New Curricula for Undergraduate Food-Systems Education: A Sustainable Agriculture Education Perspective[1]

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Abstract

New undergraduate degree programs that address food systems have appeared at a number of North American universities in the past decade. These programs seek to complement established food- and agriculture-related courses of instruction with additional curricular elements that build students' capacity to address complex food-systems issues (e.g., food sustainability, security, quality, equity and justice) in the course of their work in food-related professions. Here, we examine these emerging food-systems curricula, building on our collective experiences developing food-systems degree programs at University of British Columbia, Montana State University, University of California-Davis and the University of Minnesota. We present the conceptual framework that underlies our efforts, based on the premise that our degree programs should help students build "systemic" capacities that complement disciplinary training provided by various specialization "tracks." Thus, we intend for our graduates to have a dual preparation, in both a particular specialization, and in overarching systemic capacities that enhance their ability to address complex food-system issues. We assess our current curricula in light of our framework, and outline high-priority pathways for further development of these curricula.

Introduction

Our food comes from a complex nexus of biophysical and social factors and processes. These include physical life-support systems–land, biota, water, energy–and social dimensions that include economic, political, cultural, and even emotional and spiritual aspects. On the one hand, this nexus is producing more food than ever before. On the other hand, there are many

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problems with food: troublesome patterns of consumption, scarcity and abundance, threats to the resource base supporting food production, and complex and controversial issues of equity, justice, and quality. Here we present our vision for how to apply best practices in teaching and learning theory and systems thinking to develop undergraduate curricula that address broad issues related to food production, health, and social justice. This vision is based on our collective experiences developing food-systems majors at University of British Columbia (UBC), Montana State University (MSU), University of California-Davis (UCD), and the University of Minnesota (UMN). Our majors are four-year degree programs explicitly focused on building capacities relevant to food systems *as* "wholes," and thus differ from related efforts that are more narrowly focused, e.g., on sustainable agriculture with emphasis on production. We believe our programs provide an informative sample of efforts to develop relative extensive curricula focusing on food systems *per se*, although we are well aware of relevant curriculum development at many other colleges and universities. We begin by outlining the rationale for our curricula.

To better address the food system and its strengths, weaknesses, opportunities, and threats, we propose that society must "up-scale" analysis and action to better address broader spatial-temporal scales, biophysically, socially, and conceptually (Foley et al., 2005; Jordan et al., 2007; Robertson et al., 2008). For example, expanding the scale of agricultural management to address landscapes is seen as a critically important strategy for sustaining food production. In the same vein, up-scaling of social organization by development of more extensive and effective social networks is recognized as crucial to develop a citizenry that can address global food challenges and controversial food-system issues such as equity, justice and quality. Metaphorically, up-scaling is often described as a shift in perspective–"looking up and out"–to gain understanding and new strategies for action. As well, we believe we must enable our students to "down-scale" analysis and action, by a second shift in perspective–"looking down and in"–to gain understanding of underlying processes and local mechanisms that manifest and help explain the workings of larger-scale phenomena

Consequently, we are working to create food-system curricula that will equip our students to upscale and downscale their thinking as integral parts of their quest for sustainability, equity, and resource efficiency. To do so, we have developed curricula that build relevant learning outcomes in skills, knowledge, habits of mind, and other capacities. The first and most overarching outcome is the ability to practice systemic or holistic thinking. We conceptualize systemic thinking and action as student competence in four capacities that have the potential to foster up-scaling–deep reflection, rich observation, visioning and design, and responsible participation. Each of these, we believe, is necessary to achieve effective systemic thinking and action in our students, and so we are implementing appropriate food-system curricula. Here, we present our collective vision and goals for undergraduate curricula that promote systemic thinking about food. We present the conceptual foundation for our vision, assess the current status of our curricula in relation to our goals, and identify promising pathways for further development.

Systemic and Systematic Thought and Action

Our conceptual foundation emphasizes the interplay of two forms of thought and action: the systemic and the systematic. We draw on notions of systemic thinking (ST) that emphasize interrelationships, patterns and connectedness; understanding system processes in addition to structure; and assessing how changes to one variable will impact other variables in a system (Ackoff et al., 2010; Boyatzis and Goleman, 2007; Mathews and Jones, 2008; Senge, 1994). Our key premise is that humans continually create and use simplifying mental models of the world around them (Argyris et al., 1985), often without explicit awareness of this cognitive process. Our curricula aim to help students develop their ability to consciously create such models, and to reflect critically upon them and their influence on attitudes and actions (Mezirow, 1996).

Moreover, we contend that work on complex food-system issues is strongly aided by an ability to shift between ST and so-called "systematic" thinking and inquiry (Ison, 2008). Most current curricula in food and agriculture focus on capacity to think and act systematically, in other words by using the particular rationalities and methods of a particular discipline or form of work. Systematic thought and action are carried out using a particular way of knowing–typically, one that is characteristic of a particular discipline or profession–to address relevant facets and dimensions of a situation. In our view, systemic thinking provides holistic perspectives that are essential complements to systematic thinking–e.g., a capacity to analyze "why" work and action are needed on moral and ethical grounds, resulting in enhanced abilities to work in coordination with others. We now describe our shared understanding of specific capacities that support effective ST and its integration with systematic thought and action.

Cardinal Capacities for ST (Systemic Thinking)

In order to construct the new food-system institutions that we call for above, society needs people who are prepared to inhabit and embody these institutions. To do so, our students must learn to play new or enhanced roles that integrate systemic and systematic thought and action. These include roles as innovators, storytellers, entrepreneurs, networkers and publically-engaged scholars. To play these roles, we believe that certain attributes, skills, visions and worldviews are needed, which differ markedly from those of systematic thinking. We summarize these outcomes in terms of four cardinal capacities or capabilities (Lieblein et al., 2007; Lieblein, pers. comm.); conceptually, the set of capacities is derived from the Kolb Learning Cycle (Francis et al., 2012).

Deep Reflection. A capacity for critical and constructive reflection on actions, underlying mental models, and worldviews of oneself and others, is crucially important for competent performance in new roles that involve ST and its integration with the systematic. This capacity is needed to address a fundamental and widely recognized challenge to sustainable development: the cognitive and practical capacities of individual persons, disciplines, and professions are too limited to manage complex sustainability problems (Pahl-Wostl, 2007; Pretty, 2003; Ravetz and Funtowicz, 1999). Rather, a process of intensive interaction among people in different disciplines with divergent "ways of knowing" is apparently necessary for progress (Warner, 2006; Berkes, 2007). To be most effective, such interactions appear to depend on the deep reflection we call for (Bawden, 2005; Toderi et al., 2007).

Rich Observation and Model-Making. Many important food-system issues reflect complex interactions within and between social and biophysical elements of agriculture and food production. Therefore, we call for development of a capacity for rich observation that enables students to create heuristic models of agricultural and food systems, via an inductive approach that enables collaboration with people from many disciplines in the model-building process. The creation of heuristic models involves a variety of methods for characterizing biophysical and socio-economic dimensions of eco-social systems in agriculture (Ison et al., 2007), such as mind-maps, influence diagrams, and similar techniques, soft-systems methodology, scenario planning, and simulation-based decision-support tools.

Future Visioning and Design. Design thinking is a powerful tool for integrating systemic and systematic thinking on complex and controversial issues (Nassauer and Opdam, 2008). New food systems and their relations with other societal and life-support systems must account for–and draw energy and inspiration from–the diverse priorities of myriad stakeholders. These priorities arise from divergent positions, interests, and worldviews among stakeholders. Emerging approaches to multi-stakeholder visioning and design aim to address these challenges head-on (Jordan et al., 2013); these use deliberation-based processes of planning and design (Ison et al., 2007; Pahl-Wostl and Hare, 2004) to enable multi-stakeholder groups to search for food-system designs that accommodate divergent interests, facilitate change, and achieve the goals of multiple stakeholders.

Responsible Participation. In our view, responsible participation is active and ongoing engagement in some form of collective action, regardless of the ideological motivation for such action. Engagement, in our view, includes helping to determine the practical and ethical concerns of the group, the actions that should be undertaken by the group, and how action should be taken. Responsible participation also suggests active involvement in a group's "metacognition," or learning about the group's own processes of learning, and questioning the adequacy of its knowledge and capacities.

We propose that our students will benefit greatly from the integrative practice of deep reflection, rich observation, visioning and design, and responsible participation in their future work, and that society will benefit as well. While this proposition is supported by an extensive body of evidence as noted above, the impact of our curricula on the broadest societal outcomes we seek is hypothetical, and accordingly we approach development of our curricula in the spirit of action research. Facilitating development of these cardinal capacities, systemic thinking, and the integration of systemic and systematic in our students' future working lives is, of course, a great challenge. Below we describe curricular approaches to this challenge that have been developed at our institutions.

Our Current Food-Systems Curricula

Our programs share the conceptual foundations outlined above, but vary in emphasis and implementation. Our degree programs are recently established: the Land, Food and Community curriculum at UBC has been in operation since 2000, while the others are more recent. The Sustainable Food and Bioenergy Systems major at MSU is in its 5th year of operation, the UCD Sustainable Agriculture and Food Systems major is in its 3rd year, and the UMN Food Systems major is in its first. Among our universities, 21 distinct majors or tracks within majors are offered; there are substantial commonalities and, as well, unique offerings at each location (Table 1). These courses of study illustrate the breadth

Table 1. Undergraduate majors, tracks, or options related to food systems and/or sustainable agriculture that share common systems core curricula at each of four universities in the U.S. and Canada. Note that programs at University of British Columbia are separate majors that share a common systems core curriculum; programs at other universities are concentrations or 'tracks' within a single major at each institution.

University of British Columbia	University of Minnesota	University of California, Davis	Montana State University-Bozeman
Applied Plant & Soil Sciences	Organic & Local Food Production	Agriculture & Ecology	Sustainable Crop Production
Food & the Environment	Consumers & Markets	Food & Society	Sustainable Food Systems
Food Market Analysis		Economics & Policy	
Applied Animal Biology			Sustainable Livestock Production
Global Resource Systems	Agroecoloy		Agroecoloy
Food Science			
Nutritional Sciences			
Dietetics			
Food, Nutrition & Health			
	Individualized Track		

of opportunities for systematic learning as conceptualized above; each of these courses prepares students to enter a particular field of work or to go onto advanced study, as necessary.

Our Systems Core Curricula

Each of our curricula has a "systems" core curriculum that aims to develop the capacities for systemic thought and action that we have outlined above, consisting of a sequence of four to six core courses for all majors (Table 2). The core-course sequence at each institution begins with an introductory course that provides an introduction to systemic thinking about food systems, by examining food systems as coupled human-environmental systems. This course is followed by various combinations of agroecology, holistic analysis of social, economic and ecological sustainability, epistemological awareness, awareness of alternative perspectives and problem-based learning. All programs also require either practica or capstone experiences.

Our curricula reflect a shared "theory of change" TOC). Our TOC expresses our working understanding of how and why our curricula can enable our students to integrate systemic and systematic thinking and to practice the cardinal capacities in their food-systems work. Our TOC is based on the following:

Most fundamentally, we believe that the underlying skills and understandings of systemic thought and action require development across the curriculum. It is not enough to, say, introduce the concepts in a course or two and then expect students to apply them successfully in a senior capstone project. Evaluation and critical reflection in our curricula strongly suggest the need for such an articulated curriculum (Galt et al., 2013; Rojas et al., 2012; Strachota, 2013); such curricula support cumulative systemic learning and competency development over the undergraduate years, and allow teaching and learning relationships to form between students and faculty and among students that support complex and challenging learning activities such as working in multidisciplinary groups.

Secondly, we recognize that young adult learners typically begin university at a cognitive and developmental stage that can significantly impede development of ST (Perry, 1970; Salner, 1986; West, 2004), and that certain subsequent stages of development are necessary to enable students to practice ST. In particular, development of a critical awareness of knowledge and worldviews appears fundamental to ST (Salner, 1986). Therefore, ST learning activities, if they are offered across the curriculum, must be sequenced to engage students at their current developmental stages and support development of cognitive capacities that enable ST. For example, first-year students in our curriculum at MSU have been shown to benefit from "simple" systems learning activities, including identifying their personal backgrounds and values, visiting complex situations, and beginning to envision themselves as systems thinkers in future work (Malone et al., 2013). Similarly, role-playing and service-learning activities in our curricula that promoted empathy for experiences of ethnic minorities around food, nutrition and gardening have also been shown to be helpful to lower-division undergraduates in our curricula (Galt et al., 2013; Grossman et al., 2012).

Finally, we hypothesize that bringing students who are studying different systematic disciplines together for shared ST learning activities can spur emotional engagement (e.g, via highly vivid experiential or narrative-based activities) that feeds back to enhance systematic learning. This "virtuous circle" effect could greatly enhance efficiency of learning across a curriculum (Huber and Hutchings, 2004) thus creating time and space for both systemic and systematic learning. Evaluation and reflection efforts in our curricula (Galt et al., 2012, Galt et al., 2013; Rojas et al., 2012,) strongly support this proposition, as we find that systemic learning activities increase our students' sense of agency and enthusiasm to apply their education to food-system challenges.

Across our institutions, we are further testing, evaluating and developing our TOC and core curricula. Courses in our curricula fall into five categories: introductory courses, social-systems courses, focused systemic

Table 2. Food systems core-curriculum courses at four universities in the U.S. and Canada.

University of British Columbia		University of Minnesota		University of California, Davis		Montana State University - Bozeman	
Core Course	Course Title	Core Course	Course Title	Core Course	Course Title	Core Course	Course Title
LFS 100	Introduction to Land, Food & Community	FDSY 1660	First-Year Colloquium/ Experience in Agroecocsystem Analysis	PLS 15	Inroduction to Sustainable Agriculture	SFBS 146	Introduction to Sustainable Food & Bioenergy Systems
LFS 250	Land, Food, & Community I	FDSY 2101	Plant Production Systems	CRD 20	Food Systems	SFBS 296/298	Towne's Harvest Practicum/Internship
LFS 350	Land, Food, & Community II	BBE/FDSY 3201	Sustainability of Food Systems: a Life Cycle Perspective	PLS 150	Sustainability & Agroecosystem Management	SFBS 300	Measuring Innovation in the Food System
LFS 450	Land, Food, & Community III	APEC/FDSY 3202	An Introduction to the Food System: Analysis, Management & Design	ARE 121	Economics of Agricultural Sustainability	SFBS/ANSC 498	Internship
		FDSY 4101	Holistic Approaches to Improving Food Systems Sustainability	ESP 191 A&B	Senior Capstone - Workshop on food System Sustainability	SFBS 491	Food System Resilience, Vulnerability & Transformation
						SFBS 499	SFBS Capstone

courses, practica and capstone courses. We review each of these, identifying where and how cardinal capacities are addressed, and instances where systemic and systematic thinking and action are integrated.

Introductory Courses. These courses strive to establish a conception of food as the outcome of coupled human-environment systems. All explore food production in its social context, typically through topical case studies, e.g., of urban agriculture or competition between agriculture and other sectors for water. The UBC introductory sequence (LFS 250 and 350) strongly emphasizes social factors, e.g, exploring biophysical aspects of food, from production to waste recovery in social context and in particular, via community-engaged learning in the Vancouver region, while emphasizing observation and model-building.

Social-Systems Courses. These courses also aim to establish a conception of food as the outcome of coupled human-environment systems, but center on social factors, including, e.g., economic, historic, geographic and cultural. These courses build skill in observation and model-making, but also strongly emphasize reflection. The UCD course (CRD 20) promotes development of new mental models of food systems, critical reflection on knowledge, premises, and values related to food and society, and heightened capacity for self-awareness (Galt et al., 2013). The UMN course (FDSY 3202) explicitly introduces systemic-thinking methods, and then applies these to build student observation and model-making abilities. The UBC course (LFS 250) presents a conceptual framework, termed “ecology of knowledge” that is used to promote reflection, observation and model-making around forms of knowledge, personal and collective experience, and participation in collective action and learning. All of these courses have strong community-engaged learning elements, using these experiences in observation and participation to complement in-class examination of reflective case studies and to provoke deep reflection. This could be combined/shortened.

Courses Developing Other Systemic Perspectives. These aim to build particular aspects of the cardinal capacities by a specific focus on some particular systemic perspectives on food. They include a UMN course (FDSY 3201) that examines food from global perspectives, including processes of production, distribution, preparation, consumption, and the effects of these for human health and environmental quality. This course thus builds students’ abilities to ‘look up and around’ to perceive factors of the broader biophysical and social environments that affect food. Other examples include two courses in the MSU curriculum (SBFS 300 and 491), which, respectively, examine the nature of innovation related to food, and the resilience of food systems. In addition to supporting observation and model-making, these courses emphasize design and visioning and responsible participation.

Practice-based Learning Experiences. As with the capstone courses, practica on farms or internships in food-systems organizations are designed to provide experiential education opportunities for students and transferrable skills for future employment. These experiences challenge students to practice systematic skills related to their chosen profession and livelihood, while also engaging students in systemic thought and action, e.g., via civically-engaged learning situations that build capacity for responsible participation. More broadly, such experiences provoke synthesis of a wide range of knowledge, and heighten awareness of roles and values that may be operating in a situation, e.g., social justice issues (Niewolny et al., 2012). For instance, such insights are often observed in experiences where students must provide leadership to a public audience or organization, e.g., groups of under-served youth (Grossman et al., 2012). Practica that provide international food-systems experiences provide opportunities to apply and develop systematic skills while observing and reflecting on culture and context in food systems (Schroder et al., 2011).

Capstone Courses. To integrate and enhance systemic and systematic skills and understandings of final-year students, all curricula require a “capstone” course. The intent of these courses is to provide intense, integrative experiential learning that draws on previous systematic and systemic coursework, thus helping to prepare students to engage in creating or transforming food systems via up-scaling, down-scaling and the integration of systemic and systematic thought and action.

These courses jointly enroll students trained in a wide range of systematic tracks, challenging students to engage in methodological pluralism. All of the courses confront real-world problems and opportunities related to food, through engagement on- or off-campus. Each emphasizes rich observation, via characterizing problems/opportunities in systemic terms. For example, the UBC and UMN courses use critical reading of literature to support rich observation done in community; the MSU course features planning, site visits and data collection; the UCD course integrates the inquiry methods of a range of disciplines. In varying measures, these courses also feature other capacities. These include critical reflection: both UBC and UMN courses call on students to develop narratives of their personal experiences with food, while the UCD course asks students to assess the range of sustainability-related values that are perceived by different actors in a situation (Galt et al., 2012). All courses call for some level of design and visioning, in the form of creation of action plans, conceptual models, or a shared vision for improving the sustainability of food at UBC. As well, all courses involve responsible participation, via extensive interactions with a range of workers and participants in food systems, involving discussions, presentations, coalition building and other forms of civic engagement.

These capstone-course activities are relatively challenging and sophisticated tasks. Within the bounds of a single semester, it is unlikely that students can practice all of them deeply, nor consider their integration, and the broader issue of how these systemic capacities stand in relationship to the systematic knowledge and capacities that are also engaged in these capstone experiences. Therefore, we are striving to increase relevant learning opportunities in earlier parts of the systems core curriculum, prior to the capstone experience.

Challenges for Our Curricula. Our current curricula face a range of challenges. Among the capacities that we seek for our students, our current core curricula most strongly emphasize development of observation/model-making. Development of other capacities and practice in the integration of systemic and systematic thought/action receive considerably less emphasis in most of our curricula. The UBC curriculum, which is the longest-established of our programs, incorporates the broadest range of systemic learning activities and these activities occur and recur across the core curriculum. Thus the UBC program is the most comprehensive in pursuit of our TOC. However, it has been implemented in a cultural and institutional setting that is significantly different from our other programs, which are all situated in US 1862-Land Grant universities.

At present, our curricula emphasize a narrow range of approaches to ST and, more broadly, holism. Currently, we focus on approaches developed by pioneers such as Churchman, Checkland, Bawden and Ison. Other methods, e.g., the "thinking with hands" emphasized in design disciplines, or visualization and visual thinking are much less prominent in our curricula. Accordingly, our curricula may be effective for only a narrow range of 'thinking and doing' types.

Community-engaged learning (CEL) has many difficult aspects, but is essential to our curricula. Essentially, CEL is a pedagogical strategy in which students engage in community service to address public needs while simultaneously developing disciplinary competency (Rhodes and Davis, 2001). We believe that CEL helps to build all of the cardinal capacities that we seek for our students. However, CEL is time-consuming for all parties, particularly when it involves "one-off" arrangements that require all parties to negotiate terms and arrangements anew with each new semester. CEL experiences have a large affective component; on the one hand, students may feel inadequate; on the other hand, community members may feel powerless as partners with university; these dimensions need to be recognized and addressed or learning may be undermined for many students. Accordingly, there is a need for staged and scaffolded CEL, especially when lines of difference between students and community must be navigated. Finally, CEL carries some risk of exploitation for all participants. Several of our programs are attempting to develop and maintain lasting partnerships with civil society as settings for articulated and sequenced CEL; these partnerships have potential to reduce transaction costs of service learning, and improve the value of these activities for all parties.

Many of our students are primarily oriented to natural sciences and/or are strongly "practically-minded." In our experience, such students can be highly challenged by open-ended, creativity-focused learning activities that are more common in design and artistic disciplines and which are important to ST learning (Strachota, 2013).

It is unclear how to balance "content" in the core curriculum with "capacity" building around the cardinal capacities, particularly in the introductory courses, in which the learning activities that students encounter are quite unfamiliar, e.g., design/visioning activities. The nature and significance of potential trade-offs between systematic and systemic learning are not well understood.

We are unsure how to evaluate development of the capacities we seek for our students. Evaluation methods are needed for, e.g., capacity to design and envision, or empathic appreciation of worldviews that differ from one's own; and the integration of affective and analytical aspects of learning. These methods need to be both effective and practical. For example, for both of those reasons, peer evaluation is likely to be important to building critical self-awareness of the cardinal capacities.

An important rationale for our programs is to provide skills and capacities that are now sought by many employers. In many surveys, employers say that they seek students who are excellent communicators, lifelong learners, skillful cross-disciplinary collaborators, unafraid to go into unfamiliar disciplinary and social environments, etc. Our curricula aim to develop such skills and capacities in forms and levels that are useful in professional practice, but do they succeed? What tradeoffs with other learning goals may exist?

Pathways for Program Enhancement

To address these challenges and work toward our shared goals, we are taking a stance of collective reflection and learning. We believe that priority should be given to the following practices, which we propose as key pathways for development. These pathways are: using narrative pedagogy across the curriculum; using simulation to develop ST; and employing design thinking as a fundamental vehicle for ST. Each pathway is presently implemented to some degree in our current curricula. However, we believe that significant potential exists for expansion and enhancement.

Using Narrative Pedagogy in Food Systems Education. Storytelling is one of the earliest known methods for communicating about new discoveries (Haigh and Hardy, 2011) and provides a powerful form of communication for learning in higher education (Lindesmith, 1994). Narratives can increase student motivation for learning and engagement with unfamiliar subject areas, encourage student responsibility as co-creators of knowledge, and contribute to effective leadership development as stories can help build trust and provide inspiration. When students make contextual links with academic material, it becomes more relevant and accessible. The classroom becomes a more cooperative learning environment, as there are opportunities for collective interpretation and deep reflection, group participation, and teamwork. Relationships among learners and between students and teachers can improve (Haigh and Hardy 2011; Ironside 2003; Lindesmith, 1994; Miley, 2009). As well, stories can improve oral and written communication skills and enhance listening and critical thinking skills (Lindesmith, 1994; Miley, 2009).

Simulation as an Experiential Learning Activity. Food, agriculture and interrelated resources (water, land energy) are complex and simulation can help with understanding them. ST is not just the ability to conceptualize a system boundary, list components, or identify links between system components. ST thinking requires an appreciation that components interact to determine system level outcomes (Jacobson and Wilensky, 2006), and an interest in understanding these interactions and outcomes. Simulation models in a food-systems core curriculum aim to help students build understanding of key goals, components and their interactions, and of resulting system behavior over time and/or space. Various software have been developed to facilitate visualization of complex systems that can include social, economic and agroecological interactions, e.g., NetLogo (Gkiolmas et al., 2013, Jacobson and Wilensky, 2006).

Learning activities based on simulation must be guided with questions that prompt students to actively engage with simulations. These experiences reveal how system components interact, how human goals influence interactions and outcomes, and responses to perturbations and stress. Gkiolmas et al. (2013) conclude that active interaction with a simulation is helpful to students who have limited understanding of core systems concepts. For example, simulations can examine the resilience of alternate food systems that are designed with different goals (e.g., economic outcomes or energy conservation). Through experiments and trial and error, students can look for patterns in system behavior, ideally guided by expectations and intuitions articulated before simulation.

Learning through simulations is a form of experiential learning and requires critical reflection on experience, and we believe that simulation can strongly support development of several cardinal capacities. First, we expect that students' capacity for reflection on experience will be expanded by encountering archetypal system behaviors (e.g., reinforcing and stabilizing feedback, emergence); awareness of these phenomena is likely to transform how previous experience is understood and interpreted. Second, we believe that capacity for rich observation is likely to be heightened by simulation experiences. Specifically, if students are mindful of the conditions that create strong feedback, we propose that their attention is more likely to be drawn to interactions and the structure of relationships in a situation. Finally, we propose that capacity for design and vision is likely to be expanded by experience with simulation. For example, we expect that awareness of the dynamic behavior of systems will heighten appreciation of the need for designs that are robust to extreme situations.

Design Thinking. The use of "design thinking" (DT)–i.e., cognitive and creative activities typical of design professions by persons and groups that are not credentialed as "designers"–is becoming recognized as a powerful tool for addressing complex challenges. As discussed above, design and visioning is a cardinal capacity for ST, and we view design thinking (DT) as the most concrete and accessible vehicle for design and visioning. More broadly, we believe that a capacity to engage in DT can guide and inform the systematic practice of any food-related discipline or profession. DT is typically practiced via a sequence of activities termed empathizing, problem identification, idea formulation, prototyping and testing. Particularly when practiced by a group, the initial stages of DT are intrinsically systemic, as they probe for empathic understanding of the experiences of those affected in a situation, and consciously seek multiple framings of problematic aspects and possible responses to those aspects. DT is also intrinsically systemic because it widens cognition, encouraging the application of cognitive modes (e.g., "visual thinking," "thinking with your hands") that are seldom active in systematic approaches to food issues. We emphasize that our curriculum does not seek to develop designers in the traditional sense; rather DT is an accessible yet powerful "habit of mind" that we believe is foundational to systemic thinking. DT may be highly valuable for the development of applied systemic thinking in first-year students; it has been successfully used by first-year university students in engineering (Dym et al., 2005),. In addition, it can be brought to bear as a toolset to be applied when needed throughout the curriculum. Two directions may be taken for curricular integration. First, DT may be introduced in immersive skill-building workshops for first-year students. As well, DT can be inserted/integrated into specific courses throughout the curriculum whenever these are project-based and involve creating future designs/scenarios. In such applications, students are supported as they move among the various DT stages of empathizing, problem identification, idea formulation, prototyping and testing, as applied to particular challenges or opportunities in food systems, e.g., "food hubs" or community gardens that would be more accessible to low-income families (Grossman et al., 2012). Given the unfamiliarity of such cognitive and practical activities, students require coaching and feedback as they move through multiple iterations of the DT process (Razzouk and Shute, 2012).

Conclusion

Here we report on the benefits that can result from the application of ST in food and agricultural curricula, by drawing on experiences and co-learning activities of four universities with existing food systems programs. Our wish for our students is to provide them with solid preparation to address complex food-systems issues in a knowledgeable, just, and empathetic manner. Facing daunting global challenges to our current systems of production, distribution, access and consumption of food, it is critical that society develops food-system professionals who can be both systemic as well as systematic thinkers within their chosen discipline or profession. Of course, such integrative professional practice–e.g, the notion of civic agriculture envisioned by Lyson and Barham (1998)–is the work of a lifetime. However, solid preparation for such work will only come via the intentional design of educational programs that allow them to practice new cognitive, affective, and practical abilities in a safe environment. We propose that integration of ST learning in an integrative core curriculum, anchored in experiential and community-based learning, can provide such preparation. Our collaborative intends to test this proposition through a shared program of curricular experimentation, rigorous assessment of results, and critical reflection. We believe that our collaborative approach is essential to develop new curricula in food-systems and agricultural education at a time when "venture capital" is in scarce supply in higher education.

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