the answers to all of these questions, and more, as the tool of systems thinking is adopted by other university professors and additional evidence is gathered on its benefits and risks. In the meantime, we're going to continue to use systems thinking in our classrooms because we think it can help students better understand the world—and that's our ultimate motivation for teaching.

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Figure 1: Causal Loop Diagram Showing the Relationships Between Population, Driving, Air Quality, and Word of Mouth