frontiers in Sustainable Food Systems

ORIGINAL RESEARCH
published: 29 September 2020
doi: 10.3389/fsufs.2020.568743

Co-design of Adaptable Learning Outcomes for Sustainable Food Systems Undergraduate Education

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Specialty section:
This article was submitted to Social Movements, Institutions and Governance, a section of the journal Frontiers in Sustainable Food Systems

Received: *02 June 2020*
Accepted: *26 August 2020*
Published: *29 September 2020*

Citation:
Ebel R, Ahmed S, Valley W, Jordan N, Grossman J, Byker Shanks C, Stein M, Rogers M and Dring C (2020) Co-design of Adaptable Learning Outcomes for Sustainable Food Systems Undergraduate Education. Front. Sustain. Food Syst. 4:568743. doi: 10.3389/fsufs.2020.568743

Higher education institutions are increasingly offering Sustainable Food Systems (SFS) degree programs in response to societal demand for training a professional food systems workforce. As a relatively young field, there is a need for clearly articulated learning outcomes (LOs) for SFS education to define student learning through degree programs, design new programs, and evaluate and modify existing programs. New and established SFS programs are often fragmented over multiple academic departments which impedes the development of a coherent and holistic curriculum for approaching the complexity of food topics. Here, we address these needs through the co-creation of adaptable LOs for Baccalaureate degree-level SFS programs which are aligned to a SFS Signature Pedagogy and based on outcomes-based education toward contributing to a solid conceptual basis for SFS education. The SFS Signature Pedagogy is a framework that can be applied to develop students' systemic capacities, including holistic, and pluralistic ways of understanding sustainability challenges, multi-, inter- and trans-disciplinarity, experiential learning, and collective action projects. Our co-design of LOs was based on qualitative content analysis of existing LOs of established SFS programs, a cross-sectional survey with SFS educators and refinement of LOs from feedback in an expert panel. This process resulted in the eight adaptable LOs: (1) systems thinking, (2) critical reflection, (3) diverse ways of knowing, (4) practical application, (5) multi-context communication, (6) teamwork, (7) collective action, and, (8) advocacy for SFS. We anticipate the adaptable LOs proposed here to be applicable for diverse student communities and geographic respectively cultural contexts as well as to provide insight for sustainability-related academic programs toward developing professionals equipped with skills and capacities to address complex challenges.

Keywords: sustainable food systems professionals, curriculum development (education), curriculum assessment, collective action, systems thinking and application, co-design, outcome-based education (OBE), sustainable food systems education

INTRODUCTION

Overview of Sustainable Food Systems (SFS) Education

One of the greatest societal challenges of our times is to nourish a growing population with healthy food procured in ways that support environmental and human well-being (Tilman and Clark, 2014; Mason and Lang, 2017). While food nourishes us, food systems are a leading driver of environmental degradation (Meybeck and Gitz, 2017) and global change (Willett et al., 2019). Diet-related health conditions present one of the greatest global burdens of disease (Swinburn et al., 2019) and inequities persist from farm to table (Breggin and Myers, 2013). Several planetary boundaries of environmental thresholds recognized as safe operating spaces for humanity have already been crossed including a dramatic rate of biodiversity loss and notable changes to the global nitrogen cycle (Steffen et al., 2015). The environmental challenges associated with food systems are depleting the natural resource base upon which food and well-being depend (Foley et al., 2005; Francis et al., 2008; Gerber et al., 2013; Steffen et al., 2015). Malnutrition including obesity, undernutrition, and their coexistence, impacts every country and is a leading cause of death globally (Afshin et al., 2019). Concurrently, interacting political, market, and population factors create inequity and other food justice issues (Breggin and Myers, 2013). Climate change exacerbates these food system challenges (Willett et al., 2019). Addressing the complexity of these interconnected challenges requires engaged professionals equipped with skills beyond conventional disciplinary training in food, nutrition, and agriculture, which often approach each issue separately (Valley et al., 2018). Additionally, food system studies take into account the unique relationship between food and the human experience from a variety of perspectives lending an interdisciplinary aspect to this field that differs from more disciplinary approaches taken by food-related areas of study (Almerico, 2014).

In response to societal demand for more interdisciplinary programs, higher education institutions, including private and public colleges, universities, and polytechnics, are increasingly offering sustainable food systems (SFS) and similar degree programs. However, despite the need for enhanced interdisciplinarity in programs and classes, many courses of interdisciplinary programs remain housed in traditionally defined disciplinary departments (Cargill, 2005). In addition, there is often an expectation of faculty to develop new courses and programs that are interdisciplinary with little institutional resources or support. This lack of resource support for the design of interdisciplinary programs and courses contributes to structural and economic "siloing" of SFS and similar programs, which precludes the creation of programs that facilitate education across disciplines (Hamada et al., 2015). To overcome resource limitations as well as to strengthen the field of SFS education based on a solid conceptual basis, collaborations across SFS programs to develop curriculum is critical.

While differing in their curriculum, SFS programs are characterized by an underlying conceptual framework to build students' systemic capacities that complement disciplinary training in food and agriculture topics (Jordan et al., 2014). These systemic capacities include deep reflection, rich observation and model-making, future visioning and design, and responsible participation (Jordan et al., 2014). More recently, a SFS Education Signature Pedagogy (SFSESP) has been identified to advance SFS education by providing a guiding framework to develop and evaluate curriculum of SFS programs (Valley et al., 2018).

To transform frameworks such as the SFSESP into curricula that meet societal and professional needs, outcome-based education (OBE) has been advanced over the past five decades (Harden, 2001, 2002). The establishment of clearly articulated program learning outcomes (LOs) is an essential requirement for OBE (Spady, 1994). While LOs presently exist in numerous SFS programs, they differ in number, approach, emphasis, and style (see **Appendix 1** for examples). It is also unclear to what extent these LOs align with the SFSESP, especially since most programs evolved independently from this framework. Thus, we identified the need for LOs aligned to the SFSESP as building blocks for the development and assessment of SFS curricula. The purpose of this paper is to draw from an OBE model to co-design and propose a set of LOs for Baccalaureate degree-level SFS programs aligned to the SFSESP that can be adopted and modified in diverse educational and institutional contexts. The LOs presented here are intended to adaptable to diverse geographic and cultural contexts and for akin programs including Food Networks, Urban Food Systems, Ocean Food Systems, Food Studies, Sustainable Food and Farming, Agricultural and Food Systems, certain Agroecology programs, Community Food Systems, Sustainable Community Development, Indigenous Food-Energy-Water Systems, Eco-Gastronomy, certain Nutrition, Gastronomy, and Food Culture programs, Food Systems Management, Food Security, Food Sovereignty, Hunger Studies, as well as several Environmental, and Sustainability Studies programs.

The co-design of adaptable LOs for SFS undergraduate curricula was led by faculty ($n = 6$) and staff ($n = 3$) of three SFS programs in North America (Montana State University, University of Minnesota, and University of British Columbia). It proceeded in the following steps: a qualitative content analysis of the LOs of selected SFS programs; a survey on SFS LOs with SFS educators; and an internal review panel ($n = 8$) for the final refinement of the LOs aligned to the SFSESP.

Sustainable Food Systems Signature Pedagogy

A signature pedagogy serves as a framework in which future practitioners of a specific field are educated for their profession (Shulman, 2005; Gurung et al., 2009). It is applied across higher education institutions to align programs based on philosophies of education such as experiential and social constructivist learning (Kolb, 1984; Palincsar, 1998), and more specifically Lieblein et al. (2007) dual learning ladder toward responsible action and transformative food systems education (Galt et al., 2013), teaching practices, and LOs. Educators and students can benefit from a clearly articulated signature pedagogy of a specific field by understanding its pedagogical foundations

as well as accepted methodological approaches for developing professional capacities (Valley et al., 2018). A leading framework for organizing a signature pedagogy is based on three structural levels: (1) surface structure of visible operational acts of teaching and learning; (2) deep structure of the essential theories, concepts, and capacities for professional practice in a field, and (3) the implicit structure, comprising the set of professional attitudes, values, and dispositions of a field (Shulman, 2005).

The SFS Signature Pedagogy was developed by SFS educators from four different institutions in the US and Canada and first presented to the public in 2017 in the journal article "An emerging signature pedagogy for sustainable food systems education" (Valley et al., 2018). The article has been cited 33 times between March 2017 and July 2020. The framework was also presented at five scholarly conferences since 2017. Each component of the SFSESP exists at one of the three structural levels of a signature pedagogy (Shulman, 2005) and interacts with each other. The surface level of learning contexts and activities of the SFS Signature Pedagogy caters to multiple learning styles essential for designing inclusive curriculum which accounts for students' educational, cultural, and social background and experience (Smith, 2002). This includes contexts from classrooms to laboratory and community settings, and from individual assignments to co-producing solutions. This range of context and activities provides opportunities for students to adapt to different settings.

The deep structure of the SFS Signature Pedagogy proposed by Valley et al. (2018) consists of four principal elements:

1. Pedagogy of systemic thinking: to develop the ability to understand food systems through holistic and pluralistic approaches. Systemic thinking requires the capacity to identify the boundaries, components, and interactions within a system, as well as how different stakeholders value, define, and experience systems.
2. Pedagogy of experiential learning: to build a particular form of professionalism, here defined as capacities for thought, performance, and action with integrity (Shulman, 2005). This pedagogy is primarily based on experiential learning that features integrated engagement of "heart, head, and hands"; this 3-fold integration of engagement is considered essential to building capacity for thought and action with integrity in ethical and moral terms.
3. Pedagogy of multi-, inter-, and trans-disciplinary learning: to develop capacities to participate in the process of understanding complex situations with diverse academic stakeholders and other social actors in the food system.
4. Pedagogy of open-ended case inquiry: to develop the capacity for dealing with the uncertainty and dynamism that are characteristic of complex issues and opportunities in SFS. In particular, such inquiry aims to develop one of the most crucial aspects of SFS professionalism, namely, the ability to make judgments under uncertainty.

The implicit structure of the SFS Signature Pedagogy consists of three elements:

1. Collective Action: acknowledging the limitations of singular, uncoordinated efforts to instigate systemic change in a complex system.
2. Critical Reflection: requiring a habit of mind that recognizes historical and current power differentials within society and their resulting uneven distribution of benefits and harms related to food systems.
3. Seeking Balance: recognizing the tensions and trade-offs inherent to any intervention in a complex system, and being mindful of the potential negative consequences associated with maximizing for any one outcome in food systems (Valley et al., 2018).

Outcome-Based Education

Outcome-based Education (OBE) develops a curriculum around an explicit set of program learning outcomes (LOs) identified as critical for all students to achieve by the end of their experiences in a program (Spady, 1994; Harden, 2002). Prior to the emergence of OBE, statements regarding students' learning expectations were generally not included in program documents. Early proponents of OBE in higher education were in the medical field and argued that language clarifying student learning expectations is a catalyst to keep up with changing societal needs (Jessup, 2002). As a learning-centered curriculum approach, OBE focuses on what students know and can do, as compared to a teacher-centered model emphasizing what is presented (Tam, 2014). By aligning courses with clearly stated measurable LOs, OBE improves curriculum consistency and strengthens curriculum accountability (Spady, 1994).

Program LOs are fundamental for OBE. Some authors define them as what students know, are able to do, or are like after college education as a result of specific teaching and learning experiences (Killen, 2000; Tam, 2014). Contemporary definitions emphasize that LOs should be precise and measurable and achievable for all students during college (Spady, 1994; Hartel and Foegeding, 2004). The most frequently used definition is Spady (1994), who defines LOs as "the ability to demonstrate learning that matters." Accordingly, LOs (framed using action verbs) are not values, beliefs, or states of mind, neither approaches, means, strategies, or processes but skills, knowledge and professional attitudes. Educators can apply LOs to guide curriculum mapping, curriculum design, instruction, and assessment (Spady, 1994; Harden, 2002; Hartel and Foegeding, 2004; Frank and Danoff, 2007). Proponents of OBE highlight that the use of LOs provides students and the professional sector transparent and clear expectations about a program (Harden, 2002; Tam, 2014).

There is sometimes confusion between the term LO and the partially overlapping (depending on the school of thought and authors of each framework) concepts of learning objectives and student competencies. Hartel and Foegeding (2004) clarify that learning objectives are general statements about the larger goals of a course or program, while LOs describe specific student skills. Competencies are statements that broadly indicate the desired skills of students after graduating. Different from PLOs, competencies are acquired by students or graduates, rather than by the program and its instructors (Morcke et al., 2013).

Although there are underlying differences between outcome- and competency-based education frameworks, when referring to the point of graduation, similar descriptors can be used for LOs and competencies (Cumming et al., 2007), although achieving a single competency may require a graduate to meet several LOs. The organic incorporation of the SFSESP in SFS curricula we expect from the use of LOs would also be accomplishable using a competency-based education framework. We opted for OBE as a vehicle to implement the SFSESP because it is currently more common in higher education curriculum design and assessment than competency-based approaches.

While various SFS programs have developed LOs (**Appendix 1**), implementable LOs are needed to provide foundational building blocks for the improvement of existing SFS programs and for allowing new programs to have a foundation from which to draw. A set of shared and adaptable LOs contributes to strengthening the way SFS curriculum is developed and assessed. Clearly defined LOs also allow employers and food system stakeholders to better understand the attitudes, skills, and knowledge of a growing professional workforce with a SFS degree.

METHODS

We developed the adaptable LOs for sustainable food systems (SFS) undergraduate curricula in three steps: (1) qualitative content analysis of the LOs of selected SFS programs, (2) cross-sectional online surveying of SFS education experts (faculty and graduate students), and (3) final framing of adaptable LOs based on an expert panel and iteration.

Content Analysis of SFS Program Learning Outcomes

We analyzed the LOs of undergraduate SFS programs in the U.S. and Canada which were selected on the basis of the following criteria: (1) the program name includes the term "food systems"; (2) SFS is available as a major or minor at undergraduate (BSc or equivalent) level; (3) the program has explicit LOs framed in the context of outcomes-based education (Spady, 1994), (4) the LOs are published by the respective institution. A total of 43 undergraduate SFS programs were evaluated for the aforementioned criteria and the following five programs were selected as they best met this existence of published LOs in OBE style.

- Sustainable Food and Bioenergy Systems, Montana State University
- Food Systems, University of Minnesota Twin Cities
- Land and Food Systems, University of British Columbia
- Sustainable Agriculture and Food Systems, University of California Davis
- Sustainable Agriculture and Food Systems, University of Rhode Island

For the five selected SFS undergraduate programs, we carried out a content analysis of the published LOs to identify the skills, knowledge, and attitudes that students are expected to acquire and develop during their degree programs (Kuckartz, 2014). While we used a qualitative approach to content analysis, we quantified the results of this analysis including the prevalence of specific themes. Our content analysis was led by the following research question: *What are common and overlapping student skills, attitudes, and knowledge determination relevant to the students' ability to examine and address complex food systems challenges in undergraduate sustainable food systems program Learning Outcomes?* The coding process was facilitated by the qualitative software NVivo 12 and conducted in two steps: (1) An initial directed content analysis based on predetermined key variables as preliminary coding categories, and (2) a refined analysis using coding themes that emerged during the first step (Leech and Onwuegbuzie, 2011; Saldaña, 2015). In both steps, we split the LOs into meaning units (Kuckartz, 2014) and coded each unit. Occasionally, one meaning unit was coded to multiple themes.

The coding scheme for the initial process consisted of the four deep and three implicit components of the SFSESP (see Introduction). Any content that could not be categorized with the initial scheme was categorized as "Other." We calculated the frequency of meaning units as a percentage of total meaning units to identify extensive or underrepresented codes (**Appendix 2**).

In the second step, we grouped meaning units into categories and coded them along these categories. "Collective action" and "Critical reflection" were identified as extensive categories, and we established subcategories. "Self-reflection" was considered underrepresented and became a subcategory of "Critical reflection." The category "Open-ended case inquiry" was renamed to "Food system assessment." The same occurred with "Experiential learning" which was renamed to "Practical skills." We merged the categories "Food system assessment" and "Collective action" under the title "Civic engagement" since they shared over 30% of meaning units. The remaining uncategorized meaning units were coded to determine whether they represented a new category or subcategory of one already existing code. They were divided into "Communication skills" (two subcategories), "Attitudes," and "Knowledge." After coding, we identified 46 condensed meaning units grouped into eight categories, three of which were divided into subcategories. Six categories were related to skills, one to knowledge, and one to attitudes (**Appendix 3**).

Surveys to Identify Priority Adaptable SFS Program Learning Outcomes

We conducted surveys with SFS educators in Canada and the United States to identify priority LOs for SFS undergraduate programs. The surveyed educators have disciplinary and interdisciplinary expertise in various aspects of SFS and in interacting with stakeholders. A cross-sectional online survey was administered in two steps. First, educators associated with a SFS education project led by members of this paper were surveyed ($n = 31$; 25 faculty, 1 post-doc, and 5 graduate students; 28 responses). Second, we reached out to experienced SFS instructors outside the project-scope, teaching at 14 different institutes of higher education in North America ($n = 37$; all faculty; 17 responses). The survey responses were voluntary and

anonymous. Upon completion, a $15 gift card was provided as an incentive for participation in the survey that was provided to educators outside of the project team.

For the questionnaire, all 46 meaning units obtained in the content analysis were framed as LOs. Their style was aligned to the recommendation of Hartel and Foegeding (2004), meeting the criteria of being specific, measurable, achievable for all students, realistic, and time-bound. In our understanding, specific and measurable mean that LOs are assessable and provide a guideline for the development of assignments to objectively measure the students' mastering of these LOs. Consequently, our LOs involve skills expressed by an action verb such as "demonstrates" or "analyzes." We avoid verbs like "understands" or "appreciates," which could not be objectively assessed. We intended to be as specific as possible with the framing of our LOs given the interdisciplinary nature of SFSE. "Achievable for all students" means for us that meeting a certain LO does not privilege a specific group of students or discriminate against another one. Finally, "realistic" and "time-bound" LOs are, in our understanding, achievable based on what a SFS curriculum offers to students and the regular duration of the respective program. Thus, mastering a LO refers to what can be expected from an undergraduate student after graduation. It does not mean perfection.

All LO suggestions in our surveys began with "Upon graduating, students will be able to," followed by an action verb. For example, the meaning unit "Systems approach" was framed "Analyze complex problems using a systems approach." On three occasions, one meaning unit was presented in optional versions differing in terms of style and emphasis. The questionnaire involved multiple-choice questions and a Likert-scale ranking. In the latter section, participants were asked to rate the significance of each LO on a scale from 0 (not relevant for SFS curricula) to 10 (indispensable). The multiple-choice questions served to select one prevailing theme per LO. Therefore, the categories and subcategories from the qualitative analysis were converted into survey questions and the corresponding meaning units were the choice options. Example:

Question: "Please select the most appropriate framing of a learning outcome about systems thinking!"

- Answer (Option 1): "The student analyzes complex problems using a systems approach."
- Answer (Option 2): "Using a systems approach, the student compares and assesses alternative models for food system change."

Final Framing of Adaptable Program Learning Outcomes

In this step, an internal project panel comprised of eight instructors in the fields of SFS, education, agriculture, food, and nutrition, all authors of this article, interpreted the survey results, selecting those options with the highest approval rate and synthesizing certain content where the approval for different options was equal. The panel framed the final set of LOs as building blocks for the substantial systemic capacities that we hope our graduates will develop. This occurred through a focus-group workshop followed by a series of iteration through correspondence and conference calls. In this context, we integrated the LOs "Food system assessment" into "Collective action," "Self-reflection" into "Critical reflection." We renamed "Research skills" to "Diverse ways of knowing," "Communication skills" to "Multi-context communication," and "Professional attitude" to "Advocacy." Due to our emphasis on developing student skills such as collective action (Valley et al., 2018), we decided to process "Knowledge" as a requirement for achieving our LOs but to exclude it as an independent LO. We restructured the sequence of the LOs and shared a draft set of LOs with all project team members. After integrating their feedback, we determined the final set of adaptable LOs for SFS education. We assigned a short name to each LO and aligned the LOs to the deep and in implicit components of the SFSESP (**Table 1**).

RESULTS

Overview of Adaptable SFS Program Learning Outcomes

The final set of adaptable Sustainable Food System Program LOs derived from the study process involving content analysis, surveys of SFS education experts (see results in **Appendix 4**), and the final framing of adaptable LOs, is presented in **Figure 1**. In section Description of Individual Adaptable SFS Program Learning Outcomes, the eight LOs are described in detail focusing on their relevance for SFS programs along with teaching approaches and techniques for supporting these LOs (resumed in **Table 1**). For a detailed description of recommended pedagogical techniques and strategies for supporting our LOs, please see **Appendix 5**.

Description of Individual Adaptable SFS Program Learning Outcomes

LO 1 Analyze Food Systems Using a Transdisciplinary Approach Guided by Sustainability Principles

Analyzing and addressing the food challenges of our times requires systems thinking that takes into consideration all the parts, relationships, and interactions from food production to consumption and waste. Systems thinking is grounded in the principles of holism and pluralism (Valley et al., 2018) and draws from socio-ecological theory. Holism refers to a focus on the relationships and interactions between the components of a system to understand the whole as well as to consider the contextual factors that surround an issue or desired outcome. Pluralism refers to explicit engagement and valuing of multiple perspectives when characterizing a system (Reynolds and Holwell, 2010; Williams and Hummelbrunner, 2010). Food systems thinking further draws from a socio-ecological approach that examines the ecological, socio-economic, cultural, and human health dynamics pertaining to food (Ahmed et al., 2017, 2019; Mason and Lang, 2017; Ahmed and Byker Shanks, 2019). Food systems thinking is, therefore, transdisciplinary, involving what is between different disciplines, across, and beyond them. Its goal is the understanding of the present

TABLE 1 | Adaptable Program Learning Outcomes for Sustainable Food Systems Education, their alignment with the SFSESP Framework, and teaching activities for supporting these LOs.

Learning outcome #	1	2	3	4	5	6	7	8
Short name	Systems thinking	Critical reflection	Diverse ways of knowing	Practical skills	Multi-context communication	Team skills	Collective action	Advocacy
Alignment with SFSESP level	Deep structure	Implicit structure	Deep structure	Deep structure	Deep structure	Deep structure	Implicit structure	Implicit structure
Closest alignment with SFSESP components	Systems thinking; Multi-, inter-, and trans-disciplinarity	Critical reflection; Seek balance	Multi-, inter-, and trans-disciplinarity; Open-ended case inquiry	Experiential learning	Multi-, inter-, and trans-disciplinarity; Experiential learning	Multi-, inter-, and trans-disciplinarity; Experiential learning	Collective action; Seek balance	Collective action
Suggested teaching activities (see Appendix 5 for details).	Case Studies; Concept Mapping; In-depth Multi-day Field Courses; Power Mapping; Rich Pictures	Case Studies; Concept Mapping; Critical Reading; Debates; Deep-learning Classroom Activities; In-depth Multi-day Field Courses; Interactive Group Techniques; Power Mapping; Rich Pictures; Student-centered Guest Lecturing	Case Studies; Conversational Method of Gathering Indigenous Knowledge; Debates; Farm-based Authentic Research Modules in Sustainability Sciences	Case Studies; Experiential Learning; Internships; Roleplays; Service Learning	Critical Reading; DEAL (Describe, Examine, Articulate Learning); Deep-learning Classroom Activities; Electronic Media Communication and Literacy Training; One-to-one Relational Meetings; Participatory Writing	Capstone Projects; Experiential Learning; Farm-based Authentic Research Modules in Sustainability Sciences; Interactive Group Techniques; Internships; Public Narrative; Service-learning	Capstone Projects; Case Studies; Community-based participatory action research; Deep-learning Classroom Activities; Public Narrative; Service-learning	Capstone Projects; Community-based participatory action research; Community Arts Projects; Community-engaged Teaching and Learning; Power Mapping; Service-learning

world (Nicolescu, 2014). Also, systems thinking is not limited to Western scientific methods but informed by insights from the multiple perspectives and sensibilities of those affected by a food system (Klein, 2013). When analysis is guided by systems thinking, it reflects the multiple values and conceptions of sustainability, particularly its complex social dimensions related to equity, sovereignty, and justice (Bacon et al., 2012). We define such an analysis as a qualitative account of a food system (Moragues-Faus and Marceau, 2019), that portrays key elements, events, relationships, forces, ideas, and values in the food system in question.

Systems thinking is a means to understand a food-system situation broadly including its complexity and divergent perspectives of participants and their histories. Given the complex and "wicked" nature of food system problems, well-considered initiatives for food systems change must take a holistic view grounded in systems thinking as their point of departure or run risks of failure. "Wicked" problems are characterized by heterogeneity, non-linearity, interdependence, and self-organization (Finegood, 2011). As such, systems thinking considers how to collectively address complex food problems where the environment interacts with socio-economic, cultural, and human health factors in infinite permutations.

Although many analytical methods can be applied to investigate food systems in the classroom, few of these are explicitly transdisciplinary or reflective of the multiple dimensions of sustainability. Images and symbols, rather than verbal accounts, are often effective tools to depict the qualitative essence of a food system (Cadieux et al., 2016). In such a model, the account should describe the activities and agencies of both human and non-human actors and their interplay, and the essential dynamics and tensions that animate the food system situation, particularly as relating to sustainability challenges. The account should also be a "tale told in many voices," to capture the divergent views of people that have different understandings and stakes in a situation. We advocate that by the end of their programs, students will be able to articulate transdisciplinarity via the use of visual representations of complex systems. For example, "rich pictures" (See Glossary in **Appendix 5** for further information) is a mechanism for learning about complex problems by drawing detailed representations of them (Avison et al., 1992). Inventories such as concept or power maps (Glossary) also enhance systems thinking. Socio-environmental case studies (Glossary) are an excellent way to apply systems thinking in real scenarios.

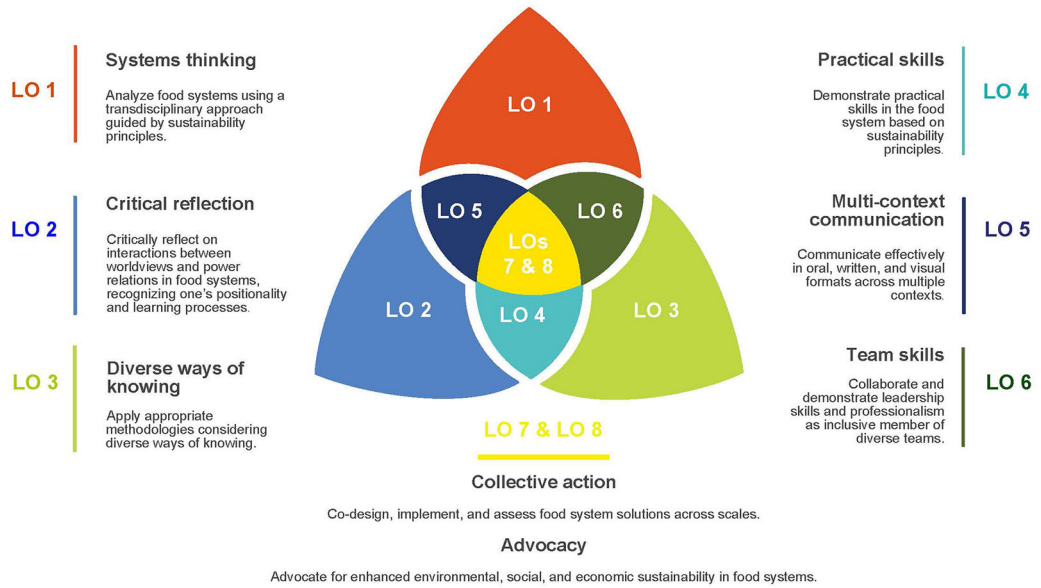

FIGURE 1 | The Eight adaptable Program Learning Outcomes for Sustainable Food Systems Education and their interconnection.

LO 2 Critically Reflect on Interactions Between Worldviews and Power Relations in Food Systems, Recognizing One's Positionality, and Learning Processes

While LO 1 is about how information is processed in SFSE, LO 2 deals with the nature and the use of this information. We consider critical reflection as a skill that allows students to develop reasoned solutions to complex problems when the needed information and evidence are unavailable, or when there is no one single resolution, a characteristic of most food systems issues (Perry et al., 2018). Further, critical reflection requires developing a habit of mind that continuously questioning one's taken-for-granted assumptions and beliefs, one's positionality, and their cumulative impact on what one values and how one acts. Further, critical reflection requires an outward orientation toward recognizing and questioning external power relations in food systems and their influence on distribution, representation, and recognition. We draw upon Mezirow (2000, 2003) transformative learning theory as an essential building block for developing an understanding of the nature of reason and associated methods, logic. Considering the social dimension of learning, we agree with Kreber (2006) that reflection must be responsive to broad social and cultural imperatives to allow critical reflection leading to action. Furthermore, we underpin our understanding of critical reflection on Andreotti et al. (2018) framing of problematic and harmful patterns of hegemony, ethnocentrism, ahistoricism, depoliticization, salvationism, uncomplicated solutions, and paternalism that permeate the food system and society broadly (Allen et al., 2003; Born and Purcell, 2006; Levkoe et al., 2016).

Critical reflection is related to the process of learning and embodies the ability not only to know content, but also to understand that knowledge is both socially constructed (and consequently strongly influenced by power relations in- and outside the food systems), and based on one's own experiences and assumptions (Lieblein et al., 2004; Roy et al., 2019). When students understand how their socioeconomic status, experiences, and (cultural, religious, and family) backgrounds shape their learning, they are better equipped to think critically and arrive at thoughtful solutions to sustainability issues.

The capacity of students to bring about positive food systems change is hinged on the depth of their ability to apply critical reflection skills following, and during, their education. Historically, most SFS academic and degree programs in the U.S. have arisen out of production-based programs such as agronomy, horticulture, or plant science. Yet the food systems issues addressed in these programs are larger in their scope, context, and stakeholder base, requiring students to learn across multiple disciplines. Most importantly, for students to be engaged in effective collective action, they must have the right tools in their toolbox and know how to select or modify these heuristics. When faced with a new issue or problem, the exploration of multiple perspectives, ways of knowing, and their assumptions, will result in more effective outcomes. Critical reflection skills help students sort through multiple perspectives and arrive at reasoned solutions that bring voices of all actors to the table. It encourages students to question how knowing occurs, where

knowledge and power reside as well as how knowledge is constructed and evaluated (Valley et al., 2018). Eventually, critical reflection is a requirement for shifting unequal power relations in the food system and the students' lives.

By the end of their programs, students should be able to validate their attainment of this LO via writing pieces that demonstrate reasoned and supported arguments for often divergent perspectives on an issue. In SFS education, rather than instructors conveying information through traditional lectures, readings, and discussions, it is common for them to instead serve as guides to help students understand the complexity of issues via structured interpretation and reflection on experiences and their learning process (Lieblein et al., 2004). Courses that involve action and participatory learning and that move beyond a lecture-in-the-field allow for the development of critical reflection skills through exposure to diverse viewpoints. Pedagogical strategies to enhance LO 2 include a wide range of community engagement activities such as in-depth multi-day field courses, service-learning, and power-mapping (See Glossary in **Appendix 5** for further information). Where community engagement is not possible, students can gain insights through case studies, debates, and student-centered guest lectures, diverse types of deep-learning classroom activities, interactive group techniques, and the subsequent integration of learned information in a "rich picture" or concept map (Glossary). Tools such as the DEAL model (Glossary) guide students through the process of critical reflection via writing. The "Iceberg Exercise," where students are encouraged to distinguish between the visual part of a complex problem, and its underlying roots (Crosby and Bryson, 2014) is an example of practicing and assessing both, LO 1 and LO 2.

LO 3 Apply Appropriate Methodologies Considering Diverse Ways of Knowing

Examining and making decisions with regards to the food system requires an evidence-based approach that considers diverse perspectives and synthesizes the totality of available knowledge sets. LO 3 is therefore, essential for SFS programs. It implies that students select an appropriate methodology for analyzing a determined problem, that this selection considers diverse ways of knowing (including those not based on Western science), and that the student is able to conduct this analysis based on the selected methodology. Specifically, diverse ways of knowing include academic, humanistic, and non-academic notions of "evidence" applied across the ecological, socio-economic, cultural, and human health dimensions of food systems. This approach requires the inclusion of perspectives at all levels of the food system from those involved in production, distribution, processing, packaging, consumption, and waste to those involved in associated education, healthcare, and policy (Valley et al., 2018). Conventional research is strongly underpinned by the epistemology of positivism. In conventional research, the application of appropriate methodologies encompasses the processes of inquiry, data collection, analysis, synthesis, and dissemination that facilitate problem-solving and critical thinking (Ritchie and Rigano, 1996). However, SFS programs facilitate research approaches tailored to the needs and interests of stakeholders of a food system that include, but go beyond, classical academic methods. For example, drawing from indigenous paradigms, appropriate methodologies further relate to the set of beliefs and ethics, that guide action and relationships including the way knowledge is acquired and information is presented (Wilson, 2001). Methodologies that consider diverse ways of knowing can be qualitative, quantitative, participatory, or mixed methods, and include, but are not limited to, experiments and trials, surveys and questionnaires, interviews, case studies, participant observation, conversation, ceremony, and storytelling (Wilson, 2009; Kovach, 2010; Creswell and Creswell, 2017). Activities that directly teach students research methodologies have been shown to foster intellectual and professional development including scientific literacy skills, career interest, and self-confidence (Hunter et al., 2007; Derting and Ebert-May, 2010; Brownell et al., 2015; Staub et al., 2016).

Independent from the diverse knowledge sets available and appropriate for analyzing a specific food system, we encourage students to apply an evidence-based approach to decide about possible interventions. By taking into account the totality of available evidence from diverse sources and types of information, food system leaders can more effectively design solutions that support sustainability while considering trade-offs with minimal unintended consequences (Stoy et al., 2018). Also, an evidence-based approach calls for students to consider their positionality, implicit biases, and preconceived assumptions as expressed in LO 2. Activities that may increase self-awareness and positionality can arise from collective processes of learning that engage with diverse ways of knowing (Tochon, 2010; Anderson et al., 2019b). Consequently, students may be more disposed to support and work toward decolonizing the food system. Decolonizing the food system points to the contemporary food system crisis arising from a globalized, modern-industrial food system built upon the hegemony of anthropocentric, imperialist, Euro/Western-centric, capitalist, and modernist ontologies, and refers to 'commons-based alternatives often rooted in non-anthropocentric cosmologies, agroecological farming methods, less androcentric land-tenure, and generally congenial relations to non-human nature (International Assessment of Agricultural Knowledge, Science and Technology for Development, 2009; Figueroa-Helland et al., 2018). As multiple scholars call for education to directly address its complicity with maintaining the food system (Napier, 2010; Meek and Tarlau, 2016; Anderson et al., 2019b) contends that experiences with otherness provide new paradigms for living and science.

It is expected that exposing SFS students to such new paradigms for living and science, their capacity to assess food system challenges and to develop concerted solutions increases. Curriculum activities about applying appropriate research methodologies require educators to critically analyze the ways in which they prepare students to ask questions, think across disciplines, test possible solutions, collaborate with a diverse range of stakeholders, facilitate community engagement, and synthesize evidence (Ahmed et al., 2017). The premise is a critical self-reflection of the instructors on their own positionality, which should be shared with the students. To sensitize students on the impact of epistemology on research results and the subjectivity of evidence, having students performing research using theoretical

lenses with different epistemologies (for example, positivism, political economy, and feminism) in their fieldwork can be a powerful experience (Galt et al., 2013). Primary research in the undergraduate classroom (Hunter et al., 2007; Derting and Ebert-May, 2010; Brownell et al., 2015; Linn et al., 2015; Ahmed et al., 2017) is a typical way to train students to apply appropriate methodologies. For example, Farm-based Authentic Research Modules in Sustainability Sciences or FARMS (See Glossary in **Appendix 5** for further information) incorporates primary research into course curricula based on input from diverse local agricultural stakeholders (Ahmed et al., 2017). Another curriculum activity to train the selection and application of appropriate research methodologies is to guide students to employ ethnographic techniques such as participant observation and the conversational method of gathering knowledge built upon an indigenous relational tradition (Glossary) (Kovach, 2010). Socio-environmental case studies and debates (Glossary) that facilitate students to reflect on their positionality and that of food system stakeholders are further curriculum activities to support LO 3.

LO 4 Demonstrate Practical Skills in the Food System Based on Sustainability Principles

Understanding food, from production to consumption, and the actors involved in the system requires the development of diverse practical skills, which are developed through hands-on approaches to deepen knowledge or solve problems within the food system. Students in SFS programs must be able to draw upon skills from multiple disciplines including food, agriculture, natural resources, and human sciences (Clark et al., 2013; Hilimire et al., 2014) to better understand the logistical aspects of those dimensions. Given the magnitude of practical skills required from food system professionals, SFS students cannot achieve proficiency in all potential sectors. A balanced SFS program should provide insight into diverse activities such as farming, culinary, processing, nutrition education, application of the scientific method, lab-based skills, and indigenous ways of knowing to research, policy advocacy, entrepreneurship, management, leadership, and communication. Existing SFS programs have faced challenges in structuring curricula that address such activities while offering students a feasible graduation timeframe.

Developing practical skills is essential to answer questions and solve real-world problems related to the interconnected challenges of changing environmental, social, economic, and health conditions in SFS. Students particularly need to critically engage with practical skills to know when to apply specific skills to certain issues or problems to support the economic, environmental, and social components of sustainability (Parr et al., 2007; Clark et al., 2011). For example, students can hold romantic or naïve assumptions regarding food production. Through immersion in farming activities such as planting, weeding, harvesting, and selling, students may contextualize alternative farming practices to their unique challenges and opportunities. Given that SFS require a multitude of practical skills, students need to know how to draw upon other resources to gain skills they do not already possess. Immersive experiences allow students to move beyond forming ideals to embodied experience where they can better understand decisions in the food systems from a logistical perspective. Experiential learning (See Glossary in **Appendix 5** for further information) provides a framework for students to practice skill-building (Lieblein et al., 2004; Parr and Trexler, 2011). These experiences are typically external but can be introduced in classroom settings, for example, in the form of problem-based case studies or roleplays (Glossary). Ideally, experiential learning also means interacting with and learning from professionals in the respective areas as in the case of internships (Glossary).

LO 5 Communicate Effectively in Oral, Written, and Visual Formats Across Multiple Contexts

Oral, written, and visual communication skills are essential for most undergraduate programs. More unique to SFS programs is the ability to effectively communicate ideas clearly and concisely using multiple modalities in cross-cultural contexts to diverse, both professional and lay, audiences. It is not enough to simply have an idea to transform food systems—one must be able to effectively communicate ideas to varied audiences across contexts for knowledge dissemination, debate, and to stimulate change or action (van Ginkel et al., 2015). This means that SFS students should be able to articulate or present food system issues clearly and in a way that is appropriate for the respective target audience. Depending on what is communicated, the process of writing, speaking, and creating visual representations always fosters one or more of the other LOs (Trumbo, 1999; Prain and Hand, 2016).

Effective oral, written, and visual communication skills are critical for a SFS workforce who has the capacity to effect change including through mobilizing stakeholders in the food system (Trumbo, 1999; Chan, 2011; van Ginkel et al., 2015). The development of communication skills should be emphasized in SFS programs to demonstrate the achievement of other LOs and competencies such as systems thinking and critical analysis [5]. Effective communication is further of relevance for training a SFS workforce capable of demonstrating leadership, stimulating action, and presenting a professional identity across different sectors of the food system as well as being capable to effectively share stories, build relationships, and synthesize feedback from stakeholders (Nisbet and Scheufele, 2009; Reynolds et al., 2012). SFS curriculum should include activities designed to allow students to learn a variety of communication strategies (Menary, 2007; Reynolds et al., 2012; Prain and Hand, 2016). To obtain feedback and rework a communication product, as it happens in the professional world, these products can be integrated across multiple courses.

Curriculum activities for deepening knowledge through communication include written service-learning reflections that use tools such as DEAL, which stands for Describe, Examine, and Articulate Learning (See Glossary in **Appendix 5** for further information). Student-led presentations and discussions on critical readings and One-to-one Relational Meetings (Glossary) are other impactful communication activities. In addition to traditional improvement of multi-context communication practices such as poster presentations and deep-learning classroom activities, assignments for co-producing knowledge

(for example, participatory writing, see Glossary) are especially beneficial for SFS students to learn how to communicate effectively in multiple contexts. Finally, in an expanding age of online media, electronic media communication, and literacy training (Glossary) is essential.

LO 6 Collaborate and Demonstrate Leadership Skills and Professionalism as Inclusive Members of Diverse Teams

SFS students need to have the ability to collaborate and demonstrate leadership skills and professionalism as inclusive members of diverse teams given the collaborative nature of SFS work, combined with an increasingly team-based workplace across most sectors (Britton et al., 2017). Solutions to complex challenges in the food system necessitate a collective action approach that addresses a given problem from a variety of vantage points that include diverse perspectives drawing from different academic fields and sectors of society. Valley et al. (2018), define collective action as "a theme demonstrated when students are empowered and motivated to act together to achieve a common objective, address critical societal issues and contribute to the public good." In a recent study, the Association of American Colleges and Universities (AAC&U) reported that 71% of surveyed employers identified "teamwork skills and the ability to collaborate with others in diverse group settings" as a LO that needs more attention in higher education (Hart Research Associates, 2009).

Addressing food system problems often involves team collaboration across a variety of food system sectors. Team skills involve the capacity to determine with whom to collaborate to achieve specific goals (Hurlbert and Gupta, 2015). They also include many interrelated behaviors and attitudes related to leadership, facilitation, professionalism, work ethic, clear communication, agency, and engagement. The development of effective team skills is especially important for engaging in collective action, which inherently brings together diverse groups around a common goal [7].

Students of SFS programs have the opportunity to develop and hone team skills through many curricular avenues including campus farm experiences, off-campus internships, place-based research projects such as FARMS, community engagement opportunities, different kinds of experiential learning, interactive group techniques, public narratives, and capstone projects (See Glossary in **Appendix 5** for further information). While assessing individual teamwork skills is challenging, improvement in the assessment of this LO is important so that these skills can be refined and improved throughout the undergraduate curriculum. Impactful collective action requires SFS students to show solidarity both within their team and with the stakeholders they are serving. Teamwork (LO 6) is, therefore, a premise for achieving LO 7.

LO 7 Co-design, Implement, and Assess Food System Solutions Across Scales

The complexity and uncertainty inherent to work within food systems result in professional practice that requires skills in project management and collaboration, as well as experience in diverse processes of inquiry and the habit of critically reflecting on project outcomes. This LO relates to the collective action component of the implicit level of the SFSESP, where students are empowered and motivated to act together to achieve a common objective, address critical societal issues and contribute to the public good (Valley et al., 2018).

The LO draws upon elements of the previous six LOs but adds applied uses of these skills, namely solution (project) design, implementation, and assessment. At the outset, co-designing projects to address sustainability requires a systems approach to help identify scale and boundaries, specific components of the system under investigation and their interactions, as well as an understanding of the diverse stakeholders involved and the power dynamics that enhance or limit the achievement of equitable outcomes for all. Background in areas such as risk assessment, life-cycle assessment, benefit-cost analysis, ecosystem-services valuation, integrated assessment models, sustainable impact assessment, present and future scenario tools, food justice, and food legislation helps student deepen their food system assessment capacity. Students may apply these tools in a real-world case study. To implement a project in the food system, students will need to draw upon context-specific methodologies, communicate effectively within transdisciplinary, collaborative settings, and develop indicators to determine if their efforts reached their intended project goals. Efforts toward reaching LO 7 relates to Spiro (1988) cognitive flexibility theory, which promotes multiple representations of concepts and cases across ill-structured or complex knowledge domains while simultaneously fostering learners' ability to evaluate diverse knowledge sources. To develop cognitive flexibility to address complexity, students in SFS programs will need to practice working on projects at different scales, with different collaborators, and on different topics.

Collective action projects are inherently team-based to allow learners to practice their organizing, communication, and project development skills within the student group, between the student group and the organization or community partner, and between the student group and the broader class/teaching team. By the time a student completes their SFS program, they should be able to identify a wide range of actors and team members who they recommend should be involved in solution development. Common curricular activities that allow students to demonstrate growth and mastery in collective action are community-based participatory action research and other collaborative projects, service learning, as well as case studies and interdisciplinary capstone projects (See Glossary in **Appendix 5** for further information). In the classroom, diverse deep-learning classroom activities and practicing public narratives (Glossary) help train collective action skills.

LO 8 Advocate for Enhanced Environmental, Social, and Economic Sustainability in Food Systems

Advocacy refers here to voicing conceptions or understandings of necessary changes in food systems, based on a values-based perspective. For example, it might entail defense of interests of groups of excluded or disenfranchised people, or efforts to defend against a wide range of abuses of public power or social

exclusion beyond strictly legal problems (Fox, 2001). Advocacy encompasses a wide range of tools, tactics, and techniques to influence the setting and implementation of policies, guidelines, laws, regulations, and other decisions that affect people's lives (Brinsden and Lang, 2015). In our understanding, advocacy must be balanced with appreciation, which refers to interactions that aim to produce mutual understanding and affinity among potential allies in efforts to advance sustainability in food systems. These interactions entail intentional and skilled inquiry to build mutual understanding about the worldview (i.e., beliefs, values, behaviors) and capacities of potential partners in collective action (Cooperider and Whitney, 2005). Potential outcomes in students include the discovery of unexpected alignments of interests and underlying values, careful and sympathetic consideration of other's views and motivations, and recognition of opportunities to exert power through collective action.

This LO is aimed to prepare students to engage in values-based deliberation about sustainability in food systems, understood as a triple bottom-line conception considering social well-being, environmental protection, and economic viability (Rogers and Ryan, 2001). As noted in Valley et al. (2020), equity-related competencies such as food justice practice (Cadieux and Slocum, 2015; Meek and Tarlau, 2016) are essential, core elements in SFS required for learners to understand and enact change in food systems (Meek and Tarlau, 2016; Anderson et al., 2019a). Future food system professionals will need to address situations in which all three aspects of sustainability must be considered and advanced, e.g., transitioning from carbon-intensive agri-food systems (Marsden, 2013), working to address food system inequities (Galt, 2013; Cadieux and Slocum, 2015), and building food sovereignty (Meek et al., 2019) while dealing with power relations across relevant scales (Cadieux and Slocum, 2015).

Students will demonstrate their ability to achieve this outcome by creating objects that record and reflect advocacy and appreciation as these have operated in values-based dialogue about environmental, social, and economic sustainability in food systems. Such dialogue can occur through participation in collective action projects, in one-to-one relational meetings, civic deliberation arenas, civic arts such as community theater, community-engaged teaching and learning, or community-based research efforts in a capstone course (See Glossary in **Appendix 5** for further information). Objects that record and reflect these processes can take the form of reflective statements that both capture the essentials of a student's advocacy (i.e., what is advocated, and why and how?), and the essential viewpoints of others involved in the situation, as understood by the student. Non-verbal media could be used to express the dualistic "both/and" understanding that is inherent to this LO.

DISCUSSION AND CONCLUSION

The complex and interconnected challenges of food systems require professionals capable of thinking beyond disciplinary boundaries and acting collaboratively with diverse stakeholders in ways that are impactful in positively transforming society toward advancing sustainability. Within the last 15 years, an increasing amount of higher education institutions has developed sustainable food systems (SFS) undergraduate degree programs to create and train a professional workforce equipped with the skills and capacities to address food systems challenges. Here, SFS educators from three institutions in North America (Montana State University, the University of Minnesota, and the University of British Columbia) apply their experiences coupled with other SFS educators toward the co-design of adaptable program learning outcomes (LOs) aligned to the SFS Signature Pedagogy (Valley et al., 2018).

Our effort for co-designing adaptable LOs was driven by our joint desire to advance the field of SFS through contributing to a solid conceptual basis for SFS education toward the development of a professional food systems workforce. This effort was further driven by our concerns for the environmental, social, economic, and human health challenges of contemporary food systems and, the need to increase the societal impact of SFS education toward addressing these concerns. We contend that critical to enhancing the field of SFS is a solid conceptual basis of SFS education that overcomes the resource and institutional challenges including departmental and disciplinary silos that impede interdisciplinarity.

The eight LOs presented here comprise of the basic set of skills and attitudes that graduates of baccalaureate-level SFS degree programs are expected to have developed upon graduation. It is expected that our program LOs can be used to assess students' ability to meet these LOs. They will also serve as measurable parameters to evaluate the effectiveness of diverse programs in facilitating the students' achievement of these outcomes. Our adaptable LOs built on previous work led by the study team authors, including extensive interactions with food system stakeholders to understand the needs of a professional workforce as well as the conceptually underlying SFSESP framework (Valley et al., 2018). The framework promotes student skills including systems thinking, multi-, inter- and trans-disciplinarity, and critical reflection, and suggests pedagogical approaches to developing these skills such as experiential learning and open-ended case inquiries. The adaptable LOs represent a departure from positivist epistemology as the exclusive framework to develop curricula (still common in most institutions, including such which offer SFS programs) and offers a considerably different epistemology that values the social and cultural processes of knowing, teaching, and learning, fundamental to develop skills required from SFS professionals. All proposed LOs are skill- rather knowledge-based (**Table 1**). We understand broad SFS knowledge as a requirement for students to achieve our LOs. Thus, we did not detect the need to propose additional knowledge LOs about topics beyond what is necessary for meeting our LOs. Skill-based LOs are also stronger aligned with what is expected from SFS professionals.

The proposed LOs for SFS have resemblances to previously presented learning outcomes and objectives. For example, Ingram et al. (2020) presented a set of nine learning objectives of the Interdisciplinary Food Systems Teaching and Learning (IFSTAL) program in the United Kingdom for the development of a future workforce of food systems analysts. Common aspects of the learning objectives of the IFSTAL program with the SFS LOs presented here include a focus on systems thinking and analysis, pluralism, inter- and transdisciplinarity, and effective communication targeted at varied audiences. Likewise, especially

regarding interdisciplinarity, there is overlapping between our LOs and a Delphi survey that generated recommendations on what a Sustainable Agriculture and Food Systems major curriculum should include (Parr et al., 2007).

We believe the co-designed LOs presented here are adaptable to diverse socio-ecological contexts with diverse student communities, the various stakeholders that students will collaborate with, the range of fields of program instructors and their technical expertise, and the institutional background and geographic location in which SFS programs are implemented. Our eight LOs constitute a basic guideline to be adapted to the context-specificity of each institution rather than rigid standards. For example, while LO 4, focused on demonstrating practical skills, was found to be critical by survey respondents in some institutions, educators of other institutions may decide to not implement this LO because of its lower relevance to their program's context. Also, the LOs presented here can further be adapted in some educational contexts to be more progressive and radical to train a SFS workforce with the capacity to bring about substantive change to the food system (Holt-Giménez and Shattuck, 2011).

While our LOs refer to Baccalaureate degree-level SFS programs, they can be adapted for graduate-level SFS programs and courses. Also, while the LOs presented here were co-designed in a North American context with educators in Canada and the U.S., we believe they have applicability globally. International collaboration with educators and food system stakeholders will allow us to continue to refine the proposed LOs for diverse settings. These LOs represent a holistic ensemble of desirable student skills that interact, reinforce, and inform each other. Therefore, most of the pedagogical activities we suggest for deepening one LO simultaneously helps strengthen other LOs. For example, integrating open-ended case studies into our courses helps to strengthen systems thinking, critical reflection, diverse ways of knowing, and collective action skills within students.

We also emphasize the need to be realistic about what is to be expected from students during an undergraduate degree. Given the level of complexity required for achieving a LO such as systems thinking or collective action, the mastery or advanced proficiency of such a LO is to be seen within the context of what a student can accomplish during their time in an undergraduate degree. It is further important to recognize that the presented LOs need to remain dynamic and be revised in response to changing societal needs. We acknowledge that interactions with our students, food systems stakeholders, and other educators, along with our experiences teach us better than any conceptual paper with regards to student, workplace, and societal needs. Thus, we will continue engaging with our students, food systems stakeholders, and networks of educators to constantly improve our programs through an iterative process.

As societal challenges, opportunities, and needs change, it is anticipated these adaptable LOs be revisited for SFS education to develop graduates best equipped to respond to current and emerging societal needs of feeding humanity in just ways that support planetary health.

SFS is such a new and complex science that teaching it can easily become an inconsistent activity which may include interesting courses but without developing a clear and precise skillset among our students. To avoid this scenario, a continuous discussion about desirable student skills in SFS is necessary. This paper serves as a basis for a long-lasting, deep, and exciting discussion about LOs for SFS education.

DATA AVAILABILITY STATEMENT

All datasets generated for this study are included in the article/**Supplementary Material**.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by Montana State University Institutional Review Board. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

SA, WV, NJ, JG, and RE led the study conception and design. RE led the acquisition of data and data analysis and developed the glossary. RE and SA led the drafting of the manuscript with contribution to writing and revising from all authors. All authors contributed to data interpretation.

FUNDING

This work was supported by the United States Department of Agriculture Higher Education Challenge (HEC) Grant, National Institute of Food and Agriculture (Award No: 2018-70003-27649).

ACKNOWLEDGMENTS

We would like to thank the students, colleagues, and food systems stakeholders who influenced our understanding of sustainable food systems education.

SUPPLEMENTARY MATERIAL

The Supplementary Material for this article can be found online at: https://www.frontiersin.org/articles/10.3389/fsufs.2020.568743/full#supplementary-material

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Conflict of Interest: The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

The handling Editor declared a past co-authorship with two of the authors, WV and CD.

Appendices

Appendix 1: Current Learning Outcomes (LOs) of Flagship Sustainable Food Systems Undergraduate Programs in North America.

University of Minnesota: Major in Food Systems	**Montana State University: Sustainable Food and Bioenergy Systems Major**	**University of Rhode Island: Sustainable Agriculture and Food Systems**	**UC Davis: Sustainable Agriculture and Food Systems (Learning Objectives framed akin to LOs)**	**University of British Columbia: Land, Food, and Community Series**
1. Foundational understanding in one or more bodies of knowledge related to food systems. 2. The ability to perceive, feel, think, and act systemically to address complex food-system challenges. 2a. Systems Thinking 2b. Problem Solving 2c. Ways of Knowing 2d. Ethics and Values 2e. Self-Empowerment 3. Foundational competence in communication regarding complex food systems challenges. 3a. Effective Communication 3b. Civic Engagement and Citizenship	1. Be capable of systems thinking. 2. Have problem-solving skills. 3. Have practical skills. 4. Be capable of critical thinking. 5. Be effective communicators. 6. Have developed agency, or the capacity to make choices and act in a society framework. 7. Have a body of knowledge related to SFBS concepts.	1. Appraise the integrated nature of agricultural & food systems. 2. Explain the scientific basis and interdisciplinary approaches used in the study of SAFS. 3. Examine the dynamics of diversity, equity, access, and security in relation to elements in the food system. 4. Discuss the different ways in which food is harvested, produced and used in different cultures. 5. Evaluate which management practices are used in the sustainable production of food at scales from local to global. 6. Evaluate the role of sustainable agricultural and food systems in producing healthy food that is equitable & accessible to all. 7. Evaluate the interrelatedness between sustainable agriculture and food systems and culture, welfare, economy, and policy from the local to the global scales. 8. Create local & global solutions to a wide variety of complex challenges related to sustainable agricultural and food systems using interdisciplinary approaches & teams.	1. Systems Thinking: Students are competent in the analysis of complex systems, integrating societal, environmental and economic perspectives. 2. Students reflect systems thinking in a deepening understanding of complexity, holistic approaches, and how the parts relate to the whole. 3. Experimentation and Inquiry: Students formulate questions, investigate current knowledge gaps, develop sound research design, learn current research methods and perspectives, experiment with new approaches to scientific inquiry, and integrate scientific and practical knowledge. 4. Interpersonal Communication: Students work in collaborative teams, present information for varied contexts and audiences, negotiate approaches and viewpoints and take leadership roles on important issues. 5. Values: Students reflect critically on their own values and examine different paradigms and perspectives, seeing beyond objective data to understand how values shape commerce, research, policy and action in sustainable agriculture and food systems. 6. Strategic Management: Students work to collectively design and implement interventions, anticipating future	1.Use systems approaches to analyze food systems issues involved in building healthy, sustainable communities, both locally and globally. 2. Select, evaluate and integrate inter-disciplinary evidence relating to food systems issues. 3. Plan, implement and evaluate actions to address local and global food systems challenges. 4. Collaborate and communicate effectively as members of diverse stakeholder teams. 5. Critically reflect on personal growth, learning and responsibilities as professionals addressing food systems issues.

			scenarios and adaptively managing information, human and natural resources for maximum impact. 7. Civic Engagement: Students work to make a difference in the civic life of their communities, through both political and non-political processes. As part of a larger social fabric, students consider social problems to be at least partly their own; make and justify informed judgments; and take action when appropriate. 8. Personal Development: Students seek deeper understanding of their own and thinking and learning processes. They can tolerate ambiguity, respecting those with differing opinions and beliefs, while setting firm standards for behavior and holding themselves and others accountable. Students work to promote open expression of individuality and diversity within the bounds of courtesy, sensitivity and respect.	

Appendix 2: Initial Content Analysis of Five Undergraduate SFS Programs in the U.S. and Canada, Meaning Units per Codes.

Code	% Meaning units per code of total meaning units
Systems thinking	10%
Interdisciplinarity	12%
Experiential learning	7%
Collective action*	17%
Critical reflection*	14%
Self-reflection**	3%
Open-ended case inquiry	11%
Other	26%

* Identified as extensive themes. ** Underrepresented theme.

Appendix 3: Refined Content Analysis of Five Undergraduate SFS Programs in the U.S. and Canada, Rating of Congruence of Coding Scheme with LOs of Analyzed Programs on a Scale from 0 (no congruence) to 2 (absolute congruence).

Category	Condensed meaning unit	MSU	UBC	UMN	UCD	URI
Systems thinking	Systems approach	2*	2	2	2	0

	Holistic approach	1	1	2	2	1
	Alternative models for food system change	0	1	0	2	0
Interdisciplinarity	Multi-, inter- and transdisciplinary approach	2	2	1	0	2
Critical reflection Subcategory Critical thinking	Examination of diverse sources	2	2	2	2	0
	Consideration of different perspectives and worldviews	1	1	2	2	1
	Consideration of power relations	2	1	0	2	1
	Consideration of current events	2	0	0	0	0
Critical reflection Subcategory Research skills	Mastering of research methods	0	2	2	2	0
	Identification of research questions	0	2	0	2	0
	Research analysis	0	2	0	2	0
Critical reflection Subcategory Self-reflection	Awareness of own learning processes	0	2	2	2	0
Civic engagement Subcategory Food system assessment	Analysis of FS processes and outcomes	1	2	1	1	2
	Design of FS interventions	2	2	0	2	1
	Assessment of FS interventions	1	2	1	2	0
Civic engagement Subcategory Collective action	Engagement in community work	0	2	2	2	1
	Service learning	2	0	1	1	0
	Implement FS change	0	2	1	1	1
	Active role in society	0	2	1	2	0
Practical skills	Sustainable agriculture	2	0	0	0	2
	Food distribution and marketing	2	0	0	0	0
Communication skills Subcategory Academic communication	Effective written, oral and media communication	2	2	2	0	0
	Nonverbal communication	2	0	0	0	0
Communication skills Subcategory Team skills	Effective collaboration	2	2	2	1	0
	Leadership	0	0	2	2	0
Professional attitude	Problem-solving	2	0	2	0	0
	Respect for values of diverse stakeholders	0	2	2	2	0
	Self-confidence	2	0	0	0	0
	Promotion of individuality and diversity	0	0	0	2	0
	Entrepreneurial attitude	2	0	0	0	0
	Compassion	0	0	2	0	0
Knowledge	Food systems	2	2	0	0	1
	Sustainability	2	0	0	0	1

	Human nutrition, food safety	2	0	0	0	1
	Bioenergy	2	0	0	0	0
	Ecology	2	0	0	0	1
	Organic and local food production	2	0	2	0	1
	Plant and animal science	2	0	0	0	2
	Economics	2	0	0	0	1
	Food policy	0	0	0	0	2
	Marketing	0	0	2	0	0

* We assigned the number 2 when the meaning unit was literally addressed in the respective institutional LOs, the number 1 when it was partially or indirectly addressed, and 0 when there was no congruence.

Appendix 4: Results of Surveys of SFS Education Experts Expressed as Rating of the Relevance of a LO and Percentage of Respondents' Choices regarding one Preferred Framing of the Respective LO.

Learning Outcome	**Rating***	**Options**	**Overall (%) (n=45)**
Systems thinking	8.9	**Analyzes complex problems using a systems approach.****	**69**
		Analyzes food systems issues using a holistic approach.	1
		Using a systems approach, (the student) compares and assesses alternative models for food system change.	30
Interdisciplinarity	9.2	**Analyzes food systems issues using multi-, inter- and trans-disciplinary approaches.**	**66**
		Analyzes food systems issues examining different perspectives and worldviews.	34
Critical reflection, Subcategory Critical thinking	9.5	Examines and evaluates different sources and perspectives.	14
		Evaluates sources of information for accuracy and bias.	23
		Understands how values shape commerce, research, and policy.	19
		Evaluates sources of information considering current events.	**44**
Critical reflection, Subcategory Research skills	9.5	Applies adequate research methodologies in FS related disciplines and has the capacity to interpret findings.	20
		Investigates current knowledge gaps, applies correct methodologies, integrating scientific and practical knowledge.	**48**
		Analyzes and critically evaluates arguments and evidence.	32
Critical reflection, Subcategory Self-reflection	8.1	**Contemplates their own thinking and learning processes and preferences when working with a community.**	**60**
		Considers the values and knowledges of diverse stakeholders in the FS.	40
Civic engagement, Subcategory Food system assessment	8.4	**Analyzes components, processes and outcomes of a FS, as well as concepts behind it.**	**65**
		Assesses a FS and designs and evaluates interventions in a FS.	17
		Assesses and designs FS interventions.	18
Civic engagement, Subcategory Collective action	9.0	**Plans, implements, and evaluates actions to address local and global FS challenges.**	**89**
		Implements service learning to address FS challenges.	5
		Implements FS change.	0

		Has the skills to make a difference in the civic life of a community.	6
Practical skills	8.5	**Has a solid understanding of best practices in sustainable agricultural production.**	**43**
		Implements best practices in sustainable agricultural production.	28
		Knows how to produce food.	3
		Is capable to assess the effect of food production on distribution and commercialization and vice versa.	12
		Has a solid understanding of food marketing and distribution.	14
Communication skills, Subcategory Academic communication	7.7	**Communicates effectively in speaking, formal writing, and through digital media tools.**	**57**
		Applies effective and professional written and oral communication skills.	31
		Applies effective verbal and nonverbal communication skills.	12
Communication skills, Subcategory Team skills	9.3	**Interacts and collaborates effectively with the community.**	**65**
		Provides leadership in FS interventions.	23
		Is proficient in communication skills in collaborative groups.	11
Professional attitude	8.0	**Solves problems professionally and can perform teamwork, knowing how and when to collaborate.**	**80**
		Solves problems professionally and shows respect for values of diverse stakeholders	4
		Is self-confident and promotes individuality as well as diversity.	8
		Has an entrepreneurial and passionate working attitude.	8

* Rating on a scale from 0 (no approval) to 10 (highest approval).

** The overall most selected LO framing in bold letters.

Appendix 5: Glossary of Pedagogical Strategies to Enhance SFS Education

Capstone Projects (LOs 6-8)

To enhance the students' transition to professional life, most SFS programs require capstone courses or similar experiences. Capstone courses usually emphasize problem-based learning but take varied forms, including seminars, practicum experiences and internships, projects, and issue-based discussion groups (Kiener et al., 2014). In the MSU program capstone course, the students are assessed relative to their team skills (leadership, professionalism, and contributions to project outcomes) through their performance on a semester-long team project. This team project most often involves a multi-disciplinary, community-based challenge and student teams collectively identify project objectives and deliverables at the beginning of the semester. The project culminates with teams leading a public presentation on outcomes and deliverables. Assessment input is gathered from community partners, program faculty, and student peers. Both UMN and UBC programs have capstone experiences that connect interdisciplinary student groups with external stakeholders to collaboratively address a community-identified food system issue. During one semester, student groups are required to submit a proposal, implement project activities, evaluate outcomes and disseminate results and findings back to community partners.

Case Studies (LOs 1-4, 7)

Case studies are an efficient pedagogical strategy to enhance systems thinking, critical reflection, and analytical skills in general (Herreid and Schiller, 2013; Wei, 2015). A case study deals with issues

that have been faced by real people at a delimited location and time. It typically centers on a decision that was (or has to be) taken by stakeholders with different perceptions and interests related to the case. These real and particularized cases are presented to the students from different points of view in the form of facts and diverse opinions. In most case study exercises, students have to argue for their preferred solution to the case (Barnes et al., 1994). Case study approaches can be applied in the classroom, related to outdoor research, and in a flipped classroom (Herreid and Schiller, 2013). Short problem-based case studies can even demand practical skills in developing tangible solutions (Wurdinger and Marlow, 2005). At UBC, students participate in food system case study analysis through on-line resources. The UBC Centre for Sustainable Food Systems created open-source case studies that highlight campus food assets and includes peer-reviewed articles as supplementary readings, guided questions for discussion, and place-based activities to support accessible experiential learning opportunities.

Socio-environmental case studies are a particular form of case studies based on socio-environmental synthesis, which focuses on connections between humans and nature from a systems perspective to deepen transdisciplinary analysis skills (among other LOs) by integrating existing knowledge, data, and methods from diverse disciplines (Wei, 2015). For SFS education, socio-environmental case studies preferably result in open-ended inquiries including stakeholders beyond academia. At MSU, a socio-environmental case study was successfully applied in two courses (Ebel and Thornton, 2019).

Community-based Participatory Action Research (LOs 7, 8)

Community-based participatory action research (and the similar but more teaching-centered community-initiated student-engaged research, bring together undergraduate students, university researchers, and community organizations. The existence of campus-community partnerships, for example with local NGOs, is a precondition for their successful implementation. In community-based participatory action research, (organized or individual) community members actively identify issues for scientists- and students can participate in both the identification and especially the research, where they work together with community members and instructors in gathering, processing, and interpreting data as well as in organizing public events related to the project (Greenberg et al., 2019).

Community Arts Projects (LO 8)

Collaborative or community arts refer to artistic activities rooted in a specific community in which participants decide, organize, and practice the arts in response to their ideas and lives. Thereby, community arts connect art and education to culture and community. Such projects involve students experientially, kinetically, intellectually, and aesthetically. They also strengthen team and interdisciplinary skills. Community-arts projects can have multiple approaches and emphasis including participatory video and photography, collaborative ethnography, community cultural development, digital storytelling, folklore, cultural and citizen journalism, Indigenous media, and PhotoVoice projects (Haviland, 2017; Schlemmer, 2017).

Community-engaged Teaching and Learning, CETL (LO 8)

CETL is an umbrella term that includes diverse pedagogical activities such as service-learning, participatory action research, certain forms of experiential learning, study abroad programs with community engagement components, and even online programs. Its characteristic is the formal nexus between curricular activities and community needs. This is achieved through an alignment between course LOs and needs identified by a collaborating off-campus community (Morton et al., 2020).

Concept Mapping (LOs 1,2)

A concept map is a graphical representation of the relationship among concepts and ideas, along with the ways they are connected or influence one another. In socio-environmental synthesis, which is frequently used in SFS education, they have emerged as a common practice. The mapped concepts (visualized as nodes) include internal or external (individual and organizational) stakeholders of a food system, as well as social dynamics and environmental factors that affect this system. The relationship between these concepts is portrayed in the form of lines, which can evolve to arrows or vectors if they describe the causal forces between nodes. Action phrases can be requested to describe the relationship between the two connected nodes. Most concept maps are designed as networks of diverse interacting factors, but linear, circular, "hub", or "tree" maps also exist. The first step for using concept maps in the classroom is the definition of the key question represented in the center of the map. Subsequently, students (usually as teams) develop a preliminary map, discuss it, update it with field research or literature review (where appropriate), and discuss it again with a broader audience before developing a final map. Concept maps stimulate systems thinking as they provide a visual means to explore the complexity of a given system. They can be used at different levels of complexity and applied in case studies as well as for resuming content. They are also powerful tools for facilitating group work. Most revealing are open-ended questions that allow students to construct their own map structure (Vanides et al., 2005; Deaton et al., 2016).

Conversational Method of Gathering Indigenous Knowledge (LO 3)

This research method gathers knowledge based on the oral storytelling tradition. It encompasses open-ended and semi-structured interview questions to prompt conversation with key informants about food system practices such as wild food procurement and consumption where the informants and the student researcher co-create knowledge (Kovach, 2010). The tool can be applied for student field research and is not limited to interacting with indigenous communities but is appropriate for every environment where conversations and storytelling are still prevailing.

Critical Reading (LO 2, LO 5)

Pre-class reading is a common practice in higher education but numbers of undergraduates seriously engaging in these assignments are often low. In contrast, critical reading stimulates the students' processing of information and their response. Therefore, the selected readings must be relevant to their reality, concerns, and interests so that they can raise vital questions and problems from the text; that they can test their interpretations against previous knowledge or experience; that they are able to examine their assumptions and the respective implications; and that they use what they have read to communicate effectively with others or to develop potential solutions to a problem. Therefore, in critical reading, students are asked to identify and describe the purpose of why the reading selection was allegedly made by the instructor (and invited to participate in the selection of readings). In the processing of the reading, the instructor should encourage reflections about connections between the text and the students' existing cultural knowledge and experience. A respective question could be "What experiences in my internship support, confound, or refute the information presented from this reading?" Other tasks include interpretation of evidence (for case studies), challenging assumptions, and applying the read information. The reading/writing prompt should be assigned when an assignment is given, not after the reading (Tomasek, 2009). Students can respond to these tasks in numerous ways such as online discussion boards, in-classroom group discussions, creative summaries including visual illustrations, or even role plays ("How would you summarize the article for your 5-year old nephew?). Sometimes, instead of assigning readings for homework, **read-aloud**

activities can be helpful as reading aloud a text of 500 words or less can focus the students' attention during a long class. In a **half-class**, the class is divided into two equal parts of which one part receives the reading material and studies it. The other half is simultaneously having a lecture on the same issue. Then, groups are switched, ending with a recap by pairs of members of opposite groups (Marotta and Hargis, 2011).

DEAL (LO 5)

DEAL (Describe, Examine, Articulate Learning) is a critical reflection model and serves to process learning from multiple perspectives. The final goal is reflective writing or learning-while-writing. The basis for the DEAL model is a concrete learning experience, for example, a case study, a service-learning experience, internships, or experiential learning. The model asks for the writer to describe the learning experience in three sequential steps: Description of learning experiences in an objective and detailed manner; examination of those experiences (based on specific learning goals of the course, which permits students to bridge the learning experience to the larger academic curriculum); and articulation of learning, including goals for future action (Ash and Clayton, 2009). DEAL is frequently applied in diverse types of civic engagement. Examples of prompts in this field include "What was I trying to accomplish in that activity?", "How did I see power being used during my internship?", or "What changes does my experience suggest are needed: within myself, within others, and within our communities?" (Ziomek-Daigle, 2017).

Debates (LOs 2, 3)

In-class debates cultivate the active engagement of students and help develop critical reflection and communication skills as well as the consideration of diverse ways of knowing. Debates are more structured and complex than common classroom discussions. Disagreement is encouraged and the debating parties search for inconsistencies in the argumentation of their counterparts. Opposing viewpoints are stressed by an appointed moderator, an experienced student, or the instructor. To increase the participation and commitment of all students, diverse debate arrangements with pedagogical intentions have been developed: In the **meeting-house** format, each team gives it's opening argument, and then the rest of the class questions the debaters or offers comments. The moderator ensures that each side receives an equal amount of questions. **Four-corner debates** mean that students contemplate their opinions of a statement and then move to one of the four corners of the room, which are labeled "strongly agree," "agree," "disagree," and "strongly disagree." The students of the same corner then develop arguments for their position. After each group defends its position, the students may switch corners. In a **fishbowl debate**, the students are divided into three groups: experts for each side of an issue and the remaining students as the audience. A circle of chairs in the center of the classroom to create the fishbowl. Each side has a turn discussing the issue with their fellow group members while sitting in the fishbowl, and then the audience group has their turn in the inner circle. This is repeated several times. Finally, in **think-pair-share debates**, students first reflect individually. Then they work in pairs to create lists of reasons to support both sides of an issue. Next, two pairs work together to come to a consensus. The size of the groups increases constantly until a class-wide consensus is achieved (Kennedy, 2009).

Deep-learning Classroom Activities (LOs 2, 5, 7)

Deep-learning is based on higher-order cognitive skills such as holistic synthesis and critical reflection but also trains communication and problem-solving skills. It stimulates metacognition to construct long-term understanding, to internalize the acquired skills, and to raise the students'

attention in class. Numerous short deep-learning activities exist, which can be integrated into almost any type of class or lecture and are mainly focused on individual student work (please see interactive group techniques for team exercises). Examples of deep-learning classroom activities include **one-sentence summaries** (students summarize a topic in one sentence), **one-minute papers** (students have one minute to write about a specific question), **advice letters** (a letter of advice to future students on how to be successful students in that course), **tabloid titles** (students develop a tabloid-style headline to illustrate the current topic), or **truth statements**, where the instructor asks students to list out "It is true that..." statements on the current topic (VanGundy, 2008; Yew et al., 2016).

Electronic Media Communication and Literacy Training (LO 5)

In an expanding age of online media, electronic media communication and literacy training such as designing and developing websites, social media, podcasts, videos, or blogs, as well as curriculum activities to understand science communication, policymaking, and networking online are relevant communication skills that have to be trained in diverse courses (Kuehne et al., 2014). Potential activities to train online media communication include student projects and presentations on YouTube, interactive video quizzes, group wiki projects, and wiki class notes, blogs (also in the form of electronic role plays, where students develop the blogs of a fictitious character), and reports from the filed using Twitter or other social media (Watkins, 2005).

Experiential Learning (LOs 4, 6)

Since it is not realistic that students become experts at every practical skill across the food system, the goal is to learn how to access resources and eventually master at least one craft with a certain degree of routine. Engaging in farming, processing foods, developing culinary capabilities, practicing nutrition education, working in laboratories, conducting community-based participatory research, advocating for policy development, and practicing business management and marketing are all feasible learning experiences that can be implemented throughout a SFS curriculum. This experiential learning should dovetail with a discussion about practical skills built and then embedded in further classroom activities. Ideal places for a first practical experience are student farms or kitchens, where horizontal knowledge co-construction (collective experiencing and development of knowledge among equal parties rather than the expert transmission of abstract theory) can occur (Parr and Trexler, 2011) and which allow students to enhance their practical knowledge in the form of small, innovative experiments. Especially at an initial stage of practical skill development, learning from mistakes (and unlearning old habits) is more valuable for students than perfecting experimental design (Cunningham and Dawes, 2016). Experiential learning does not only enhance practical but also team skills. During the MSU campus farm practicum, team skills are assessed through a collaborative on-farm project where the students' leadership skills, professionalism and overall contributions to the team projects are assessed through both peer and instructor feedback.

Farm-based Authentic Research Modules in Sustainability Sciences (FARMS) (LO 3, LO 6)

FARMS are place-based research projects that test sustainability solutions for managing agricultural systems. Specific management practices are identified through community engagement with local food system stakeholders. Students are guided through the process of inquiry and are called to synthesize scientific evidence from their primary research and the literature coupled with input and perspectives from local food system stakeholders (Ahmed et al., 2017).

In-depth Multi-day Field Courses (LO 1, 2)

In-depth multi-day field courses train critical reflection among students. These courses can be described as case studies with active research activities on a field trip: Students are first exposed to a variety of perspectives and then asked to develop solutions to issues, or respond to journaling prompts, which force students to develop empathy and recognize views that may come into contrast with their assumptions and knowledge (Wiedenhoeft et al., 2003; Roberts et al., 2019).

Interactive Group Techniques (LOs 2, 6)

Interactive group techniques increase the students' deep learning, enhance teamwork, facilitate solving complex tasks, encourage self-reflection, and stimulate creativity as well as tolerance within the students. They are more effective in smaller groups. Interactive group techniques also work very well in collective action projects (Szitar, 2014). Such techniques can be used to achieve all eight of our adaptable LOs but primarily train critical reflection and team skills. Some interactive techniques are designed for pairs and small settings, others for larger teams. Examples of numerous available group techniques include the **forced debate** where a class is first divided among their position on an issue and then, each side must defend their opponent's point of view (commonly, each student can only speak once). This technique also works in pair-arrangements. In **peer reviews** of writing assignments, the students exchange drafts with a partner who should not correct the text in terms of style and grammar but outline strengths and problems in the content. In the **psychoanalysis** technique, students get into pairs and interview one another about a recent learning experience. It may include questions like "How did your beliefs change after learning about this topic?" or "How will your decisions change?". In **jigsaws** (group experts), one of the most popular dynamics in SFS education, students are divided into groups which are all given different topic. The students then study information about this topic (or implement field research) to become "experts". Finally, the groups are remixed with one planted "expert" on each topic, who now teaches the new group (Carpenter, 2006; VanGundy, 2008; Szitar, 2014).

Internships (LO 4, LO 6)

Internships are an excellent strategy in this regard, also because they can help foster team skills and intercultural sensibility. One study showed that organic farm internships enhanced classroom learning and that joint fieldwork also advanced their skills and professional attitude in leadership, decision making, personal initiative, and communication (Reeve et al., 2014). However, an internship or practicum is only effective if the worksites are meticulously selected and if there is constantly mentoring through a course instructor (Simons et al., 2012). In MSU's off-campus internships, mentors are asked to provide feedback through a post-internship evaluation on aspects of leadership, professionalism, and contributions to the organization's outcomes and culture.

One-to-one Relational Meetings (LO 5)

One-to-one Relational Meetings serve to open a public relationship with another person and to get to the root of that other person's self-interest and belief system through listening to this person's anecdotes, experiences, passions, and tribulations. They usually involve a 40-50 minutes face-to-face meeting between one student (not a group of students) and another person, which is initiated by an appointment. During this meeting, the other person's self-interests, ideas, motivations, and visions for their institutions and communities should be explored. However, one should not attend the meeting with a prepared list of questions. Conversation topics include the other person's family (where the person grew up, their parents, etc.), education, work, hopes, and dreams, as well as frustrations. About 80% of the meeting time should be spent listening to the invited person. One-to-

one Relational Meetings demand a developed set of interpersonal and listening skills as they should not convert into a two-way conversation or small talk on the hand, neither into a counseling session, negotiation, or quantitative interview on the other hand. Hence, they should be meticulously practiced in the classroom before sending the students out to the field (Fretz, 2010; Boyte and Finders, 2016).

Participatory Writing (LO 5)

Participatory writing involves students collaborating with members of a partnering community organization or another stakeholder group to create a formal written piece on a jointly selected food system topic that includes visual elements (Clughen and Hardy, 2011).

Power Mapping (LOs 1, 2, 8)

Developing inventories and maps is an effective community-engaged pedagogical approach to teaching systems thinking, critical reflection, and collective action via student exposure to diverse stakeholder perspectives. Maps are useful to narrow and clarify the dynamics of a complex and broad issue into something concrete and workable. Power maps, a special type of concept map, should be developed by as diverse as possible student teams. They are visual representations of all the stakeholders (any person, party, organization, or institution who are connected to or involved in an issue) that constitute a problem or project (Hildreth, 2014). Power mapping is not a specific and exact analysis technique but rather a family of methods for assessing power relationships (Noy, 2008). In the classroom application of power-mapping, students interview stakeholders who are identified as holding some level of power related to the issue being addressed, to learn their perspective on the issue (Boyte and Finders, 2016). To develop the map, the students list all individual or organizational actors (formal and non-formal decision-makers) involved in the specific power issue (pre-mapping). The list may then evolve to a power matrix, which includes the range of actions of the diverse stakeholders, quantifies their power-level, and describes whom they are interacting with. Pre-mapping concludes in the drawing of a preliminary power map. Most important is a constant discussion within the mapping team. In the subsequent research phase, the team members research the actual power and interests of the identified stakeholders. They report their finding to the team and the preliminary map is updated with field information (re-mapping). The eventually resulting power map is not a geographical map, but a sketch of the stakeholder groups involved in the analyzed issue, how they are interacting and where their power overlaps. The shape of the map depends on the issue as well as on the interviewees' perception (Schiffer, 2007; Hildreth, 2014). Power mapping allows students to critically reflect on where power resides in the food system and how authority, privilege, and oppression in the food system play out in the daily lives of others. It can also be the starting point for subsequent action plans (Hildreth, 2014).

Public Narrative (LOs 6,7)

Developing leadership and "bridging" to a community on behalf of social change often requires telling a new, public story, or adapting an old one. This skill is exceptionally important for students who want to engage professionally in collective action. A public narrative is a communication tool that helps break the ice with a community and increase the commitment to a common issue. Every public narrative includes three stories: a story of self (the speaker), a story of us, and a story of now. Credible and authentic public work requires giving a public account of oneself: The story of self is a way to share one's values by providing lived experience. It is constructed around personal choice points. The story of us provides values that the speaker shares with the target community. It uses

collective (often historical) choice points (choices made, challenges faced, outcomes achieved, and lessons learned). Finally, stories of now articulate contemporary challenges and coming choices (Ganz, 2011). Instructors can train public narratives by first providing their public narrative, then having students practicing in the classroom, and finally letting them narrate to an external audience.

Rich Pictures (LOs 1, 2)

Rich pictures of food systems is a systems-thinking tool that is associated with the soft systems methodology (Avison et al., 1992). A rich picture is a graphic image that portrays key elements, events, relationships, forces, ideas, and values in a complex situation. It makes little to no use of words, using images and symbols in relation and context to depict the essence of a complex situation, including the essential dynamics of the situation and the experience and perspective of all major stakeholders (Bell and Morse, 2013; Cadieux et al., 2016). Competence in food systems analysis via rich picture implies the ability to work collaboratively to create such a picture, to identify and depict a narrative that describes the system's history and trajectory, to carry out these analytic tasks intentionally and systematically, and to reflect critically on process and outcomes of the effort (Francis et al., 2017). Many particular curricular activities support food system analysis via rich pictures: Interviews with participants in a food system are fundamental, as is the analysis of texts, symbols, and other communicative activities of participants, to infer the essential understanding of a situation from the point of view of particular participants. Elicitation of storylines describing the genesis and history of a food system, its present state and significance, and potential future pathways is a key task in rich picturing (Avison et al., 1992; Bell and Morse, 2013).

Roleplays (LO 4)

Experiential learning does not necessarily have to occur outdoors or in a lab. It can be introduced in the classroom as well, for example, in the form of game simulations such as roleplays (Wurdinger and Marlow, 2005). For a roleplay in SFS education, the instructor develops a case-like scenario and assigns roles for a play, preferably an open-ended situation where students have to solve a concrete problem by interacting as stakeholders (with as different points of view as possible) in a simulated meeting (for example, a community town hall, a press conference, or a jury trial). Depending on the complexity of the play, students may be asked to develop biographies of their alter egos or do research at home. In a role reversal, the teacher role-plays as a student, asking questions about the content, and the students (as collective teachers) answer the questions (Carpenter, 2006; VanGundy, 2008; Szitar, 2014).

Service-learning (LOs 4, 6-8)

Service-learning describes course-based teaching and learning strategy in which students participate in an organized service activity that meets identified community needs and subsequently reflect on the service activity (Bringle and Hatcher, 2000). This way, service-learning integrates meaningful community service with instruction and reflection to enrich the learning experience, enhance the students' civic responsibility, and strengthen communities (Butin, 2010; Niewolny et al., 2016). It also helps deepen the relationships between programs and universities on the one hand and the local civic society on the other hand (Bringle and Hatcher, 2000). However, service-learning is a type of experiential learning (with elements of community-based and action research, among others) and the students' learning experience is its central outcome. The often high expectations in the social justice outcomes of service-learning practices are not always achieved (Butin, 2010).

Student-centered Guest Lecturing (LO 2)

Guest lectures serve to improve and diversify student learning experiences. Traditionally, they are speaker-centered. In student-centered guest lecturing, student interactions with the speaker (a scholar, industry expert, or community member) are stimulated, enhancing their critical reflection on an issue. Students first study the course content and then work in groups to determine questions for the guest speaker. The speaker is then interviewed in front of the class by an on-site course representative. The instructor should act as a facilitator to create an environment where students can freely deepen their understanding of the subject matter. Student-centered guest lecturing also works in online environments (Li and Guo, 2015).

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