Urban Agriculture

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Research Approaches in Urban Agriculture and Community Contexts

Springer

Urban Agriculture

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Chapter 1
An Introduction of Research Approaches in Urban Agricultural and Community Contexts

Levon T. Esters

Abstract This volume highlights the importance of research in urban agricultural and community contexts. The authors showcase innovative research approaches that can be used by future researchers and practitioners who work in urban agriculture. In particular, research-based perspectives of the impact of urban agriculture programs on student learning are shared in addition to effective models and principles on designing urban agricultural programs being highlighted. This volume focuses on the educational outcomes, the research that is being conducted, and programs that impact youth across a variety of contexts embedded in urban settings.Authors also share innovative approaches in examining the effectiveness of urban agriculture in formal, non-formal/informal educational contexts. Topics such as STEM integration, science learning, student engagement, learning gardens, environmental education, and curriculum design are a part of this volume.The content level of the chapters are geared toward undergraduate and graduate students, practitioners, and researchers. Lastly, the primary audiences that will benefit from the contents of each chapter include those who are PK-12 teachers; postsecondary faculty; non-profit organizations that focus on formal, non-formal/informal education; urban STEM educators; agricultural education teachers; and career and technical education researchers. In sum, this volume will help expand what we have come to know thus far on research related to urban agricultural and community contexts.

Keywords Program design · Learning outcomes · Urban agriculture · Contextual learning · Student engagement · Science learning · Learning gardens · Environmental education · Curriculum design · STEM integration

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This book is divided into eight chapters written by14 researchers and practitioners who have varying expertise and connections to urban agriculture, and who represent a broad array of disciplines and institution types. This volume will fill a void in the literature around research and program design and the impact of such experiences on learning outcomes within urban agricultural contexts. This volume focuses on the educational outcomes, the research that is being conducted, and programs that impact youth across a variety of contexts embedded in urban settings. In particular, this book covers topics connected to agriculture, STEM integration, science learning, student engagement, learning gardens, environmental education, and curriculum design. Additionally, the content level of the chapters are geared toward undergraduate and graduate students, practitioners, and researchers. Lastly, the primary audiences that will benefit from the contents of each chapter include those who are PK-12 teachers; postsecondary faculty; non-profit organizations that focus on formal, non-formal/informal education; urban STEM educators; agricultural education teachers; and career and technical education researchers. Simply, this volume will help expand what we have come to know thus far on research related to urban agricultural and community contexts.

In Chap. 2, "What Role Does Motivation and Engagement in Garden-Based Education Play for Science Learning in At-Risk Middle School Students? A Self-Determination Theory Perspective", Ellen Skinner and Una Chi explored how a motivational model based on self-determination theory can be used as a guide for specifying some of the elements of garden-based education necessary to promote science learning and achievement. Their work centered on how this framework can be used to enrich current garden-based education programs as well as to guide future research, including the selection of measures, the generation of motivational hypotheses, and the use of longitudinal designs to study key processes of engagement and learning in the gardens and in science class.

In Chap. 3, "Developing a Researchable Question: Open Inquiry in a School Garden", Eric Berson and Isha DeCoito examined how students' scientific questions emerge and the roles that phenomena, tools and consultations play in the development and refinement of students' researchable questions. Their findings suggested that instructional scaffolds played different roles for different students as they generated and refined their research questions.

Dilafruz Williams, Sybil Kelley, and Cary Sneider examined the role school gardens have in providing culturally relevant learning opportunities for youth in applying science and engineering to solving real-life challenges in Chap. 4, "Science in the Learning Gardens: Designing Middle School Curriculum Integrated with Next Generation Science Standards." They focused their work on a curriculum project that was pilot tested at two middle schools that serve predominantly low-income and ethnic and racial minority students. The authors found that the curriculum provided holistic, integrated, hands-on, project-based and place-based learning experiences and embedded formative assessments.

In Chap. 5, "Science in Action: Biological and Ecological Principals of Urban Agriculture", Bruna Irene Grimberg and Fabian D. Menalled present and discuss learning progressions for urban agriculture from a socio-agroecological perspective based on networks of concepts associated to the cross-cutting concepts of *Interdependence*, *Diversity*, *System*, *Matter/Energy Flow*, and *Scale* for four grade ranges. The chapter concludes with a discussion of the applications to classroom instruction and future educational research needing to be undertaken.

In Chap. 6, "Urban Agricultural Experiences: Focusing on Twenty-First Century Learning Skills and Integrating Science, Technology, Engineering, and Mathematics (STEM) Education", Isha DeCoito reports on a study which explored how school gardens involved in urban garden initiatives addressed the issue of social justice. Her findings indicated that the urban garden initiative started with a school garden and moved outward into the community. Students were empowered, as well as the school's extended community through good nutrition, the experience of successfully growing food, and the relationships formed in the process.

Anne Stephens and Heidi Ballard utilize a case example in California of how science and environmental education can be merged in a holistic urban high school program focused on understanding food systems in Chap. 7, "Developing Environmental Action Competence in an Urban High School Agriculture and Environmental Program." Using ethnographic methods, the authors followed 120 students in an urban, comprehensive high school, along with their teachers and community partners over a three year period. The chapter concludes with implications for practitioners, suggesting how EAC can provide a framework to combine the leadership and experiential elements of traditional agricultural and environmental education to support students' development of STEM competencies.

In Chap. 8, "Growing a Culture of Sustainability: Urban Agriculture Experiences and Undergraduate Student Attachments and Behaviors", Kerri LaCharite examines how concerns related to global climate change and the industrial food system are propelling college and university administrators, faculty, staff, and students alike to take interest and action in sustainability and alternatives to the modern food system. Using a phenomenological approach, she examined the experiences of undergraduate students enrolled in campus farm internships at two universities to determine if students experienced changes in knowledge, internal locus of control, and pro-environmental and social behaviors necessary to justify a commitment of resources by colleges. Participants reported increases in pro-environmental behaviors and behavioral intentions. The chapter concludes with important implications for policy and practice.

In the final chapter, "An Overview of Urban Agriculture Youth Programs in Major Cities of the U.S. and the Integration of STEM Curriculum and Activities", Tara Pisani Gareau and Alex Moscovitz examine the extent to which urban agriculture projects are incorporating youth STEM education by providing resources or programs to teach project-based learning related to STEM subject areas into their operations and typify them based on their programs. The authors elucidate the largely unrecognized roles that urban agriculture programs (UAPs) play in fostering student engagement in STEM learning. The authors conclude with recommendations for future research to determine the educational outcomes of these programs.

1.1 Conclusion

Overall, this volume brought to light the importance of research in urban agricultural and community contexts. Collectively, the authors highlighted innovative research approaches that will be of use to future researchers and practitioners who work in urban agriculture. Across each chapter, research-based perspectives of the impact of urban agriculture programs on student learning were shared in addition to effective models and principles on designing urban agricultural programs being highlighted. Additionally, the authors pursued innovative approaches in examining the effectiveness of urban agriculture in formal, non-formal/informal educational contexts. In summary, not only will this volume become a useful resource for teachers and policymakers on how to conduct research that will help determine the efficacy and impact of urban agricultural programs; our hope is that the text will invigorate future discussions on the importance of engaging students in more contextualized learning opportunities through urban agriculture.

Chapter 2
What Role Does Motivation and Engagement in Garden-Based Education Play for Science Learning in At-Risk Middle School Students? A Self-Determination Theory Perspective

Ellen A. Skinner, Una Chi, and The Learning-Gardens Educational Assessment Group

Abstract The goal of this chapter is to explore how a motivational model based on self-determination theory can be used as a guide for specifying some of the elements of garden-based education necessary to promote science learning and achievement. This model posits that students' intrinsic motivation and constructive engagement with garden-based activities are "active ingredients" in their learning, and that programs will succeed in fostering motivation and engagement to the extent that they support key student experiences in the gardens, including feelings of belonging and self-efficacy, and a sense of purpose and ownership for garden-based activities and outcomes. The utility of this framework is illustrated with research from an interdisciplinary collaboration organized around the Learning Gardens Laboratory (LGLab), a garden-based education program grounded in sustainability

The **Learning-Gardens Educational Assessment Group** (or ***LEAG***) is an interdisciplinary group of faculty and students from the Department of Psychology and the School of Education at Portland State University and the leadership of Lane Middle School of Portland Public Schools organized around a garden-based education program, the Learning Gardens Laboratory (LGLab). *LEAG Faculty*: Ellen Skinner, Thomas Kindermann, Dae Yeop Kim, Dilafruz Williams (co-founder of the Learning Gardens Laboratory), Pramod Parajuli (co-founder), Karl Logan (Principal, Lane Middle School), Terri Sing (Asst. Principal), Heather Burns (Coordinator of the LGLab), and Weston Miller. *LEAG Students*: Lorraine Escribano, Una Chi, Jennifer Pitzer Graham, Amy Henninger, Shawn Mehess, Justin Vollet, Price Johnson, Heather Brule, Shannon Stone, Hyuny Clark-Shim, Jennifer Wood. We gratefully appreciate and acknowledge the contributions of the Garden Educators and volunteers at the LGLab, and the students, families, and teachers at Lane, especially the Science teachers who participated directly in the LGLab.

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pedagogy and carried out in cooperation with a middle school serving mostly low-income, minority, and immigrant youth. Analyses of information from 310 sixth and seventh grade students, their 6 Science teachers, and school records collected at multiple time points during the year suggested that, consistent with the motivational model, students' engagement in garden-based activities predicts improvements across the school year in their science learning in the garden and achievement in science and other core subjects taught in the garden (math and social studies). Moreover, one way in which students' garden engagement contributes to improvements in learning and achievement is by boosting their engagement in science class. Different patterns of meditational effects were found depending on the target outcome. For science learning in the garden, engagement in the garden and in science class both make unique contributions; for science achievement, the effects of garden engagement are fully mediated by science engagement; and for core achievement, garden engagement contributes to achievement not only directly, but also indirectly – by shaping students' subsequent engagement in science class. Discussion centers on how this framework can be used to enrich current garden-based education programs as well as to guide future research, including the selection of measures, the generation of motivational hypotheses, and the use of longitudinal designs to study key processes of engagement and learning in the gardens and in science class.

Keywords Garden-based science education · School gardens · Middle school · Self-determination theory · Self-system processes · Motivation · Engagement · Science learning · Achievement

The past 40 years have witnessed a resurgence of interest in school garden programs (Hirschi 2017; Waliczek and Zajicek 2016; Williams 2018; Williams and Brown 2012). Many states and their departments of education actively promote school gardening through legislation or by providing curricula and evaluation tools (Blair 2009; Gaylie 2011). Today tens of thousands of school gardens exist in the US, with several thousand in California alone (California School Garden Network 2020). Current enthusiasm reflects an appreciation of the potential of garden-based education to promote many aspects of students' learning and well-being, including their knowledge and appreciation of the natural world (Brynjegard 2001) and the development of healthy eating habits (Robinson-O'Brien et al. 2009). As garden programs have flourished, educators have increasingly recognized their potential as a vehicle for promoting school success across the curriculum (Cutter-Mackenzie 2009; Williams 2018; Williams and Dixon 2013).

One reason principals and teachers are so enthusiastic about garden-based education is that such programs seem to capture students' interest and energize their learning (Desmond et al. 2002). Qualitative studies consistently report students' delight, enthusiasm, and vigorous participation in gardening activities (Alexander et al. 1995; Brynjegard 2001; Canaris 1995; Moore 1995; Thorp 2006), including programs for youth (Eick 1998) and at-risk youth (Fusco 2001; Hudkins 1995). These findings are echoed by a small number of quantitative studies suggesting that learning activities organized around the environment result in higher levels of interest and effort (Lieberman and Hoody 1998; Pranis 2004; Williams et al. 2018). Research on students' academic motivation points to some of the design features of garden-based programs that are likely to enhance student enthusiasm and effort. Its core activities, which entail contextualized authentic, project-based, hands-on, peer-involved learning, are exactly the kinds of activities that studies have shown fuel students' interest and engagement more generally (e.g., Chen and Yang 2019; Kokotsaki et al. 2016; Krajcik et al. 2003; Rivet and Krajcik 2008; Swarat et al. 2012).

Such learning opportunities are increasingly important as students progress to middle school, because they may help to counteract the typical declines in motivation found across this school transition (e.g., Eccles et al. 1993; Gottfried et al. 2001; Wigfield et al. 1991). Authoritative reviews of research on the development of achievement motivation identify the transition to middle school as a turning point, during which students typically show sharp losses in interest, intrinsic motivation, engagement, and perceptions of the value and importance of learning in school (Wigfield et al. 2015). These motivational declines are especially steep for science and math (Vedder-Weiss and Fortus 2011, 2012), and for students from low socioeconomic, ethnic minority, and immigrant families (Graham and Hudley 2005; Meece and Kurtz-Costes 2001; Zusho et al. 2016). Losses in academic motivation during middle school are seen as a serious problem, because they predict poor performance and eventual desistence from high school (Fredricks et al. 2004). As a result, garden-based programs would be especially valuable if they could bolster engagement in science and other core subjects in middle school for students who are otherwise at risk for underachievement and drop-out (Bircan and Sungur 2016).

Critics, however, question the value of garden-based education, arguing that the time at-risk students spend in gardens would be better spent in classrooms focusing on the acquisition of basic literacy and math skills (Flanagan 2010). Moreover, the current climate of high stakes testing and reduced resources has put enormous pressure on educational decision-making, pressure that increases as students move from elementary to middle school, especially for decisions involving underachieving youth. Hence, as educators make judgments about whether to implement garden programs, especially for at-risk youth in middle and high school, they rely heavily on evidence about whether such programs have a measurable impact on students' academic outcomes, especially achievement in core subjects, like science and math.

Such decisions are informed by qualitative and quantitative research documenting the value of outdoor learning in general (Evergreen 2000; Malone and Tranter 2003; Rickinson et al. 2004), and outdoor science in particular, to both informal learning and academic achievement in school (ASEOS Working Group 2010; Blair 2009; Berezowitz et al. 2015; Diaz et al. 2019; Ozer 2007; Ratcliffe et al. 2010; Smith and Motsenbocker 2005; Williams and Dixon 2013). In a review examining the connection between garden-based programs and academic outcomes, Williams and Dixon (2013) synthesized the results of 22 studies, concluding that the "results showed a preponderance of positive impacts on direct academic outcomes with the highest positive impact for science followed by math and language arts" (p. 212). At the same time, however, they concluded that although the growth of garden-based learning programs is commendable, "the movement falls short in that there has not been a parallel focus on rigorous research to understand the academic learning outcomes in a systematic manner" (p. 227). Of special interest is the identification of essential elements of garden-based programs, that is, the elements that are necessary if such educational experiences are to be effective in promoting learning and achievement in core subjects, like science.

2.1 Motivational Framework to Specify "Active Ingredients" in Garden-Based Education

The goal of this chapter is to offer a motivational model grounded in self-determination theory (SDT) that has been used to provide a framework for conceptualizing and studying some of the elements that are needed for garden-based programs to be successful in promoting student learning and achievement. This model focuses on the role of constructive engagement and identifies the student experiences that should foster such engagement in the garden. To illustrate the utility of this framework, we describe a garden-based educational program for middle school students that embodies these essential elements, and present a study that examines the role of student engagement in explaining the effects of this program on at-risk middle school students' science learning, both in the gardens and in science class.

Engagement and Learning To conceptualize the motivational effects of garden-based learning environments, we relied on the construct of engagement (Christenson et al. 2012). For educators, one core definition of *academic engagement* refers to students' active enthusiastic, sustained, cognitively-focused participation in challenging academic activities (Connell and Wellborn 1991; Reeve 2012; Ryan 2000; Skinner et al. 2009a; Wentzel 1993). Engagement is considered a multi-dimensional construct that includes behavioral and emotional components (Fredricks et al. 2004). *Behavioral* engagement depicts students' focused attention, concentration, effort exertion, vigor, and persistence while working on academic tasks. These motivated actions can be contrasted with behavioral disaffection, in which students are distracted, passive, give up easily, or just go through the motions. *Emotional* engagement entails students' motivated emotions, such as enthusiasm, interest, and enjoyment, and can be contrasted with disaffected emotions, such as boredom, frustration, and anxiety. Both emotional and behavioral engagement are important to academic success. Some studies have suggested that emotional engagement (i.e., interest, enthusiasm) fuels behavioral engagement (i.e., effort, persistence) which, in turn, fosters student learning (Skinner et al. 2008). Taken together, these components of engagement and disaffection combine to characterize students that teachers would describe as "motivated" or "unmotivated."

Research has demonstrated that, in the short-term, students' engagement predicts their learning, grades, and patterns of attendance; over the long-term, engagement predicts students' achievement test scores, retention, and graduation rates (Fredricks et al. 2004; Jimerson et al. 2003; NRC 2004). These connections have been found in heterogeneous samples including Black, White, Latino, and Asian-American students from various SES levels (e.g., Connell et al. 1994, 1995; Finn and Rock 1997; Johnson et al. 2001; Smerdon 1999; Voekl 1997). Educators appreciate the construct of engagement because (compared to status indicators like student SES or ethnicity engagement represents a malleable motivational state that is potentially open to influence from outside factors, such as interpersonal relationships, classroom climate, and educational tasks. The challenge for schools is to provide a social and academic context in which engagement flourishes (NRC 2004).

Self-Determination Theory Many important facilitators of engagement have been integrated into a model of positive motivational development based on self-determination theory (SDT; Connell and Wellborn 1991; Ryan and Deci 2017; Skinner et al. 2009a). SDT is grounded in the assumption that all students have a wellspring of intrinsic motivation that can be channeled into energetic and enthusiastic engagement with school and its learning activities – as long as children's basic needs are met. The motivational model focuses on three fundamental needs, namely, for relatedness, competence, and autonomy. All three needs are considered to be intrinsic and universal, meaning that they have the potential to be (re)awakened in all students.

As depicted in Fig. 2.1, the model holds that when parents, teachers, and peers support children's basic needs, students experience themselves as competent to succeed, related (belonging) in school, and as autonomous or self-determined learners. Moreover, motivation and engagement are shaped by the nature of the *academic work* students undertake in the classroom (Wigfield et al. 2015). Active participation, engagement, and effort are promoted by tasks that are hands-on, heads-on, project-based, authentic, relevant, progressive, and integrated across subject matter, or in other words, intrinsically motivating, inherently interesting, fun, and connected to the world outside school (Blumenfeld et al. 1991; Brophy 2010; Deci 1998; MacIver et al. 2002; Renninger 2000). Taken together, these social and educational experiences support students' engagement with learning activities and their resilience in the face of challenges and setbacks, which shapes their learning and achievement.

Engagement in Garden-Based Education When viewed through the lens of the motivational model, it becomes clear why garden-based educational programs have the potential to meet the needs of at-risk youth. The need for *relatedness* can be met by working together with friends, classmates, teachers, master gardeners, and sometimes parents, on a project that is highly valued by the entire "village." The inclusion of cultural traditions makes diverse students feel welcome. Gardens can provide

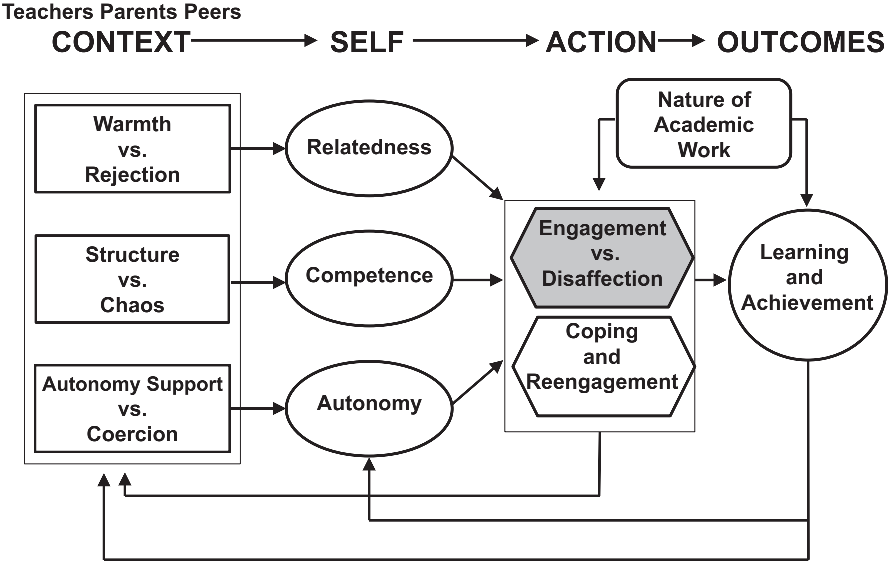

Fig. 2.1 A motivational model of engagement and learning, in which support from teachers, parents, and peers contribute to students' experiences that their needs for relatedness, competence, and autonomy are being met, which in turn promotes their engagement and coping with challenging and authentic academic work, leading cumulatively to students' educational success, as seen in their learning and achievement

refuge and feelings of safety where students can connect with nature and nurture living things. School gardens may also shape the way that students interact with teachers and cooperate with each other, thus altering school culture and identity, instilling pride and a sense of community. *Competence* needs can be met by the experience that problem solving, effort, and persistence pay off in tangible outcomes that matter (and taste good). Garden activities also offer multi-sensory learning by providing an array of sights, textures, aromas, and tastes. For students who struggle academically, the realization that gardening is part of science can awaken a sense of efficacy in areas from which they have typically been excluded.

Most importantly, garden-based education supports a sense of purpose, ownership, and *autonomy*, a need that is increasingly important and increasingly undermined by schooling as students approach adolescence. Gardening introduces activities that are meaningful, and inherently interesting because they are experiential, place-based, and project-based. The progressive activities of designing, planting, tending, harvesting, and consuming produce engage youth in ongoing authentic real-world learning activities, distinguishable from typical hands-on activities in the classroom, which tend to be simulations of real-world experiences. The "hands-on" and "heads-on" learning activities taking place in school gardens are of the kind hypothesized and found to support high quality engagement in learning activities during middle school and especially in science and math (e.g., Chapman and

Feldman 2017; Chen and Yang 2019; Darling-Hammond 2008; Fusco 2001; Krajcik et al. 2003; MacIver et al. 2002; Rahm 2002; Rivet and Krajcik 2008).

2.2 Learning Gardens Laboratory

The research described in this chapter is focused on an interdisciplinary collaboration organized around the Learning Gardens Laboratory (LGLab), a garden-based education program carried out in cooperation with a middle school serving mostly low-income, minority, and immigrant youth. The current LGLab curriculum frames garden-based activities using pedagogical design principles drawn from ecological systems and sustainability pedagogy (Burns 2011; Burns and Miller 2012; Capra 2003; Holmgren 2002; Orr 2004; Sterling 2004; Williams and Brown 2012). Sustainability education aims to reconnect learners to each other and the land, and to prepare students to participate in positive changes for local communities and ecosystems. It requires a shift in educational culture toward systemic, connective, and ecological ways of learning (Sterling 2004) and toward reflective, problem-based, and collaborative activities, which focus on learning through inquiry, experience, and reflection (Burns 2011; Moore 2005).

Although the LGLab curriculum incorporated learning goals from science, (as well as math and social studies), holistic garden-based education has its own logic and pattern of activities, reflecting its underlying ecological systems framework. Based on principles of sustainability, permaculture, and engaged pedagogies, curricula are grounded in a sense of place and stewardship for the land. Education is designed to recognize, create, and nurture communities by focusing on whole systems, acknowledging embeddedness in larger networks, emphasizing quality instead of quantity, and highlighting process and patterns (Capra 2003). Instead of looking at the world as a series of linear cause and effect chains, learning embraces a relational paradigm, noticing systemic interrelationships, and honoring what emerges from the learning process. Instead of starting with all the answers, this process encourages uncertainty and requires creativity from teachers and learners. Hence, learning is dynamic and engages the whole person. The LGLab has the potential to help students create their own connection to the land, watersheds, and communities where they live. These principles provide a pedagogical framework for the current LGLab curriculum (see Burns and Miller 2012; Williams and Brown 2012, for details). It is the holistic, hands-on, authentic, progressive, and social nature of garden-based learning activities that is expected to reenergize students, and reinvigorate their intrinsic motivation for learning.

Garden-Based Science Education Program The LGLab operates on four acres using two greenhouses located across the street from the middle school it serves. The program, a joint venture of Portland Public Schools and Portland State University, is coordinated by university faculty and supported by horticultural experts from the university extension service and volunteers. At the time of this study, the program was staffed by two Garden Educators, who were graduate stu-

Table 1 Overview of the elements of the garden-based program in the Learning Gardens Laboratory

Average dose	Sixth grade: 1.5 hrs per lesson, 1 time per week, 30 weeks.
	Seventh grade: 1.5 hrs per lesson, 1 time per week, 15 weeks.
Conceptual framework	Multi-level integrative developmental systems Model for Garden-Based Education (Ratcliffe et al. 2010).
	Holistic integrated learning tied to the elemental experience of the natural environment and growing things (Thorp 2006).
	Intrinsic motivation as a source of energy and engagement in learning when fundamental needs are met (Ryan and Deci 2017).
Learning objectives and content	Coordinated with science classes and grade-based science concepts.
	Incorporates math, English, and social studies concepts.
	Based in systems thinking, ecological awareness, and an appreciation for multicultural diversity.
Projected outcomes	Engage students in gardening and science learning, and promote academic motivation, engagement, and resilience.
	Improve learning and achievement.
	Instill a sense of purpose, belonging, community, self-efficacy, autonomy, and ownership.
	Promote ecological awareness and stewardship for the land.
Curricular principles	*Curricular learning environment*: Provide hands-on, project based, place-based education engaging youth in authentic ongoing activities that integrate curricula across disciplines, reinforcing concepts and abstract ideas (Ratcliffe et al. 2010).
	Physical learning environment: Improve quality and diversity of learning environments and safe spaces, including opportunities for visual learning and direct experiences of abstract concepts (Ratcliffe et al. 2010).
	Social learning environment: Foster caring relationships, provide high expectations and clear feedback, and explain the relevance and importance of activities and rules while soliciting input from students and listening to and respecting their opinions (Ryan and Deci 2017).
Examples of gardening activities	Planning activities: Students diagram their own 3 by 4 foot garden plot, including types of plants.
	Soil preparation activities: Students dig new beds and mix compost.
	Planting activities: Students transplant seedlings.
	Tending activities: Students water and weed beds.
	Harvesting activities: Students pick and wash vegetables.
	Preparing and eating activities: Students cook and eat vegetables.

dents in the university's Leadership for Sustainability Education program. As is typical for garden programs, the LGLab paired science curriculum with garden activities. Middle school students and their Science teachers participated directly in the gardens where LGLab Educators offered an integrated seasonally-based curriculum that featured hands-on learning experiences in planning, designing, planting, tending, growing, harvesting, cooking, and eating a variety of seasonal vegetables, fruits, herbs, and flowers (Williams and Brown 2012). The curriculum for the LGLab started in mid-September and ended in June. Table 2.1 contains an overview of its elements.

The sixth and seventh grade curricula consisted of 30 weeks of programming organized around a full year of science. Each week of programming included a lesson lasting 1.5 hours, during which students participated in at least four kinds of activities in the classroom and the gardens: (1) science and math; (2) culture, geography and history; (3) food and nutrition, including harvesting, cooking, and eating; and (4) work in the gardens. These activities incorporated science content from the state-wide benchmarks but were also designed to contribute to student learning in math and social studies. Activities were organized sequentially by seasonal themes, with alternative activities depending on the day's weather and how the growing season was progressing.

Engagement in the Learning Gardens Lab Student engagement in the garden context can be seen in students' active behaviors and enthusiastic emotions. For example, in the LGLab, students began designing their individual garden plots in late winter, by staking them outside using wooden frames that were 3 feet by 4 feet in size. Then, using large sheets of graph paper spread out on utility tables inside one of the greenhouses, students worked on their own individual designs in groups of 3 or 4. Students had already learned about, and cooked and tasted, many kinds of vegetables and discussed how different combinations of plants can grow together. For example, in fall they had studied the Native American "three sisters garden" planted the previous year, in which corn, beans, and squash help each other grow. Corn stalks acts as a trellis for bean vines to climb, which stabilize the corn plants so they do not blow over; shallow rooted squash vines create living mulch, by shading weeds and holding moisture; spiny squash plants also protect corn and beans from predators; the large amount of residue from these crops, combined with the nitrogen that beans fix on their roots, help build up soil quality for the next season.

Students used colored pencils and small cut-outs of the vegetables that were available for planting to design how they would plant their plots in the early spring. Indicators of engagement in these learning activities included their interest and excitement while drawing and selecting vegetable cut-outs, their consultation with the Garden Educators and each other, their persistence in completing their designs, their desire to show their designs to their Science teacher, their willingness to discuss plans for starting seedlings of these plants in the early spring, and their reluctance to stop work when the period ended. In subsequent sessions outside, when students began planting their plots, engagement was also evident in students' energy and excitement about getting outside, their attention to instructions about how to transport and use tools, their bubbling anticipation when collecting their seedlings, their reliance on the design plans (held down by rocks) to figure out where to plant their seedlings, the care and cooperation they showed with their classmates in getting the seedlings settled properly, and their desire to show their progress to Garden Educators and Science teachers. The experience of enthusiastic participation was salient to students and visible to Science teachers.

2.2.1 Research on Engagement in the Learning Garden

As part of this collaboration, we have been developing teacher- and student-report measures of many aspects of SDT in the garden, including engagement, intrinsic motivation, feelings of relatedness, competence, and autonomy, and support from teachers, parents, and peers, all of which show the pattern of concurrent associations that would be expected among elements of the motivational model (Skinner et al. 2012; Williams et al. 2018). Although our long-term goal is to test the entire model depicted in Fig. 2.1, we decided that, in order to illustrate research from this program of study, we would focus first on student *engagement* as a core motivational process through which garden-based activities may contribute to science learning and achievement.

To capture engagement, we relied on a survey measure that was adapted for use in garden programs from a published measure of engagement that had been validated with multiple reporters and classroom observations (Skinner et al. 2009b) and was based on a review of the engagement literature (Skinner et al. 2009a; Skinner and Pitzer 2012). The measure of garden engagement shows both satisfactory psychometric properties and the hypothesized structure, indicating that it taps important dimensions of behavioral and emotional engagement and disaffection. Moreover, both student- and teacher-reports of student engagement in gardening activities are associated with students' feelings of competence, autonomy, and intrinsic motivation for gardening (Skinner et al. 2012).

2.3 Research Questions

The current study aimed to explore the role of engagement in explaining the effects of the garden-based educational program on at-risk students' science learning, both in the gardens and in science class. We wanted to capture the quality of students' participation in garden-based activities, using student- and teacher-reports, and to examine whether students who evinced high levels of garden engagement at the beginning of the school year also showed improvements in their science learning and achievement as the year progressed. Previous studies have shown correlations between student engagement and achievement (e.g., Skinner et al. 2012). These associations are consistent with the notion that engagement contributes to achievement, but they may also be interpreted as support for feedback effects, more specifically, the idea that achievement contributes to engagement, since students who do well in science or school are likely to show more engagement in the garden. Compared to correlational analyses, a better estimate of the effects of garden engagement can be obtained by using regression analyses that examine the contribution of garden engagement to *changes* in achievement over the year (e.g., Williams et al. 2018). These analyses examine whether students' garden engagement makes a significant contribution to their subsequent learning or achievement, while controlling for their previous learning or achievement.

In addition, we wondered whether engagement in the gardens shaped science learning and achievement by sparking students' engagement in science class, and so we examined science engagement as a potential mediator. It seemed possible that students' enthusiasm about learning in the gardens, perhaps buoyed by the connections these activities provide between science and the real world outside the classroom, could boost students' interest and curiosity about science learning activities *inside* the classroom. Because these engaged emotions seem to promote engaged behaviors, like effort and persistence in learning activities (Skinner et al. 2008), we thought that they might be one pathway through which garden engagement contributes to achievement in science and other core subjects. To test these effects, we used regression analyses, which examined the direct effect of garden engagement on target outcomes, and then determined whether those effects were reduced (partial mediation) or eliminated (full mediation) when the potential mediator, in this case science engagement, was entered into the equation. We expected that students' garden engagement would not only have direct effects on their learning and achievement, but also indirect effects, by bolstering students' engagement in science class.

Figure 2 contains a process model depicting how engagement in the gardens might shape science learning, performance, and achievement in school. As can be seen, students' engagement in the garden is expected to contribute directly to their

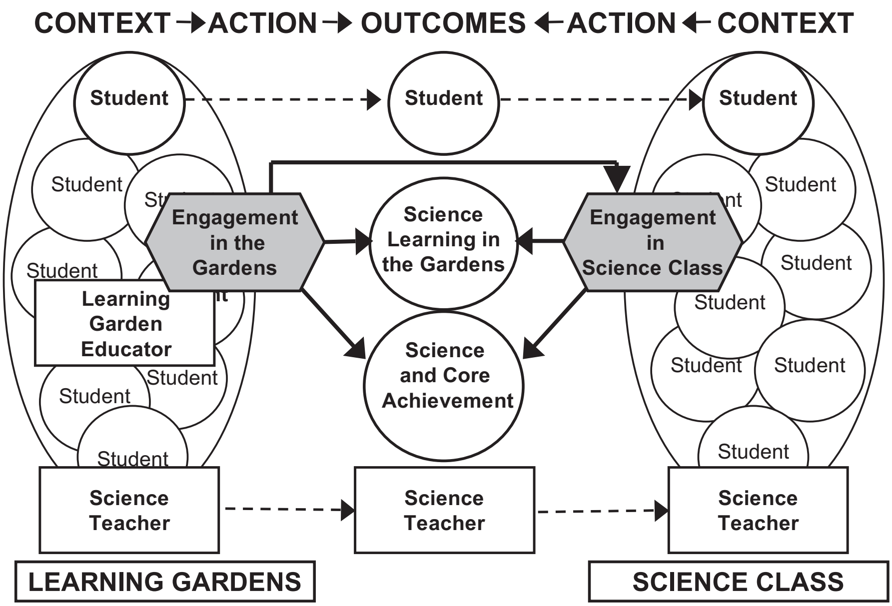

Fig. 2.2 A process model of engagement as a core motivational process in the learning gardens, in which students' engagement in garden-based learning activities shapes science learning in the garden, engagement in science class, and science and core achievement in school. Engagement in garden-based activities is hypothesized to work directly, by promoting students' science learning in the gardens and in science class; as well as indirectly, by boosting student engagement in science class, which itself promotes learning and performance

science learning in the garden as well as to their performance in science and in other core topics offered in the gardens. Garden engagement is also expected to boost students' engagement in science class, and through this pathway to make further contributions to both science learning in the gardens and learning and achievement in science and other core subjects. To test this process model organized around student engagement, we first calculated correlations among target constructs. Second, we conducted multiple regressions that examined garden engagement as a potential predictor of *changes* in learning outcomes. Third, we conducted meditational analyses that examined science engagement as a pathway through which garden engagement could exert its effects on academic performance. Together, these analyses aimed to shed some light on the role of engagement in garden-based education, testing the idea from SDT (and other motivational frameworks) that students' enthusiastic participation in learning activities in the garden is an essential element of the success of such programs in supporting student learning and academic development.

2.4 Sample, Design, and Measures

To answer these questions, we used information from 310 sixth and seventh grade students, their Science teachers, and school records collected at multiple times during the year about the quality of students' participation in garden-based activities, their learning, and academic performance.

Sample Participants included 310 middle school students ages 11 to 13 in grades six and seven and their 6 Science teachers from a middle school that was culturally and linguistically diverse: 54.6% of its students were minorities (8.4% African American, 24.1% Latina/o, 15.3% Asian, 3.3% Native American; 3.5% multiple ethnicities); 41% spoke English as a second language; 19 languages were spoken by students. Students came from predominantly low-income families: 75% of students qualified for free or reduced lunch.

Design and Measures Data from students, their Science teachers, and school records were collected in fall after about 6 weeks of the garden program (October) and spring (May) of one school year; additional measures were collected in spring only. On survey measures, teachers and students responded using a 5-point rating scale from not at all true (1) to very true (5). Scores were calculated by reverse coding negative items and averaging them with positive items to create scores ranging from 1 to 5, with 5 indicating higher levels of the respective construct. *Teacher-reports of engagement and disaffection in the garden* (Skinner et al. 2012) were adapted from a measure of students' participation in academic activities in the classroom (Skinner et al. 2009b). Teachers responded to the stem "In the Learning Gardens, this student…" and rated 6 items tapping behavioral engagement (e.g., "gets very involved"), emotional engagement (e.g., "is enthusiastic"), behavioral disaffection (e.g., "is not really into it"), and emotional disaffection (e.g., "does not really like it"). Internal consistency reliabilities, calculated using Cronbach's alpha were satisfactory (α = .93 and .95 in fall and spring, respectively).

For *student-reports of their own engagement and disaffection in the garden*, students responded to the stem "When I'm in the garden…" and rated 10 items tapping behavioral engagement (e.g., "I listen carefully to our garden teacher"), emotional engagement (e.g., "Gardening is interesting"), behavioral disaffection (e.g., "I can't wait for it to be over"), and emotional disaffection (e.g., "Gardening is boring"; Skinner et al. 2012). Internal consistency reliabilities were satisfactory (α = .89 and .90, in fall and spring, respectively). Moreover, teacher- and student- reports of engagement were positively and significantly correlated with each other at both time points ($r = .31$, $p < .001$, and .37, $p < .001$, in fall and spring, respectively).

Science learning in the garden was measured using six items tapping students' perceptions of how much they had learned in the garden about science (e.g., "I learned how to do science – experimenting, measuring, observing, finding out new facts"), plants (e.g., "I learned how plants grow"), the environment (e.g., "I learned how I can treat the environment better"), and food ("I learned about things I like to eat that I did not like before"; Skinner et al. 2012). Internal consistency reliabilities were satisfactory (α = .82 and .88, in fall and spring, respectively). Moreover, student ratings of their science learning in the garden were correlated positively and significantly with their overall GPA, $r = .26$, $p < .001$.

Indicators of *student academic performance* were extracted from students' records, based on graded performance in core subjects (math, science, and social studies) each quarter. Letter grades were converted to a standard 4-point GPA scale, with "A" as 4. Science GPA was calculated as grades in the respective science class for sixth or seventh grade each quarter. Aggregate indicators of core GPA were calculated by averaging grades in science, math, and social studies.

Finally, in spring only, each *student's engagement in science* class was captured using Science teachers' responses to the stem "In science, this student…" with six items tapping behavioral engagement (e.g., "works hard"), emotional engagement (e.g., "seems interested"), behavioral disaffection (e.g., "refuses to do anything"), and emotional disaffection (e.g., "does not really care"; Skinner et al. 2012). Internal consistency reliability for the scale calculated using Cronbach's alpha was satisfactory (α = .96).

2.5 Results

Data analyses examined three key questions:

1. Are patterns of correlations among constructs consistent with the idea that students' engagement in garden-based activities is important to their learning in the garden, engagement in science, and performance in science and other core subjects taught in the garden (math and social studies)?

Table 2.2 Means, standard deviations, and cross-time stability correlations for student engagement in the garden, science learning, and achievement

	Descriptive statistics				
	Means and standard deviations (SD)				Cross-time stability
Measure	Fall		Spring		Fall to Spring
LGLab Engagement	*Mean*	*SD*	*Mean*	*SD*	
Teacher-report	4.12	.87	3.78	1.02	.31**
Student-report	3.75	.82	3.55	.93	.52***
Learning outcomes					
Science Learning in the Garden Student-report	3.45	.88	3.22	1.05	.43***

Note. $N = 310$. *Range* = 1 (not at all true) to 5 (totally true)
***$p < .001$; **$p < .01$

Achievement	Science		Core		GPA correlations between Periods		
	Mean	SD	Mean	SD	Total Science and Core	.81**	
GPA total	2.53	1.11	2.74	1.14	*Periods*	*Science*	*Core*
GPA period 1	2.63	1.17	2.63	1.14	1 and 2	.78***	.79***
GPA period 2	2.46	1.22	2.71	1.03	2 and 3	.78***	.70***
GPA period 3	2.53	1.11	2.89	.92	1 and 3	.74***	.60***

Note. $N = 310$. *Range* = 0 ("F") to 4 ("A"). *Core GPA included grades for science, math, and social studies*
*$p < .05$; **$p < .01$; ***$p < .001$

2. Does student garden engagement at the beginning of the school year predict *changes* across the year in students' science learning in the garden and achievement in science and other core subjects?
3. Does garden engagement contribute to learning and achievement not only directly, but also indirectly--by shaping students' subsequent engagement in science class?

Descriptive and Correlational Findings The descriptive statistics for all variables appear in Table 2.2. These statistics reveal that both teachers and students reported relatively high levels of student engagement in the garden (average = 3.80); all means were above the mid-point of the scale (3.0). Students also reported that they learned quite a bit in the garden (average = 3.34). Table 2.2 also presents the means and standard deviations for science and core GPA at the three grading periods as well as the correlations between periods. The average science GPA across the year was 2.53 (a "C") and the average core GPA across the year was 2.74 (a "C+"). As expected, cross-time stabilities in GPA were high (average $r = .78$ for science, and .70 for core). These stabilities made it more difficult to predict *changes* in GPA.

Correlations If the process model depicted in Fig. 2.2 is a good account of one pathway through which engagement in the garden shapes engagement and learning in science, then both teacher- and student-reports of garden engagement should

Table 2.3 Correlations between student engagement in the garden, science learning in the garden, and achievement

	LGLab Engagement (teacher-report)		LGLab Engagement (student-report)	
	Fall	Spring	Fall	Spring
Science learning in the garden Student-report	.40***	.27***	.63***	.73***
Science achievement				
Science GPA Total	.37***	.38***	.27***	.27***
Science GPA period 1	.35***	.38***	.20***	.23***
Science GPA period 2	.33***	.32***	.31***	.30***
Science GPA period 3	.32***	.34***	.24***	.21***
Core achievement				
Core GPA Total	.51***	.47***	.35***	.25***
Core GPA period 1	.45***	.42***	.23***	.16***
Core GPA period 2	.46***	.41***	.35***	.24***
Core GPA period 3	.45***	.46***	.36***	.29***

$N = 310$. *Core GPA included grades for science, math, and social studies*
$^*p < .05$; $^{**}p < .01$; $^{***}p < .001$

show positive associations with science engagement and both science and core GPA. As predicted, correlations between engagement in the garden and indicators of science learning in the garden as well as science and core achievement supported these hypothesized connections. As shown in Table 2.3, both teacher- and student-reports of garden engagement were correlated positively and significantly with student science and core GPA during each grading period (science GPA average $r = .29$, range .20–.58; core GPA average $r = .37$, range .16–.51) and with student-reports of science learning in the gardens (average $r = .51$, range .27–.73). As might be expected based on differences in reporters, students' ratings of their own engagement were more closely linked to their reports of their learning, whereas teacher-reports of engagement were more closely connected to students' GPA.

Predicting Changes over the School Year Correlational analyses showed that garden engagement is *associated* with concurrent learning and achievement. However, if garden engagement is actually *shaping* student learning and achievement, then student engagement in the garden in fall should predict *changes* in student learning and GPA from fall to spring. In other words, students who are highly engaged in the garden in fall should show *improvements* in their learning and achievement as the year progresses, whereas students who are relatively less engaged should show no improvements or might actually decline in learning and achievement over the same period of time.

A series of structural equation models were calculated to examine this hypothesis. These were conducted separately for each combination of the two reporters of student engagement in the garden (students and teachers) and for the three outcome

Table 2.4 Student- and teacher-report of student garden engagement in fall predict changes in science learning in the garden (student-report) from fall to spring

Outcome: Science Learning in Spring (Student-report)		
Model	*Path coefficient*	p value
LGLab Engagement in fall *(Student-report)*	.29***	$p < .001$
Controlling for Science Learning in Fall[a]	.25***	$p < .001$
Stability index:	.12	
Outcome: Science Learning in Spring (Student-report)		
Model	*Path coefficient*	p value
LGLab Engagement in fall *(Teacher-report)*	.20***	$p < .001$
Controlling for Science Learning in Fall[a]	.35***	$p < .001$
Stability index:	.04	

$N = 310$. Models run in Amos 17.0
*$p < .05$; **$p < .01$; ***$p < .001$
[a]Also controlling for gender

variables (students' reports of their science learning in the garden, science GPA, and core GPA). It was expected that all the structural analyses would reveal that garden engagement in fall predicted learning outcomes in spring, even after controlling for the prior levels of those learning outcomes in the fall. At the same time, it was expected that these path coefficients would be relatively small, given the high levels of stability in learning outcomes from fall to spring (see Table 2.2).

Analyses examining the effects of students' garden engagement on their science learning in the garden (student-reports) are presented in Table 2.4. As can be seen, all the predicted effects were found. Student-reports of garden engagement were a significant predictor of changes in student-reported learning over the school year (standardized path coefficient = .29, $p < .001$). Likewise, teacher-reports of garden engagement made a significant and unique contribution to student learning in the garden in spring (standardized path coefficient = .20, $p < .001$), even after controlling for the strong effects of learning in the fall (path coefficient = .35, $p < .001$). These results indicated that students who were more engaged in fall (as appraised by students or teachers) showed greater increases over the school year in how much they felt they learned in the garden.

The effects of garden engagement on changes in science and in core GPA are depicted in Table 2.5. All hypothesized effects were found, although they were weaker for science than for core GPA, perhaps because science GPA was more stable from fall to spring. For science achievement, student-reports of their garden engagement were a significant unique predictor of science GPA in spring (standardized path coefficient = .10, $p < .05$), after controlling for the strong effects of science GPA in fall (path coefficient = .72, $p < .001$). Teacher-reports of garden engagement were a marginally significant predictor of changes in science GPA from fall to spring (standardized path coefficient = .07, $p < .10$). In terms of core achievement, student- reports of garden engagement predicted core GPA (standardized path coefficient = .23, $p < .001$) in spring, even after controlling for the strong effects of GPA in fall (path coefficient = .54, $p < .001$). Teacher-reports of garden engagement were

Table 2.5 Student- and teacher-reports of student garden engagement in fall predict changes in science and core achievement (GPA) from fall to spring

Science achievement		
Outcome: Science GPA period 3		
Model	*Path coefficient*	*p* value
LGLab Engagement in fall *(Student-report)*	.10*	$p < .05$
Controlling for Science GPA period 1[a]	.72***	$p < .001$
Stability index:	.01	
Outcome: Science GPA period 3		
Model	*Path coefficient*	*p* value
LGLab Engagement in fall *(Teacher-report)*	.06^	$p < .07$
Controlling for Science GPA period 1[a]	.72***	$p < .001$
Stability index:	.03	
Core Achievement		
Outcome: Core GPA period 3		
Model	*Path coefficient*	*p* value
LGLab Engagement in fall *(Student-report)*	.23***	$p < .001$
Controlling for Core GPA period 1[a]	.54***	$p < .001$
Stability index:	.01	
Outcome*: Core GPA period 3*		
Model	*Path coefficient*	*p* value
LGLab Engagement in fall *(Teacher-report)*	.23***	$p < .001$
Controlling for Core GPA period 1[a]	.49***	$p < .001$
Stability index:	.03	

$N = 310$
Note. Models run in Amos 17.0. Core GPA included grades for science, math, and social studies
^$p < .10$; *$p < .05$; ***$p < .001$
[a]Also controlling for gender

also a significant predictor of changes in core GPA from fall to spring (standardized path coefficient = .23, $p < .001$). These results indicated that students who were more engaged in the garden at the beginning of the school year, (compared to those who showed relatively lower levels of engagement), evinced greater improvements in their performance in science and in core subjects as the year progressed.

Mediational Analyses To determine whether science engagement was one pathway through which garden engagement shapes science learning, science achievement, and core achievement, we conducted mediational analyses in which we examined science engagement as a potential mediator between garden engagement and changes in science learning and achievement. The key idea was that students' engagement in outdoor science (in the garden) might contribute to increases in their learning and achievement by boosting students' engagement in indoor science (in science class).

To test this proposition, we conducted multiple regressions using the four-step procedure recommended by Baron and Kenny (1986). Preliminary conditions

Table 2.6 Correlations between student engagement in science class and garden engagement, science learning in the garden, and academic achievement

Science engagement in spring (*Teacher-report)*	
Student engagement in the garden	
Teacher-report in fall	.38***
Teacher-report in spring	.70***
Student-report in fall	.29***
Student-report in spring	.27***
Learning in the garden in spring (student-report)	.24***
Science Achievement	
Science GPA period 1	.56**
Science GPA period 3	.58**
Total Science GPA	.61**
Core Achievement	
Core GPA period 1	.56***
Core GPA period 3	.72***
Total Core GPA	.69***

Note. Core GPA included grades for science, math, and social studies
$N = 310$; $^{***}p < .001$

require that the antecedent (in this case, garden engagement) is related to both (1) changes in the outcome (i.e., science learning and achievement) and (2) the proposed mediator (i.e., science engagement) and that (3) the proposed mediator (i.e., science engagement) is correlated with changes in the outcome (i.e., science learning and achievement). The step of most interest is (4) whether, in a regression using both the antecedent and the mediator as predictors of changes in the outcome, the unique effect of the mediator remains significant whereas the effect of the antecedent is significantly reduced (partial mediation) or no longer reaches significance (full mediation). By calculating a standard error for the product of the mediated paths, we can determine whether the mediation is statistically significant (Sobel 1982). Significant mediation would suggest that some or all of the impact of garden engagement on learning and achievement were exerted via the effect of garden engagement on science engagement.

As shown previously and in Table 2.6, which contains the correlations between science engagement and all the other variables, the preliminary conditions for testing a mediational model were met: (1) The antecedents, namely, garden engagement in fall (teacher- and student-reports) significantly predicted all three learning outcomes (changes in science learning in the garden and changes in science and core achievement from fall to spring); (2) the antecedents (garden engagement in fall) were significantly correlated with the proposed mediator (science engagement in spring); and (3) the proposed mediator (science engagement) was correlated with all three learning outcomes in spring. The step of most interest was (4) the last one, in which both garden engagement in fall (the antecedent) and science engagement in spring (the potential mediator) were used as predictors of changes in each outcome. If science engagement acted as a mediator, the effects of garden engagement on learning outcomes in this regression would be diminished.

The results of these analyses are presented graphically in Fig. 2.3. In this figure, the target outcome in the spring is pictured in a circle at the right. The dashed arrow labeled (1) represents the stability of the outcome over the school year. It extends from the target outcome in the fall (pictured at the left) to the outcome in spring. By controlling for the outcome in fall, these analyses examined *changes* in the outcome from fall to spring. The more stable the outcome, the more difficult it was to predict changes from fall to spring. Garden engagement in fall is also pictured at the left. The solid arrow labeled (2) extends from garden engagement to the target outcome, and represents the direct (unmediated) effect of garden engagement on changes in the outcome. Solid arrows labeled (3) and (4) represent the mediated effects of garden engagement on the outcome; it extends from garden engagement to science engagement (arrow 3) and from science engagement to changes in the outcome (arrow 4). The results for regressions using teacher-reports of student engagement in gardens are pictured above the arrows; the results for regressions using student-reports of their own engagement in the garden are pictured below the arrows.

On the two solid arrows that lead to the outcome are the zero-order correlations between garden engagement and the outcome (in parentheses on arrow 2) and between science engagement and the outcome (in parentheses on arrow 4). Mediational effects are revealed by the extent to which these correlations are reduced when both kinds of engagement are added to the regression equation predicting changes in the outcome from fall to spring. If the correlations are significantly reduced and no longer significant, full mediation is shown. If the correlations are significantly reduced but they are still significant, partial mediation is shown. If the correlations are not significantly reduced and are still significant, there is no evidence for mediation.

We expected that science engagement would partially mediate the effects of garden engagement on all three outcomes: science learning in the garden, science achievement, and core achievement. However, the findings were more complex and interesting than predicted – whether science engagement mediated the effects of garden engagement depended on the specific academic outcome. When the outcome was changes in *science learning in the garden* (depicted in the top panel of Fig. 2.3), science engagement did *not* mediate the effects of garden engagement. Garden engagement remained a significant unique predictor of learning (average *beta* = .21), but the unique effects of science engagement were only marginally significant (average *beta* = .11). Instead of mediation, these analyses revealed that *both* kinds of engagement made *unique* contributions to changes in students' science learning in the garden: Students' science learning in the garden benefitted from hard work and interest (i.e., engagement) in *both* science and garden learning activities. This pattern held for both student-reports and teacher-reports of garden engagement.

In contrast, when the outcome was changes in *science achievement* from fall to spring (depicted in the middle panel of Fig. 2.3), science engagement *fully* mediated the effects of garden engagement. When both garden engagement and science engagement were entered into the multiple regressions predicting changes in science GPA, science engagement remained a significant unique predictor (average *beta* = .40), but the unique effects of garden engagement were no longer significant

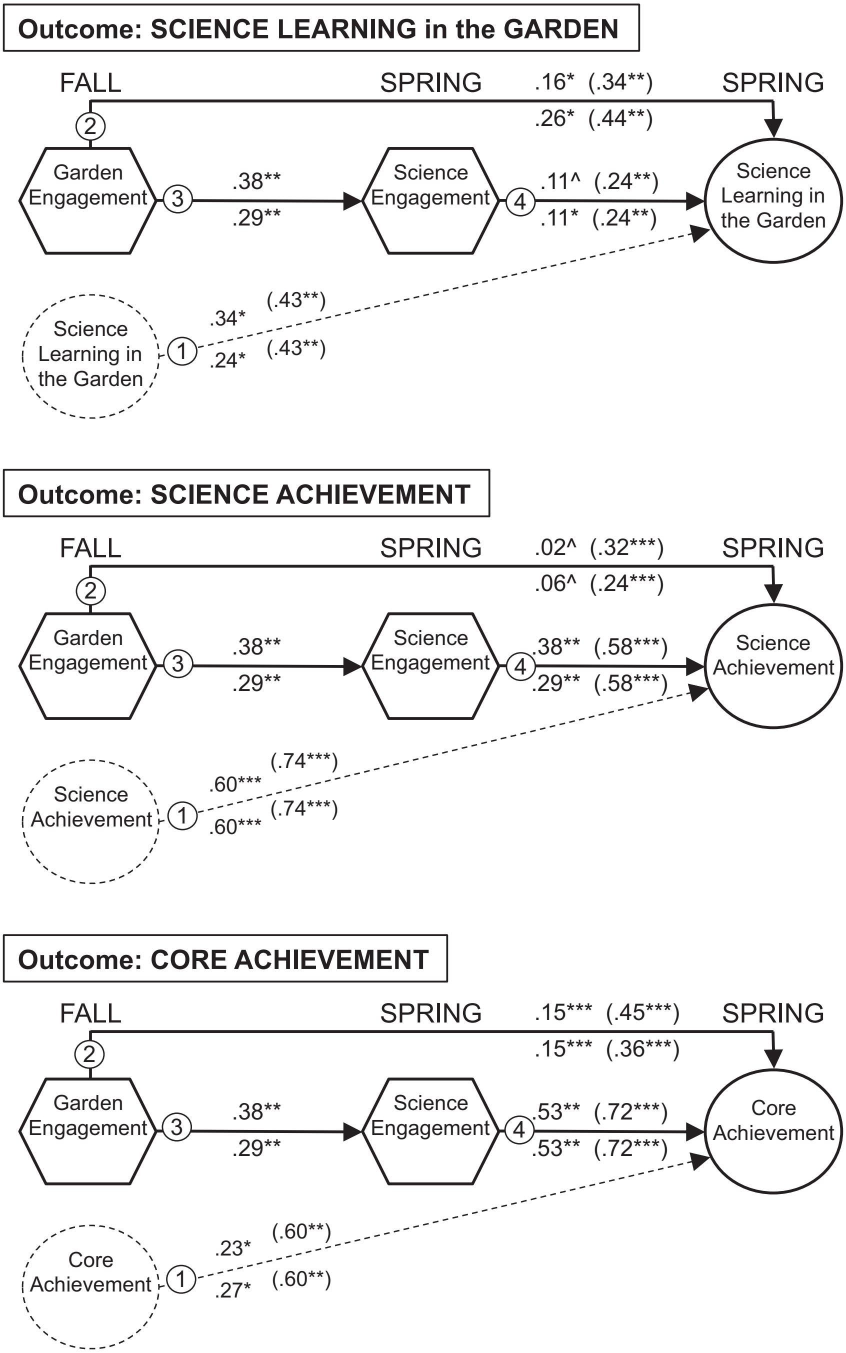

Fig. 2.3 Results of multiple regressions testing models in which students' engagement in science class mediates the effects of students' garden engagement on changes in their science learning in the gardens, science achievement, or core achievement. *Note*. Above the arrows are standardized coefficients for regressions calculated using teacher-report of garden engagement; below the arrows are student-reports of their own garden engagement. In parentheses are zero-order correlations. Science Learning refers to students' self-reports of the science content they learned in the gardens. ^$p < .10$; *$p < .05$; **$p < .01$; ***$p < .001$

(they were reduced from an average correlation of .28 to an average *beta* = .04). These findings indicated that all the effects of garden engagement on changes in science achievement were exerted through its effects on engagement in science class. This pattern held for both student-reports and teacher-reports of garden engagement.

Finally, for predictions of *core achievement* (depicted in the bottom panel of Fig. 2.3), *partial* mediation was found. When both garden engagement and science engagement were entered into the multiple regression predicting changes in core achievement, science engagement remained a strong significant unique predictor (average *beta* = .53), but the unique effect of garden engagement, although it remained significant, was significantly reduced according to the Sobel tests (from an average correlation of .41 to an average *beta* = .15). These results suggested that garden engagement followed two pathways in predicting changes in core achievement: a pathway directly from garden engagement to core achievement, and an indirect pathway through engagement in science class. This pattern held for both student-reports and teacher-reports of garden engagement.

2.5.1 Implications for the Enrichment and Study of Garden-Based Educational Programs

The Learning Gardens program, grounded in principles of sustainability education and integrated with sixth and seventh grade science curricula, involved six Science teachers and 310 of their students in designing, planting, tending, and harvesting produce on the four acre garden site across from the participating middle school. Findings revealed that, consistent with the motivational model, student- and teacher-reports of engagement in the garden showed the expected pattern of positive and significant connections with the academic outcomes of science learning in the garden and achievement in science and in core subjects (science, math, and social studies). Most notably, and consistent with the notion that engagement *shapes* student learning, garden engagement predicted *changes* in all three learning outcomes over the school year. This pattern held true for both student- and teacher-reports of students' engagement in the garden.

These results suggest two ways in which garden engagement combines with engagement in science class to contribute to changes in science learning from fall to spring – directly through participation in garden activities themselves, and indirectly by promoting students' engagement in science class. For the most proximal science learning, namely learning in the gardens, garden engagement has an additive effect, in which it makes a unique contribution, along with science engagement, to what students report they are learning in the gardens. For more formal science learning in the classroom (as marked by science GPA), no unique contribution of garden engagement was found. The effects of garden engagement on these outcomes seemed to be exerted wholly by boosting engagement in learning activities in science class. However, when examining core achievement (as captured by GPA in science, math, and social studies), garden engagement seems to work along both pathways: indirectly, by shaping engagement in science class, as well as directly – perhaps by contributing to engagement in other core classes or in school in general. Importantly, these patterns of effects, although not predicted, were replicated across student- and teacher-reports of student garden engagement.

Taken together with previous studies (Skinner et al. 2012; Williams et al. 2018), these findings suggest that the proposed self-determination model holds promise for describing some of the "active ingredients" in garden-based educational activities: When garden programs are linked with science class, students' engagement in both settings are important to science learning and achievement. Moreover, one way in which garden programs may contribute to improved science learning is by promoting engagement in science class. This perspective has several important implications, which we explore in the final sections of this chapter. First, it suggests that student engagement should become a central target of all garden-based programs, and that the larger literature on the factors that promote and sustain enthusiastic engagement (e.g., warm student teacher–relationships, self-efficacy) can guide garden educators in refining and enriching their programs. Second, it suggests that studies of the effects of garden-based programs may wish to incorporate motivational and longitudinal hypotheses and to include measures of engagement in garden activities, similar to the ones included in qualitative studies or the quantitative student- and teacher-report surveys used in the current study.

2.6 Enriching Garden-Based Educational Experiences

Educators are increasingly turning to school gardens as a way of integrating a variety of curricula, focusing on science, math, health, nutrition, and sustainability, into a set of outdoor activities that they believe will awaken enthusiasm and promote learning in their students. Previous research has provided testimonial and quantitative evidence that garden programs can make a positive contribution to students' motivation and achievement in school (Blair 2009; Ozer 2007; Ratcliffe et al. 2010; Williams et al. 2018; Williams and Dixon 2013). However, this research base is thin (Rickinson et al. 2004), and it is thinner still during the crucial years of middle and high school, and for youth otherwise at-risk of underachievement and dropout. The current study attempted to add to research on garden-based programs by examining the effects of one high-quality program for middle school students from low socioeconomic, ethnic minority, and immigrant families.

As a core motivational process in science learning, student engagement, which includes enthusiasm as well as interest, enjoyment, and hard work, may provide a conceptual and empirical anchor for garden-based science education programs, identifying a pathway to desirable academic outcomes, such as increased engagement and achievement in science and in school more generally. Most importantly, a focus on engagement identifies a worthy target around which to organize other essential program elements. The learning environments of school gardens can be selected and designed to optimize student motivation by focusing on the facilitators of engagement identified by the SDT framework (Connell and Wellborn 1991; Ryan and Deci 2017). These include: (1) contributing to a sense of *relatedness* to teachers, peers, and the land itself by focusing on building relationships, inclusiveness, cultural traditions of growing and eating, and cooperative group gardening activities; (2) boosting feelings of *competence* in science and school by offering new pathways to success, multisensory avenues for learning, and direct experiences of producing something important through one's own efforts; and (3) supporting students' *autonomy* by allowing them some freedom to follow their own interests and by demonstrating the relevance of science and school to everyday life (Skinner et al. 2012; Williams et al. 2018).

Full Integration with Science Curriculum and Standards Although engagement seems to be a necessary condition for learning, it is not by itself sufficient. Equally crucial are the kinds of academic tasks with which students are engaged. On the one hand, tasks must support students' intrinsic motivation and engagement, by offering *authentic academic work*, which makes clear that the activities of science are meaningful, important, and worthy of serious effort because they help, not only to enrich and beautify the neighborhood, but cumulatively to feed people and save the planet. On the other hand, academic tasks must be challenging and pedagogically sound, that is, designed so that, when students engage fully with them, this process cumulatively leads to learning core science. There are many activities in the garden that capture students' full engagement (such as digging holes); however, participation in these activities will not necessarily lead to science learning. Likewise, there are many activities that contribute to science learning (such as the memorization of science concepts) that students do not typically find interesting or important. The key is to identify and adapt learning activities that serve a dual function – work that is *both* engaging *and* academically fruitful.

An important next step for garden-based educational programs, especially those targeting middle school populations at risk for underachievement, is to find the "sweet spot" in which academic work in the garden not only feeds intrinsic motivation but also drills down into current demanding core standards for science learning (Williams et al. 2018; Williams et al., other volume). A focus on engagement can be helpful in this regard. Because it is observable (Skinner et al. 2009b), teachers can fine tune program lessons as they are implemented based on their effects on student effort and enjoyment.

Developmental Calibration of Garden-Based Programs for Adolescents from Under-Served Groups Although the motivational model is hypothesized to be universally applicable, in that the psychological needs on which it is based are considered to be fundamentally human (Ryan and Deci 2017), nevertheless, an important next step in using it to enrich garden-based programs would be to carefully analyze how such educational experiences can be adapted to meet the specific needs of middle school students who are at risk for underachievement (Camasso and

Jagannathan 2018; Cutter-Mackenzie 2009; Duncan et al. 2016; Richardson 2011). Although some forms of outdoor science, such as fieldwork, are often designed for middle and secondary school students, the vast majority of garden curricula and evaluation studies target students in preschool through grade five (Blair 2009; Williams and Dixon 2013). As Rickinson et al. (2004) note, students become "critical consumers" of outdoor learning activities as they get older, and securing their whole-hearted participation is not always an easy task. Hence, garden-based programs like the one described in this study (and in more detail in Williams and Brown 2012) are of special value to middle and high school science educators.

Information about how to adapt garden-based programs that have the potential to reach at-risk young people can also be found in studies of community-based garden programs for youth (Draper and Freedman 2010). Prototypical programs involve mentoring and training youth in urban gardening, horticulture, or agriculture, often as projects that take place after school (Fusco 2001) or during summer school (Rahm 2002), with the intent to both educate and employ youth or to support gardening activities by selling garden produce (Feenstra et al. 1999; Lawson and McNally 1995). Projects also involve gardening as part of community action (e.g., for homeless youth; Fusco 2001) or multi-generational projects (Hake 2017; Hudkins 1995). One well-documented project is an informal science program that combines mentoring and community action in which youth are hired to document ethnic minority and immigrant gardening practices in urban areas, and take action to benefit the gardens (Krasny 2005; Krasny and Doyle 2002).

An explicit goal of such programs is to maximize *youth participation* through a variety of strategies, such as encouraging youth to identify community problems and solutions, calling on outside community members and resources, planning and designing action projects, working cooperatively with other youth and garden experts, creating marketing plans, selling or distributing produce, or acting as garden consultants and teachers themselves (Eick 1998; Feenstra et al. 1999; Fusco 2001; Krasny and Doyle 2002; Lawson and McNally 1995; Lekies et al. 2006, 2007; Rahm 2002). These projects suggest developmentally- and culturally-appropriate practices, focusing on purpose, ethnic and immigrant identity and pride, peers, independence, autonomy, and ownership, that can be intentionally woven into garden-based educational experiences for adolescents from low socioeconomic (SES), ethnic minority, and immigrant families (Cutter-Mackenzie 2009; Elliott 2015), who have not typically been well-served by standard academic curricula.

2.7 Guiding Motivational Research on Garden-Based Educational Programs

The motivational model, grounded in SDT, as well as findings from the current study may provide additional evidence helpful to proponents in convincing skeptical educators (and parents) that garden programs have lasting academic value. We hope that the model and the study it inspired might also suggest a set of empirical strategies to guide future research, including, for example, the use of quantitative measures of engagement that rely on perspectives from multiple reporters, designs that allow prediction of changes in learning and achievement over the school year, and the examination of multiple pathways of effects. Especially important, we think, is the longitudinal nature of the design, which allowed us to examine students' engagement in garden learning activities as predictors of *changes* in their learning and achievement over the school year. By controlling for previous levels of academic outcomes, such a design allows researchers to identify the "causal candidates" that may turn out to be active ingredients in garden programs. It also suggests that high quality garden programs may serve, not only to impart science knowledge, but also to change students' academic pathways in science and other core subjects over time. This may be an especially worthy goal for educators of students who are at-risk for underachievement.

The current study had several limitations, which can also be used as a basis for improving subsequent research. First, assessment of student science learning in the garden relied on student perceptions of the content they acquired through participation in garden learning activities. Although students' perceptions were correlated with their grades, a better assessment would be a direct test of knowledge about science, gardening, the environment, and food, using current assessments devised to capture this information (e.g., Klemmer et al. 2005; Morris and Zidenberg-Cherr 2002; Skelly and Zajicek 1998). Second, student engagement was assessed through student and teacher reports. Although reporters agreed on their ratings, future studies would do well to include direct assessment of student participation using observational measures (e.g., Reeve et al. 2004; Skinner et al. 2009b).

Third, although a strength of the present research was its grounding in Self-Determination Theory, the study did not capture all the motivational processes hypothesized to link garden-based educational programs to achievement and positive development. Especially important would be an examination of the nature of the curricular, physical, and social learning environments, and the effects of engagement in the garden on students' feelings of belonging, competence, purpose, ownership, and community in the garden and in school. Fourth, although a strength of the study was its inclusion of two times of measurement, this design did not allow us to directly investigate whether students who were constructively engaged in the gardens were able to maintain their motivation and achievement over the transition to middle school, when student engagement and performance otherwise typically decline (Wigfield et al. 2006).

Finally, the study was limited by its reliance on student- and teacher-report questionnaire measures. A richer picture of the garden activities would have been provided by more detailed qualitative observations of the LGLab, accompanied by interviews with the Garden Educators, Science teachers, and students themselves (Williams and Brown 2012). Hence, future studies can examine the effects of student engagement in the gardens on learning and achievement, using both quantitative and qualitative methods as well as observations of engagement and direct assessment of student knowledge acquisition. Such studies can explore how learning environments in the garden support the development of student sense of belonging, self-efficacy, ownership, and engagement over the transition to middle school, and whether engagement in the garden in turn contributes to students' motivation in science and in school more generally.

2.8 Conclusion

This chapter explored the utility of a motivational model based on self-determination theory for directing the attention of program developers and researchers to the quality of students' engagement and learning in garden-based educational activities, and to the social and academic factors that foster them. This model suggests that students' intrinsic motivation and constructive engagement with garden-based activities are "active ingredients" in their learning, and that programs will succeed in fostering motivation and engagement to the extent that they support key student experiences in the gardens, including feelings of belonging and self-efficacy, and a sense of purpose and ownership for garden-based activities and outcomes. The promise of this perspective for guiding research was illustrated with a short-term longitudinal study that relied on reports from youth and their Science teachers about student engagement in the gardens, and found that such engagement seems to contribute both directly to the experience of learning science in the garden, and indirectly to science achievement by boosting science engagement in the classroom. If garden programs can be intentionally constructed to support student interest and engagement, while incorporating the lessons from project-based contextualized science instruction (Chen and Yang 2019; Kokotsaki et al. 2016; Rivet and Krajcik 2008), they offer a promising pathway for promoting both motivation *and* achievement in science and school, especially for students from low socioeconomic, ethnic minority, and immigrant families.

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Chapter 3
Developing a Researchable Question: Open Inquiry in a School Garden

Eric Berson and Isha DeCoito

Abstract Learning how to ask questions about the natural world is a central enterprise of science. Yet typical instruction seldom provides students with the opportunity to develop and investigate their own scientific questions. School garden ecosystems offer a rich setting for students to investigate their own questions. In this study, middle school students participate in a 15 week after school science program situated in their school's garden. After engaging in teacher led empirical garden investigations, students are asked to develop scientific questions of their own to investigate. In this design experiment, we examine how students' scientific questions emerge and the roles that phenomena, tools and consultations play in the development and refinement of students' researchable questions. Findings suggest that instructional scaffolds played different roles for different students as they generated and refined their research questions.

Keywords Inquiry · School garden · Scientific questions · Design experiment · Instructional design · Open inquiry · Researchable questions

3.1 Introduction

Scientific questions are central to the enterprise of science. Questions motivate scientists to investigate the world and construct new understandings about how the world works. As such, recognition of the importance of the disciplinary practice of asking scientific questions is reflected in the vision for science education outlined by the K-12 Framework for Science Education (NRC 2012) and the Next Generation

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Science Standards (NGSS Lead States 2013). Asking questions is one of the central scientific practices advanced by these new reforms as an authentic practice of science. Despite the fundamental role questioning plays in scientific practice, students are seldom provided opportunities to generate their own questions for investigation (Chinn and Malhotra 2002; Germann et al. 1996; Van Booven 2015).

The design of science curriculum and instruction dictates the role students play in scientific inquiry. For example, if the scientific question and the methods for investigating the question are provided to students, little is left as problematic for students to resolve themselves. Schwab (1962) proposed a three-level taxonomy to characterize the varying degrees of *openness* of inquiry: (1) the first level is the simplest in which the problem is defined for the student as well as the methods for solving the problem; (2) the second level in which problems are posed for the student but the methods are left undefined; and (3) the third level in which both the problem and the method are to be determined by the student. In the first two levels, the problem or research question is well-defined by the curriculum or the instructor. In the third level, the problem is ill-defined or ill-structured, requiring students to determine the "problem space" (Newell and Simon 1972) requiring a framing of the problem and research question.

Open inquiry refers to inquiry settings in which students develop and pursue their own research questions. Several open inquiry studies have compared student experiences in open-inquiry contexts with settings where the instructor determined the research question. Krystyniak and Heikkinen (2007) found that students who engage in open inquiry are more self-reliant and participation was more evenly distributed amongst students. Moreover, Berg et al. (2003) found that students in the open-inquiry context were better able to describe and evaluate what they had done in the experiment, suggest potential revisions to the experiment, and come up with new ideas. In a comparison of high school biology students, Sadeh and Zion (2009) found that students in the open-inquiry setting exhibited more characteristics of what they referred to as *dynamic inquiry*. The open inquiry students in their study tended to have a greater awareness of change during inquiry as well as deeper procedural understanding.

3.2 Instructional Models for Open Inquiry

It is possible for students to engage in open inquiry with the support of carefully designed instruction. According to Zion and Mendelovici (2012) open inquiry "simulates and reflects the type of research and experimental work that is performed by scientists, thus demanding higher order thinking capabilities (i.e., questioning, designing an experimental array, critical and logical thinking, reflection)" (p. 384). Open-inquiry research studies have employed a variety of instructional models and scaffolds to support students' inquiry. The models have different constraints around questions, different degrees of teacher-directed inquiry prior to the open-inquiry opportunity, and different instructional scaffolds that support students as they pursue their own inquiry projects.

The conceptual scope of open inquiry tasks can be broadly defined, such as "find out and report about the relationships between biotic and abiotic features" of the schoolyard (Roth and Bowen 1993, p. 171) Alternatively, the scope of students' research questions can be strategically focused on a particular conceptual terrain such as pond dynamics (Lehrer and Schauble 2008) or cricket behavior (Metz 2004). In open-inquiry research, the instructional design typically involves a series of teacher directed activities or whole class investigations that build towards open-inquiry (Keys 1998; Metz 2004). As students begin their own investigations, instructional models support students by including scaffolds such as question heuristics and a menu of research methods (Metz 2004), regular research consultations (Lehrer and Schauble 2008), time management tools (Eilam 2002), and data collection equipment (Roth and Bowen 1993).

During open inquiry, van Uum, Verhoeff, and Peeters (2017) noted that scaffolding enables teachers to balance support and transfer responsibility to students for their own learning. Hard scaffolds consist of documents with explanations and/or exercises focusing on difficult parts of the inquiry process. Soft scaffolds include explicit references to and additional explanations of the hard scaffolds. Combining hard scaffolds with additional soft scaffolding promoted students' scientific understanding and contributed to a shared guidance of the inquiry process by the teacher and students. Thus, effective design of open inquiry instruction can leverage these scaffolds to support student investigations. Furthermore, developing students' skills to pose and respond to questions and actively engage in inquiry behaviors, enables students to problem solve and critically engage with learning and society. Additionally, implementing a community of inquiry within an inquiry science curriculum develops students' questioning and science inquiry behaviors and allows teachers to foster students' inquiry skills (Nichols et al. 2017).

3.3 Motivating Questions for Scientific Inquiry

Ernst Mayr (1997) wrote about the motivation behind scientific inquiry and noted that "in most cases, scientists are largely motivated by the simple desire for a better understanding of puzzling phenomena in our world" (p. 40). When confronted with 'puzzling phenomena' scientists seek to explain how the world works by designing investigations to test their hypotheses. Simon (2001) observes that curiosity motivates both scientists and children, as "idle or purposeful, curiosity is the motor that interests children in science; it is also the principle motor that energizes and steers the education of professional scientists and the conduct of their professional work" (p. 5). It is important to recognize the role of curiosity in driving and sustaining scientific inquiry with children, as they are curious about the world around them and, given the opportunity, they ask many questions.

Scardamalia and Bereiter (1992) analyzed the types of questions posed by students and distinguished between ‘basic’ questions and ‘wonderment’ questions. *Basic questions* pertain to factual, orienting information that one might find in a textbook, while *wonderment questions* reflect curiosity, puzzlement, skepticism, or a knowledge-based speculation. It is the latter that drives the enterprise of science. Chin, Brown, and Bruce (2002) found that wonderment questions were more likely to arise in classroom science contexts when students were engaged in open-inquiry tasks compared to engagement in more structured inquiry. Additionally, students’ interests in topics for investigation may simply come from passing thoughts, fleeting concerns, phobias, obsessions, or fascination with media-related characters (Katz and Chard 1998). Students’ interests may not be of high educational value or amenable to empirical investigation. For example, Chin and Kayalvizhi (2002) found that when sixth graders generated questions for investigations, very few of these questions (11.7%) could be answered through classroom investigations. The authors classified questions as ‘investigable’ if they ‘allow pupils to generate and collect original data, analyze and interpret their findings based on these data and finally, make a conclusion that answers the investigative question posed, on the basis of available first-hand evidence’ (p. 274). ‘Non-investigable’ questions were classified as questions involving basic information, complex information or philosophical or religious questions. If students are to develop ‘investigable’ or ‘researchable’ questions, they need assistance in transforming their interests into a question that can be investigated empirically.

Singh, Shaikh, and Haydock (2019) indicate that even with very little teacher guidance, students can engage in questioning and thereby ask each other a surprising number of investigable science questions. Their questioning can be authentic, and both explicit and implicit. The reality is that in most science classrooms, students do not receive adequate opportunities to develop and pursue their own research questions, a process characteristic of authentic scientific inquiry. Thus, through the context of a school garden science class, the authors explore the origin of students’ interests and strategies for cultivating and refining their interests into research questions.

3.4 School Gardens as a Strategic Context for Open Inquiry

School gardens are increasingly common features of schoolyards (Blair 2009; Desmond et al. 2004) and are strategic settings for open inquiry research for several reasons. First, the school garden is a complex ecology and the scientific concepts at play include big ideas from many key disciplines such as botany, zoology, and soil science. The school garden phenomenology can be leveraged to teach big ideas such as nutrient cycling, biodiversity, soil ecology, artificial selection or plant growth and development. These ideas, among many others, comprise the conceptual terrain that undergirds the school garden ecology. This conceptual terrain is sufficiently complex to support a wide range of student research questions. The school garden ecology is a web of intertwined biotic and abiotic relationships that can be explored through open inquiry. While constraining inquiry within the boundaries of the school garden context and its associated conceptual terrain begins to focus inquiry on questions of educational value, additional instructional scaffolds can further foreground important aspects of the conceptual terrain.

Second, school gardens ecologies are also rich in phenomenology that can stimulate students' curiosity and interest. Experiencing phenomena first-hand stimulates students' curiosity which can, in turn, motivate inquiry (Simon 2001) and working in school gardens induces many student questions (Rahm 2002). Metz (2011) makes a convincing case for the importance of immersing students directly in phenomena in order to build domain knowledge, which is critical for more sophisticated scientific reasoning. The rich phenomenology of school gardens is a unique space for students to get a 'feel for the organism' by affording them a direct experience with the subtleties and complexities of a real ecosystem. It is strategic to capitalize on the school garden as a unique accessible space with rich phenomenology.

A third affordance is the compelling environmental and societal motivators associated with school gardens. Many school gardens aim to reflect sustainable agricultural practices such as compost piles, diversified crops, and non-chemical pest management strategies, reflective of a larger movement towards urban agriculture and sustainable farming (Stone 2009). In contrast to industrial methods of agriculture such as monoculture and chemical inputs, school gardens are diversified food systems that produce fruits and vegetables for consumption. The emphasis on growing food teaches students how healthy food can be grown while caring for the environment. Science in school gardens, and inquiry in particular, can be motivated by these same societal and environmental concerns: How can we grow food in sustainable ways? How does an ecology that supports food production function? How can we best conserve water and soil fertility while producing healthy vegetables? It is in this context of authentic, practical, societal concerns that students' questions can be encouraged and supported (Fusco 2001).

Finally, open inquiry science instruction in school gardens can draw from the scientific discipline of agroecology, the study of ecologies that produce food (Altieri 1989; Francis et al. 2003; Gliessman 2007). As Lehrer (2009) argues, it is important for science learning to be grounded in the practices of particular scientific domains. Different scientific domains have particular ways of conducting investigations with tools and data representations that are particular to that discipline. Agroecologists study ways in which ecological principles can be applied to sustainable food production. Agroecology is oriented around problem-solving, including research into the effectiveness of ecological methods for improving soil fertility, controlling pests, conserving water and managing food systems in concert with the economic, social and cultural well-being of local communities (Francis et al. 2003; Gliessman 2007). With agroecology as a disciplinary referent, inquiry in school gardens can be grounded in authentic scientific practices.

Thus, school gardens can provide meaningful learning experiences for students. Yet, factors that are important for such success are sufficient budget, parental involvement, and support from community, school administrators, and teachers

(Burt et al. 2018a). Research demonstrates that school gardening is a promising pedagogical strategy for promoting students' healthy physical, psychosocial, and dietary behaviors as well as their achievement (Burt et al. 2018b; Kuru et al. 2020). They are also considered a positive way of teaching young children environmental and agricultural practices while improving social cohesion between them.

From a pedagogical perspective, several conditions are required to ensure good learning outcomes. These factors entail developing a subject-integrated school garden curriculum and teaching practices that include experiential learning and hands-on activities as teaching methods, making the subject content less abstract, stimulating the students' senses, and increasing the feeling of meaningfulness. Still, it is important to further explore the contribution of gardens to the development of students' critical minds and whether its impact is a long-term progress (Roscioli et al. 2020).

3.5 The Study

3.5.1 Rationale and Research Questions

This study examines the development of students' research questions in the context of students' own investigations. Specifically, this study tracks the emergence of students' interests and how instruction functions to transform those interests into researchable questions. In particular, the authors examined two research questions:

1. In an open inquiry setting, how stable are students' research interests?
2. How does instruction function to support the emergence and development of students' research questions?

3.5.2 Methodology

This study uses a design experiment approach (Cobb et al. 2003) to investigate how students develop research questions in a particular instructional context. Design experiments "entail both 'engineering' particular forms of learning and systematically studying those forms of learning within the context defined by the means of supporting them" (p. 9). This study analyzes both the research questions that students develop *and* the specific instructional context in which these questions are generated and refined. Since self-regulated student inquiry in school gardens is uncommon, an after-school garden science class was designed to support these inquiry practices.

3.5.3 Instructional Design: After-School Garden Science Class

The following set of principles guide the instructional design. For each principle, an elaboration on the rationale and a brief description are presented to address how the principle is reflected in the instructional design for the garden science class.

1. *Situate scientific inquiry in a context motivated by compelling social and/or environmental concerns.* When inquiry has a larger goal, it adds meaning and purpose to the endeavor. Situating inquiry in the school garden context connects inquiry to a social goal of producing healthy food while minimizing environmental harm. The garden science class is framed in terms of the value of understanding the garden ecology for sustainably growing food. This framing provides both social and environmental motivations for students to conduct scientific research in the garden.
2. *Privilege student interest as motivator for self-regulated inquiry.* Learning and motivation are deeply connected. In self-regulated inquiry, students' interests function to motivate them as they pursue inquiry projects. In the garden class, students were expected to generate a research question of personal interest to them. Student interest was a central criteria for determining which question to pursue.
3. *Immerse students in phenomenology to activate student interest and build domain knowledge.* Direct experience with natural phenomena can stimulate curiosity that drives inquiry (Simon 2001), and puzzling phenomena can lead to questions (Mayr 1997). Students are immersed in the school garden phenomenology immediately. The whole class research also facilitates their exposure to different features of the school garden.
4. *Anchor inquiry in the authentic practices of a scientific domain.* Scientific inquiry with students can begin to approximate authentic practices of real scientists by enlisting particular scientific disciplines as referents (Lehrer 2009). In this curriculum, the scientific field of agroecology was used as a domain referent. Students use agroecological research methods and instrumentation to conduct their inquiry projects.
5. *Develop student competence in quantitative methodology as a source of academic and scientific rigor.* While math and science may be commonly taught as separate subjects in schools, mathematics and science are deeply intertwined. Mathematics is a language used by science to record data that is then modeled and analyzed to uncover patterns, correlations, or comparisons. By incorporating the collection of quantitative data as evidence in service of students' investigations, mathematics is applied for a purpose. This makes the investigation an opportunity for students to practice and apply math skills as part of scientific inquiry.

3.5.4 Setting and Participants

The research site for this study was a large, public middle school in an urban school district in a mid-size city in a western state. The school has a well-established school garden as well as a kitchen for teaching students how to cook. The school garden is approximately one acre in size with 40–50 garden beds, fruit trees, a chicken coop, a greenhouse, and a small pond. The school garden is maintained by a staff of garden educators who teach gardening classes to students at the school. Classes come to the garden weekly to engage in gardening tasks (e.g., planting, harvesting, cultivating, etc.) for 6–8-week rotations. Each class at the school attends 1–2 rotations each school year. Students also attend rotations in the kitchen where they learn how to cook with the produce from the garden. While science is not an explicit focus of the garden classes, teachers make connections between the science curriculum and the students' experiences in the garden. Students do not engage in scientific inquiry during the regular garden class. However, students do build content knowledge about the garden ecology through working in the garden and through informal lessons by the garden educators.

The school has an ethnically diverse student body (7.8% Asian, 16.1% Hispanic, 23.2% African American, 34.7% Caucasian and 17% multiple/no response), with 40% economically disadvantaged. Participation in the garden science class was entirely voluntary. The class was advertised as part of the catalog of after school classes offered at the school. Brief recruiting presentations were also given to each sixth and seventh grade science classrooms to encourage students to register for the class. Five sixth graders and two seventh graders (4 girls and 3 boys) participated in the study. Four students were Caucasian, two students were African American, and one student was an English language learner from South Asia. All names used in this chapter are pseudonyms.

3.5.5 Procedures for Conducting the Study

The garden science class convened for two hours after school, one day a week over the course of 15 weeks. For the first seven weeks of the program, the students engaged in a series of teacher-directed research projects that investigated characteristics of different soils. The investigations focused on developing an understanding of the biological, chemical, and physical properties of healthy soil. In particular, the investigations highlighted the connections between compost, organic matter, biological activity, and soil health.

One of the authors was the instructor and researcher, determined the research questions and led the design of the investigations. An example of a question pursued as a class: *How does the biological activity of the soil in the garden beds compare to the biological activity of the garden soil by the trees and soil outside of the garden?* Students played a central role in each investigation by making predictions, selecting sampling locations, collecting samples, analyzing data, and drawing conclusions. Students were exposed to different methodological techniques, such as worm counts, decomposition papers, nitrate tests and invertebrate traps (Gliessman 2007; Miles and Brown 2003). While participating in the group inquiry projects, the students recorded their emerging thoughts about what interested them in the garden. They documented potential research questions or research interests that were not formulated on a regular basis in their science journals. These are categorized as *emerging interests*.

During weeks 8 and 9, each student participated in a 20–45-minute research consultation. The goal of the consultation was to help students transform their interests into a researchable question. During the consultation, each student reflected on their initial research questions from the pre-interview and the emerging questions taken from their notebooks or interests they stated during class. Each initial question from their pre-interview and each question or interest from their notebooks was presented one at a time to the student. The student reflected on each question as an object of thought and stated whether they were interested/not interested in the idea. Students discarded ideas that no longer interested them and kept those of interest in front of them. They shared their current thinking about potential research directions.

Collectively, the class helped each student develop, specify, and refine their interests. Students helped each other to evaluate their interests in relation to class-generated criteria of what makes a good research question (Table 3.1). Through successive rounds of reflection on students' prior ideas and feedback from the class and instructor, the students gradually refined their interests into a single researchable question.

In the second half of the garden class, students conducted an investigation driven by their research question. Students designed a research plan, collected data and analyzed their results. The inquiry projects spanned 4–5 weeks, with students working each week on their projects. Since students were at different stages at different times, they often helped each other collect data for their respective research projects.

Students used desktop publishing computer software to create individual research posters explaining their investigations, and including the following sections: Title, Introduction, Research Question, Hypothesis, Methods, Results, Conclusions, Limitations, Implications, and Future Research. Due to the time-consuming nature

Table 3.1 Criteria for good research questions

Criteria	Description
Interesting	A question of real interest to the student
Genuine	A question that the student does not already know the answer to
First-Hand	A question that can be answered through first-hand research in the garden
Doable	A question that can be investigated given the time and resources available
Important	A question that is important for understanding how the school garden works and has implication for how to grow food
Original	A question that is different from the questions that others are asking

Informed by Chin and Kayalvizhi (2002)

of the poster creation, most students had to spend additional time outside of the garden class to complete their posters. Students' electronic posters were then printed on large (3′ × 5′) poster-size paper and hung using wooden dowels. During the last session of the garden science class, the students hosted a *Garden Science Research Poster Conference.* The students' classroom teachers, families and the school garden staff were invited to attend. Students took turns presenting their research and conference attendees took the opportunity to examine the posters individually and engage with the students about their research.

3.5.6 Data Sources and Analyses

This study draws on several data sources for analysis including semi-structured interviews, students' science notebooks, video tapes of garden class, and researcher/instructor field notes. Semi-structured interviews were conducted with each student prior to the beginning of the garden science class (pre-interview) and at the end of the garden science class (post-interview).

During the pre-interview, students were asked to generate three questions that they might want to investigate during the garden science class. Each student generated three potential research questions (referred to in the analysis as the "initial" questions or interests.) The pre-interview also included questions about the students' garden content knowledge and epistemological beliefs about science, however those questions are not part of the analysis presented in this paper. Post-interviews focused on how students developed their research question and how useful different features of the instruction were for supporting the development of their question. These reflections were used to corroborate findings from the instructional analysis. The audio recordings of the interviews were transcribed and analyzed.

During the course of the class, students were also asked to record emerging research interests and questions in their science notebooks on a weekly basis. Students also used their notebooks to record information relating to their investigations. During the subsequent consultations, ideas from their notebooks (and initial interests from their pre-interview) were shown to the students on sentence strips for the students to consider and reflect upon.

The final source of data for this analysis is a video record of the instruction. The video record was largely restricted to the use of a single camera. While whole class discussion related to the teacher-directed investigations and the student-centered consultation are captured by the video, the video record does not include every comment or exchange during the course of the garden science class. In particular, the video is only a partial record of exchanges that occurred while students were collecting data separately in the garden or as they worked on their individual investigations. Video records of the consultation were transcribed. Students' treatment of their initial and emerging interests was interpreted based on the transcript and visual placement of the sentence strips from the video record. The transcript was used for analysis of the consultation dialogue.

In addition to researcher field notes, the aforementioned data sources constitute the database which the analysis in this study is based. For analyses that involved all students in the study, particular sections of the interviews or transcripts were analyzed across all students. For the case study analyses, data relevant to each case study student formed the basis of the findings.

3.6 Findings and Discussion

The results and associated discussion are organized in two sections. The first section is an analysis of the stability of students' developing research interests. The second section examines how the central features of instruction functioned to support the development of individual student interests and research questions.

3.7 Part I: Continuity of Students' Research Interests

In an open inquiry context, students pursue research questions that are of interest to them. To foster the development of students' interests, it is important to understand how their interests originate and whether these interests are stable or if they change significantly over time. How do students' interests originate? How stable are students' interests and to what extent do they change over time?

As Mayr (1997) noted, scientists' interests are often motivated by 'puzzling phenomena' that they encounter. Students in this study had prior garden experience before beginning the garden science class. To what extent did they enter the class with 'puzzling phenomena' in mind? How attached were students to their initial research interests? To investigate these questions, the students' initial interests expressed during the pre-interview were compared with the final research questions that students decided to pursue. In comparing students' research questions with their initial interests, all of the students' eventual questions were different from their initial interests. There was not a single question that persisted from the pre-interview through the course of instruction. Of the 21 initial questions that students generated in the pre-interview, only four of them were even loosely related to the student's eventual question. For example, one of Edward's initial questions was "If we used different fertilizer that was man-made that had better plant growing stuff, but it wasn't as good for the earth what effects would it have?" Edward's eventual question was "How does the nitrate level change as you go deeper into the Earth?" These two questions are loosely related in the sense that both relate to soil health. However, the relationship between the two questions is indirect and one is not a refinement of the other.

Further analysis explicitly examined students' attachments to their initial and emerging interests. Students generated a total of 85 research interests through the seventh week of the garden science class. This includes initial interests from the

Table 3.2 Percentage of students' prior interests still of interest during consultation

	# of Interests (Initial and emergent)	% Interests maintained (Initial and emergent)	% Interests maintained (Initial)	% Interests maintained (Emergent)
Total	85	45%	18%	54%

pre-interview, emerging interests recorded in their science notebooks, and vocalized interests recorded in the researcher field notes. During the consultation in the eighth and ninth weeks, students classified each of their stated interests as either potentially "still of interest" or "no longer of interest." Table 3.2 shows the percentage of prior interests that were still of interest to students at the consultation. Collectively, students classified only 38 of these interests as potentially "still of interest." In other words, when it was time for students to evaluate their prior interests (both initial and emerging) they expressed continued interest in 45% of the questions and ideas.

Interestingly, further analysis shows that students only found 18% of their *initial* questions still interesting. Students no longer expressed interest in the vast majority (82%) of their initial, pre-interview research questions. In fact, in several cases, students completely disassociated themselves from their own pre-interview research question suggestions, denying that they had even asked those questions. Students maintained interest in 54% of the interests that emerged during instruction.

These findings indicate that students' interests changed during the course of instruction. Beyond vague similarities, the students' initial and eventual research questions were entirely different. Furthermore, students had weak attachment to their initial questions but greater attachment to the interests that emerged during instruction. Thus, instruction has the potential to foster the development and refinement of students' interests. Given that students may have weak attachments to initial ideas about research, it is important for instruction to allow for the emergence and development of more robust student interests.

3.8 Part II: Role of Focal Instructional Features for Supporting Student Interests

In this study, the instruction was designed to support open inquiry in an authentic, meaningful context. Additional analysis is needed to understand *how* the instruction functioned to support the emergence and refinement of students' research interests. It is important to analyze the specific trajectories of student interests and how these interests were influenced or not influenced by instruction in order to evaluate the utility of the instructional design. To investigate the interplay of interest and instruction, the analysis concentrates on the role of three focal instructional features of the garden science class: phenomenology, variables (with associated instrumentation), and consultation. The school garden phenomenology was emphasized from the start of the garden science class. Students engaged directly with the school garden phenomenology as the class conducted group research during the first half of the class. Throughout the instructional program, students worked directly with garden soils, plants, and organisms. This hands-on exposure to the garden ecology was designed to evoke student curiosity and to give them a "feel" for the garden phenomenology.

Instruction also emphasized the diversity of potential research variables that could be examined as part of an investigation. Explicit attention was given both to a range of measurable variables (e.g., worm counts, soil moisture levels, levels of soil compaction, plant height, decomposition rates, etc.) and the associated instrumentation to measure these variables. The measurable variables were emphasized during the whole group inquiry projects and as a menu of potential measures, which students could draw from as they developed their research focus.

The final focal instructional feature was the use of a consultation feedback format (Lehrer and Schauble 2008) during which each student reflected on their interests with the support, feedback, and suggestions of the class as whole. These focal instructional features form the basis of the subsequent analysis of the interaction between the instruction and the students' emerging research interests.

To examine the ways that instruction functioned to support the emergence and development of students' research questions, the analysis centers on case studies of three individual students in the study. Case study students were selected in a principled way (Yin 2003). Based on preliminary analysis of all of the students in the study, the case study students were selected based on the trajectory of their interests in relation to particular focal instructional features. For each focal instructional feature, one case study student was selected who was particularly influenced by that feature. Nina (pseudonym) was strongly influenced by the school garden phenomenology, while Laura was influenced by the variables and associated instrumentation, and the consultation played a critical role in the development of Alison's research question.

In the following case study analyses, each of the three students' research questions is considered in the context of the three focal instructional features. The case study analysis highlights the different roles that the focal instructional features play in the development of research interests and questions for these students.

3.8.1 Case Study of Nina

Nina is 12 years old, and an English language learner in the sixth grade. Over the course of the garden science class, Nina developed a strong interest in earthworms, an interest that she did not have before the class began as evidenced by a question from the post-interview (T = teacher/interviewer):

Teacher: Did you like worms before this class or did you always like worms or did you not like worms?

Nina: Not really, I thought worms were icky and scrawling [crawling] too much.

For her open inquiry investigation, Nina pursued the question, "How many worms are in all parts of the garden?" To investigate this question, Nina sampled soil from a garden bed, counted the worms and then estimated how many worms there might be in all of the garden beds in the garden. As part of her estimation process, she calculated the cubic feet of soil in one garden bed, counted the number of garden beds in the garden and used the worm count to estimate the total worms in the garden. Nina was very enthusiastic about her research. Given her initial lack of interest in worms, how did her interest emerge and transform into a researchable question? How did the three focal instructional features support Nina as she developed and refined her interests?

Different facets of the instructional design fostered Nina's research interests. An analysis of Nina's science journal shows a clear interest in worms developing in the third week of the garden class. During that third week, the group began research on earthworms in the garden, comparing worm counts in different parts of the garden (and outside of the garden) with different cultivation histories. None of Nina's reported interests during the pre-interview or prior weeks related to worms. However, the worm phenomenology piqued her interest, evidenced by the emerging interests and questions in her journal. In the post-interview, Nina was asked about the extent to which the early group research and working in the garden was helpful to her as she developed her research interests:

Nina: It did help me because we worked about worms and I started to like worms that group research and then I started to do research about worms.

In the Week 7 instruction, students were introduced to a variety of measurable garden variables that could become part of their research question as needed. While these variables did elicit non-worm interests (as seen in interests she expressed in Week 7), Nina was ultimately undeterred in her commitment to researching worms.

Nina's research consultation helped her to refine and consolidate her interest in worms. At the beginning of the consultation, Nina discarded her prior research ideas that did not pertain to worms. Her interest in worms was so robust that she had difficulty relinquishing any of the research questions that involved worms and even added one:

Teacher: I noticed that Nina discarded … that she's not that interested in the fruit being buried under the ground, she's not that interested any more in terms of the worms having brown things on them, and she's not that interested in how long it takes for a leaf to decompose. Why are you not interested in these anymore?

Nina: I don't know … I just don't like them anymore.

Teacher: Why did you keep the ones that you kept?

Nina: Because I'm interested in worms and they are all about worms.

Teacher: Okay, so which of those interests you the most?

Nina: How do you know when worms get pregnant? How long worms are? The most I want to do … oh! I forgot something! How do you know if a worm is a boy or a girl?

A discussion ensued about how to tell if a worm was pregnant. While some students argued that this question was easily answerable on the Internet (and therefore not an appropriate question for empirical research), the class concluded that the circumference could be measured as a potential indicator of pregnancy. Students helped Nina frame research in terms of a comparison between the garden and her backyard at home and suggested the idea of calculating the average length. Nina attempted to combine her interests in worm counts and lengths:

> Nina: Can I put some of these together? I want to put these two together.
> Teacher: What kind of combined question would that be?
> Nina: I would say that when I estimate … when I found worms in one place, they were this long and when I found worms … when I estimated them in the whole garden they changed to a different sizes?

Her consultation continued until Nina decided to estimate the count and length of worms in the entire garden based on a sample count. Ultimately, in the process of conducting her investigation, Nina made estimations only based on the counts, rather than the counts and lengths.

Nina's case is one of intense curiosity and interest sparked by immersion in the school garden phenomenology. Her interests were robust and unwavering. The diversity of research variables minimally influenced her interests. The consultation primarily functioned to consolidate her questions and to help her select a research question that could accommodate her interests. It is also notable how she conceived of a linked set of questions as a potential inquiry trajectory for herself, when this aspect of science was not emphasized in the instruction.

3.8.2 Case Study of Laura

Laura is a high achieving seventh grade student who is 12 years old. She reported having had experience doing science inquiry projects at her prior school but had never conducted an investigation in the garden. Laura was quite independent throughout the class and very articulate about her thoughts and ideas.

Laura considered the whole class research to be helpful in exposing the research possibilities within the school garden. In the post-interview, she explained:

> I think it was good to have the group research first, because we didn't know that much about the garden and the possibilities in the garden and I think we thought there was a lot less than there actually was. So then when we did the group research, I don't think a lot of us would have thought about counting the invertebrates to see if it was healthy.

Laura eventually decided to pursue the research question: What is the average level of soil moisture in the soil with mulch and without mulch in the garden? How does it compare to soil moisture outside of the garden? Laura developed her eventual research question while listening to other students' research consultations. Laura was one of the last students to have her consultation, but she offered ideas and suggestions to other students during their consultation, as highlighted during her post-interview.

> Laura: As other people got people to talk about their research questions, I started getting ideas so then when I had a bunch of ideas I wrote them all down during the consultations and then I said some of them and people said, well that's not doable, so they helped me figure out which one would be the best one to do in our garden.

Teacher: So, you're saying that when you were listening to other people's consultations, even though it was their consultation, it was actually helping you, because you were thinking of ideas yourself?

Laura: Yeah, so like Nina was talking about the worms and then I was thinking about the healthy soil and then I saw soil moisture on the table, and I thought, oh that would be cool.

When it was Laura's turn for a consultation, she dismissed all but one of her prior ideas. Instead, she shared her new idea about researching soil moisture. The question she reported was, "What is the average level of soil moisture in different parts of the garden and how does it compare to the triangle?" [The triangle refers to a non-cultivated section of dirt on the school grounds.] In her post-interview, Laura explained her new-found intrigue with soil moisture.

Teacher: Why soil moisture? Do you feel like you were interested in it because we hadn't done it in the class?

Laura: It seemed kind of unique, and it wasn't really like all the other ones, and the way that you would find the soil moisture, that was kind of cool, so I wanted to do that.

Laura was attracted to the uniqueness of the variable and the associated instrumentation that is used to measure soil moisture. Her consultation was relatively short since she had selected her question. Instead, the class helped Laura develop her research design, suggesting places to sample the soil including different locations for collecting data. These suggestions helped her incorporate the notion of testing garden beds with and without mulch.

Laura's research interests were ultimately influenced most by her intrigue with a particular garden variable and its associated instrumentation. As a class, we had not measured soil moisture, and yet it was an important variable that could be measured in the garden. Laura developed an interest around soil moisture and was able to develop her research question independently. While her own consultation was brief, she clearly benefited from participating in the consultations that preceded hers. Furthermore, because her question was more fully developed, the time spent on her consultation could be more efficiently spent helping her develop her research design.

3.8.3 Case Study of Allison

Allison is a 12-year-old student in sixth grade. She came into the garden science class with relatively sophisticated prior knowledge about the school garden ecology. She had many garden experiences at home and often made contributions to the class discussion that indicated her understanding. However, Allison's research interests were diverse, unfocused, and inconsistent.

In the pre-interview, Allison expressed interest in researching what might happen if a tropical plant was grown in the garden, what damage potato bugs can do and the role of ants in the garden. Her emerging interests during the whole class research did not reflect a persistent pattern of interest. Her interests generally wandered based on the weekly focus of the garden class.

Allison's research consultation was long and involved a lot vetting of different research question possibilities. The class offered suggestions to Allison with the goal of transforming her interests into a single researchable question. In some cases, the class compared Allison's ideas and potential research questions with the class criteria for what makes a good research question. Allison's peers considered her interest in potato bugs (expressed during her pre interview) as an idea that could be researched on the Internet and therefore not worth pursuing. Amidst the doubt expressed about the potato bug plan, Allison turned to one of the variables she had previously expressed interest in – soil compaction. Allison shared a sentence strip where she had written the following question: *How well can a plant grow when the soil is compact and/or no worms?*

Allison went on to describe a mixture of ideas related to soil compaction, water permeation and worms. While these ideas were all related, Allison struggled to clarify how these ideas may take the form of a research question. The instructor asked the group if they had any ideas for how Allison might simplify her research question.

Jeffrey (raises his hand): I have one! How about she just picks one variable so she could just do soil moisture instead of making it so complicated.

Laura: How about if you wanted to use more than one, for example you could say, does the number of earthworms in soil vary depending on the compaction of the soil.

Laura's suggestion stemmed from Allison's expressed interests while transforming those interests into a researchable question. These ideas were pursued further in the consultation.

Teacher: Can we take up what Laura just said? (To Laura) Can you repeat what you said?

Laura: Does the number of earthworms in soil vary depending on the compaction?

Teacher: (Holds up compaction and earthworm count variable cards). So, what would that mean? You would go look for …

Laura: Soil with like different compaction levels and then count the earthworms.

Teacher: So, Allison, do you hear what she is saying? She's suggesting that one idea … you don't have to go with this if you don't like it … but one idea to simplify all this … (points to the variables) because you've got so many ideas … is to take just these two variables (compaction and earthworm count) and say, is there a relationship between the level of compaction.

Teacher: Laura just gave a really interesting idea and I want to see if Allison wants to pursue that or not. Do you understand the idea? You take soil outside and you measure the compaction in different places and then you do an earthworm count and you see if there's a relationship, Allison, between the compaction of the soil and the amount of earthworms that are there … what do you think about that idea?

Allison: That sounds nice.

Rather than fully committing to the idea, Allison opted to think about it for a while and decide for herself. As the consultation ended and a new one began for a different student, I assured Allison that she had time to think about the idea to determine if it was an idea that she would like to pursue for her research. The following week, Allison still seemed reluctant to move forward. Instead, Allison returned to the variable cards that she had expressed interest in the previous week and reached for the compost temperature card.

Allison: (looks at variables) I could probably try compost temperature … I've always wondered how hot compost could get.

Teacher: Have you? It didn't show up in any of your questions …

Allison: Well, I didn't think about it until now. Then I just realized that compost can get *really* hot and like, well … what if it's hot enough to like… sort of like it makes it so warm that you can barely touch it…

Teacher: So, what would you ask, what would the question be?

Allison: How hot can compost get?

Teacher: Okay, so what would you do in order to test that question?

Allison: Stick a big ol' electric thermometer in like one of those compost piles out there and in the horse manure because that like is considered compost too.

Ultimately, Allison decided to research the temperature of the compost. Her research questions were: *How hot does compost get? How does the compost temperature change from day to day?*

Even though Allison eventually decided on a research question that was not entertained during her consultation, the consultation still served an important function. Allison had diverse and wide-ranging interests, and the consultation functioned to help Allison explore and evaluate her different interests. Many of her interests were deemed impractical or too complex during the consultation, but it was still an important forum for her to share her diverse ideas and get feedback from others in the class.

Allison found numerous garden variables appealing and made attempts to construct a research question out of multiple variables. It is notable that of all the students, she was the only student who resumed interest in one of her initial questions from the pre-interview (potato bugs). However, Allison needed an extended consultation to arrive at an idea. The idea of researching the compost temperature seemingly appeared to arise randomly. While the compost temperature was listed as one of the potential garden variables, Allison contended that it had been a long term of interest of hers. It is possible that Allison's curiosity about compost temperatures was, in fact, a long-term interest. It is also possible that the garden variables ultimately triggered Allison's interest in compost temperature. Allison may have decided to pursue compost research after learning from the consultation experience about the types of questions that are amenable to empirical investigation.

3.9 Discussion

This study examined the generation and refinement of student research questions and the instructional features that supported their development. An analysis of students' initial, emergent and eventual research questions shows that students' research interests changed during the course of instruction. Students exhibited considerably weak commitments to their initial interests, yet they generally found their ultimate research questions to be both interesting and important. These findings offer an example of how open inquiry settings and scaffolding (van Uum et al. 2017) can offer students the opportunity to develop and pursue research questions (Chinn and Malhotra 2002; Germann et al. 1996; Van Booven 2015) that they find motivating and valuable. Students reported that they considered their questions to be not too easy and not too difficult.

An analysis of how the focal instructional features supported the emergence and refinement of students' research questions shows how the features can function differently for different students. While some students became captivated by particular topics, other students struggled to narrow their focus among a range of diverse interests.

For some students, exposure to the garden phenomenology induced the curiosity referred to by Simon (2001) and Rahm (2002). However, since the garden phenomenology was embedded in a whole group research context, it is hard to disentangle the role of the garden phenomenology from the role of the group research. Would Nina have been as captivated by the worms if she had discovered them outside of a research context? That question cannot be readily answered by the data from this study. However, it is clear that her exposure to the worm phenomenology did result in a robust, continued interest in worms, an organism that she previously disliked.

The consultation activity structure was adaptive to the particular needs of different students. Since the focus of each consultation was on the individual student and their interests, the group's feedback could attend to the specific issues that each student was facing. While certainly time-consuming, the consultation format is particularly powerful and arguably targeted the students' individual zone of proximal development. In Allison's case, the consultation activity structure was especially important as a space for her to evaluate each of her many ideas. In contrast, Nina's consultation functioned to consolidate closely related interests.

There is also evidence to suggest that the consultation is beneficial for the other students who are offering feedback to the focal student. Laura was an active contributor of ideas and suggestions during other students' consultations. Since Laura had essentially decided upon her research question by the time it was her turn, her consultation was able to advance her research design plans, more appropriately targeting her needs at the time.

The role of the garden variables and instrumentation in this study is less straightforward. The garden variables were sources of possibility and potential intrigue or interest (Lehrer 2009). But scientists measure variables in service of a question that they are pursuing. The measures are utilized as a way of operationalizing the research question or design, not necessarily objects of inquiry in and of themselves. However, in writing about expert problem solving in the context of scientific inquiry, Simon et al. (1981) explains that, in comparison to the *weak methods* used by novices, experts use *strong methods* as "powerful techniques that are carefully suited to the specific structure of the domain to which they are applied."

Experts approach scientific problems with a repertoire of particular methods and techniques that are well suited to that domain. Therefore, it is important for students to learn data collection methods that are specific to agroecological research *(strong methods)* if they are to conduct authentic inquiry in the school garden. To fully appreciate research possibilities in the school garden and to help operationalize their research questions, students need to be familiarized with relevant variables and techniques for measuring those variables. More research needs to be done to examine how to strategically introduce research instrumentation into open-inquiry settings so that they can both expose research possibilities and help to operationalize students' questions.

Another challenge facing open-inquiry research is how to design instruction that optimizes the parallel goals of student interest and the conceptual richness of the inquiry question (Roscioli et al. 2020). This study privileged students' interest as the top-level criteria for researchable questions. While the instruction did focus on explicit science ideas such as the ecology of soil, feeding relations and nutrient cycling, the conceptual terrain was only targeted to varying degrees by students' research questions. Future research should examine how to optimize student ownership and interest as well as strategically focus the inquiry on the important conceptual terrain of the target domain. This challenge is a matter of instructional design and may take many different forms or approaches.

This study is a unique existence proof that open inquiry in school gardens is possible under particular instructional conditions (Burt et al. 2018a, b; Kuru et al. 2020). Students developed and pursued their own research questions, an authentic process that is critical to scientific practice and yet rarely expected of students in science classrooms (Nichols et al. 2017). This study offers insight into questions of instructional design for scaffolding student question development in open-inquiry settings. Furthermore, for practitioners in urban agriculture, findings from this study offer insights into pedagogical approaches for developing students' skills to pose and respond to questions and actively engage in inquiry behaviors in non-formal settings. It also suggests one possible direction for the advancement of garden-based science education. Future research is needed to further evaluate the scaffolds that support open inquiry (van Uum et al. 2017) and how to integrate this instructional model into existing school garden programming and science instruction.

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Chapter 4
Science in the Learning Gardens: Collaboratively Designing Middle School Curriculum to Bring the Next Generation Science Standards to Life

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Abstract School gardens offer culturally relevant learning opportunities for engaging children and youth in applying science and engineering to solving real-life challenges, helping teachers meet the needs of all students, including underrepresented minorities. Consistent with the Next Generation Science Standards, gardening experiences provide opportunities for students to explore topics that integrate science and engineering in depth over extended periods of time. Science in the Learning Gardens (SciLG), described in this chapter, is a middle school curriculum project that was pilot tested at two middle schools that serve predominantly low-income and ethnic and racial minority students. The curriculum provides holistic, integrated, hands-on, project-based and place-based learning experiences and embedded formative assessments.

Keywords School gardens · Middle school · Curriculum development · Next generation science standards · Place-based education · Project-based learning · Real-life problems · Culturally responsive teaching · Underrepresented minority students · Food production

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4.1 Introduction and Rationale

There is growing concern among policy-makers and practitioners alike that while demographic trends show an increasing rate of growth among minority groups, African-Americans, Hispanics, and Native-Americans continue to be underrepresented in STEM majors in colleges and in STEM careers and professions (Bettencourt et al. 2020; Elliott 2015; Museus et al. 2011; National Research Council [NRC] 2011, 2012, 2015; National Science Foundation [NSF] 2017; Quinn and Cooc 2015). Research shows that student disengagement from learning starts early, and that if by eighth grade students lose interest in STEM, they are less likely to pursue these subjects in higher education (Christensen and Knezek 2017; Fraser et al. 2011; Tai et al. 2006). A robust body of research also shows the inadequacies of teaching ethnic and racial minority students overall, resulting in a widening achievement gap among non-white and white students at all grade levels in schools (Bingham and Okagaki 2012; Brown and Crippen 2017; Howard 2010). To address these concerns, scholars have called for:

1. Culturally relevant curriculum and pedagogy (Atwater 1994; Babco 2003; Boykin and Ellison 1995; Fordham and Ogbu 1986; Gay 2010; Gutierrez and Rogoff 2003; Mueller 2011; Sheets 2005);
2. Real-life active learning (Hrabowski and Maton 2009; Kelley 2009; Museus et al. 2011; Williams and Brown 2012); and
3. Challenging academic activities provided within supportive contexts that facilitate engagement and motivational outcomes of commitment (Bircan and Sungur 2016; Newmann 1996; Skinner et al. 2012; Skinner et al. 2009).

To address the troubling trends of underrepresentation and student disengagement in STEM, Science in the Learning Gardens (SciLG), funded by the National Science Foundation[1], 2014–2017, seized the opportunity to bring together two significant education movements. First, Oregon is one of 44 states that bases its science standards on *A Framework for K-12 Science Education: Practices, Crosscutting Concepts, and Core Ideas* (National Research Council [NRC] 2012) or the subsequent *Next Generation Science Standards: For States, By States* (NGSS Lead States 2013). The new standards are fundamentally different from older standards, which were lists of what students should "know." In contrast, the new standards are a set of performance expectations that combine practices of science and engineering with core ideas and crosscutting concepts across the science disciplines. Adoption and implementation of the NGSS require curriculum developers, school districts, and teachers to align curriculum, instruction, and assessment with these performance expectations by providing opportunities for students to explore STEM topics in

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depth over extended periods of time. These new standards have the potential for long-term impacts on science teaching and learning across the country for all students.

Second, there has been a surge of interest in school gardens in Oregon and across the nation and other countries related to a convergence of several serious public concerns: all-time high childhood obesity rates (Eisenmann et al. 2011; Harrison et al. 2011; Niklas et al. 2003; Utter et al. 2015); increases in Type 2 diabetes among children especially affecting some minority groups (Hedley et al. 2004; Vivian et al. 2011); and food insecurity (Coleman-Jensen et al. 2019) with urban food deserts, and the scarcity of fresh food compounded by waves of salmonella, *E. Coli* and other outbreaks resulting in foodborne illnesses. As a result, there is heightened interest in teaching students how to grow food, and with more than 30,000 school gardens in the country (Ratcliff 2013) school grounds are considered prime places for local food production and garden-based learning (Azuma and Fisher 2001; Birch 1990; The Edible Schoolyard 2009; Morgan et al. 2010; Ozer 2006; Williams and Dixon 2013; Williams 2018). Given these trends and the national interest in gardens at school sites (Hayden-Smith 2006; Obama 2012), the school garden movement and garden-based learning are becoming significant features in educational institutions to address academic learning as well as health issues (Schneider et al. 2017; Williams 2018; Williams and Brown 2012).

4.2 Curriculum Design of Science in the Learning Gardens

SciLG's uniqueness lies in its cross-cultural and cross-organizational partnership approach to serve underrepresented minority students in STEM. The SciLG project systematizes and connects NGSS and formative assessment with middle school science curriculum, while simultaneously integrating school gardens as context for science learning. Furthermore, it weaves the much-needed cultural underpinnings of gardens into curriculum and instruction. SciLG is aligned with NGSS both for its framework and assessment tools (Sneider and Wojnowski 2013) and also uses a model of motivation and engagement with a tested instrument (Skinner et al. 2012) to measure student outcomes. It draws upon and synthesizes four bodies of scholarly work:

1. School garden-based curriculum for increased depth of both knowledge and practice of science;
2. 6th– 8th grade science instruction and assessment integrated with NGSS;
3. In-garden instruction using a pedagogical framework that is research based and culturally responsive; and
4. Academic contexts for learning that facilitate student motivation and engagement.

SciLG provides promising, practical connections for science learning with the growing school gardens movement nationally. Piloted in two Portland Public Schools that serve predominantly low-income and ethnic and racial minority students, the defining features of garden-based education — holistic, integrated, hands-on, project-based, experiential learning activities (Blair 2009; Ozer 2006; Williams and Brown 2012) — were adopted in SciLG to capture students' interest and engagement. Such learning opportunities are increasingly important as students progress through middle school, because they may help reduce or even reverse steady declines in academic motivation (especially for science) found across the middle school transition, declines that are especially steep for students from low socioeconomic, minority, and immigrant families (Wigfield et al. 2006). A meta-analysis and synthesis of research from 1990–2010 on garden-based learning showed positive outcomes on a variety of academic variables including science, language arts, and mathematics; and on a variety of indirect academic outcomes including development of self-concept, change in eating habits, and positive environmental attitudes (Williams and Dixon 2013). These findings showed the potential of garden programs for benefitting academic and academic-related outcomes.

4.3 SciLG Included the Following Programmatic and Research Endeavors

Activity 1: Selection of Garden-Based Learning Resources Relevant to SciLG Existing garden-based educational resources were assessed and integrated for locale/place-based alignment with NGSS (National Research Council [NRC] 2015) in the development of SciLG 6th-8th grade instructional units. Among key resources used were: *Life Lab* (2013), *Living Classrooms* (2013), and *The Edible Schoolyard* (2013) programs which were examined and adapted as samples for middle level. None of the programs aligned explicitly with NGSS or the learning progressions articulated in the *Framework for K-12 Science Education* (NRC 2012) as uniquely proposed in SciLG. Additionally, the curriculum team mapped NGSS performance expectations for middle school to align with the activities presented in the *Science Education for Public Understanding Program* (SEPUP), the curriculum adopted by the school district, and to identify opportunities for integrating garden-based learning experiences that could teach and/or enrich core ideas. The outcomes of this process were meant not only to benefit the teachers and students in the two participating schools, but also to provide instructional sequencing and units for utilization by other schools throughout the district and state. Furthermore, the collaborative, design-based approach (described below) used for curriculum development can serve as a model as other districts and curriculum developers work to align their existing programs to the NGSS.

Activity 2: Embedded Assessments Aligned with NGSS SciLG specifically addressed NGSS alignment and assessment (Penuel and Reiser 2018; Saxton et al. 2014; Sneider and Wojnowski 2013) by proposing to develop and test embedded formative assessments and proficiency-based assessments, utilizing an iterative,

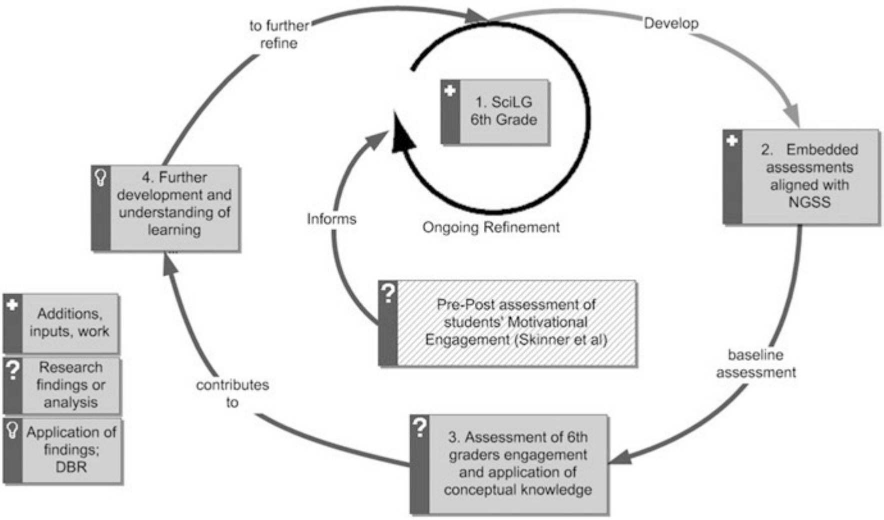

Fig. 4.1 NGSS & Learning Gardens-Based Design Research as an iterative process

design-based approach (see Fig. 4.1). In alignment with NGSS, assessments wove together disciplinary core ideas, science and engineering practices, and crosscutting concepts in the context of the garden. Design-based research takes a pragmatic approach to research and curriculum design through an iterative process of development, implementation, testing, and refinement. Formative information provides continual feedback for ongoing improvement (Barab and Squire 2004; Design-Based Research Collective 2003). This design-based approach reached into all aspects of the SciLG curriculum design, including instructional planning and assessment development. In the beginning phase, the collaborative curriculum team of teachers, garden educators, and SciLG faculty cycled through the process of alignment and design, ensuring that SciLG explicitly addressed NGSS performance expectations (Penuel and Reiser 2018). At the same time, the team tuned into the unique needs of schools and teachers, and kept adolescent development and motivation at the forefront.

As shown in Fig. 4.1, the first stage of our work involved developing SciLG curricular materials focused on sixth grade, adding seventh and eighth grades in each of the following years. The team used formative data to refine the sixth, seventh, and eighth grade instructional plans, resulting in nine instructional units spanning the 3 years of middle school, for each fall, winter, and spring season in school (or community) learning gardens.

Activity 3: Further Development and Understanding of Learning Progressions The NGSS were created with a strong focus on developmental learning progressions outlined in Appendix E of the Next Generation Science Standards (NGSS Lead States 2013, Volume 2) for each disciplinary core idea. Through this design-based research process, the SciLG project contributes insights into different learning pathways that students experience in disciplinary core ideas related to garden-based science. Table 4.1 presents a sample of NGSS Middle School Performance Expectations that can be addressed through garden-based learning. For middle school, there are natural connections to learning in gardens across all of the disciplinary core ideas, but particularly in Life Sciences, Earth and Space Sciences, and Engineering Design. Additionally, by learning through well-planned instruction connected to school gardens, students are expected to gain direct experience applying scientific and engineering practices and observing crosscutting concepts such as energy and matter, structure and function, patterns, systems, and cause and effect as they interact with the natural world.

4.3.1 Research on the Core Idea of Engineering Design

School garden curricula commonly incorporate core ideas in the Life Sciences and Earth and Space Sciences, such as those listed in Table 4.1. However, the curricula developed in this project also focused on the core ideas in engineering design—more specifically on the four performance expectations in the NGSS (NGSS Lead States 2013; Sneider 2012) that are listed in the previous table. Engineering design is especially well suited to school gardening because the purpose of gardening is well defined—to grow healthy plants and nourishing food. In contrast to science inquiry, which aims to answer fundamental questions, engineering design aims to solve practical problems and meet goals. And while garden education also relies heavily on understanding of scientific concepts, the creative aspects of gardening involve the solution to such practical problems as how to best germinate seeds, where to plant species that have different requirements for light, or how to protect plants from diseases and grazers.

Although the idea of including such apparently "mundane" problem-solving skills in the science curriculum was strongly resisted by the science education community for many years (Lewis 2004; Sneider 2008; Sneider and Rosen 2010), both the practices of engineering design and the related core concepts were eventually embraced by the National Research Council committee that established the guidelines for developing new science standards (NRC 2012) and the state teams primarily responsible for developing the *Next Generation Science Standards* (NGSS Lead States 2013).

Given the widespread misunderstandings of technology and the nature of engineering among the general public (Rose and Dugger Jr 2002; Rose et al. 2004), we recognized that the task before us could be daunting (Sneider 2016a). However, significant research conducted over the past 20 years was extremely helpful in the curriculum design and implementation process. Crismond and Adams (2012) review of more than 400 studies of teaching and learning the design process provides especially useful information for curriculum developers on students' common misconceptions about engineering design, and what educators can do to help students

Table 4.1 NGSS Middle School Performance Expectations addressed via Garden-based Learning (NGSS codes: MS = Middle School (gr 6–8); LS = Life Science; ESS = Earth and Space Science; ETS = Engineering, Technology, & Applications of Science)

Disciplinary Core Ideas (Framework)	Disciplinary Component Ideas (Framework)	Middle School Performance Expectations (NGSS)	Potential Examples in Gardens
Molecules to organisms: Structures & Processes	**LS1.B** Growth & development of organisms	**MS-LS1–5.** Construct a scientific explanation based on evidence for how environmental and genetic factors influence the growth of organisms.	Investigate microclimates in the garden and the impact on growth of particular varieties of plants; comparing fruit production of different strains/ varieties of plants.
	LS1.C Organization for Matter and Energy Flow in organisms	**MS-LS1–6.** Construct a scientific explanation based on evidence for the role of photosynthesis in the cycling of matter and flow of energy into and out of organisms.	Explorations of food webs and matter flowing from air to plant to soil and back. Develop a molecular model of the complementary processes of plant photosynthesis and respiration.
		MS-LS1–7. Develop a model to describe how food is rearranged through chemical reactions forming new molecules that support growth and/or release of energy as this matter moves through an organism.	
Ecosystems: Interactions, energy, & dynamics	**LS2.A** Interdependent relationships in ecosystems	**MS-LS2–1.** Analyze and interpret data to provide evidence for the effects of resource availability on organisms and populations of organisms in an ecosystem.	Studies of plant growth rates/ biomass production in comparison to planting density; water quantities; compost and nutrients; and other factors.
		MS-LS2–2. Construct an explanation that predicts patterns of interactions among organisms across multiple ecosystems.	Observe and explain different relationships in the garden (e.g., ladybug and aphid; legumes and nitrogen-fixing bacteria).
	LS2.B Cycle of matter and energy transfer in ecosystems	**MS-LS2–3**. Develop a model to describe the cycling of matter and flow of energy among living and nonliving parts of an ecosystem.	Construct visual models demonstrating carbon cycle, nitrogen cycle, and energy flow through the garden system.
	LS2.C Ecosystem dynamics, functioning, & resilience	**MS-LS2–5**. Evaluate competing design solutions for maintaining biodiversity and ecosystem services.	Cover-cropping and compost; water catchment and plant density; plant communities to attract beneficial insects.
	LS2.D Biodiversity and humans		

(continued)

Table 4.1 (continued)

Disciplinary Core Ideas (Framework)	Disciplinary Component Ideas (Framework)	Middle School Performance Expectations (NGSS)	Potential Examples in Gardens
Earth's systems	**ESS2.A** Earth's materials & systems	MS-ESS2–1. Develop a model to describe cycling of Earth's materials and the flow of energy that drives this process.	Include abiotic factors in models of nutrient cycles.
Earth & Human Activity	**ESS3.C** Human impacts on earth systems	MS-ESS3–3. Apply scientific principles to design a method to monitor and minimize a human impact on the environment.	Student groups identify aspects of food production impacting environment (e.g. water consumption, run-off, burning fossil fuel, etc.), articulate connections between population growth and consumption, then design strategies to minimize and/or mitigate negative impacts.
		MS-ESS3–4. Construct an argument supported by evidence for how increases in human population and per-capita consumption of natural resources impact Earth's systems.	
Engineering design	**ETS1.A** Defining & delimiting engineering problems	MS-ETS1–1. Define the criteria and constraints of a design problem with sufficient precision to ensure a successful solution, taking into account relevant scientific principles and potential impacts on people and the natural environment that may limit possible solutions.	Any number of student-identified problems and design-based solutions related to the goal of growing healthy plants.
	ETS1.B Developing possible solutions	MS-ETS1–2. Evaluate competing design solutions using systematic process to determine how well they meet criteria and constraints of the problem.	
	ETS1.C Optimizing the design solution	MS-ETS1–3. Analyze data from tests to determine similarities and differences among several design solutions to identify the best characteristics of each that can be combined into a new solution to better meet the criteria for success.	
		MS-ETS1–4. Develop a model to generate data for iterative testing and modification of a proposed object, tool, or process such that an optimal design can be achieved.	

transition from beginners to expert problem solvers. Given the unique focus of this curriculum, and the relative paucity of information on how best to implement engineering design in the science classroom, we summarized a few of the key findings from that study, which Crismond (2013) has organized for teachers by practices of engineering design specified in the NGSS.

Defining the Problem An engineering design instructional unit often begins with a design brief, which is a general statement of the problem to be solved, with few clues about the nature of the solution. Beginners are likely to assume that the design brief is a clear statement of the problem, which they then proceed to solve with the first idea that comes to mind. Expert problem solvers spend considerable time exploring the problem space, learning as much as they can about the nature of the problem, in order to ensure that they are solving the right problem, and specifying the problem in terms of criteria for success, and constraints or limits to an acceptable solution. For example, a design brief stating that lettuce was being eaten by slugs, might be immediately answered by a beginning student who might recall his parents putting out slug poison. Teachers can motivate their students to become expert problem solvers by encouraging the students to think of ways to make sure that in fact the slugs are the culprits causing the greatest damage, and if so, whether there might be ways to prevent them from eating the lettuce without introducing toxic materials into the environment.

Planning and Carrying Out Investigations Beginners tend to implement the first solution that comes to mind right away, rather than conducting investigations to determine which of several solutions might work best. Teachers can encourage their students to become expert problem solvers by asking them to generate a number of possible solutions and to design an experiment to see which would work best. For instance, in science, often students conduct controlled experiments to answer questions. In engineering, students also conduct controlled experiments, but the goal is to determine which solution is best, or to improve a solution. Thus, students might divide the garden into three or four plots, each of which uses a different method of eliminating slugs. Although some lettuce might be lost, the students will learn which method works best, so they can engineer better gardens in the future.

Analyzing and Interpreting Data Beginners expect simple definitive answers from their experiments—either the method worked or it did not. Teachers can encourage their students to become expert problem solvers by focusing on the data. If a method for keeping slugs out of the garden failed, how did it fail? Did it succeed in some instances? How could this method be improved? Such questions help students troubleshoot their solutions, and recognize that even good ideas do not always succeed at first. They may need to be modified and tested a number of times—a problem solving process that engineers call *iteration*.

Arguing from Evidence When asked to talk about different solutions to a problem, beginners tend to describe the pros of solutions they like, and the cons of the solutions they do not like. Teachers can help their students become expert problem solvers by encouraging them to list the pros and cons of several alternative solutions. Another good exercise is to create a design matrix, in which the criteria for success are listed in the first column of a table, and a number is assigned to each one based on its importance in solving the problem. Alternative solutions are listed as headings of subsequent columns. The students then fill in the cells of the matrix by rating each solution against each criterion. Finally, they add up the points to see which solution best meets the criteria of the problem. Although such a process may seem tedious, most middle school students find the process of using a design matrix novel and motivating. Activities of this sort help students defend their choice of a solution by citing both the pros and cons of the chosen solution, and of the alternatives that were rejected. Recognition that even preferred solutions are not perfect also helps the students include both positive and negative evidence from investigations when reporting final results.

Similar to the engineering design process, we employed an iterative, design-based approach to curriculum development (See Fig. 4.1). This approach is consistent with the recommendations for implementing Next Generation Science Standards released by the National Research Council and called for in the research (NRC 2015; Penuel and Reiser 2018). Of special importance is the need to integrate the new standards into curricular methods already being used by the teachers to implement Common Core State Standards in mathematics and English language arts. Fortunately, the district where we have piloted the curriculum has been implementing an issue-oriented science curriculum, *Science Education for Public Understanding Program* (SEPUP) that is consistent with the engineering approach emphasized in the NGSS (Nagle 2015), and with the science-technology-and-society approach that appears in the NGSS as a crosscutting concept (Sneider 2016b).

4.3.2 Culturally Responsive Place-Based and Experiential Pedagogy

To meet the needs of culturally diverse middle school students and promote their motivational engagement, SciLG nurtures a connection to place and community and a sense of belonging and purpose at school and in the garden, opportunities that are often limited for many low-income racial and ethnic minority youth due to systemic inequities (Williams and Anderson 2015). In today's educational climate, it is crucial that educators advocate for multicultural populations so that all students are successful (Merino and Hammond 1998; Richards et al. 2006). Geneva Gay (2010) has argued that "all students must be benefactors of these efforts" (p. 20). Research overwhelmingly concurs that educators must adapt to increase the academic achievement of populations traditionally not successful in our schools. Effective

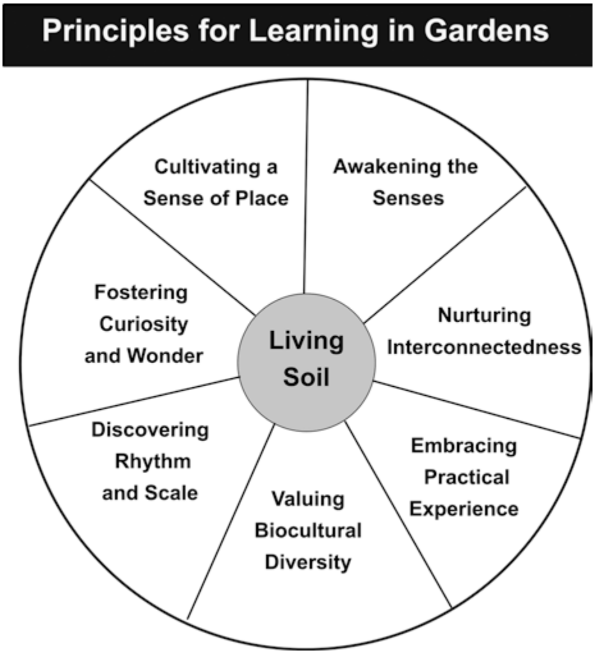

Fig. 4.2 Principles for Learning in Gardens. (Adapted from Williams and Brown 2012)

diversity pedagogy views the natural connectedness of culture and cognition as key to linking the teaching-learning process to diversity (Sheets 2005). Culturally responsive pedagogy has interconnected dimensional elements, which guide teachers, including: consciousness of difference; ethnic identity development; social interaction and interpersonal relationships; and safe and inclusive classrooms. For many of the culturally diverse students who are either immigrants or refugees often uprooted from their birthplaces, gardens support the establishment of roots in a place that students can call "home." By digging, planting, designing garden beds, growing food, harvesting, and cooking, students begin to connect with a place: a particular place. Place-based education is experiential, providing context that is specific to the dynamics of the place. As seen in Fig. 4.2, the seven pedagogical principles specific to garden-based learning (Williams and Brown 2012) enhance overall learning: (1) Cultivating a Sense of Place; (2) Fostering Curiosity and Wonder; (3) Discovering Rhythm and Scale; (4) Valuing Biocultural Diversity; (5) Embracing Practical Experience; (6) Nurturing Interconnectedness; and (7) Awakening the Senses. These pedagogical principles align with our understanding about how people learn (Bransford et al. 2000).

Sobel (2005) stressed the advantages of experiential teaching. "By emphasizing hands-on, real-world learning experiences, …[it] helps students develop stronger ties to their community, enhances students' appreciation for the natural world, and creates a heightened commitment to serving as active, contributing citizens" (p. 7).

Similarly, Orr (2005) explains, “in the reciprocity between thinking and doing, knowledge loses much of its abstractness, becoming in the application to specific places and problems, tangible and direct” (p. 91). David Orr (2005) captures the significance of place as promoting “diversity of thought and a wider understanding of interrelatedness. Places are laboratories of diversity and complexity, mixing social functions and natural processes” (p. 91). For Smith and Sobel (2010), “one of the primary strengths of place-based education is that it can adapt to the unique characteristics of particular places, and in this way, it can help overcome the disjuncture between school and children’s lives that is found in too many classrooms” (p. 584). Considering these attributes, school gardens provide an important context for students to connect to the land, the plants, the vegetables, their group, their teacher, their families, their culture, and themselves. Experiencing an integrated, hands-on curriculum also allows them opportunities to relate with each other and with the environment.

Such learning opportunities are increasingly important as students progress to middle school, because they may help to counteract the declines in motivation generally found across this school transition (Eccles et al. 1993; Gottfried et al. 2001; Harter 1981; Wigfield et al. 2006). Authoritative reviews of research on the development of achievement motivation identify the transition to middle school as a turning point, during which students typically show sharp losses in interest, intrinsic motivation, engagement, and perceptions of the value and importance of learning in school (Skinner et al. 2012; Wigfield et al. 2006). These motivational declines are especially steep for math and science (Anderman and Young 1994; Osborne et al. 2003; Simpson and Oliver 1990; Vedder-Weiss and Fortus 2011), and for students from low socioeconomic, ethnic minority, and immigrant families (Graham and Hudley 2005; Meece and Kurtz-Costes 2001). Losses in academic motivation during middle school are a serious problem. As a result, garden-based programs that have the potential to bolster engagement in science and other core subjects in middle school students can be highly valuable for students who are at risk for underachievement and drop-out.

The scope of this chapter does not permit a full description of our research findings that bear on the development of gardening curricula. However, the results of the first year of implementation of the project have been published (Williams et al. 2018). This study reported results from 113 students and three science teachers from middle schools participating in SciLG. Longitudinal data collected in spring of sixth grade in 2015 and fall of seventh grade in 2015 for the same set of students included a measure of students’ overall motivational experiences in the garden (that combined their reports of relatedness, competence, autonomy, and engagement, and teacher-reports of re-engagement in garden-based learning activities) to predict four science outcomes: engagement, learning, science grades, and science identity. Findings suggest that garden-based activities show promise for supporting students’ engagement and learning in science classes and in fostering students’ interest in pursuing science long-term (Williams et al. 2018). Further, unpublished results from the three-year longitudinal study, including 161 students in 6th through 8th grade and their ten science teachers showed that engagement in SciLG helped mitigate motivational declines typically observed in middle school, and were positively correlated with the science outcomes (Brule et al. 2019). Consistent with previous research findings (Williams and Dixon 2013), results from SciLG suggest that garden-based education is a powerful approach for achieving the vision and goals laid out in the Next Generation Science Standards (NGSS Lead States 2013). With the convergence of these educational movements—NGSS and school gardens— the time is right for the synergy manifested in Science in the Learning Gardens for engaging students at the *middle* level, to enhance health and advance equity in STEM.

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Chapter 5
Science in Action: Biological and Ecological Principles of Urban Agriculture

Bruna Irene Grimberg and Fabian D. Menalled

Abstract The development and implementation of a sustainable and resilient urban agriculture system depends on the interactions occurring between its biophysical basis, the ecological processes that either synergize or offset the provision of agro-ecosystems services, and the socio-economic context where it occurs. Urban agriculture can be conceptualized as complex socio-ecological systems in which human-nature interactions define the dynamic of such systems. The study of urban agriculture requires understanding a web of interrelated concepts and principles, providing an ideal context for science teaching and learning aligned to the demands of current reforms in science education. In this chapter we present and discuss learning progressions for urban agriculture from a socio-agroecological perspective based on networks of concepts associated to the cross-cutting concepts of *Interdependence*, *Diversity*, *System*, *Matter/Energy Flow*, and *Scale* for four grade ranges: K-2, G3-5, G6-8, and G9-12. Applications to classroom instruction and future educational research in this arena are also discussed.

Keywords Science education · Cross-cutting concepts · Learning progressions · Urban agriculture · Socio-ecological systems

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5.1 Introduction

The development and implementation of a sustainable and resilient urban agriculture system depends on the interactions occurring between its biophysical basis, the ecological processes that either synergize or offset the provision of agroecosystems services, and the socio-economic context where it occurs (Robertson et al. 2014). In this context, urban agriculture can be conceptualized as complex socio-ecological systems (Gallopin 2006) and, as in any urban ecological system, human-nature interactions define the dynamic of such systems (Collins et al. 2011; Grimm et al. 2013; Alberti et al. 2020). Thus, the success of urban agriculture depends not only on scientific advances focused on feedback loops between ecosystems, organisms, and humans, but also on the benefits and vulnerabilities it brings to society (Tanner et al. 2014; Berrouet et al. 2019). As such, the study and practice of urban agriculture intertwines different disciplines in a web of related concepts and principles, it requires systemic approaches for solving complex problems, and necessitates critical thinking. However, learning interrelated concepts across disciplinary domains may present challenges as instruction traditionally focuses on isolated domains (NRC 2012; Donovan and Bransford 2005). We argue that sustainable urban agriculture provides an ideal context for science teaching and learning aligned to the demands of current reforms in science education.

Cross disciplinary instruction, systemic thinking, and problem solving are at the foundation of the vision for science education included in the *Next Generation Science Standards* (NGSS 2013), as is shown by the Standards' three-dimensional framework: Core Disciplinary Ideas, Cross-cutting Concepts, and Science and Engineering Practices. The current science education reform aims at learning outcomes based on high levels of science content knowledge, and application of such knowledge to real-world situations. These aims are captured by the notion of *deeper learning*, a concept developed in the last few years to capture the processes suggested by the competencies and skills included in the *New Framework for K-12 Science Education* (NRC 2012) and later in the NGSS. *Deeper learning* is "the process through which an individual becomes capable of taking what was learned in one situation and applying it to new situations (i.e., transfer)" (NRC 2012) and it unfolds in three main domains: cognitive, interpersonal, and intrapersonal. The cognitive domain includes competencies related to content knowledge and critical thinking, interpersonal domain includes collaboration and communication, and the intrapersonal domain refers to metacognitive competencies (Hubberman et al. 2014). The implementation of *deeper learning* instruction is characterized by real-world applications and project-based learning, the latter is an approach that focuses on finding a solution to a problem/question that is relevant to the students through the application of prior knowledge and acquisition of new knowledge.

Research on the impact of *deeper learning* instruction shows that students experienced superior learning outcomes, measured as higher mathematics test scores, increased levels of collaboration, engagement, motivation to learn, and self-efficacy, as well as on-time high school graduation with respect to a comparison group

(Zeiser et al. 2014). More specifically, project-based learning is conducive to student's mastery of content knowledge, making connections across disciplines, critical thinking, and peer-collaborations. It also correlates with increases in standardized science test scores and net gains in science inquiry skills when comparing pre and post project-based learning results (Rivet and Krajcik 2004; Marshall and Craig 2019) and with increasing students' ability to analyze complex environmental problems (Nagarajan and Overton 2019) The study of sustainable urban agriculture provides a suitable context for *deeper learning* due to its relevance to students' everyday life as a source of food and other ecosystem services, its socio-economic complexity, and the multidisciplinary scientific concepts it encompasses.

Urban gardens are managed ecosystems in which bio-physical interactions can be analyzed following ecological principles. In this context, the cross-cutting concepts (concepts that cross-cut multiple disciplines) of *scale, systems, interdependence, diversity, and matter and energy flow* are critical to understand the processes that take place in these small-scale agroecosystems. The conceptual links between these ideas and the increasing cognitive complexity that unfolds throughout the learners' age suggest a progressive sequence of topics and practices. In this chapter, we propose learning progressions for the five aforementioned cross-cutting concepts -scale, systems, interdependence, diversity, and matter and energy flow- and associated concepts by addressing content knowledge and scientific competencies for sustainable urban agriculture for four grade ranges (K-2, G3-5, G6-8, and G9-12). First, we discuss learning progressions. Second, we present a rationale for the choice of the core ideas and concepts. Third we present four learning progression matrices for the four grade ranges. Fourth, we discuss the implication of urban agriculture learning progressions for curriculum and study programs' design. Finally, we conclude with remarks about future work regarding learning progressions for sustainable urban agriculture.

5.2 Learning Progressions

The disconnection between school science curricula and how students learn contributes to students' lack of understanding of scientific concepts. Presenting science as an inventory of isolated subjects and skills poses obstacles to student's sense making (NRC 2007; Schmidt et al. 2005) while using a coherent approach for concept development (from intuitive to scientific) proved effective to increase students learning (Jin et al. 2019). Advances in cognitive and sociocultural psychology, the success in the use of learning tools and technologies to scaffold learning, and the benefits of student assessment focused on formative or "for learning" purposes, hint towards the idea that learning involves a sequence or trajectory of interconnected concepts and competencies (Duschl et al. 2011). The integration of cognitive and sociocultural research along with discipline-specific concepts, and discourse led to the development of learning progressions. Learning progressions refer to a sequence (or progression) of concepts that lead to the understanding of a topic. The level of complexity of a sequence concepts increases conforming school grades, such that full understanding of a topic might take a broad period of time (e.g., all school years). Learning progressions have a starting-concept point (usually called anchor) based on learners' prior knowledge and ways of reasoning at the time they enter formal education. Learning progressions trace the pathways of concepts and practices that connect the anchor concept with the full understanding of a topic. These pathways are based on the way students learn (NRC 2007).

Learning progressions branch out of the idea that learner's understanding develops in a predictable way. Based on the notion of learning as a scaffolded process, Brown (1997) proposed the term *developmental corridor*, "Children remain in this corridor for several years, during which time they delve more deeply into the underlying principles of a domain" (Brown 1997, p. 408). Learning progressions represent predictable and scaffolded conceptual increments between the lower and upper anchors of the progression. These levels result from strong empirical evidence about learners' knowledge understanding (Wiser et al. 2009). Examples of learning progressions include the description of students understanding of force and motion (Alonzo and Steedle 2009), genetics (Shea and Duncan 2013; Duncan et al. 2009), carbon cycle (Mohan et al. 2009), earth motion (Plummer and Krajcik 2010) and argumentation (Berland and McNeil 2010). In addition to the vertical incremental connection between learning levels, some learning progressions have horizontal connections among core ideas or dimensions. All learning progressions derive from canonical discipline-specific concepts and incorporate research on how students learn such concepts.

Anderson (2008) suggested three qualities to ensure theoretical and empirical validation of learning progressions: (a) *Conceptual coherence;* (b) *Compatibility with current research*; and (c) *Empirical criteria.* This scheme implies the use of empirical data to refine the learning progression. Different approaches can be used for the development and refinement of learning progressions. In some cases, empirical data is drawn from student assessments administered in "controlled-like" classrooms (Mohan et al. 2009; Jin and Anderson 2012) in which instruction is not based on the hypothetical learning progression but on educational research outcomes. In other cases, student assessment data is collected after implementation of instruction aligned with the hypothetical progression (Shea and Duncan 2013; Songer et al. 2009). A more drastic method is the bottom-up approach used by Wiser et al. (2009) and Lehrer and Schauble (2012) in which the first phase of the learning progression is derived from teaching experiments in different grades, and refinement occurs in subsequent implementations of the instruction.

The proposed learning progressions include a set of teaching pathways based on the logic of agroecology and students' conceptual development (Grimberg and Hand 2009; NRC 2007; Furtak 2012). In order to validate these progressions, it is imperative "*to correlate initial conjectures about the learning process with empirical data about students learning*." (italics in the original, Shea and Duncan 2013, p. 5). The transition from a hypothetical learning progression to an empirical one requires iterative cycles with different validation methods depending on the iteration phase (Shea and Duncan 2013; Stevens et al. 2010).

In the following sections, we propose landscaped learning progressions of core ideas and concepts for teaching sustainable urban agriculture in K-12 learning environments. The selection of the core ideas of the learning progression is based on the analysis of conceptual and content domains, and on teaching experiences (Duschl et al. 2011; Harlen 2010). Concepts associated with a core idea constitute a cluster. Concepts in one cluster might be interconnected and/or connected to concepts of a different cluster (Catley et al. 2004), forming a complex network of concepts, suggesting alternative learning paths for the development of science content knowledge with increasing level of complexity. Each path results from the connections between concepts, such that one landscaped learning progression contains many different paths. These learning progressions are based on the principles of sustainable agroecology (Snapp and Proud 2008; Gliessman 2007). The organization of the concepts associated to these principles follows the recommendations of the *Project 2061's Atlas of Science Literacy* (AAAS 2007) and of the *Next Generation Science Standards* (NGSS 2013).

5.3 Rationale for Urban Agriculture Learning Progression Core Ideas

As was stated by Smit and collaborators, "[urban agriculture] is an industry that produces, processes and markets food and fuel, largely in response to the daily demand of consumers within a town, city, or metropolis, on land and water dispersed throughout the urban and peri-urban area, applying intensive production methods, using and reusing natural resources and urban wastes, to yield a diversity of crops and livestock."(Smit et al. 2001, p. 1). As a practice conducted in urban and peri-urban systems, urban agriculture includes the production, distribution, and marketing of food products in densely populated areas. Examples of places in which urban agriculture is practiced include community gardens, school backyards, and rooftop gardens designed to produce mostly horticultural crops and/or small-size livestock.

In many cases, urban agriculture involves innovative food-production methods aimed at maximizing production in small areas and their sustainability requires the application of ecological principles to food-production; providing a ground to understand and experience the interrelation of these principles. In this section we present the ideas that define and rule the dynamics in ecological systems and align them to the cross-cutting concepts introduced in the NGSS. The relation between concepts is derived from agroecology practice and research (Snapp and Proud 2008; Gliessman 2007), while the association of concepts to grade bands is based on educational research (AAAS 2007; NRC 2005; NGSS 2013) and on the level of organization alluded by the concepts. Levels of organization high in the ecological hierarchy involve more complex processes (Odum and Barrett 2005).

Ecology is defined as "the study of the abundance and distribution of organisms" (Begon et al. 1996) and "is concerned with different scales over time and space, from the individual to the community, from population to ecosystems" (Snapp and Proud 2008, p. 54). The interactions occurring among organisms at the same or different trophic levels influence interdependence, diversity, and matter and energy flow among the ecosystem's components. Ecological processes that drive the dynamics of ecosystems can be described, explained, and predicted by eight principles that apply to a wide range of organization levels in urban agroecosystems: (1) adaptation, (2) behavior, (3) diversity, (4) emergent properties, (5) energy flow, (6) growth and development, (7) limits, and (8) regulation (Odum and Barrett 2005). More specifically, adaptation refers to changes of a system's form and function in response to a dynamic environment. Behavior refers to the responses of the biotic components to stress and disturbances. Diversity refers to the variety within each level of organization (organism, population, and community). Emergent properties result from the interaction of different levels of organization.

There are overlaps between the conceptual frameworks provided by these ecology principles (Odum and Barrett 2005) and cross-cutting concepts (NRC 2012). The ecological principles of adaptation, behavior, and growth and development are associated to the cross-cutting concept of Interdependence; the principle of diversity is associated to the cross-cutting concept of Diversity; the principles of emergent properties, limits, and growth and development are associated to the cross-cutting concept of System; and the principles of energy flow and regulation are associated to the cross-cutting concept of Energy and Matter Flow. Finally, the ecological notion of incremental organization levels can be associated to the cross-cutting concept of Scale. Therefore, developing a learning progression for urban agriculture based on a socio-agroecological perspective requires the identification of networks of concepts associated to the cross-cutting concepts of Interdependence, Diversity, System, Matter/Energy Flow, and Scale. The meaning and rationale of each cross-cutting concept in the context of urban agriculture is explained below.

Scale refers to a temporal, spatial, and organizational domain. Temporal and spatial scales play a central role in the distribution of ecosystem's environmental resources –such as moisture, temperature, and light, which in turn impact agricultural yields (Snapp and Proud 2008; Levin 1992). Indeed, the notion of variable scales is central to ecological phenomena, as "systems generally show characteristic variability on a range of spatial, temporal, and organizational scales" (Levin 1992, p. 1960). Therefore, *Scale* is a core idea of urban agriculture that helps explain the variability of the kind and scope of ecological interactions.

Systems are collections of interdependent parts that form integrated units with emergent properties due to the existence of synergistic interactions within its components (von Bertalanffy 1968). The idea of *Systems* is critical to understand the effect of interactions among the different components of an ecosystem, including urban agroecosystems, where sub-systems are not isolated but nested within larger systems (e.g., crops within communities of plants that includes weeds, and crop production conceived within local food systems) and changes at one system-level can affect systems at lower or/and upper levels (e.g., weeds could decrease yields, reducing economic net returns; and a decrease in crop production could impact food availability, increasing prices).

Interdependence refers to the different types of connections and interactions occurring among organisms, and between organisms and the environment. In urban agroecosystems, the relative abundance of individuals and the diversity of species are critical components to maintain its stability. For example, lady beetles, also called lady bugs, are predators of aphids which are common pests in urban agro-ecosystems. By regulating the population of aphids, lady beetles and other beneficial insects such as parasitoids can help regulate pest pressure without pesticides. The abundance of these beneficial organisms is in turn impacted by human activities (e.g., spraying insecticides to control pests could have non-target effect and kill beneficial insects). Assessing the interdependence of animals, plants, insects, microbes, abiotic factors, and humans in the context of urban agriculture provides evidence of the impact of urban agriculture on people's health and community and vice versa.

Matter and energy flow is a concept that prevails in ecosystems -including urban agro-ecosystems- and it refers to the cycled energy originated in sources that are external to the system through a series of trophic interactions. Primary producers such as plants, algae, and some bacteria, use solar energy to produce sugars through photosynthesis. Animals eat plants or other animals, and energy and matter is passed to the higher trophic levels of the food web. However, not all the produced energy is passed between trophic levels as a fraction is used for respiration, growth, and reproduction. Decomposers –worms, insects, mold, fungi, and bacteria – are important organisms to keep the ecosystem's matter and energy flowing as they return nutrients to the ecosystem by breaking down waste and dead organisms. During the decomposition process energy is released, mostly as heat. The sustainability of agro-ecosystems depends on the flow of matter and energy within the system.

Diversity refers the degree of variation of subsystems within a system. In ecology, biodiversity, or the relative abundance of living organisms of different species is a core concept that relates to its function and stability (Magurran and McGill 2011). In urban agro-ecosystems organisms constitute either the planned or the associated biodiversity. Planned biodiversity consists of the suite of crop species intentionally included in the system. Associated biodiversity refers to the pest, beneficial, and neutral species not deliberately included, but that normally occur in the system or colonize it from adjacent habitats (Vandermeer et al. 2002). In urban agro-ecosystems, both the planned and the beneficial or neutral components of the associated biodiversity helps maintain the stability of the ecosystem and facilitates the provision of ecosystem services such as protection of soil and water sources, pest management, and increasing plant reproduction through the presence of pollinators (Snapp and Proud 2008). As a general rule, a system with high level of diversity is more resilient, thus stable, to disturbances. The relation between human activities and the biodiversity of urban agricultural ecosystems is also addressed in the learning progressions.

Each of the five cross-cutting concepts has associated a cluster of ideas specific to urban agriculture and aligned with the ecological principles. Connections between ideas of the same or different cluster result in a network of concepts. Concepts within a cluster are arranged from simple to complex, according agroecology criteria. The sequence of cross-cutting concepts is arranged based on the cognitive demands of the cluster concepts. Cognitive demands can be categorized based on the number of cognitive domains involved in a task. Lower cognitive tasks refer to operations related to structure or form, whereas upper cognitive tasks refer to operations related to functions (Grimberg and Hand 2009). The sequence (from low to high) of cognitive tasks that apply to urban agriculture cross-cutting concept clusters is: observation, measurement, comparison, causal relations, induction, and deduction. The directionality from less to more complex ideas within clusters and across them provides the network of concepts a sense of progression.

5.4 Learning Progressions for Urban Agriculture

In this section, we present four learning progressions for grade levels: K-2 (see Fig. 5.1), grade 3-5 (see Fig. 5.2), grade 6-8 (see Fig. 5.3), and grade 9-12 (see Fig. 5.4). These learning progressions focus on the ecological principles encompassed by urban agriculture. The agroecology concepts applicable to urban agriculture and associated to each cross-cutting concept are aligned with the strands and concepts of the *Project 2061's Atlas for Science Literacy*, (NRC 2007), the *New Framework for Science Education Standards* (NRC 2012), and research findings on the impact of urban agriculture on human health and communities.

Urban agriculture lends to the implementation of learning progressions and research-based recommendations for science instruction (Kaldaras et al. 2020; Scott et al. 2019) and for addressing the disciplinary cross-cutting concepts and core ideas included in the *Framework for K-12 Science Education* (NRC 2012). In this regard, urban agriculture can be seen as a teaching strategy and a learning outcome. We envision the use of these progressions to develop K-12 curriculum and assessment for formal and informal learning settings. Each learning progression presents many different paths resulting from the connections between concepts; each path proposing a sequence of concepts with an increasing degree of complexity. These sequences represent different teaching pathways for learning agroecological concepts. For example, the *Matter/Energy Flow* concept *"*Animals eat plants that produce the material and energy they need. In turn, they might be eaten by other animals*"* in the G6-8 learning progression (see Fig. 5.3, third box under *Matter/Energy Flow* column) can be approached from the notion of "At the base of any food web are organisms that make their own food" (Fig. 5.3, first box under *Interdependence*) or "The output from one part can become the input of the other" (Fig. 5.3, third box under *Systems*). The multiplicity of teaching pathways increases the opportunities to associate new knowledge to prior knowledge and uses multiple representations, enhancing student learning (Krajcik et al. 2010).

It is important to note that the sequence of clusters corresponding to the cross-cutting concepts are not the same for all grade ranges, because the concepts

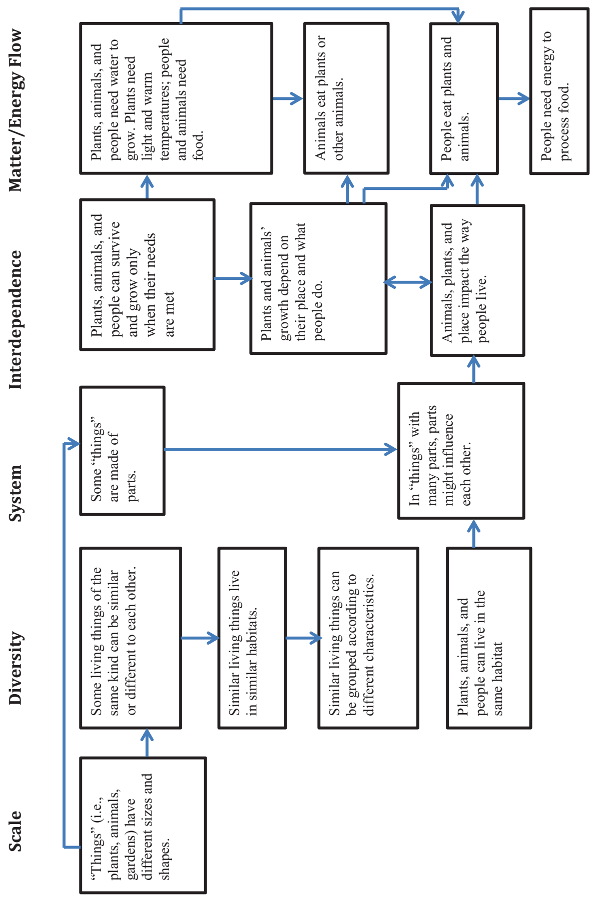

Fig. 5.1 Grade K-2

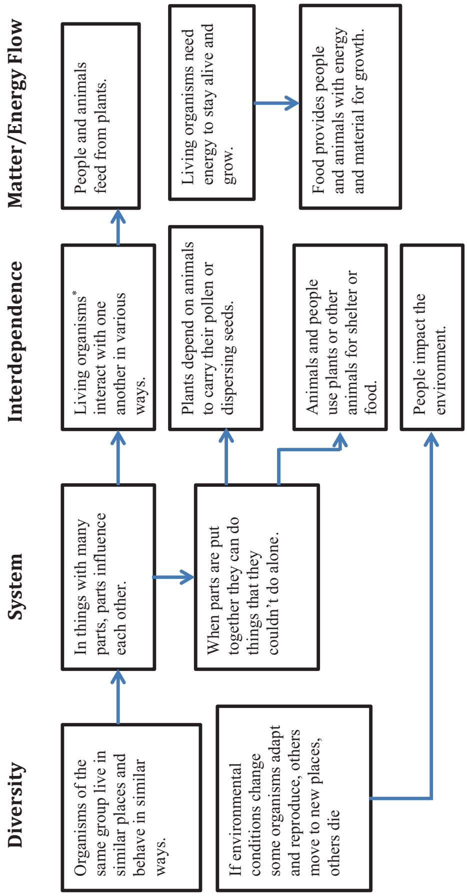

Fig. 5.2 Grade 3-5

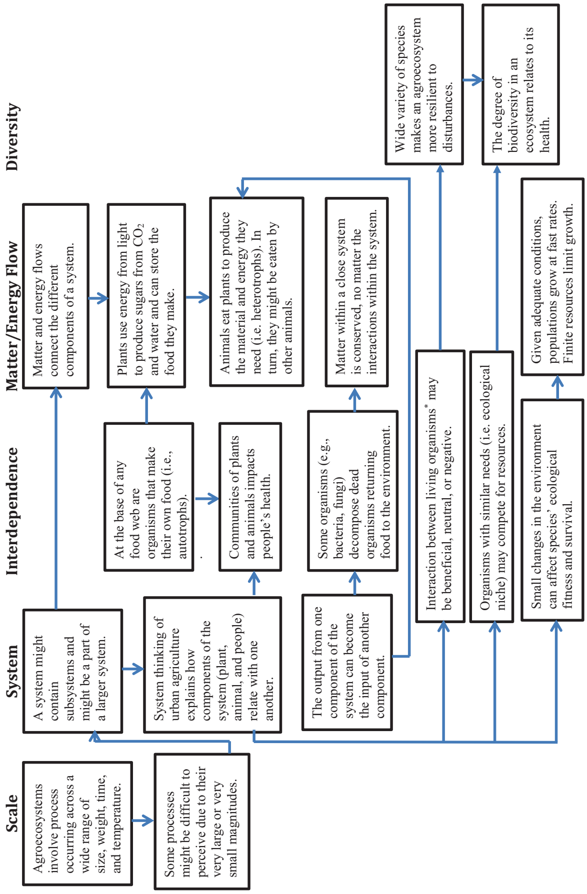

Fig. 5.3 Grade 6-8

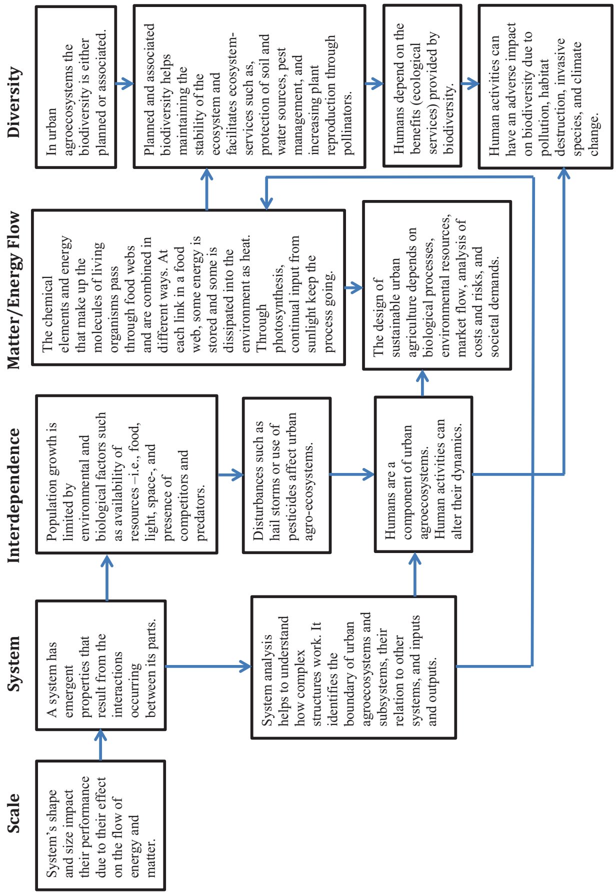

Fig. 5.4 Grade 9-12

associated to each cluster require cognitive demands with different degree of complexity depending on the grade range. For example, the concepts in the Diversity cluster for kindergarten through grade five imply activities and learning tasks that involve observations, measurements, and comparisons. These tasks focus mainly on structures or forms; thus, they are on the left side of the progression. Conversely, the concepts associated to Diversity in grades six through twelve focus on processes/functions and this cluster is on the right side of the progression. The cluster arrangement not only depends on their cognitive demands but also on the agro-ecological prior knowledge required by the concepts included in these learning progressions.

5.5 Teaching Implications of a Learning Progression in Urban Agriculture

The premise underlying learning progressions is that learners construct their knowledge and this process can be facilitated with teaching approaches that emphasize linkages between concepts. Developing teaching sequences of ecological processes is difficult because of their systemic nature and non-linear dynamics (Jordan et al. 2009). Moreover, the concepts involved in ecological processes present different degrees of complexity in terms of their cognitive demands and prior knowledge.

Learning progressions for sustainable urban agriculture based on agro-ecological principles and cognitive complexity, have implications regarding student learning, curriculum development, and assessment. These learning progressions provide multiple teaching pathways to achieve learning objectives for ecology. Multiple teaching sequences are helpful to engage students with different prior knowledge as each learning pathway involves a different set of concepts and cross-cutting clusters. Additionally, achieving the same learning objective through multiple teaching sequences allow to revise concepts in different conceptual clusters. Such "revision" might facilitate increasing student conceptual understanding.

The learning progressions presented in this chapter can inform curriculum development to address the eight principles of ecology in the context of urban agriculture. The strong presence of human activity in the design and management of urban agricultural systems -as they are planned systems- provides great opportunities to integrate science teaching with social science and language arts. Connections between science and other curricular areas are possible through the concepts that address human impact and interactions in the clusters corresponding to Systems, Interdependence, Matter/Energy Flow, and Diversity. Such integrations are suggested by the Common Core (NGAC 2010), and proved effective to increase student engagement in science learning by making science topics relevant through socio-scientific topics (Jho et al. 2014). Due to the small scale and intensive nature of urban agriculture, hands-on inquiries activities are feasible in K-12 school environments. The suggested learning progressions can inform the development of sequences of inquiry activities with increasing levels of cognitive demands.

Activities that build on one another in a sequential manner are prone to increase student science understanding and retention.

The intersection of science and society that characterizes urban agriculture allows developing assessment tools with factual, divergent, and higher order questions focused on decision-making, inference, application, and problem solving (Blosser 2000). The suggested learning progressions can inform assessment development for the concepts associated to each cluster across K-12 grades and within grade bands. Learning progressions of sustainable urban agriculture can provide student-relevant contexts to assess the eight principles of ecology, and the scientific skills and practices suggested in the NGSS (NGSS 2013).

5.6 Conclusions

Current available K-12 educational curricula that focus on urban agriculture provide educators with great repositories of lesson plans (for example see National Agriculture Literacy Curriculum, School Garden Curriculum from University of Georgia, California School Garden Network's Curriculum). These lessons are rich on project-based learning experiences promoting *deep learning* but they usually address a single isolated concept under the label of a single discipline (e.g., Life Science, Earth Science, and Math). The learning progressions on urban agriculture proposed here have direct implications on teaching practices. These learning progressions will facilitate the development of curricula that follow two-dimensional learning paths involving cross-cutting concepts and their associated cluster of agroecological principles and concepts. The multiplicity of teaching pathways – each with different anchor concept- lends to multipronged teaching approaches suitable to engaged diverse learners and to adaptive instructional designs. Additionally, teaching through the progression of interrelated agroecological concepts reinforces the application of an earlier learned concept into the next step of the progression, facilitating information processing and knowledge acquisition.

The proposed learning progressions and teaching pathways are hypothetical theory-driven trajectories, yet plausible due to their foundation on agroecology principles and educational research. In order to refine the progressions, we propose future research focused on the following:

1. Validation of the progressions. This task will require the implementation of instruction and assessment tools aligned with the teaching pathways for different grade levels and the use of assessment data to adjust the proposed learning paths.
2. Inclusion of practices within the network of concepts. These progressions focus mainly on content domains but practices should be included and validated through assessment. The integration of practices and content prove beneficial to reinforce science conceptual understanding while at the same time, practices constitute learning objectives by themselves (NRC 2007, 2012).

Learning progressions anchored on general knowledge domains reflect how students learn because they rely on associations between prior and new conceptual knowledge. Urban agriculture is a genuine multidisciplinary practice and body of knowledge, providing a ground for teaching strategies that are responsive to cognitive development views of learning, in which learners construct conceptual understanding when prior knowledge is recalled and applied to new learning situations in different disciplinary contexts.

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Chapter 6
Urban Agricultural Experiences: Focusing on Twenty-First Century Learning Skills and Integrating Science, Technology, Engineering, and Mathematics (STEM) Education

Isha DeCoito

Abstract School gardens are considered non-formal learning settings and a source of experiential learning and have been used to teach core academic subjects such as science, history, art, language, and mathematics in a hands-on, experiential learning environment. More recently, some schools have promoted school gardens as outreach programs intended to help underprivileged citizens. The author reports on a study which explored how school gardens involved in urban garden initiatives addressed the issue of social justice. Findings indicate that the urban garden initiative started with a school garden and moved outward into the community. Students were empowered, as well as the school's extended community through good nutrition, the experience of successfully growing food, and the relationships formed in the process. In addition to fostering environmental stewardship and community building, the school garden program addressed the issue of hunger and poverty within and beyond the school walls and into the wider community. Environmental stewardship, food security, youth empowerment, and proper nutrition are some outcomes of this urban agriculture initiative.

Keywords Stewardship · STEM · School gardens · Social justice · Place-based education · Global competencies · Experiential learning · Community · Urban garden initiative · Youth empowerment

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6.1 Introduction

Gardening programs are currently a trend in schools around the world as teachers and schools seek pedagogical approaches to engage students in experiential learning and work towards tackling societal concerns such as environmental sustainability (Blanchet-Cohen and Reilly 2017; Cutter-Mackenzie 2009). School gardens are considered non-formal learning settings and a key source of experiential learning (Bell 2001; Jose et al. 2017; Waliczek et al. 2003) and can be integrated into all areas of the school curriculum, making learning more meaningful (Canaris 1995; Rios and Brewer 2014). In addition to teaching core academic subjects such as science, history, art, language, and mathematics; school gardens are focusing on integrating science, technology, engineering, and mathematics (STEM) education in an inquiry based, hands-on, experiential learning environment (Klemmer et al. 2005; Williams et al. 2018). School gardens are a flexible teaching tool that can be shaped by the educational needs, preferences, and goals of schools, school boards, teachers, and students. Furthermore, school gardens have the potential to promote the development of twenty-first century learning including critical thinking, problem-solving, collaboration and cooperation, community, self-discipline, and wise use of resources (NRC 2011; Waliczek et al. 2000). School gardens also offer spaces where immigrant children can share their cultural heritages, feel a sense of belonging, and form connections to the local environment (Blanchet-Cohen and Reilly 2017; Cutter-Mackenzie 2009).

The multiple benefits of school gardens entail three main aspects: environmental, educational, and nutritional. There is now a wider recognition of the role of school gardens in environmental and nature education, in local food biodiversity and conservation, food and eco-literacy, diets, nutrition and health, and agricultural education. The current concerns about environmental degradation and the disconnect of young people with nature and agriculture have resulted in school gardens receiving unprecedented attention (Gonsalves et al. 2020).

A growing number of school gardens are engaging the practice of urban agriculture by growing food crops such as tomatoes, beans, lettuce, and potatoes and then consuming these products and/or donating them to local food banks and/or other community organizations. For example, in the research being reported, 10 to 15 students are taking time after school to tend to an astounding 10 varieties of tomatoes, zucchini, eggplant, Swiss chard, cucuzza (Italian squash), as well as a patch of pumpkins. Last year, the secondary school (one of the sites for the study in this chapter) harvested 1500 pounds of crops. Weekly, the food was delivered to a nearby food bank. Urban agriculture is an excellent way for students, teachers, and the community at large to connect with the earth and the environment (Arvai et al. 2004; Lerner et al. 2005). At the same time, the process of growing food crops and donating them to local food banks and other community organizations helps shed light on important local, social and global issues of hunger, poverty, malnutrition, and food security (Morris and Zidenberg-Cherr 2002; Reynolds 2017).

Overall, the focus of the chapter is on school gardens as a vehicle for developing twenty-first century learning skills, integrating STEM education, and promoting social justice. The author reports on a research project which explored two school gardens in the Participation, Acknowledgement, Commitment, and Transformation (PACT) Grow-to-Learn Schoolyard (GTL) Gardening Program and Food Initiative in Ontario, Canada. An elementary/middle school and a secondary school were research sites for the study which utilized a social justice and critical place-based framework to explore the extent to which social justice was addressed through the activities of school gardens. Thus, the research explored the potential of school gardens to impact (1) students' twenty-first century learning skills, (2) the development of communities of learners, and (3) students' environmental awareness and stewardship.

6.2 School Gardens and Urban Initiatives

6.2.1 School Gardens

School gardens have evolved through the ages, changing with the philosophies of our education systems and the values developed by various cultures (Desmond et al. 2002). The objectives for school gardens have, however, differed greatly, determined by the purpose, the targeted audiences, and the proponent(s) of the initiative. In the developing world, the purpose of urban agriculture initiatives have included teaching improved farming skills, supporting community food production, raising funds, and demonstrating exemplary agricultural practices to the communities surrounding the schools. In the industrialized world (and increasingly in the global South), school gardens have served a broader education function, helping children understand science, nature, and the environment (Gonsalves et al. 2020).

From students' perspectives, the positive impacts of school gardens are numerous. This includes fostering better health and nutrition (Dawe et al. 2020); enhanced emotional well-being (Dawe et al. 2020; Lam et al. 2019); providing socialization and fun opportunities (Kuru et al. 2020); enhanced agroecological and ecological knowledge (Roscioli et al. 2020); enhanced student motivation and interest which is related to autonomy, competence, relatedness and cooperation, enjoyment, and acquirement of new knowledge and experiences (Christodoulou and Korfiatis 2019); enhanced academic achievement (Berezowitz et al. 2015); and better food literacy (Lam et al. 2019).

Despite the current perceived importance and potential of school gardens, historically their educational value has been inconsistent. In the early twentieth century (1900–1930s), progressive education and social reform movements encouraged garden-based learning. For example, the histories of school gardens reveal that by 1918, every state in America and every province in Canada had at least one school garden (Sealy 2001). Mid-twentieth century (1960–1970) saw counterculture and environmental movements create a resurgence in school and community gardens. However, weakened by the conservatism of the 1980s, the Evergreen Foundation estimated that less than 1% of Canadian schools operated a garden, and the percentage is relatively higher in the primary grades and lower among middle-school and high school populations. The late twentieth century (1990–2000) witnessed the rebirth of progressive education coupled with renewed interest in environmental education and nutrition/health issues for children. By 2006, 0.5% of Canada's 16,000 schools had school gardens, and these are primarily at elementary schools. In contrast, 5–10% of schools in the UK have school gardens and 30% of California schools have them (Evergreen 2006). Today, there are numerous school garden initiatives across Canada, including *Think and Eat Green at School* in British Columbia, *Healthy Schools* in Manitoba, as well as numerous initiatives in Ontario, such as the *Grow-to-Learn Schoolyard (GTL) Gardening Program and Food Initiative*. There are two nation-wide school gardening related initiatives: *School Garden Network*, an initiative of *Nutrients for Life Canada*, which is designed to be a resource for science-based gardens by providing a showcase for existing school gardens and by fostering collaboration, innovation and best practices, and *Agriculture in the Classroom* (AITC), a Saskatchewan based charity which promotes agricultural education and awareness across the country.

As we moved past the endpoint of the United Nations Decade of Education for Sustainable Development (2005–2014), it is evident that on a global scale, a wide variety of environmental education and sustainability initiatives have been implemented. In Ontario, the Ministry's policy framework *"Acting Today, Shaping Tomorrow: A Policy Framework for Environmental Education in Ontario Schools*" (2009) is designed to guide school boards and schools towards the development of the skills and knowledge needed to implement environmental education in a community-centred context. According to the policy framework:

> Ontario's education system will prepare students with the knowledge, skills, perspectives, and practices they need to be environmentally responsible citizens. Students will understand our fundamental connections to each other and to the world around us through our relationship to food, water, energy, air, and land, and our interaction with all living things. The education system will provide opportunities within the classroom and the community for students to engage in actions that deepen this understanding. (p. 4)

The Ministry's policy framework not only promotes teaching about the environment, but it also embraces inquiry-based learning, experiential learning, and stewardship. The implementation of a school garden-based curriculum aids in meeting many of the policy framework requirements, as well as offers opportunities for students to participate, through hands-on gardening activities, in their own learning.

6.2.2 Urban Garden Initiatives

Urban agriculture has entered the lexicon as a way to describe a myriad of food-growing practices that are increasingly taking place in cities throughout the country and, indeed, the world. In fact, globally, it is common for a significant portion of food consumed in cities to be grown within and immediately surrounding those same cities. City schools are starting garden projects in schoolyards and integrating food literacy and career-oriented horticulture into the curriculum. The research being reported in this chapter involves the PACT "Grow to Learn" (GTL) Urban Agriculture Initiative. PACT founders, David Lockett and Dan Cornacchia had previously created the Redwood Shelter for survivors of family violence in Toronto in the early 1990s. Together, they developed a program (PACT) that addresses the causes of violence, not just its effects. PACT expanded its peace mandate by partnering with the schools in high-risk neighborhoods, the police (and their pre-charge diversion programs) and several youth-focused employment/community agencies. PACT's GTL initiative identifies and establishes a number of schoolyard gardens in which students, teachers, and community volunteers grow produce under the supervision of a PACT Urban Agriculture Leader. One of PACT's mandate is to provide fresh organic produce to food banks and their low-income clients as well as to school and community based culinary programs in priority neighbourhoods. PACT simultaneously empowers and educates schools and communities through experiential learning opportunities and curriculum linked workshops in safe nurturing green spaces that increase awareness and help break cycles of poverty and health problems associated with hunger, obesity, and malnutrition.

Recently, school garden projects have been evolving. A specific example of this development is the concept of biodiverse edible schools that reconnect schoolchildren with nature and food production in an urban setting, especially through the role of edible wild plants and local urban biodiversity (Fisher et al. 2019). The key elements of the concept of biodiverse edible schools include: a school kitchen supplied with foods from local producers, a school garden actively producing food, a nearby empty wild space as a habitat for wild edible plants, and stakeholder participation and collaboration in planning and implementation (Fisher et al. 2019). Another recent school garden form is the "virtual school garden exchanges" in which learners plant school gardens and use digital media (e.g., videos, photos, video conferences) to engage in virtual communication about their gardens and related topics (Lochner et al. 2019).

6.3 Theoretical Framework

6.3.1 Place-Based Education and Social Justice

Many schools have created school gardens for numerous purposes. School gardens may be created for aesthetic purposes, as a component of a science or horticultural program, or as part of greening school grounds policy. More recently, some schools have promoted school gardens as outreach programs intended to help underprivileged citizens. PACT school gardens encompass over three acres across five schools in low income neighbourhoods. Each year, over 20,000 pounds of organic fruit, vegetables, herbs and flowers is harvested in the PACT gardens – most of which was donated to local food banks, used for culinary programs in the schools or sold at local farmer's markets with the proceeds going back into the program. Students volunteer in the gardens, often accumulating community service hours, through after school Eco-Clubs, co-op placements, court-referrals, and summer student programs, with PACT supporting 3000 hours of community service and volunteerism in 2013. In 2015, PACT grew and donated 20,000 pounds of vegetables to food banks across Toronto.

The development of school gardening programs can also be considered a type of critical place-based education (Gruenewald 2003; Smith 2007) with the aim of providing closer links between the outdoor element of green school grounds and the socio-political and environmental learning agendas of citizenship and sustainability education (Dyment and Reid 2005). Successful place-based programs involve students as participants in the life of their communities. These include projects in which (1) learning takes students out of the classroom and into the community and natural environment, (2) students' contributions make a difference to environmental quality and to the well-being of communities, (3) students collaborate with local citizens, organizations, and agencies, and (4) students work alongside community members to help make plans that shape the future of their social, physical, and economic environments.

The term social justice education has been frequently used by theoreticians and educators (Sensoy and DiAngelo 2011). However, there exists no specific definition for social justice education. Tapper (2013) maintains that, "one common, but certainly not ubiquitous, idea is that it explicitly recognizes the disparities in societal opportunities, resources, and long-term outcomes among marginalized groups" (p. 412). According to the Toronto District School Board (TDSB), social justice is "the movement towards a more socially just world through the actions of a group of individuals working together to …. 'give back' or to contribute to the greater good in their community or abroad" (TDSB Social Justice Action Plan 2010, p. 3). In addition to learning and attitudinal outcomes, school gardens can potentially help students understand their role in the community and in the world. Social justice education is teaching and learning in schools that fosters action to support local and global communities, and that is embedded in an understanding of the underlying causes of injustices that communities face. In this context, learners will engage in

Fig. 6.1 Ontario's six global competencies

the issues that will help them to become empowered and contributing twenty-first century global citizens (TDSB Social Justice Action Plan 2010; Willhelm and Schneider 2005). A primary challenge for education today is to transform students' learning processes in and out of school and to engage student interest in gaining twenty-first century skills; skills identified as being crucial for success. These skills are outlined in Ontario's six global competencies and include: critical thinking and problem solving; innovation, creativity, and entrepreneurship; learning to learn/self-awareness and self-directed learning; collaboration; communication; and global citizenship (DeCoito 2014; Twenty-first Century Competencies 2016) (Fig. 6.1).

6.3.2 Experiential Learning

According to Blair (2009), "the style of learning that happens in school gardens, using direct contact with natural phenomena, is considered experiential, inquiry-based learning grounded in concrete experience" (p. 19). Children and adults alike truly learn best by doing. Not only is it important to encourage inquiry, but in today's technological world, it is also important to give children the opportunity to get outdoors and experience nature. Experiential learning is not a new concept; nearly a century ago, John Dewey (1938) advocated a hands-on approach to learning and called for experiential learning that engaged students in their own environments, as he believed that involvement is the key to intellectual development.

Tooth and Renshaw (2009) suggest five experiential elements essential to outdoor and environmental education: (1) being in the environment, (2) real life learning, (3) sensory engagement, (4) learning by doing, and (5) local context. Experiential learning is vital to schooling for sustainability. Only through direct contact with the natural world will students develop an in-depth understanding of fundamental ecological principles. By working with others to solve real-world problems, they also develop skills at the heart of sustainable living. With traditional teaching methods, students must rely on memory and abstract thought to learn science concepts. Hands-on learning allows students to be part of the learning process and not just spectators; they become active participants instead of passive learners (Haury and Rillero 1994). An experiential approach to teaching in a natural setting provides a way for teachers to help children physically, intellectually, emotionally, and spiritually connect with nature and internalize their learning (Chiarotto 2011). The author contends that the school gardens being reported on in this chapter encompass the five experiential elements and are ideal settings for experiential learning.

6.3.3 Stewardship

Gardens are a microcosm of the environment. A school garden can give students a point of reference for understanding the larger ecosystem and provide an excellent springboard for the study of the local environment. By deepening students' sense of connection with nature, school gardening can inspire environmental stewardship (Upitis et al. 2013). A school garden offers many occasions for achieving insight into the long-term human impact on the natural environment. From the water shortage to the over-use of pesticides, students who engage in gardening have first-hand opportunities to observe the importance of conservation and intelligent allocation of resources. Hence, in addition to school gardens supporting academic study, they also have the potential to foster environmental stewardship, creativity, and community building (Krasny and Tidball 2009).

The ways in which environmental stewardship has evolved as an educational construct are varied. Weaver-Hightower (2011) calls on education researchers to consider food issues in their research because of their impact on student learning, environmental sustainability, and public health. Schoolyard gardening is one way for science and environmental educators to address food issues and improve science achievement, environmental attitudes, physical activity, and student food-choice behaviour (Ratcliffe et al. 2009). Researchers have explored teacher attitudes towards school gardening and found that there are positive attitudes toward gardening programs, but a perceived dearth of teacher knowledge, relevant curricula, and training experiences (Graham and Zidenberg-Cherr 2005).

6.3.4 Pedagogical Orientations and Integrated STEM Education

In Ontario, science and technology curricula for grades 1–12 require students to analyze socioscientific issues (SSI) through curriculum expectations in which they "relate science and technology to society and the environment" (STSE Expectations) (Ontario Ministry of Education 2009). Many teachers avoid the integration of socioscientific issues (Forbes & Davis, 2008) into the science classroom because they possess limited content knowledge and skills to deal with complex issues, lack teaching strategies for dealing with these issues, and tend to place more worth in teaching the value-free concepts and skills of science than messy socioscientific concerns (Lee & Witz, 2009). Proponents of STSE education advocate literacy grounded in the context of ethical, individual and social responsibility (Krug, 2014; Kumar & Chubin, 2000). Gray and Bryce (2006) concede that this new focus on complex, value-laden science requires a careful consideration of the professional updating of teachers' knowledge and skills. One way to address the professional updating of teachers' knowledge and skills is supporting them in learning to effectively use curriculum materials. Forbes and Davis (2008) suggest that with support, educators can learn to make effective adaptive decisions regarding existing curriculum materials. One way to support educators' work with curricula is through the development of educative curriculum materials, or those that are designed to promote teacher learning as well as student learning.

Addressing social justice issues and engaging in social justice action projects will make school more relevant and meaningful for students, where the school plays a central role in using the local community (Barton 2003) and environment to strengthen the teaching of concepts taught in the curriculum. For example, one school garden in the study being reported is teaching lessons not only in biodiversity, but also in math, science, geography, English and civics. Thus, pedagogy framed around social justice concerns can become a medium to transform individuals, schools, communities, and the environment, in ways that promote equitable practices (Robinson and Zajicek 2005). These curricular connections are also essential to integrated STEM education as failure to motivate student interest in math and science is prevalent in most K–12 systems, as math and science subjects are disconnected from other subject matter and the real world, and students often fail to see the connections between what they are studying and both their everyday world and career options (Alexander et al. 2012).

Briefly, effective instruction capitalizes on students' early interest and experiences, identifies, and builds on what they know, and provides them with experiences to engage them in the practices of science and sustain their interest. Studies comparing learning outcomes for students taught via project-based learning, such as school gardens, versus traditional instruction show that when implemented well, project-based learning increases long-term retention of content, helps students perform as well as or better than traditional learners in high-stakes tests, improves problem-solving and collaboration skills, and improves students' attitudes towards learning (Strobel and van Barneveld 2009). In addition, project-based learning enhances twenty-first century skills by fostering critical and analytical thinking, enhancing higher-order thinking skills, promoting collaboration, peer communication, problem-solving, and self-directed learning (DeCoito 2019).

Integrating STEM subjects can be engaging for students, can promote problem-solving and critical thinking skills and can help build real-world connections. A conceptual framework for STEM education requires an understanding of the intricacies associated with how people learn, specifically learning STEM content. The emphasis on social learning as the locus for creating a more sustainable and desirable world is especially meaningful. Integrated STEM education sees to locate connections or intersections between science, technology, engineering and mathematics and provide a context for learning the content. For example, e-STEM is considered transformative as it encompasses environmental topics at the forefront, notably dissimilar to the STSE framework mentioned previously. Moreover, STEM is situated within the environmental context and the integration of the disciplines is seen through the lens of the environment (DeCoito 2015).

Recently, PACT started a new initiative developing curriculum linked workshops and nature-based education opportunities for educators and students. For example, *Food Deserts: Mapping the Food in Your Hood,* is a geography based workshop that focuses on curricular expectations related to sustainability of human systems; the growth of urban settlements and impact on the economy, the natural environment, society, and politics; and characteristics of land use. These topics are good examples of integrated STEM education as students will learn about the phenomena in urban spaces known as "Food Deserts", where some neighbourhoods have better food access than others, usually divided by wealth and racial brackets throughout major urban cities. A senior level workshop, *Career Opportunities in Urban and Organic Gardening/Sustainable Food Sector,* provide opportunities for students to learn about the new emerging market of urban gardening and sustainable food education that is becoming popular in urban centres and beyond, and why it may be such a critical movement. *Vermicomposting! – Indoor Worm Composting Systems and the Red Wriggler* is a workshop that integrates curricular materials across grades 9–12, and beyond. Some fundamental concepts covered in this workshop include systems and interactions, and sustainability and stewardship with the goal of relating science, technology, society and the environment. In addition, scientific solutions to contemporary environmental challenges, human impact on the environment, human health and the environment, sustainable agriculture and forestry, reducing and managing waste, and energy conservation are topics that necessitate an integrated STEM education approach and have the potential to develop students' twenty-first century learning skills.

6.4 The Study: School Gardens in the Grow to Learn Urban Agriculture Initiative

6.4.1 Rationale and Research Questions

The fact that the PACT "Grow to Learn" Schoolyard Gardening Program and Food Initiative has partnered with schools over the past 10 years, research on the impact of this program on teaching and learning was warranted. Thus, the author conducted a project which focused on two school gardens established through the PACT GTL program and reports on findings related to the following research questions:

1. What effect, if any, do school gardens have on the development of communities of learners?
2. To what extent do school gardens promote the development of twenty-first century skills, such as critical thinking, communication, collaboration, creativity, flexibility, adaptability, initiative, and self-direction?
3. What can school gardens teach students, teachers, and community members about environmental awareness and environmental stewardship?

6.4.2 Methodology

Realistically, integrating a school garden into a school's curriculum requires time, funding, physical resources, and effort. It also requires student and staff support, especially from school administrators (Grant and Littlejohn 2001). The goal(s) of the research project was to investigate the potential of school gardens from three vantage points: (1) broader impacts on students, teachers, and the community; (2) program structure and educational outcomes, and (3) program assessment in terms of community connections and program sustainability.

A mixed-methods design (Tashakkori and Teddlie 2003) was utilized over 2 years. The study utilized a variety of data sources (data triangulation), as well as quantitative and qualitative methods (methodological triangulation).

Participants The participants of the larger study involved 122 students – 95 elementary students (53 males; 42 females) in grades 4, 5, 6, and 7 and their teachers (4 females; 1 male), three volunteers, and a principal (female) in an urban junior middle school; and 27 high school students (10 males; 17 females) in grades 11 and 12 and their teachers (6 females; 2 males), and a principal (male) in an urban high school in South-Western Ontario. The schools have a high population of students from immigrant families, thus catering to students of diverse ethnic and socioeconomic backgrounds.

Data Collection The primary sources of data for this portion of the study were (1) survey (adapted from DeMarco 1997), (2) school garden observations, and (3) interviews. Teacher surveys explored teachers': (a) views, interest, and knowledge about school gardens, (b) pedagogical orientations inherent in school garden-based learning, and (c) knowledge and understanding of school gardens. Student surveys explored students': (a) attitude towards and interest in school gardens, (b) preferred learning styles, and (c) knowledge of school gardens. Teacher and student interviews were audiotaped and conducted once during the study and further explored survey items related to: ((a) implementing school gardens, (b) cross-disciplinary approaches to teaching and learning with school gardens, and (c) general attitude towards and interest in school gardens as a vehicle for fostering environmental stewardship, creativity, and community building. Finally, volunteer/parent interviews explored their motivation for participating in school garden programs, experiences with school garden programs, perceived learning opportunities offered by school garden programs, and a general understanding of school gardens.

Data Analysis Quantitative data were analyzed using statistical analysis (Microsoft Excel) and descriptive statistics. Qualitative data obtained from teacher and student surveys, teacher, student, and volunteer interviews, teacher resources pertaining to school gardens, and observation/field notes were analyzed through an interpretational analysis framework involving thematic coding and a constant comparative method (Stake 2000). By comparing and contrasting the data collected across the set of participants, the researcher sought common (and uncommon) patterns and themes pertaining to school gardens': (1) broader impacts on students, teachers, and the community, (2) program structure and educational outcomes, and (3) program assessment in terms of community connections and program sustainability.

6.5 Findings

6.5.1 Fostering Environmental Literacy and Awareness

Survey data indicate that participants held similar views related to the importance of environmental education, with 99% of junior middle school students agreeing that education about the environment should be part of every grade. Ninety-seven percent of the participants agreed that everyone should have some knowledge of the environment. Most students exuded confidence when asked if they felt that they knew anything about the environment. For example, one student mentioned:

> I feel I know some, but not the top student because. I do a lot of the eco stuff, so a couple of us are doing this play about how we can do more eco environment in our school, and it's like this eco game show. So, kind of like an interview.

Overall, 15% of the participants felt that they did not have some knowledge of environmental problems. One grade 5 student felt that we should be aware of environmental problems because "the gas, the cars and stuff, they affect the environment and people who cut down trees in the forest, they also damage the environment … if we are not aware, then we will not know what to do."

One grade 4 student articulated his views as to why we should learn about the environment:

> Everybody should know about the environment. Everyone should keep it clean, because if we don't, soon, if people just leave garbage all over the place, it's going to keep building, building, and building and then what's going to happen, you're going to see garbage all over the planet, if it is built up that high with garbage.

Despite the fact that 25% of the students had never visited a farm, and 40% did not have a garden at home (most of the students lived in apartments), some students did take advantage of opportunities to interact with the environment and enhance their environmental literacy. According to a grade 5 student:

> I don't have a garden at home, but my great uncle does. Normally I would work for him. I would help him garden and everything that he has, I would plant everything. I would help him use a hoe. If something died, I would use a sickle and I would put it in the green bin, which is also being environment friendly. Reduce, reuse, and recycle. And that's what I normally do.

The school's views of recycling are reinforced across responses during student interviews, and it is evident that students adopted this practice beyond the school and classroom, and into their homes. Ninety-six percent of the participants felt that they had some understanding of school gardens and that they learned about the environment through the school garden program at their school. When asked what school gardens meant to them, students' responses were positive and optimistic, as illustrated in a grade 6 student response:

> What it means to me, I guess, is helping the environment the best you can. Don't take it for granted, and by having the school garden they show us that the environment is a very delicate system.

Students reported that the school garden program encouraged them to be more interested in learning about the environment in and outside of school.

> That garden really makes me smile when I look at it and how beautiful it is and I look at it and say to myself, 'if we do not act now, we will not have any more beautiful plants, no more beautiful anything. It will all just disappear, and we'll be left with nothing.' So that helps me embrace my feelings about the earth.

6.5.2 Focusing on Social Justice and Community Building

Findings indicated that the urban garden initiative started with a school garden and moved outward into the community. Students were empowered, as well as the school's extended community through good nutrition, the experience of successfully growing food, and the relationships formed in the process. This was evident from K-12, as illustrated in the following quotes from students, administrators, urban initiative leaders, and teachers:

> We talk about poverty in kindergarten. That the things we grow in our garden … we're lucky that we can participate in using it in our lunch program, and we talk about there are places in the world where there isn't food …. That we can get those beans out of the garden that we're going to plant and get lettuce out of the garden and use that for lunches and not everyone has that. And there are people all over the world and in our own community that lack good nutrition because they can't afford to buy a head of lettuce for $1.39. (Teacher)

> The first year we put some of the harvested produce into the fridge like tomatoes to be used later on for the hot lunch program, and then in the fall, we had a Harvest Fest. We also did one activity called a seed ball, which is an Aboriginal cultural practice where they would roll the seeds in mixture which has some clay in it and then later on throw the seeds into the wild area to promote germination and spreading of the seeds. (Principal)

The school garden program addressed the issue of hunger and poverty within and beyond the school walls and into the wider community. The relationships developed within the school and the wider community as a result of the interaction with the school gardens are illustrated in the following quotes:

> Some of the food we harvest in autumn, we would go to the front foyer of the school and we would hand them out …. For me that really builds your community for you to come together and share what you have with one another ….Then there is the food bank, not that far from the garden … they would always welcome us. We provide food and such for their community and they really enjoy that we bring produce and the person that cooks the food there, she is so welcoming to us. They're like "oh my gosh, good job guys. Thank you so much." And for me, that was really nice. (Grade 11 student)

> I think our community is very much aware of hunger and poverty within the community, within our city. We do get involved in different food drives and so on throughout the year, but I think the fact that a lot, or a majority of the vegetables grown do get donated to the [food bank]. I think that does sort of bring another element of awareness that yeah, poverty, unfortunately, does exist, hunger is rampant. Some of our students probably are very much aware personally as well, but I do think it does bring an awareness of the overall community, because this is where the majority of the produce goes to. But, as I say, it just adds a bit more awareness to realize that we all have a stake in it and we are all in it together, type of thing. (Principal)

The impact of the school gardens on the school and wider community are clearly illustrated below:

> Last year we were donating most of our food to [food bank]. This year, most, if not all was given directly to the students at [school]. So, I personally, feel that is the best model for the school that I'm at….It's considered a high priority neighborhood. It's kind of in a food desert. There aren't many grocery stores nearby. I wanted to see it really go to the community and actually be used, so this year throughout the summer, I was giving it to the parents at the day care centre, and most of those parents are either students of the collegiate or of the adult education centre….So, by giving it to those parents, I felt that it was going directly to the community. I feel like that is social justice oriented, for sure. (Grade 11 student)

According to one of the grade 12 student volunteers in the after-school garden program:

> We have a local organic stand and food bank users get to see the fruits of our labours … they get to interact with food that they don't always interact with, because we grow heirloom varieties. We grow all different kinds of foods that they might not have access to, and the

> food bank is so grateful because they often do not get fresh produce … now with local organic food produce that was picked maybe an hour ago, and that's a really special relationship that doesn't exist everywhere. So, it's really exciting.

The school gardens also fostered and facilitated collaborative relationships between seniors, schools, and youth:

> Seniors from the [food bank] that work at their on-site garden have now come to our garden, sort of working to help with the garden, as well, to help instruct use, and they are really excited to have another space where they can have access to local organic produce, because that's a benefit for them. If they're on fixed income, they often cannot afford organic produce, and so coming in and working an extra day of the week gets them more organic produce and also gives them some activity and some ways to reach out and interact with youth in a meaningful way … and for those seniors, they really appreciate that. (Urban Garden Leader)

There was unanimous agreement amongst the students related to their enjoyment of the school garden program at their school. Students overwhelmingly agreed (98%) about the role of school gardens in terms of: (a) providing opportunities to engage in hands-on activities, (b) understanding the world around them, (c) learning about the environment, (d) learning about health lifestyles and food choices, (e) caring for the earth and the environment, (f) learning about hunger and poverty, (g) promoting team-work, (h) learning about school subjects (math, science, technology, geography, art, etc.), and (i) bringing the community together. When students were asked about whether their participation in the school garden program allowed them to connect with the community around their school, a grade 5 student commented:

> Yes, because a lot of the neighbors will come over and help us. Like one guy was working on his car. He saw that we were building the garden, he stopped and dropped everything and came and helped us, and that made me feel that if we keep this attitude up, we *will* change this world.

The junior middle school hosts a Harvest Festival each year and an appreciation tea for volunteers in the community. Through collaboration with community members, administration felt that it promoted good character building in students in terms of teamwork, developing respect for each other and for the environment.

6.5.3 School Gardens and Integrated STEM Education

Teachers used several avenues for incorporating school gardening into the curriculum, including math, writing, history, science, physical education, art, and geography, as captured in interviews. According to the science teacher who heads the school garden program at the secondary school:

> There are a lot of curriculum connections. The art teacher took her class out to do sketches. I taught a lesson on biodiversity. The science class was involved in the planting. The woodshop may build us beds, composters, trellises in the future. It is a learning tool in the school.

Interview data points to the fact that the junior middle school teachers in this study had been using the school garden for teaching a multiplicity of content areas, as illustrated below:

> Definitely all the measurement activities can be based on the garden. Writing about it, procedural writing is great when you are actually teaching somebody how to do a certain thing like the distance between plants …

> I bring, for example, geographical things. What can grow here? And what can grow in soil that is rich? What can grow in sandy soil? Certainly, you can do that at an older grade, and certainly you can do that at a younger grade.

> The math is there and the fractions … the cooking, and the science, art … the design of the school garden and drainage is there, and the history can even be there. Talking about the pioneers coming over, planting their own food. It is all there. We can work on all of it. So, I think it's a really great learning opportunity for our kids.

There was agreement in teachers' survey responses and interview data that the school garden program helped students: (a) learn about the environment and environmental stewardship, (b) experience hands-on activities, (c) understand the world around them, including poverty and outreach (e.g., food banks), (d) learn about healthy lifestyles and food choices, and (e) learn about team work, community, decision-making, and cooperation. In addition, teachers conveyed that the school garden program impacted the affective domain (i.e., students' attitudes, motivation, and willingness to participate).

6.6 Discussion and Implications

School gardens can be seen as catalysts for action among young citizen learners in the areas of social and environmental justice and the progression described is a relational one, beginning with individuals and rippling outward into the human community and then to society (Dyment and Reid 2005). The findings reported in this chapter focused on social justice through raising environmental and community awareness, increasing youth empowerment in at-risk neighbourhoods, and addressing the social effects of urban poverty (Morris and Zidenberg-Cherr 2002; Reynolds 2017). Furthermore, the school gardens encouraged environmental education and youth civic engagement, while providing a local food system which supports planting, growing, eating, and composting as part of holistic programming (Gonsalves et al. 2020).

The urban garden initiative started with a school garden and moved outward into the community. Students were empowered, as well as the school's extended community through good nutrition (Dawe et al. 2020), the experience of successfully growing food, and the relationships formed in the process. The school garden program addressed the issue of hunger and poverty within and beyond the school walls and into the wider community (Fisher et al. 2019). The relationships developed within the school and the wider community were as a result of the interaction with the school gardens. Hence, the schoolyard gardens promoted *community* and *local responsibility* by "equipping students with a clear sense of civic responsibility, as well as opportunities to shape their communities' social development, thus encouraging life-long citizenship, character development and other relevant skills" (TDSB Social Justice Action Plan 2010, p. 5). The school gardens acted as both a living classroom for the teachers to integrate science, technology, mathematics, geography, and art education for students, and as after-school programming where students learned through experience (Klemmer et al. 2005; Williams et al. 2018), and completed required community service hours.

School gardens provided students a point of reference for understanding the larger ecosystem and provided an excellent springboard for the study of the local environment. By deepening student's sense of connection with nature, school gardening can inspire environmental stewardship (Cairns 2017; Cutter-Mackenzie 2009). As witnessed in the study, the school garden offered students many occasions for achieving insight into the long-term human impact on the natural environment. Students who engage in gardening have first-hand opportunities to observe the importance of conservation and allocation of resources. As reported by the participants, in addition to school gardens supporting cross-disciplinary integration, such as STEM, they have the potential to foster twenty-first century skills including critical thinking, communication, collaboration, creativity, flexibility, adaptability, initiative, and self-direction, as well as environmental stewardship and community building (NRC 2011; Waliczek et al. 2000).

Finally, the findings illustrate the impact of critical place-based education (Gruenewald 2003; Smith 2007), such as urban garden initiatives and clearly demonstrate the potential of gardens to promote social justice education, foster environmental literacy, awareness and stewardship (Upitis et al. 2013), and establish community relationships (Krasny and Tidball 2009). The intention is to engage educators to extend beyond the task of meeting expectations, to not only promoting scientific or ecological literacy, but also the development of reciprocal relationships of care and ecological identity that are established through gardening. The knowledge, skills, and attitudes that students gained through their experiences in social justice projects serve to deepen their understanding of their place in their community and in the world and how they, as individuals and as groups, can bring about positive change (Sealy 2001). Establishing community connections beyond the classroom and schoolyard through school gardening is one pathway toward engaged, scientifically literate citizenry.

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Chapter 7
Developing Environmental Action Competence in an Urban High School Agriculture and Environmental Program

Anne K. Stephens and Heidi L. Ballard

Abstract A key way that STEM (Science, Technology, Engineering and Mathematics) disciplines and agricultural education can be integrated into school-based curriculum and structures, particularly within urban contexts, is via an environmental education (EE) approach. We provide a case example in California of how science and environmental education can be merged in a holistic urban high school program focused on understanding food systems. Specifically, we discuss and apply the concept of environmental action competence (EAC) as a theoretical means of bringing together traditional science education (focused on ecological literacy) with the interdisciplinary and action-oriented focus of environmental education (civics literacy, values awareness and self-efficacy to take action). Using ethnographic methods, we followed 120 students in an urban, comprehensive high school, along with their teachers and community partners during the 2011–2012 and 2012–2013 school years. Interviews with 26 youth and adult participants, were transcribed and coded, then analyzed along with field notes, participant observations, and secondary source data to determine how program elements contributed to the development of students' EAC. While many students exhibited some of the elements of EAC, only the students who had been in the academy for 3 years were able to base their actions toward the environment in sound ecological reasoning. While program elements supported students' self-efficacy, students' ecological understanding was not as well developed. We discuss implications for practitioners, suggesting how EAC can provide a framework to combine the leadership and experiential elements of traditional agricultural and environmental education to support students' development of STEM competencies.

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7.1 Introduction

We provide a case example in the United States of how science and environmental education (EE) can be merged in the context of a holistic urban high school program focused on understanding food systems. Sustainability and agro-ecosystems have been key topics in EE for decades, such that environmental education research, particularly with respect to linking learning with action in urban settings, can offer a unique lens through which we can examine impacts of urban agriculture STEM education practices. Specifically, we discuss and apply the concept of environmental action competence (EAC) as a theoretical means of bringing together traditional science education (focused on ecological literacy) with the interdisciplinary and action-oriented focus of environmental education (civics literacy, values awareness and self-efficacy to take action). In order to study how one urban school's agriculture and environmental education program may impact the students' EAC, we examined the school organizational structure, the interactions between students, teachers, mentors, non-formal providers and the physical settings in which these interactions occurred. Drawing on these data, we suggest ways programs can best create learning situations where students can gain experiences, develop self-efficacy, and exercise their knowledge and skills toward the environment and sustainable food systems.

7.1.1 Environmental Action Competence

An environmental education framing of urban agriculture and STEM learning allows us to examine the particular role and importance of youth learning how to "take action" on behalf of the environment and their communities with respect to the food system. The focus of EE has shifted from changing the environmental knowledge, attitudes and behaviors of the individual, toward one of developing an environmental citizenry with an emphasis on taking action. Yet as the U.S. becomes increasingly diverse and urbanized, we must consider the potential socio-cultural factors facing many of our students from underserved communities that might result in roadblocks to taking action on an issue that concerns them (Schutz 2006; Uzzell 1999). Environmental education research has demonstrated that a strong sense of community and a strong positive ethos can help to make the connection between conditions for learning and positive student outcomes (Roth and Lee 2004; Grant

1988). Schools that operate within communities of practice are culturally responsive. They build on the knowledge of the local community, incorporating local knowledge, involving families and community members in activities (Schutz 2006). Flowers and Chodkiewicz (2009) argued that partnerships between communities and schools have the potential to offer more authentic and transformative learning experiences for students, but that these links are frequently under-utilized. Urban agriculture and school-based environmental programs are promising approaches to making such linkages.

Many such programs are developing environmental literacy through school gardens and urban agriculture programs (Krasny and Tidball 2015). However, Berkowitz et al. (2005) observed that being environmentally literate does not necessarily mean that one will act in a literate manner, and suggested another term, "environmental citizenship." They define this as "having the motivation, self-confidence, and awareness of one's values, and the practical wisdom and ability to put one's civics and ecological literacy into actions" (p. 228). While there are multiple definitions for environmental literacy, researchers have generally agreed on the fact that being environmentally literate involves more than just having content knowledge.

Rather than focus solely on science literacy and environmental literacy of youth, we expand these goals to include the notion of action competence, coined by Jensen and Schnack (1997) as the term for environmental citizenship in youth. Action competence considers the role of youth as active participants in influencing the future of the planet and the well-being of people through the development of a civil, sustainable society. Action competence is based on the premise that all people have a right to a good and healthy life, and the belief that education should help develop confident, critical and responsible citizens by focusing on the experiences of youth that occur in the broader context of their interactions with family, other significant adults and mentors and their peers in their everyday lives (Benson and Saito 2000; Schusler and Krasny 2010). In culturally responsive school programs, students should be working directly with members of their own community and have a voice in decision making at a level that is accessible to them (Berkowitz et al. 2005; Darner 2009). While the term "action competence" is well known in in parts of Europe and the Pacific (Breiting and Mogensen 1999; Eames et al. 2006), it is not regularly used in the context of environmental education in the United States. We suggest that a framework combining the notion of action competence with Berkowitz et al. (2005)'s four components of environmental literacy, termed environmental action competence, provides a means of examining the most salient impacts of an urban agriculture and environmental education program on youth. Environmental action competence therefore consists of five inter-related elements:

Ecological literacy includes the wide range of interactions between humans and the natural world, including agriculture and those built environments where most people now live. Using the concept of "ecological address," (Berkowitz et al. 2005) students are encouraged to consider their physical, biological, and social systems in their immediate environment. Ecological literacy also includes the scientific reasoning skills that allow students to work toward environmental action. These skills are explicitly outlined in the Science and Engineering Practices of the Next Generation

Science Standards (NGSS) and will be discussed in more detail throughout the chapter.

- *Civics literacy* is developed when students can identify local environmental issues and identify the participants involved in environmental decision-making. This particularly includes interpersonal and communication skills, and the "21st Century Skills" (Trilling and Fadel 2009) that enable people to engage in and take leadership roles in the social, economic, political and cultural facets of environmental problem-solving, including:
- Participating effectively in civic life through knowing how to stay informed and understanding governmental processes
- Exercising the rights and obligations of citizenship at local, state, national and global levels
- Understanding the local and global implications of civic decisions

Values Awareness as a component of EAC recognizes that youth come from a variety of cultural backgrounds, such that it is crucial for students to identify their personal values with respect to the environment and help them to connect these values with their knowledge and motivation to action. With 81 percent of the population in the United States living in urbanized areas (U.S. Census 2010), it is unreasonable for educators to expect all youth to value natural, wild spaces to which they may not have access, especially those who are poor and living in urban areas. Urban agriculture and environment programs can provide an important access point for students to explore their values toward natural resources.

Self-efficacy is about youth having the capacity to learn and act with respect to these personal values and interests in the environment, and *action* is using that capacity toward a desired outcome. A person exhibits self-efficacy, or the perception that he or she can achieve the desired goals through his or her own actions (Schutz 2006). The locus of control resides in the student, not with his parents or a teacher, and he is able to understand his own motivation to act (Kollmuss and Agyeman 2002).

Taking Action. Youth have few avenues to take action in their lives on behalf of the environment; they can't vote, they can't make major purchases. But they can engage in civic actions like letter writing and participating in public hearings, doing stewardship activities like planting gardens, restoring habitat, and improve their own neighborhoods through recycling, trash removal, and advocating for more sustainable practices in their schools and communities. Jensen and Schnack (1997) noted that, "experiences and actions are thus very closely linked. Without action competence, one cannot become rich in experiences, which in turn can help to qualify action competence" (p. 167).

Finally, all of these constructs work together to develop *environmental action competence (EAC)*, where students demonstrate the confidence and initiative and move toward action to participate in the creation of a sustainable society. A growing number of researchers have investigated action competence with respect to environmental literacy (Breiting and Mogensen 1999; Jensen and Schnack 1997; Schusler and Krasny 2010; Uzzell 1999), and so we use the term "environmental action competence" to refer to the quality of being ecologically and civically literate, as well as possessing skills and values that lead to the motivation and confidence to take action to solve issues in one's environment. A student who has EAC understands how their concern about an issue or situation is connected to their actions, and can draw on conceptual knowledge and skills to inform their decisions to act. Students might understand the ecological issues but not feel they have the skills and self-efficacy to address them. Conversely, they may be very motivated to take action, but might lack the ecological understanding required to carry out the action or convince others of the importance of doing so. As in Berkowitz et al.'s (2005) model, this model provides multiple points of entry that are accessible to a diversity of learners, but also considers the important construct of student self-efficacy. As students develop EAC, they are able to engage in more experiences that support additional growth in the individual components.

An EAC framework requires an integrated approach to learning that can be achieved through STEM programs. STEM is sometimes a loosely used term; in some cases, it refers only to the four distinct subject areas, Science, Technology, Engineering and Mathematics. However, in the context of this research, we refer to the holistic definition of STEM that includes supporting students in their development of the skills and abilities to apply their knowledge to their health choices, environmental concerns, and use of natural resources (Bybee 2013). The three dimensional approach of the Next Generation Science Standards (NGSS), including the "Disciplinary Core Ideas," the "Science and Engineering Reasoning Practices," and "Cross Cutting Concepts" provides guidance for teachers to help students' build skills and knowledge, which, if facilitated, could lead them to take action on complex multi-faceted issues (National Research Council 2012) such as the food system or climate change.

The place-based, hands-on nature of agriculture and environmental programs has the potential to create interdisciplinary, in- and out-of-school spaces where by the student takes a more active role in their own learning, and in doing so develops the conceptual understanding, skills and self-efficacy to take action regarding their environmental concerns. Creating these conditions in a traditional high school setting is difficult due to scheduling conflicts, testing calendars, and lack of teacher planning and collaboration time. One potential solution is the California Partnership Academy (CPA) Model that takes a smaller learning community approach around a Career Technical Education theme. To receive CPA funding, programs must demonstrate to the state that they are addressing these impediments by supporting collaborative planning time, integrated curriculum, and community partnerships. We conjectured that environmentally-focused CPAs would be able to create the physical and social spaces for students to practice their skills and gain confidence in taking action, both critical elements for achieving EAC. For this reason, we chose the CPA model as a place to examine how students develop EAC.

7.1.2 The California Partnership Academy Model

In 1984, the California State Legislature passed Assembly Bill 3104 that launched the California Partnership Academies (CPAs). Based upon a policy of promoting multiple pathways to postsecondary education and career, these academies are organized around major industry sectors (including agriculture and natural resources) and combine career and technical courses with academics to provide high school students with work-based learning opportunities (Hoachlander and Dayton 2007). In 2013, there were 477 CPAs in California, with 18 of them focusing on the environment. These programs combine the following high school reform measures: grouping 10th -12th grade students into common classes; placing teachers in cross-curricular teams (both academic and career-technical); all classes broadly address the career theme while still completing state college entrance requirements; connections between in school and off-campus activities; and employer and community support through advisory groups, guest speakers, field trips, job shadowing and internships (California Academy Support Network 2010). The California State Plan for Career Technical Education (2008) guides the implementation of the California Partnership Academies. Under this plan, the common focus is to provide rigorous and engaging curricula, experiential learning, supportive relationships, and demonstrated outcomes. At least 50% of the student in each incoming class of CPA sophomores must meet at risk criteria, such as poor attendance record, economically disadvantaged, and low state test scores.

Importantly, despite the fact that CPAs serve a greater percentage of at-risk youth, the performance of these programs is very promising across several metrics. Three major reports funded by the College and Career Academy Support Network (CCASN) found that CPA students are outperforming their peers based upon test and attendance indicators, and represent a larger percentage of at-risk students (Conchas and Clark 2002; Hoachlander and Dayton 2007). These reports revealed that CPAs show promising results in increasing student engagement and performance in the following areas: increased student attendance, more credits attempted and completed, higher pass rates on the California High School Exit Exam (CAHSEE), and greater completion of A-G requirements for university entrance. Despite these reported successes, little research has been conducted on how the academies are achieving these results. Specifically, no research has been carried out on the effectiveness of the environmentally-themed CPAs to determine their effectiveness in developing EAC. We begin to address this gap with a case study of an environmentally-themed CPA with a focus on the food system, the Tate Environmental Organization (TEO)[1] in Northern California, USA.

[1] All names have been anonymized to protect confidentiality

7.2 Research Objectives and Questions

We conducted a case study of the TEO Academy to identify evidence of whether or not students were developing EAC as a result of the agriculture and environmental program elements over a two-year period. The study was designed to answer the research questions:

- What is the relationship between program elements and the development (or lack of development) of EAC in students?
- What is the evidence that students are (or are not) developing EAC?

7.3 Methods

7.3.1 Study Context: Tate Environmental Organization (TEO)

This case study took place at the Tate Environmental Organization (TEO) Academy in Northern California, USA. TEO was one of four in the Agriculture and Natural Resources Sector that focused specifically on sustainable agriculture and the environment during the years of this research. The program was also representative of schools that are consciously trying to build bridges between school and community, a factor that Uzzell (1999) cited as significant in developing action competence in youth. This particular academy was selected because of the collaborative research relationship between the teachers and university researchers formed during an earlier grant-funded project on linking local high schools to the University.

Tate is an urban comprehensive high school that serves a high percentage of immigrant students of very low socio-economic status. The demographic breakdown of the academy reflects that of the school, with 35% Latino, 27% Asian (Hmong), 25% African American, 7% White, 4% Hawaiian or Pacific Islander, and 2% other or declined to state. Students identifying as white are largely Ukrainian and Russian immigrants (Ed-Data 2011).

TEO has many non-formal partners in the community that contribute to the program. TEO students take several field trips each quarter to field sites where they do activities with these partners. The most frequently visited site includes the Almond Valley Sustainable Farm, the headquarters and parent organization of three agriculture and environmental field programs, including a leadership program where students visit agricultural sites in the region to learn sustainable agricultural practices; a watershed stewardship program where students experience restoring habitat on local working farms and ranches, and finally, a summer work program that employs students to work on agricultural an environmental projects.

TEO Academy, as with the other CPAs in the agriculture and natural resources industry sector, is structured to link academic course work to authentic experiences that increase in complexity over the 3 years of the program. In addition to the core

Table 7.1 TEO academy course progression

Grade Level	Course Description
10th grade environmental horticulture	This course focuses on the propagation and use of plants for human and environmental benefit. Students learn about plant structure and physiology, propagation, pruning, garden design, soils, integrated pest management and native plant restoration. Students work in the campus garden, learn to cook healthy meals in the school kitchen, participate in a year-long restoration project with mentors from the Almond Valley sustainable farm, and an environmental service learning project through the Grant advisory Board for Youth (GABY).
11th grade environmental design	This course focuses on environmental design, city planning and restoration. Students learn the elements of design, landscape architecture, plant identification and uses, technical drafting, sketching and color theory, and computer aided design techniques. Students also learn about the historical and cultural traditions of architecture. Student from the UC Davis landscape architecture program provide mentorship and support. The goals of the AP environmental science course are to (1) provide students with the scientific principles, concepts and methodologies required to understand the interrelationships in the natural world, (2) to identify and analyze environmental problems or challenges (both natural and human-made), (3) to evaluate the relative risks associated with these problems, and (4) to examine alternative solutions for resolving and/or preventing them. (https://apstudent.collegeboard.org/apcourse/ap-environmental-science)
12th grade student salsa business	This course provides students with the experience of running a green business, including purchasing organic produce (the business has outgrown the capacity of the campus garden), production, bottling, distribution, marketing, and accounting. Students work with a community advisory board whose members provide mentorship and feedback on the performance of the business.

(TEO Academy Website)

high school curriculum, students take one CTE course in the agriculture and natural resources each year. The coursework from 10th to 12th grades includes the four core STEM disciplines as well as applied environmental and agricultural contexts (Table 7.1).

These courses provided the context in which we observed and interviewed students and educators to determine the ways in which students demonstrated aspects of EAC during and after participation in TEO programs.

7.3.2 Data Collection

We employed an ethnographic approach for this case study (Yin 2009), beginning with examining secondary source data from California's Ed-Data and DataQuest databases and the California Department of Education's High School Initiatives Office, and continuing with participant observations in classroom and field settings over the course of 2 years from 2011–2013, with interviews with students (n = 20), teachers (n = 3), alumni (n = 3) and non-formal partners (n = 3) at the end of the school year 2013.

We were active participants during the 2 years of the study, aiding in classrooms, helping on field trips and competitions, and engaging in informal conversations with students on average for 2–3 h each week. At the school site, observations were made in both classroom settings and in communal spaces on campus, such as the school garden or kitchen. Observations were also made at the field sites visited by students in the program, including their Salsa Business demonstrations, field trips to a University student farm, and other venues. These regular visits allowed us to get to know the students both in and out of the classroom, and engage in casual collective discussions in addition to the formal interviews. Field notes were taken during each visit, followed by memos that explored developing themes. During the 2 years of the study, we observed students as they worked on various grade-level projects ("Program Activities") as part of the Academy curriculum focused on longer-term project engagement. In each of these settings, we looked for evidence (as well as counterevidence) of students demonstrating EAC, or the components of EAC. Evidence for EAC included demonstrating ecological and civics literacy through presentations, taking leadership roles with other students, negotiating with adults during projects, and practicing new skills.

Interview questions were developed based upon earlier ethnographic field research looking for evidence of EAC in students, as well as from a review of the literature on environmental behavior and action competence (Arnold et al. 2009; Chawla 1999; Hungerford and Volk 1990; Schusler et al. 2008; Schutz 2006; Stern et al. 2008).

We selected a representative sample of students from each grade level, taking into consideration level of achievement, gender, ethnicity, English Language proficiency, and socio-economic status. Students were interviewed in groups of 2 or 3 at the school site for 30 min on average to determine their perceptions of their participation in field and mentoring activities and how these activities influenced their college attendance and career interest in agriculture and environmental science. Interviews were audio-recorded and transcribed. Students were interviewed in small groups to elicit more rich and detailed insight into the social aspects of their experience (Frey and Fontana 1991), as well as to create a more comfortable environment. Each student was given the opportunity to respond to each question. Questions focused on students' experiences in various agricultural and environmental activities in the academy and how they felt after participating; their concerns about environmental issues in their neighborhoods, and whether they were making connections between the various program elements. Three alumni of the program were also interviewed to determine what aspects of TEO had the longest and deepest impact upon them as adults, especially in their environmental behavior. While this was not a representative sample, their responses contributed to the overall understanding of student experience in the program.

To understand the experience of community partners, we conducted 30–40 min semi-structured interviews with 2 staff members of the Almond Valley Sustainable Farm who had been involved with the cohort of students each year. Interview questions focused on how these non-formal partners perceived of their role with students and how they felt they supported student development.

7.3.3 Data Analysis

The interviews, field notes and memos were transcribed, coded, and analyzed using NVivo qualitative data analysis software. The codes were based upon the constructs of EAC explained above developed from previous research on action competence and environmental education (Schusler and Krasny 2010; Jensen and Schnack 1997). We also coded for when respondents described key experiences during their program participation, and created a list of important program elements. During the 2 years of the study, we observed students as they worked on various grade-level projects as part of the Academy curriculum, and the students made many references to these projects during their interviews. We then examined the relationship between program elements and the components of EAC by running NVivo queries to examine where program elements and specific activities were associated with evidence of EAC in students (Fig. 7.1).

Through queries for themes across data sets, we were able to triangulate between coded field notes from observations, interview transcripts (from students, alumni, teachers, and partners) and secondary source data taken during the two years of the study. For example, for each component of EAC, we analyzed student interviews from TEO Academy for evidence that they had developed the component of EAC

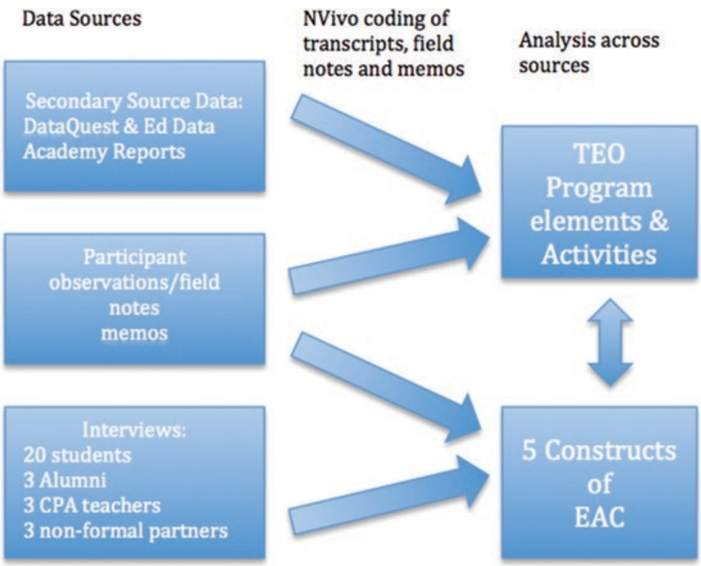

Fig. 7.1 Data analysis

Table 7.2 Components of environmental action competence with examples from interviews

5 Constructs of Environmental Action Competence	Description	Exemplar from student interviews:
Ecological literacy (including requisite skills)	Student explains the ecological concepts behind an issue and exhibits a skill related to ecological principles (restoration work, monitoring)	"*We are using permeable concrete and bio-swales (in the Promenade design) that helps clean the water that flows off of the bus yard" – Tarika (12th grade)*
Civics literacy (including requisite skills)	Student displays an understanding of the environmental decision-making process and the related soft skills for expressing his/herself, including communication, presentation, leadership and people skills	*"I think TEO provided better presentation and communication skills- cuz we got to do lots of demos and presentations…you get to stand in front of people and talk about your product"-Vang (alumni)*
Values awareness	Environmental awareness. Student identifies with an issue concerning natural or built systems Community/social awareness: Student identifies with an issue concerning society or social issues other than natural systems	*"There's a lot of emptiness where I live…there's no close park around here…" -Angelo (10th grade)*
Self-efficacy	The student's belief in his/her capabilities to address an issue or achieve a goal.	*"I think that TEO showed me that I could make a difference…in my life, in my family's life, and my friends' lives"- Jackie (alumni/college sophomore)*
Taking action	The student can identify actions that were taken to address an environmental concern	*"Our goal is to benefit the community and teach them more about how to live a better and more healthier life than what they've been doing" Maria (tenth grade)*

through specific activities or program elements, and the counter-evidence of this as well (Table 7.2).

We first report our findings for the main activities youth engaged in during the TEO programs (Table 7.3), then report evidence, or lack thereof, of each individual component of EAC. We then provide examples of where students did (and did not) exhibit EAC from the holistic definition described in the introduction.

Within each of the established program elements, we observed youth engaging in a variety of related activities that they then subsequently referred to throughout their interviews. By triangulating the field notes and field memos taken during these activities, with student interviews, we identified the activities that influenced their perspectives, reflections on their experiences, and development of EAC.

Table 7.3 TEO academy program activities

Grade level	Program activities	Description
Sophomore year	Grant advisory Board for Youth (GABY) project	TEO students applied for $500 "GABY Grants" to implement community action projects related to what they learn in the TEO program. Students had to develop an application and make an oral presentation to the Board at the City Hall Chambers to be considered for funding. During the 2012–2013 school year, the students used this funding to bring elementary school students from feeder schools to campus for a morning, and created lessons related to healthy eating from the garden. While the teacher provided guidance as to general theme that their proposals should have (gardens and nutrition), the students had the freedom to create their own proposals and budgets given the $500 grant limit.
Junior year	Environmental design project	The "promenade project" was an academy-wide project spearheaded by the environmental design teacher to create a "promenade" to link the main Tate campus with west campus where TEO is located. The objective was to provide shade for students making the walk between campuses during the 7 min passing periods; to provide a seating area for students and community members to gather and a space to host a weekly farmers' market and to mitigate the oil and runoff from the district school bus yard that was flowing into storm drains. In this project, the students were asked to research, create, and submit landscape designs that were based upon the environmental design principles used in class. Students from UC Davis and local landscape designers served as mentors and helped by critiquing presentations, and students had to make a final presentation before a foundation board as part of the application process. The students were ultimately awarded the $1.5 million grant, competing against other professional entities.
Senior year	The youth energy summit	The youth energy summit is an annual contest held at the state capitol where seniors create and present alternative energy and energy conservation projects to the public and legislators. Students work on these projects in the advanced placement environmental science (APES) class. During the 2013 event, TEO seniors presented a "vermi-composter" (worm composter) device that they had developed, explaining the energy savings from composting kitchen waste. The students later won $1000 each for their entry, which was a great source of pride for both themselves and the school.

(continued)

Table 7.3 (continued)

Grade level	Program activities	Description
Senior year	Forestry challenge	During their senior year, APES students can choose to participate in the Forestry Challenge that is a 4-day competition held at sites in the Sierra Nevada Mountains and Coastal California. In 2013, students stayed in dormitories alongside students from around the state and worked with professional foresters to learn about forest practices and formulate plans to address a problem in forest management. The Challenge culminated with each team of students presenting their proposal before a panel of forestry experts and local community members.

7.3.4 Ecological Literacy

The principles of ecological literacy, or the understanding of the interactions between living and non-living elements in one's environment, were addressed in the environmental horticulture and Advanced Placement Environmental Science (APES) courses described in Table 7.1. TEO Academy Coordinator, Mr. Winters voiced his concern about APES. Despite the fact that APES courses address ecological concepts at the same level as an entry-level college courses, Winters said that advanced placement courses place too much of an emphasis on the preparation for the spring tests, taking away time that could be spent working on actual projects. In the TEO Academy, he felt that the ability for students to work on projects was critical to helping them develop their ability to act upon their knowledge. Winters shared that although the students made great strides in developing confidence and awareness of issues through the APES curriculum, by the end of junior year their conceptual knowledge about ecological principles was weaker than he would have liked. Mrs. Kingsley, the horticulture teacher also shared her concern about most students' low levels of conceptual understanding, and that she was looking for ways to address this in her instruction. Winters reminisced about helping his students prepare for the Youth Energy Summit by beginning with an energy audit of the school. He recalled, "…they did the energy audit and understood it on most levels, but then we asked them to do a presentation on it…they couldn't explain what they'd learned." Winters cited the importance of using presentations as a way to assess students' conceptual understanding.

In examining evidence for students' ecological understanding, we determined from the interviews with students that while they could discuss *what* activities they did that were related to the environment, they frequently were not able to accurately explain *how* their actions benefitted the environment. In an interview with two seniors, Anna and Vladimir, both had difficulty explaining *why* they restored a pond with perch as part of their sophomore field experience at the Almond Valley Sustainable Farm. When asked to explain the importance of maintaining habitat for native species, many students' answers were conceptually underdeveloped. For example, Anna and Vladimir explained how the restoration work made them "feel good" because they were "helping a little fish." However, when pressed about why it was important to help native species, neither student could respond with an answer related to ecological concepts such as "preserving biodiversity." In another example, Jacinto described building bird and bee boxes to encourage native species into a restoration area. When asked why it is important to have native animals as opposed to exotic species, he replied, "mainly to preserve culture…we don't want to be just a place that's mixed." Although he felt he was doing something positive for the environment, he was unable to use ecological concepts to explain the issues posed by invasive species, such as out-competing native pollinators that crops depend upon. These students learned about biodiversity from the sole perspective of their science class. In another instance, we found that when a core idea (such as climate change) was taught through an interdisciplinary approach in several academy classes (the sophomore chemistry and English classes, the environmental design course, AP Environmental Science, and the student salsa business class), the students showed much greater competence in explaining the environmental effects of carbon emissions.

For example, in their sophomore English class students read *The Carbon Diaries* (Lloyd 2008) while studying *The Life and Times of Carbon* unit from the *Education and the Environment Initiative (EEI)* (*www.calrecycle.org*) curriculum in their APES class. The students learned about the issues of rising carbon dioxide in the atmosphere in science, and then experienced what it would be like to go through carbon rationing in the future by reading the science fiction novel in their English class. While in the salsa business class, students visited a farm in the Sacramento Valley that provided them with the organic tomatoes and herbs used in the salsa. During their visit, they helped with the farm operations to learn about sustainable agricultural practices, including how to lower fossil fuel consumption. This interdisciplinary approach provided several access points for students to develop an understanding of environmental problems caused by carbon emissions. In their interviews, all of the students were able to articulate that the buying of locally sourced tomatoes for their salsa business minimized mileage and thus reduced the carbon footprint of the business. We see these examples as evidence that they were able to make a clearer connection between their knowledge of fossil fuels and resultant carbon emissions, and tie this understanding to their own decisions about how to run their sustainable salsa business. While the teachers indicated in their interviews that they knew students' conceptual understanding increases with this approach, they found interdisciplinary unit planning very time consuming and were unable to incorporate this approach as much as they would like, even within the CPA model.

7.3.4.1 Civics Literacy

In addition to being ecologically literate, students also needed to identify the roles in environmental decision-making and the procedures involved with taking actions on an issue. We found that the opportunities to develop civics literacy were not necessarily connected to the environment, rather to the local concerns of the community, students, and their families around litter, the availability of fresh healthy food and safe outdoor gathering spaces.

TEO teachers placed a priority on developing students' soft skills, including communication and presentation skills, getting along with others, leadership and listening skills as a means for them to become civically literate. Mr. Winters of the TEO Academy said, "I would hope that the students are leaving with a skillset that would allow them to enter many different careers." When asked about why it is so important to work on skills, he replied: "A lot of our kids here, they're wonderful, they're very warm. Their sense of community is amazing. But they have not had as many life skills as a lot of folks in other schools." He used a scaffolded approach for student projects, breaking the process of identifying problems, conceptualizing and implementing solutions into separate steps. He described how he had shifted from an "anything goes" approach to projects, to giving students a list of three to four ideas that related to the course content. He found that students achieved greater success when they were given more parameters and guided through the steps of the problem solving aspect of civics literacy. This need for scaffolding was evident during an interview with two sophomore students, Felicia and Bella, who brought up the issue of crime in their neighborhood. Felicia recalled how she learned in horticulture class that there is a correlation between the number of trees in a neighborhood and crime rates. The neighborhood surrounding Tate High School had very few trees on the street or in yards as compared to the greater urban area. Felicia commented, "I should try (to get trees planted) for my neighborhood, but I don't know…I would have to go around my neighborhood and make a petition, have everybody sign it, see what they think…" Another sophomore student (in the same interview) concurred, "…the more trees there are, the less criminal rates or crime rates there are." Although the students understood the relationship between crime and trees, they were not able to elaborate on a plan for getting more trees planted in their neighborhood. In contrast, students in the environmental design course (junior year) were trained in designing spaces, making presentations, and writing proposals and were able to give specific details in how to address a community issue such as the lack of trees. These students demonstrated their highly developed civics literacy when they submitted a grant and received a one million dollar award from a regional foundation to install their proposed redesign of an outdoor campus space.

7.3.4.2 Values Awareness

Values awareness as it applies to EAC is when students are able to personally identify with issues in the natural and built environment. Through field trips, projects, and classroom lessons, the TEO Academy had the capacity to expose students to new situations. We examined coordinator interview transcripts to determine where these situations were in place, and made observations and examined the student interview transcripts to ascertain what situations were having impacts on their values. While it has been a long held belief of environmental educators that exposure to nature will stimulate awareness and concern, this was not necessarily the case for urban youth in the TEO Academy.

Our field notes made in the neighborhood surrounding the high school found a dearth of markets selling any sort of fresh food. While liquor stores and mini-marts were numerous, the area could be described as a “food desert.” With the food supply system being a focus of the TEO Academy, the twenty students interviewed were very aware of this situation, and expressed concern (especially for younger students) that they have healthier food options. Maria, a sophomore, made this the focus of her environmental horticulture class project. She and her group members wrote a grant to bring an elementary classroom to the TEO garden where they picked fruits and vegetables, then prepared healthy snacks in the TEO kitchen.

We found that the teachers in the TEO academy did not explicitly discuss values with students during any of the observations made over the two-year period of the study. However, they did develop lessons that required students to reflect on issues of concern. In the environmental design class, students were given a project to explore their cultural landscape. Students were motivated to explore aspects of their environment that represented them and their families, and in doing so became more in touch with their values. The coordinator and fellow teachers did not give students total freedom to choose projects that concerned them and rather narrowed the focus to several options. During interviews, students and alumni expressed awareness and concern about issues in their neighborhood that were unearthed while working on projects. In an observation made during their classroom discussion about where they wanted to go on their end of the year trip, we saw an example of community and social awareness when the students were not interested in the option of staying at a mountain lodge or visiting Yosemite. They were more interested in visiting San Francisco. In the ensuing discussion, the students said that their motivation to behave environmentally was not driven by a desire to preserve or experience wild spaces such as Yosemite. Rather, they were more interested in safe outdoor spaces within their own communities where people could gather.

The value that arose most frequently in student interviews was that of improving the cleanliness of the neighborhood. Students repeatedly cited the trash on the streets and the lack of trees as being of major concern. Angelo talked about the impact of the lack of outdoor gathering places in his neighborhood when he said, “there’s a lot of emptiness….where I live, there’s no close park around there, so you have to walk almost five minutes, maybe ten to go to one.” The environmental design class exposed Angelo to a vision of what his neighborhood could look like with more trees and parks. His growing understanding of design principles helped him to see the possibilities for his community, and the impact it would have for children. Jackie, a TEO alumni (currently a college senior), reflected that because there were not a lot of gardens in her neighborhood, it was encouraging to her to see the TEO staff using the school garden to educate visiting elementary students. Many of the students in Jackie’s neighborhood lived in apartment complexes where they could not have gardens. The use of the garden as an outdoor classroom enabled Jackie to see the greater possibilities for growing food and educating children in the community.

7.3.4.3 Self-Efficacy

Throughout the interviews and observations of student presentations, students expressed their growing capacity to act independently and to make choices either in groups or on their own. During the environmental design class, Angelo used CAD software and engineering principles to design features for the school promenade that would link the two school campuses together, provide shade and seating areas, and address run-off from the bus yard.

Tatiana shared about her experiences in working with adults during a presentation to local community supporters and foundations. The Academy had received a $1 million grant from the local Tree Foundation to implement their environmental design plan for the promenade. She noticed that the audience did not seem to take the project seriously until they learned that the students were behind the design and that it was funded through this large grant award. She said, "it seems like things didn't really seem to register for them until we told them that we had money backing this up." The students were integrally involved in the writing of the funding proposal, and as such, owned the knowledge. They thoroughly understood what they were proposing to do, and conveyed the plan to adults.

Some of the TEO students experienced barriers dealing with adults. Student Jerry realized how power differentials could be set up by the use of language to which he did not have access:

> So the hardest thing would probably be keeping up with the civil engineers and all the other professionals when they're talking, because they use their abbreviations, and they have certain words that I don't know at the moment. So just being able to keep up with things is the hard part. Presenting wasn't too hard. It was pretty easy.

Here, Jerry was able to call on the presentations skills that he had practiced in the academy to help him keep up with the adults with whom he was working. All of the students, regardless of grade level, were able to identify instances where they were confident enough in their skills to take action on something they cared about. The sophomores spoke with pride of bringing elementary students to visit their garden and kitchen as part of their GABY projects; the juniors pointed to their efforts to design and build the Promenade, and the seniors spoke about the many presentations they had to make as part of the Salsa Business.

7.3.4.4 Taking Action

While often considered as part of self-efficacy, we examined action as a separate construct from environmental self-efficacy to delineate between having the confidence and motivation to do something, and then going the next step to actually take action. This was an especially important delineation for students who might experience roadblocks that were beyond their control when it came to initiating the action, and that the CPA model could possibly mitigate. In our interview with Tarika, a senior, she clearly articulates the importance of taking action, as well as the impact that her and her classmates actions have on other high school students.

> I think it's really important because we're promoting sustainability on the campus, and a lot of – not very many high school students get the chance to do that. So I feel like that's really important because we're first setting an example for other high schools to invest in something like that, and we're also reducing our carbon footprint by implementing bio-swales using permeable concrete, which helps clean the water that comes from the bus yard near us….and it also cleans the air around us because all the trees we're going to plant, too.

One senior, Meng, alluded to the lack of parental support for students and how the community aspect of the promenade project helped support students in taking action.

> In this neighborhood, a lot of parents tend to not get involved in their students' educations, which can be a really big problem because a lot of the time, students aren't motivated to work and be their best in high school. So when we bring the community into it, the students realize that all eyes are on them to do something with themselves.

The students' plan for the promenade was to host a weekly farmers' market for the local neighborhood, thus taking action on the issue of a lack of fresh locally available produce. By including the community, this also contributed to the students' ability and motivation to take action.

7.3.4.5 Demonstrating Environmental Action Competence

While students may exhibit dispositions in each of the constructs, they must be able to consciously link all of the component pieces to arrive at what we would holistically consider environmental action competence. In other words, could the students identify their values and motivations for why they were taking action on an issue that concerned them, were they exhibiting the knowledge and skills necessary for successfully attempting and carrying out the desired action, and did they have the confidence in their ability necessary to complete the action?

We found that students varied a great deal in their ability to link their values and motivations with knowledge and skills to take action. When TEO students were asked in interviews to discuss environmental issues that concerned them, and what knowledge and skills they would need to take action to resolve the issue, some students were not able to make connections between their actions and the conceptual understanding behind those actions. This was especially true for younger students.

In an interview with a TEO alumnus, Jackie, demonstrated her well-developed EAC. She described how she benefitted from TEO academy during her troubled years as a high school student and how the TEO Academy shaped her view of the environment. At the time she was interviewed, she was in her senior year at a state college and involved in campus sustainability programs.

> I think I'm more confident… I think TEO showed me that I could make difference, and it didn't have to be a huge difference, but I could make a difference in my life, and my family's life, and my friends lives. Like, I care about the environment, but I didn't know what to

> do. You don't have to go out protesting or stop buying this product, but you can, at home change the way you do things. And so that gave me confidence to be like, you don't need to be the most environmentally friendly person you've ever seen, but you can change a few things and be helpful and less wasteful.

Throughout her interview, Jackie discussed the many small things she did that were positive for the environment, such as getting her roommates to recycle and buying locally sourced food at her college campus. More significantly, she was able to provide the reasoning and motivation behind her actions, exhibiting well developed EAC.

7.4 Discussion

The presence of physical spaces on campus and in field settings that allowed for skill development in realistic settings and a schedule that allowed for extended fieldwork both contributed to students ecological and civics literacy. Students were given authentic problems through which they could learn about ecological principles and how they fit into the larger interdependent system in their community. While the students had the opportunity to learn ecological concepts, they appeared to need more time to reflect upon how these concepts connected to their behaviors. Acquiring a habit for reflection requires practice, as well as instruction on the part of teachers (Dewey 1938; Kolb 1984). Kolb noted, "Knowledge is continuously derived from and tested out in the experiences of the learner, and this can only take place where those experiences can be reviewed and analyzed retrospectively"(p. 27). The TEO teachers agreed that students needed more support in relating their experiences to their conceptual understanding. The opportunities for civic engagement required that students engage in reflection.

Dimick's (2012) study of an environmental justice project in a high school science classroom revealed the importance of explicit instruction. She observed that when one of the teachers in her study did not scaffold scientific concepts or make specific requirements for integrating science skills into projects, this resulted in a lack of ecological understanding on the part of the students.

Ecological literacy can serve to not only aid students in their cognitive reasoning regarding environmental action, but can also lead to motivation. Jordan et al. (2009) and Orr (1992) discussed the importance of students developing an understanding of ecological principles so that they can see themselves as part of an interconnected web, and then are motivated toward stewardship of that web for their own health and well-being. The TEO teachers' holistic approach to STEM subjects included presenting environmental engineering problems that required not only ecological understanding, but also technology skills (using CAD to render designs) and spatial reasoning. Students experienced a sense of accomplishment and competence as a result of their successful completion of these projects, contributing to their overall self-efficacy.

In their study on the effects of environmental education programs on urban youth, Stern et al. (2008) found that many of the students who were involved in environmental projects were engaged not because of the environmental context, rather for the civic and social engagement they experienced. These project-based learning experiences engaged students with their local communities and allowed for sustained relationships with mentors. These experiences focused on the development of soft skills (including presentation and communication skills), and were critical in the students' sense of environmental self-efficacy (California Standards for Career and Technical Education 2013). The confidence that the TEO students developed during their many opportunities to make presentations to adults, especially influential adults, helped to reduce perceived power differentials and support their feelings of environmental self-efficacy. The scaffolding was an important aspect of the TEO Academy. Students were able to stretch the limit of their skills while experiencing success. Felicia and Bella were able to connect one of their concerns (crime) to a solution (planting trees to create a greater sense of community), and link it to a concept (writing and circulating petitions) that they had learned in their academy English class. Although they were not able to take this idea to the next step in terms of what would be accomplished after a petition was circulated, they exhibited the beginning of an understanding that something could be done about an issue that was affecting them and their community.

The availability of physical spaces where students could interact outside of the confines of a typical classroom was an important part of building students' awareness of their values. As Jackie revealed, she did not see many gardens in her neighborhood. The TEO garden provided a new perspective for her and increased the value she placed on gardens, gardening, and educating others. Angelo's field trip outside of the neighborhood exposed him to settings that enabled him to visualize solutions to a problem he wanted to fix: the lack of places for people in the neighborhood to gather. The TEO students' growing understanding of the food supply system through their Salsa Business activities helped them become aware of the food desert surrounding their school and to turn this awareness into a concern.

In their study of the impact of an adventure center program targeted at diverse audiences, Stern et al. (2013) found that for many students, focusing on quality of life and physical health was more motivating than focusing on the natural environment. Schusler and Krasny (2010) also found that approaches that included the social dimensions relevant to young people's lives helped them to connect their concerns to action. For the urban youth in the TEO Academy, improving their quality of life and that of younger students was the value that motivated them to take action. The TEO teachers did not give students total freedom in choosing the topic for projects was due to their desire to help students experience success. Narrowing the students' focus did not diminish the value of the students' interest; rather the evidence suggested that it helped them to be more successful than they otherwise would have been, and this ultimately supported their self-efficacy. Bandura (1982) noted that "people avoid activities that they believe to exceed their coping capabilities, but they undertake and perform assuredly those they judge themselves capable of managing" (p. 123). The scaffolding provided by the teachers and the team approach to projects enabled students to progressively build their skills and confidence over the three years in the academy.

Teachers gave students progressively more autonomy in their projects, allowing them the opportunity to encounter obstacles and work to persevere. As was discussed in a previous section, the development of essential skills and the opportunities to make presentations to a wide range of audiences provided a foundation for students to gain confidence with their peers, teachers and community members. While it was important for students to experience positive interactions with adults in the development of their sense of self-efficacy, those cases in which students experienced differentials in power also helped them to draw on their newly developed skills to push back. Tarika was able to refer to the budget she helped to develop for the promenade project to argue her case in front of her local community foundation. When Jerry found himself in the situation with the engineers speaking in acronyms, he was presented with what Gutierrez et al. (1995) referred to as a “disruption” that he needed to navigate. The fact that Jerry was aware of this barrier provided him with a starting point for negotiating with adults, and he was able to get past it and give a successful presentation. His knowledge of the project, regardless of not knowing the acronyms and jargon used by the engineers, gave him status and confidence to take action.

Students’ ability to identify ecological issues did not necessarily correspond with a desire or ability to take action with regard to that issue. This is supported through the observations of Hungerford and Volk (1990) and Kollmuss and Agyeman (2002) that noted that external factors such as socio-economic status and sense of agency within one’s community influenced behavior. The TEO students expressed concern about issues facing their school and neighborhood, such as the lack of pleasing environmental spaces and accessibility to healthy food, and were not as interested in other global issues such as sea level rise, loss of biodiversity, or water quality. As an example, Meng and Tarika were able to link their action project to real concerns that they had about their school and the community. They understood the design concept of the promenade and how tree-lined areas with seating can serve to bring people together. Tarika was clearly able state her motivations behind the promenade project, explaining how it would reduce contaminated runoff from the bus yard; create shade and habitat, and bring students together for more interaction. She also demonstrated that she had a clear grasp of the relevant ecological concepts. This understanding was put into action to address her concern for the local environment. This was a concept learned in her environmental design course, but she demonstrated that she had connected the concept to her own values about where she lived.

In the case of TEO alumnus Jackie, she demonstrated a concern for living sustainably and an understanding of the ecological concepts necessary to do so. The TEO Academy provided the first experiences in EAC, and she was able to continue on this pathway. Researchers have found that social action projects must intentionally teach organizational leadership and interpersonal tools and skills needed for social activism and organizing (Dimick 2012; Epstein and Oyler 2008). Oyler (2012) found that schools can provide an opportune platform for students to develop their ability to take action because they are already set up for making presentations to audiences. Educating others is a form of taking action, and this was an important avenue for students in the TEO Academy.

While all of the program elements were important, involving the community was of special importance for the TEO Academy. Students exhibited self-efficacy in their interviews when they discussed their action projects and the outcomes of those projects, and this was much more evident in the projects within their own communities, rather than in the field settings. For example, sophomore Maria was very confident during her interview when she discussed her GABY project that brought a local elementary classroom to TEO to learn how to make healthy snacks from the garden. This was in contrast to Vladimir who was not very sure of why he was building a pond habitat for fish on a farm in another county. Heimlich and Ardoin (2012) also noted the importance of social learning when it was situated in the students' own community, and suggested the important implications for environmental education in general. While it is likely that all experiences, both in the community and in the field settings were important, it was when students had the opportunity to excel and be leaders in the community where they lived that appeared to be a significant aspect of developing their sense of self-efficacy in dealing with issues in their environment.

As was evident in the student interviews, having positive role models in the form of community members and providing situations where students could interact with adults on an equal playing field resulted in many opportunities for students to practice their communication skills and develop their confidence. Research by Lave and Wenger (1991), Rogoff (1994) and Rogoff et al. 2001) found that learning and development occur as people participate in the sociocultural activities of their community, transforming their understanding, roles and responsibilities as they participate. Maddox, Johnson, and Willis (1997) noted the importance of social learning for students to construct meaning in their own minds, facilitated by collaboration with peers and mentors. The TEO students had ample opportunity for such collaborative learning, however, based upon the interviews with students, it appeared that they could have benefitted from more focused reflection activities to help them make the connections between their knowledge, values, and actions.

Stern et al. (2008), Ardoin et al. (2012), and Schusler and Krasny (2010) noted that students who do not identify as "environmentalists" or who list environmental concern as a motivating factor often feel more comfortable in built, as opposed to natural, environments. This suggests that while environment and agriculture was a focus for the TEO Academy, the broader goals of the CPA model (which are to improve outcomes for at risk youth and prepare them for college and career) were the instrumental elements for developing the self-efficacy that could ultimately lead to EAC.

7.5 Conclusion

By examining the relationship between the program elements of the TEO Academy and students' development of the constructs of EAC, this study offers a new perspective of the educational potential of agriculture and environmental programs in urban schools.

These constructs, which include ecological and civics literacy along with their requisite skills, values awareness, self-efficacy, and taking action, were exhibited in conjunction with one another in students with developed environmental action competence. While many students exhibited some of the constructs, only the students who had been in the academy for 3 years were able to discuss the connection between all of them when taking action toward the environment. Of the five constructs, ecological literacy appeared to be the weakest area as was evident in the student interviews.

This evidence suggests a need for educators to more explicitly point out the relationship between knowledge, values and action through lessons that encourage students to reflection on their learning. Students need time for reflecting upon how the content and activity relate to their own awareness and concern about their environment. Students can be introduced to content knowledge, exposed to activities that support the content, and taught skills that help put the content into practice, however, if they don't know WHY they are engaging in an activity or behavior and connect that to their own level of concern, it is unlikely that they will continue to take action in the future.

The evidence that the 20 students interviewed exhibited self-efficacy and pointed to their improved soft skills as a result of their TEO Academy experience has strong implications for the focus of environmental education in general, and especially for schools. EE has historically focused on providing environmental knowledge and experiences in natural settings as a way to nurture pro-environmental behavior. We argue that a more meaningful goal is for students to move beyond simply exhibiting behaviors, and to demonstrate the conceptual understanding, skills, and motivations to take positive action toward the environment in which they live and learn. More research is needed to link pedagogical methods to an environmental action competence framework, and to determine the readiness of educators to teach according the framework. There is clearly a need to move beyond traditional "transfer of content knowledge" from teacher to student. However, professional learning opportunities in this area are limited in helping teachers develop the skills that support students' development of EAC. Environmental educators might look more closely at the traditional agricultural education model for how to establish school-based EE programs, because of its incorporation of leadership (through Future Farmers of America) and experiential learning (through Supervised Agricultural Projects) that our study found to be key elements in developing student EAC.

Our application of the EAC framework for uncovering what youth are learning illustrates the need for better assessment of student outcomes in urban agriculture and environmental education programs in schools. Standardized tests only assess a very narrow range of academic achievement. As Hoachlander (2005) noted, these metrics do not measure students' diagnostic abilities, capacities for bringing interdisciplinary knowledge to bear on complex programs, understanding of systems, or facility in applying abstract knowledge and academic skill to authentic situations, all of which are the ultimate goals of twenty-first Century Learning. Investigations such as ours are needed to determine the effectiveness of school programs that take a broader view of student outcomes such as those associated with EAC, and we hope the results of this study provide additional evidence of the rich opportunities that can be created for students at the intersection of agricultural, environmental, and STEM education. Finally, many of the same underserved students facing environmental justice issues in their communities are also underrepresented in STEM college pathways and careers (National Research Council 2012). A deeper look at programs such as the TEO Academy could provide possible mechanisms for engaging students both in environmental action and STEM-related pathways.

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Chapter 8
Growing a Culture of Sustainability: Urban Agriculture Experiences and Undergraduate Student Attachments and Behaviors

Kerri LaCharite

Abstract Concerns about global climate change and the industrial food system are propelling college and university administrators, faculty, staff, and students alike to take interest and action in sustainability and alternatives to the modern food system. While campus farms and gardens have in recent years become centers of sustainability efforts and environmental education in the United States, limited research exists on the effects of these experiences on students' environmentally responsible behaviors. Using a phenomenological approach, this study examined the experiences of 23 undergraduate students enrolled in campus farm internships at Yale University Farm and the University of Montana Program in Ecological Agriculture and Society (PEAS) Farm during the summer of 2013 to determine if students experienced changes in knowledge, internal locus of control, and pro-environmental and social behaviors necessary to justify a commitment of resources by colleges. Data collected through interviews, photo-elicitation, and observations reveals campus agriculture projects create opportunities for learning that deepen attachment to place and offer substitutes to anthropocentric behaviors. Participating students reported increases in pro-environmental behaviors and behavioral intentions including: buying and eating habits; continued participation and study at the campus agriculture projects; awareness of plants, animals, weather, and farms; involvement in food access and security; and increased interest in gardening and farming as hobbies or careers.

Keywords Campus agriculture projects · Sustainability education · Higher education · Pedagogy · Educational farms · Place attachment · Environmentally responsible behavior · Pro-environmental behavior · Eating habit · Urban agriculture

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8.1 Introduction

On the edge of Yale University's urban campus, sits a student farm. The 1-acre farm boasts a chicken coop, brick pizza oven, fruit trees, flowers, and sustainably grown produce harvested and sold at an area farmers market by students. Students and community members volunteer their time in the running of the farm in addition to a small group of interns in the summer, a farm manager, and a couple of part-time staff student positions during the school year. An unlikely place to practice agriculture, Yale University is known better for educating the nation's social elite than instructing students about growing practices (Shannon-DiPietro 2011). However, as Yale University President Richard Levin asserts:

> Yale has always been a launch pad for leaders, a place that seeks and rewards critical thinking, ingenuity and passionate engagement. Food and agriculture are so deeply linked to so many fields of study–politics and law, economy and trade, environmental studies, and almost every discipline of natural science–that it seems only natural to utilize our energy to reimagining the food system, creating a generation of food-literate leaders capable of integrating food and sustainability into their lives and careers. (2012, p. 3)

According to Yale Sustainable Food Project director, Mark Bomford the function of Yale Farm "is to poke at food systems. Poking is a reinventing…we would be delighted to have students going on to take that role in the food system" (field notes, 2013). What Bomford is describing is a growing reaction at U.S. private and public colleges and universities to address sustainability in food systems at global, campus, and individual levels.

Similarly, the University of Montana does not offer agriculture degrees, nor is it a land grant university, positioned to teach, research, and disseminate best agricultural practices. However, the PEAS Farm serves as a physicality of experiential learning in the university's Environmental Studies program. The nearly 10-acre farm on the edge of the city of Missoula operates as a hub of student learning in agriculture and sustainability year-round. According to Josh Slotnick, farm director at PEAS Farm, "An educational farm is a medium for teaching sustainability via experience—even more than it is a vehicle for transferring the tools and techniques of a certain type of agriculture" (Slotnick 2011, p. 233).

As human demand on the environment mounts, campus agriculture initiatives in higher education have taken responsibility to teach students issues, ethics, and practices in sustainability. The University of Montana PEAS Farm and Yale University Farm exemplify a shift that is occurring in higher education from farming practices and management taught as part of agriculture degrees to campus agriculture initiatives teaching sustainability and sustainable agriculture practices in a variety of contexts or degrees (Barlett 2011; Eatmon et al. 2015; Gardner 2012; LaCharite 2015; Sayre and Clark 2011). Pramod Parajuli of Prescott College calls this shift "farming to learn" as opposed to "learning to farm" (personal communication, November 14, 2014).

Furthermore, campus agriculture projects situated in urban settings are poised to challenge assumptions of nature as separate from society (Bailey 1911; Classens

2015; Leopold 1968; Williams and Brown 2011, 2012) and that environmentalism is only concerned with wild places (Classens 2015; De Young et al. 2016; Light 2001, 2003; Travaline and Hunold 2010). Urban agriculture while broadly defined as existing in cities, its suburbs, and edges, also infers a communal resource that meets "current needs associated with subsistence, protection, and civic functions" (Lawson 2005, p. 3). This includes a societal need for fostering sustainable behaviors. Engaging in urban agriculture offers students a "fertile soil in which to conjoin environmentalism to urban citizenship" (Travaline and Hunold 2010, p. 581).

However, while campus agriculture initiatives are emerging as vehicles to address and teach sustainability in higher education, limited research exists on student outcomes. With the challenges nascent campus agriculture projects face identifying internal and external funding sources and the tension of reframing agriculture outside of agriculture degrees, research is needed to assure their continuance. For this reason, in this research I ask: In what ways do academic courses connected to campus agriculture projects outside colleges of agriculture impact participating students' pro-environmental behaviors?

The following study explores indirect sustainability learning outcomes on urban campus agriculture projects. This research analyzes qualitative data from interviews, photo-elicitation, and field observations with 23 undergraduate students enrolled in internships at Yale University Farm and the University of Montana PEAS Farm. In my findings, students reported an increase in pro-environmental behaviors and behavioral intentions. I conclude the paper by discussing the evolving function of campus agriculture projects in addressing sustainability and the role of place attachment in influencing buying and eating habits; continued participation and study at the campus agriculture projects; awareness of plants, animals, weather, and farms; involvement in food access and security; and increased interest in gardening and farming as a lifestyle or career.

8.2 Conceptual Framework for Agriculture-Based Education

Agriculture-based education has a long and intermittent history caught in the ongoing debate between traditional didactic education and experiential, place-based pedagogies starting heavily in the mid-nineteenth century but with roots in the seventeenth century with writings of John Amos Comenius and Jean-Jacques Rousseau (Subramaniam 2002). Agriculture-based education ascribes to deeper educational philosophies of uniting practice and theory, and students and their immediate natural community. Comenius stated every school should have a garden for students to learn how to appreciate nature (Weed and Emerson 1909). Rousseau advocated for experiential learning, identifying the problem with teaching students "about" things instead of allowing students to experience the world itself. Rousseau believed nature is the greatest teacher (Subramaniam 2002). Often paralleling theories in child and adult development and learning, school gardens have always incorporated progressive pedagogies and the environment.

In the mid-nineteenth century Frederick Froebel (1906) wrote, "Education…is permanently manifested in nature" (p. 5). Thompson and Geddes (1863), while building upon the theories of Froebel, argued for more place-based education. Students' natural exploration and learning starts with their immediate surroundings and progressing further and further. Thompson and Geddes, early proponents of place-based education believed students understood the world- natural, human and cosmic alike through widening circles of "inter-relations" (p. 105).

Agriculture-based pedagogies first found wide spread acceptance in the U.S. as the basis of the Nature Study Movement popularized by Anna Botsford Comstock (1911) and Liberty Hyde Bailey (1905), and promoted by John Dewey (1956) at the dawn of the twentieth century. Although not explicit in politically supporting school gardens, Dewey recognized both the value of the ethical and sentimental attachment to nature and the scientific learning offered by studying nature. To critics of school gardens and nature study, Dewey (1956) argued for an increased focus of scientific knowledge alongside sentimental and ethical bonds with the environment. He distinguished nature study and garden-based learning as a balanced interdisciplinary mode of teaching. According to Dewey, the school and school garden acted as microcosms within the larger human and earth community. He put forth, "The common needs and aims [of the school and community] demand a growing interchange of thought and growing unity of sympathetic feeling" (1956, p. 15).

In higher education Bailey (1905), now lauded as a father of the sustainable agriculture, advocated for agriculture-based education to move outside land grant extension services into general education of the masses. Bailey saw a love of the land as essential to lasting societal health and environmental stewardship. In order to address societal and ecological ills he insisted on faculty, staff, and students alike to take on a more active role in transforming education, society, and land ethics. Bailey perceived the education methods of the past were unable to deal with issues of the day. A "new day" that he prophesized would call for new strategies and solutions especially within education (Minteer 2006).

The place-based learning theories of Comenius (Weed and Emerson 1909), Rousseau (Subramaniam 2002), Thompson and Geddes (1863), Bailey (1905), Froebel (1906), Comstock (1911), Dewey (1956), Orr (2004), and Williams and Brown (2012) provide the underpinnings for this study. Specifically, place-based learning theories provide insight into how students learn through experiences in nature and develop attachments and commitments to a plant, a garden plot, a school, or an ecosystem that ultimately affect behaviors. Proudman (1992) suggested it is the inclusion of the affective component that differentiates between experiential pedagogy, including agriculture-based and place-based, and traditional pedagogies. Within campus agriculture projects, students spend hours throughout a semester or school year actively transforming a piece of land while also cultivating a sense of belonging, and emotional attachment (Cvetkovic 2009; Thorp 2006; Thorp and Townsend 2001; Williams and Brown 2012). As Williams and Brown (2012) explained, "Humans protect what they love" (p. 62).

8.3 Campus Food Production as an Embodied Ecological Paradigm

Agriculture-based education and campus agriculture initiatives have strengths that enable them to distinctively cultivate environmental and social responsibility in students through attention to sustainability, whole system thinking, community, and values-based pedagogy (Barlett 2011; Eatmon et al. 2015; Galt et al. 2012; Hoover and MacDonald 2017; LaCharite 2015; Sayre and Clark 2011). De Young et al. (2016) describe campus agriculture initiatives as a gateway behavior, "possibly leading to the development of higher pro-environmental attitudes and/or an interest in other sustainability behaviors" (p. 171). These core characteristics embody the underlying beliefs, values, attitudes, and norms of an ecological paradigm as put forth by Dunlap and Van Liere (1978) and furthered by Beus and Dunlap (1990) in agriculture, and Sterling (2001) in education.

The alternative agriculture paradigm, as conceived by Beus and Dunlap (1990) advanced the concept of an ecological worldview, understood to encompass a wide range of beliefs on economics and sociological thought stemming from the acknowledgement of the intrinsic worth of nature. Beus and Dunlap's (1990) analysis of an alternative agriculture paradigm identify decentralization, independence, community, harmony with nature, locally adapted diverse systems, and consideration of short-term and long-term outcomes as the basis of alternative agriculture and an ecological paradigm. Similarly, Sterling (2001) argues an ecological view "entails a shift of emphasis from relationships based on separation, control and manipulation towards those based on participation, empowerment and self-organization" (p. 49).

Fundamental to the debate between mechanistic and ecological paradigms, and conventional and alternative agriculture is how humans relate to nature (Beus and Dunlap 1990; Dunlap and Van Liere 1978; Dunlap et al. 2000; Sterling 2001). Instead of working from a position of dominance and superiority over nature, proponents and subscribers of alternative agriculture and an ecological view believe humans exist within nature. Students by placing themselves and the needs of humans within the greater context of nature consider the costs of exploitation (Beus and Dunlap 1990).

Campus agriculture initiatives by nature focus on community building whether internally or externally. Campus gardens and farms provide a space for social interaction and cooperation through shared goals. From individual plots to cooperative campus farms, students work together in varying degrees to grow food. In a 2013 survey of 148 campus farms and gardens, 74.3% described their agriculture project as a student community model and 70.3% described as a community model (LaCharite 2015). Research also shows students play central roles in the creation of campus agriculture projects on university and college campuses (Biernbaum et al. 2006; Gardner 2012; Hoover and MacDonald 2017; Parr and Trexler 2011; Parr and Van Horn 2006). Campus agriculture initiatives with a focus on community and student leadership democratize both food production and learning (Barlett 2011).

As the 148 surveyed campus farms and gardens are unconnected to agricultural degrees (LaCharite 2015), a majority of students will not become farmers professionally, but are gaining skills, values, and knowledge to integrate food, agriculture, and sustainability into their careers and daily lives. Campus agriculture projects exemplify the ecological paradigm's value of systems-thinking and interdisciplinary learning as opposed to a reductionist specialization of agriculture. Mayer and Mayer (1974) in a landmark article described agriculture in higher education at the time as "intellectually and institutionally…an island" (p. 87). Thirty-five years later, in an assessment of agriculture in higher education in the U.S., the National Academy of Sciences (2009) called for agriculture to be integrated into the broader undergraduate curriculum. Campus agriculture initiatives by existing outside of agriculture degrees encourage connections between food, agriculture, sustainability, and a host of other disciplines to create what Yale University President Levin (2012) called "a generation of food-literate leaders" (p. 3).

Sustainability and sustainable agriculture is inherently values-based (Berry 1977; Beus and Dunlap 1990; Galt et al. 2012). According to Beus and Dunlap (1990) a major difference between conventional and alternative agriculture paradigms is the consideration of social and environmental dimensions in addition to short and long-term economics. In a debate between Earl Butz, former Secretary of Agriculture and a famous proponent of conventional agri-business and Wendell Berry, a longtime farmer/writer and advocate of an ecological view, Berry states the difference between the two men was Butz was "arguing from quantities and I'm arguing from values" ("Earl Butz Versus Wendell Berry," 1978, p. 58). Campus sustainable agriculture initiatives diverge from conventional agriculture and the western Dominant Social Paradigm by striving to consider the true or full cost of agricultural activities and food choices on society and the environment (Barlett 2011; Berry 1977; Beus and Dunlap 1990). To this point Barlett (2011) argues campus agriculture initiatives "evaluate, disseminate, and legitimize critiques of the conventional food system, both inside the classroom and in co-curricular activities" (p. 102).

In this chapter I argue campus agriculture initiatives including Yale University Farm and the University of Montana's PEAS Farm can impact participating students' pro-environmental behaviors. By prescribing to an ecological and alternative agriculture paradigm through attention sustainability, community building, systems-thinking, interdisciplinary learning, and value-based pedagogy, urban campus agriculture projects are situated to create a generation of students able to understand complexity and true costs within systems, the interconnectedness of all life, and integrate sustainability into their lives.

8.4 Background of Yale Farm and PEAS Farm

The two study sites, Yale University Farm and the University of Montana PEAS Farm were chosen for several reasons: each offered internships for undergraduates in which students work five or more days a week at the campus agriculture project; both campus agriculture projects are associated with environmental studies programs as opposed to traditional agriculture degrees; students take active leadership roles in each project; and most importantly, each in essays written for *Fields of Learning: The Student Farm Movement in North America* (Sayre and Clark 2011) posited student perceptions of and connections to nature are affected by experiences on their campus agriculture projects. Neither research site perfectly represents the various campus agriculture projects in existence in the U.S., however, they each have components that help situate and explain how campus agriculture projects function in relation to the growth of projects and agriculture-based pedagogy occurring outside colleges of agriculture.

The PEAS Farm Internship and Lazarus Summer Internship at Yale Farm follow a cognitive apprenticeship model of learning (Collins et al. 1989) in which students learn through modeling and coaching, while increasingly take responsibility for farm operations. Students learn cultivation practices and participate in marketing activities, such as selling produce and flowers at a New Haven farmers market and setting up CSA pickup in Missoula. Students rotate through farm "chores" including farm animal responsibilities, cooking, and cleaning. From June until August, participants constitute the daily workforce for the operation of each farm. Students enrolled in the PEAS Farm internship for six credit hours in Environmental Studies spend 4 h working or in class, then convene for lunch. Yale students spend a full 8 h day at Yale Farm with a communal lunch.

Each site has a different scale of production. The 1-acre Yale Farm produces a diversity of vegetables, fruits, flowers, and eggs from a small clutch of eight chickens. Yale Farm markets its produce and flowers at a New Haven farmers market every Saturday from May to December. Additional deliveries are made to local restaurants. The Yale Farm also provides food for occasional university events including nationally known speakers and pizza work sessions. The near 10-acre PEAS Farm runs a CSA providing weekly shares of produce and flowers to the Missoula community. Community is at the core of the PEAS farm and its values. The PEAS Farm donates more than 15,000 pounds of food to the local food bank each season and operates a mobile market that travels to senior housing. PEAS Farm interns regularly engage with school children visiting on educational field trips and Little PEAS Summer Camp. The farm in conjunction with Garden City Harvest, Missoula Youth Drug Court, and Willard Alternative High School also runs Youth Harvest Project, a service-orientated work therapy program.

Field trips are a major learning component for both summer internships. PEAS Farm interns visited several sustainable, community focused farms including Lifeline Produce Farm, River Road Garden and Neighborhood Farm, Garden City Harvest Community Gardens, and an heirloom grain farm among others over the course of the summer of 2013. Similarly, Yale University students visited Thimble Island Oysters, Yale-Myers Forest Timber Farm, Common Ground High School Urban Farm, Northeast Organic Farm Association summer conference, Massaro Community Farm, and Stone Barns Center for Food and Agriculture.

Both internships also integrate classroom instruction into the internships. Students at the University of Montana PEAS Farm participate in discussion and lectures each Friday. Weekly classroom time at the PEAS Farm involves lectures, discussions, and activities on soil, seeds and transplanting, weeds, insects, botany, farm planning, orchard, biodynamics and Permaculture, grain farming, tractors and tools, and farm economics. PEAS Farm Interns complete small group presentation of plant families, specific crops, and issues within farming and a reflective journal of the experience with at least ten entries that summarizes and integrates significant points of classes, fieldtrips, and learning. For students at the Yale Farm, weekly classroom time every Thursday involves topics such as lacto-fermentation, and food and farm lexicon. Lazarus Interns are assigned an independent project on a topic within the nexus of food, agriculture, and sustainability. Interns in the summer of 2013 completed projects on mayoral positions of city food policy, capturing the face and impact of food insecurity in New Haven, developing Judaic curriculum on food justice, and informational produce cards for the farmers market.

8.5 Methods: Qualitative Inquiry

This exploratory phenomenological study used participant-driven photo-elicitation paired with in-depth interviews as recommended by Van Auken et al. (2010) to assess the impact of enrollment in internships on campus agriculture projects outside colleges of agriculture on participating students' pro-environmental behaviors. Findings presented in this chapter are derived from 13 in-depth semi-structured interviews with undergraduate students, 80 h of field observations, and participant photo-elicitation conducted during the summer of 2013 at Yale University Farm and the University of Montana PEAS Farm. The layers of data add depth to the factors and effects involved as well as adding validity through triangulation.

Participants included the six undergraduate students from Yale Farm and 17 undergraduate students enrolled in PEAS summer internship credits. The 23 participants at both farms ranged in age from age from 18 to 24. Females accounted for 34.78% (n = 8) of all participating undergraduates. Females and males were evenly split in the Yale University sample. Males comprised a greater proportion in the University of Montana sample. Twenty-two students out of 23 were Caucasian. One student was Asian. Fifty-seven percent (n = 13) of participating students were or were planning on declaring environmental studies majors. Other majors included: Community Health, Economics, English, French, Geology, Physiology/Biology, Psychology/Anthropology, Sociology, and Resource Conservation in Forestry.

Participating students were asked to take three photographs (although many took much more) of a place(s) or subject(s) within the campus agriculture project that they felt connected to with provided disposable cameras to study emotional attachments of participating students regarding nature, agriculture, food, community, and their relationship with the campus agriculture project. Cameras were distributed at the start of the summer semester in June then collected in August. Students were instructed that photographs should exemplify their relationship to the campus agriculture project.

In-depth semi-standardized interviews were conducted with 13 participating students, the six Yale Farm students and seven of the PEAS Farm students. Interview participants were chosen at random within the University of Montana sample. All participation was voluntary. A loose set of questions were developed based on a review of connection to nature and agriculture-based learning literature, discussions with staff, field notes, and elicited photographs. Using photographs as prompts and a means to produce a deeper conversation (Collier Jr. 1957; Loeffler 2005), questions evaluated photographic choices, participants' emotional attachments to the farm, perceptions of agriculture and nature, past experiences, and behaviors. Interviews were conducted until data collection no longer produced new information or understanding.

Over 80 h of observations were conducted at the PEAS Farm and the Yale Farm during the summer of 2013. Field notes captured contents of class lectures, details of farm activities, detailed descriptions of the farms, and informal conversations with students about their experiences and backgrounds then digitally transcribed. Spending substantial amount of time with each group allowed first, a measure of familiarity needed to first understand each student's personal experience and allow deeper conversation during interviews. Second, field observations provided rich context about students' experiences and the farms to interpret interviews and photo-elicitation. Phenomenological approaches recognize descriptions contribute to understanding of meaning (Husserl 1964; Van Manen 1990). It is important to note that phenomenology does not separate the research from the researcher. Subject and object cannot be separated from each other and the environment (Merleau-Ponty 1996).

Data for the study was analyzed through several cycles utilizing NVivo qualitative software. The 160 photographs taken by 17 students who returned cameras that contained developable photographs were coded first by content, including farm spaces and structures, people, plants, animals, foods, and activities. Initial codes were compared back to student interviews, field notes, and memos. Values, pattern, focused, and theoretical coding frameworks drawn from Salañda (2013) were then applied to reflect participants' values, attitudes and beliefs along with behavior patterns. After second and subsequent coding phases in interviews, field notes, and memos, photos then were coded with the developed codes to construct and confirm meaning.

8.6 Findings: Development of Pro-Environmental and Social Behaviors

Interns at Yale Farm and PEAS Farm reported changes in pro-environmental and social behaviors and behavioral intentions relating to food and agriculture including:

1. Buying and eating habits;
2. Intention to farm or garden as a hobby or career;
3. Intention for continued participation and study at the campus agriculture projects;
4. Awareness of plants, animals, weather, and farms; and
5. Involvement in food access and security.

As noted in Table 8.1, behaviors were noted by the number of statements made and the number of students making these statements. These numbers were utilized for general reference, but do not express the significance of each statement. As interviews were semi-standardized, some statements were initiated by students and were not asked of each student. Any opposing or non-changing behavior is also noted throughout findings.

Based on self-reported behaviors during interviews and observations, students increased sustainable buying and eating behaviors and behavioral intentions. One University of Montana student stated, "Being up here [at the farm] dictates what I want to eat… and what tastes good." Another said he had "changed eating habits by eating lunch here together." During interviews several statements came up repeatedly. Students professed to eat more vegetables through eating lunch at the farms, even with reporting interest in eating healthy prior to the experience. Students also spoke of trying new foods and vegetables, such as kohlrabi, kimchi, and vegan meals. Sharing foods and cooking for each other seems to factor heavily into this. Participating students mentioned their standards for taste and quality increased as a

Table 8.1 Frequency of References of Students' Behaviors

	Positive Impact		No Impact		Negative Impact	
	PEAS Farm n = 7/17	Yale Farm n = 6	PEAS Farm n = 7/17	Yale Farm n = 6	PEAS Farm n = 7/17	Yale Farm n = 6
Behaviors						
Buying & Eating Habits	7	5	2	2	0	0
Intention to farm	11	3	1	2	0	0
Intention to garden	6	2	0	0	0	0
Commitment to farm	7	5	0	0	0	1
Awareness of plants,	4	5	0	0	0	0
Animals, Weather & Farms						
Involvement in Food Access & Security	0	3	0	0	0	0

result of tasting field ripened produce as opposed to industrial grown produce most often available. One University of Montana student described losing a lot of weight over the summer from not eating breakfast or dinner off the farm as a result of his rising standards for food and meals. According to him, "I feel like subconsciously, why would I eat anything else … this is like the best meal you could ever have harvested you know, 15 feet away." Several students from both institutions mentioned their unwillingness to eat or buy tomatoes from "anywhere else" after eating varieties grown at the campus agriculture project. Through cooking meals together on the farm and for themselves, often being responsible for their meals for the first time in their lives, students accounted being more comfortable cooking and cooking for groups. A Yale University student talked of incorporating sauerkraut, kimchi and other fermented foods into his diet after a lacto-fermentation workshop.

Students from both Yale Farm and PEAS Farm also reported valuing produce, especially organically grown produce after witnessing and participating the amount of labor involved in growing vegetables organically. A Yale University student said, "You just become very skewed. I will go to market and see squash being sold and start to calculate how much time and energy I put into our squash, and like was it really worth it?" This statement is more significant with four students (two students from each school) expressing frustration and dismay of the expense of organic foods available in stores and their inability and the inability of everyone to afford fresh, organic foods. For example, a Yale student expressed:

> Because I am around food all the time, so there is this access of like tomatoes, and amazing food, and I also don't have any money. So, I also don't feel like I don't have access to food because I can't buy groceries, so there is like this weird, I am here around all of this food, and I don't really take a lot of it home because it's like my job. I have also eaten some great food from the farm don't get me wrong.

Students interning at the campus agriculture projects seem to be caught between the dichotomy of valuing and purchasing organic produce and the perceived costs associated with buying organic foods while on a fixed or non-existent income.

Not all students believed their eating, buying, or cooking habits changed. Two students experienced changes in eating preferences but had no significant changes cooking skills. Both also avoided cooking either for shared lunches or at home. A Yale University student purported she is "unwilling to change my habits and spend more money" with so much conflicting information on what is healthy or sustainable. One University of Montana student expressed high levels of prior cooking, eating and buying habits and preferences. "I already buy things in bulk, and I cook a lot of my own food and eat a lot of veggies and things." He saw minor changes in cooking skills, such as making salad dressing.

An emergent theme from interviews and observations was the high level of intention to garden and farm as a lifestyle or career, especially by University of Montana students. Eleven of seventeen undergraduate students at the University of Montana expressed interest to farm or work in agriculture after graduation either fulltime or part time. Half of the six Yale University students expressed intention to farm or work in agriculture. The experience on the campus agriculture project in conjunction with field trips to area farms, "totally changed where I want to go with my life." The same student admitted they believed farming is hard, but that the life and the work were worth the challenges. Meeting successful farmers that students could identify with allowed students to view farming as a "feasible option" or that the "quality of life is wonderful." Although farming was described as "my fantasy dream" by a University of Montana student and considered an aspiration by two Yale University students, students from both universities seem to grasp the financial and physical difficulties of farming. A Yale student described farming as, "you get really intimately familiar with how much your physical body can produce in a day, which is pretty cool. One the other hand it is totally exhausting and leaves no other room for anything else in your life." According to a University of Montana student:

> So it…in an indirect way gives a perspective on how difficult it would maybe be to run a farm because it is going to be you and a couple of people not you and 20 other people and all the same shit that we get done still needs to get done and so it is like gives a perspective of I don't know maybe the difficulties in farming even though we don't physically feel them ourselves.

The data suggests the behavioral intention to farm was not necessarily a prior interest. Several students mentioned coming to this decision during the course of the summer. For example, a student reported, "I had such a great time up here…One day trellising tomatoes Ellie asked if I could see myself one day growing tomatoes and I said yes…and that slowly happened with everything."

Six of the seven, University of Montana students interviewed also expressed interest to garden or described gardens they started after starting the summer internship at the PEAS Farm. As one student described, "I started gardening within a week of being up here, I mean I have planted stuff and just to compare myself to what we have going on up here. So I definitely think I'll be continuing that." From Yale Farm, two students identified they planned to continue to garden after the experience. According to one, "I will definitely like to grow some things. And um, which I can't say I would have said before this because I couldn't say I know how to."

Students also came to understanding that they did not want to farm. The one student interviewed at the University of Montana that had no intention to farm, expressed "it is really interesting for me to see and like hear about how satisfying this work was for them knowing that it probably wouldn't be for me." Seeing the remoteness and limited social engagement of farmers during field trips made her realize farming would not meet her social needs. Another Yale University of Montana student held the lifestyle of farming was not for her, that "I like it, but I have so many other things that I am interested in."

Student commitment to both Yale Farm and PEAS Farm also were evident during the 80 h of observation, especially at the University of Montana PEAS Farm. Students came early, stayed late, and volunteered on weekends when not required. "I volunteer my time, I mean, I didn't have to come up this weekend. I wanted to do watering duty because it is pleasant to be up here and get food from the field." The same individual then shredded his hand in an off-farm accident requiring several stitches and still came to the farm trying to weed and water with one hand the next day. A committed Yale University student also refused to stop working in the tomato high tunnel during a heat wave, then suffered from a heat stroke needing I.V. fluids according to Yale Farm staff. Data suggests attachment to plants and community, as well as sense of ownership plays a role into student commitment. For a University of Montana student:

> I am, like happy to help in the afternoons because there is so much cool stuff going on. I just genuinely, like, want to be a part of especially this last week. I've like been home for like maybe 7 hours to sleep. I am just trying to soak it all up.

For many, the farm community seems to become part of their identity. According to another Yale University student, "if some part of it were to get damaged, I feel like a part of myself would get damaged."

When students were asked whether they had plans to continue to participate and study at the campus agriculture projects, I received overwhelming positive responses. All but one of the 13 students interviewed at both PEAS Farm and Yale Farm intended to continue to participate in the campus agriculture project. Students from University of Montana planned to do everything from volunteering, to taking additional credits and classes. Students expressed feelings of commitment, pride over knowledge gained and seniority, and desire to "see the season through." Similarly, Yale University students planned to volunteer and/or apply for school year positions at Yale Farm, as well as a desire for future integration with their studies and the campus agriculture project. Yale University students spoke of wanting to give back to the campus agriculture project as it and the staff had given so much to them. The one Yale University student who had no plans or want to stay involved gave several reasons, all pertaining to a loss of intimacy or connection to the farm resulting from not being at the farm every day. According to this student:

> [T]o me the farm exists as my summer, you know, it is still going to be here once the year starts but it is not going to be mine anymore…it is very silly and selfish, but I don't want to come back when it is not my space any more.

The student went on to say:

> I won't know what is going on, on the farm every day so when I come here I will feel more disconnected and less like I am actually contributing because I haven't seen the process like luxuriously unfolding day by day.

Even the one dissenting student expressed sense of belonging and ownership in their answer.

Students also reported increased awareness of plants, animals, weather, and farms as part of the internship experience. Tending and caring for crops broadened student perceptions of rain, hail, and other weather patterns to include needs of the plants and farmers. Students mentioned thinking and talking about weather constantly, especially within the context of crops and working out in the fields. Students also increased awareness of animals on the farm, both domesticated and wild. They spoke of knowing when the pigs or chickens were agitated and the hierarchy of dominance. Through being out-of-doors on the farm for substantial amounts of time, students noticed killdeer, squirrel, and other wild animals patterns, habitats, and behaviors. Students at Yale Farm and PEAS Farm also spoke about noticing potential issues on the farm from sunburn on tender plants to irrigation, as well as farming practices on other farms during interviews. One student also reported now seeing wild lettuce everywhere in Missoula after weeding the native plant area. The increased awareness and broadened perspectives seem to be a result of increased knowledge of cultivated and uncultivated plants, wild and domesticated animals, farms, and farmers.

Another emerging theme in interviews and field observations was student involvement in food access and security. While concern for food security, access and justice came up repeatedly in both University of Montana and Yale University students, the final project in Yale's Lazarus Summer Internship seemed to provide impetus for students to develop and execute projects in food security, justice, and access. Half of the six Yale University students completed projects in food security, justice, and access; specifically interviewing mayoral candidates on city food policy, capturing the face and impact of food insecurity in New Haven, and developing curriculum for school students around, "what Judaism says about food justice."

8.7 Discussion

Existing literature about the effects of agriculture-based learning on sustainability knowledge, awareness, concern, locus of control, and behaviors has focused on elementary school gardens. School gardens have already become significant tools used by primary and some secondary schools to teach ecological education and provide experiences in nature (Aguilar et al. 2008; Williams and Brown 2012; Williams and Dixon 2013). Given their relationship to the environmental movements of the late twentieth century, the goals of garden programs in K-12 schools provide a possible example to campus agriculture projects in higher education. Involvement in school gardens positively correlate with increased knowledge on local sustainable food systems (Cramer et al. 2019; Graham et al. 2004; Moore 1995; Morris et al. 2000) and increased knowledge, preference, and consumption of fresh fruits and vegetables (Berezowitz et al. 2015; Savoie-Roskos et al. 2017). Although both Williams and Dixon (2013) and Ohly et al. (2016) in systematic reviews note lack of rigor in the research methods, including self-reported outcomes.

Consistent with evidence that school gardens increase students vegetable consumption, a majority of students at the PEAS Farm and Yale Farm reported changes in vegetable consumption and specifically organically grown. Such connections between farming and increased vegetable consumption and other pro-environmental behaviors are a result of physical, social, and psychological influences of the campus farm internships. Prominent theoretical frameworks explaining the formation of environmental behaviors view environmental behavior as a result of attitudes, beliefs, norms, affect, self-efficacy, and external factors (Ajzen 1985, 1991; Hines et al. 1986–1987; Kollmuss and Agyeman 2002).

First, students have an increased exposure and access on the farms. Interns at Yale Farm and PEAS Farm reported to snacking on produce such as cherry tomatoes, husk cherries, beans, blackberries, and strawberries while working. However, students also reported increased consumption of vegetables not grown on the campus farms indicating a change in preferences, beliefs, attitudes, and values underpinning their food choices. In a study of college students that gardened individual plots at a college community garden or college family housing unit, Mecham and Joiner (2012) found no increase in consumption of fresh vegetables. According to Mecham and Joiner (2012) "Availability [of fresh produce alone] does not necessarily equate to increased consumption" (p. 239). The campus farm internships in contrast to the individual garden plots from Mecham and Joiner's (2012) study, include an experiential curriculum within an ecological paradigm and a cohort community that provided normative influences through eating communal meals and working closely together in the fields.

A change in preferences, beliefs, attitudes, and values underpinning their food choices is also illustrated by the change of position of food as merchandise or consumed good to a means to achieve environmental and societal health. Students made comments on valuing organically grown foods remarking that they had "greater appreciation for the process of growing organic. You know if there is the USDA sticker on it that there is quite of bit of work behind that." Students from both farms also commented on perceived interconnections between the individual student, community, and the environment, "We are definitely part of a system," and "Everything is connected." Half of Yale Farm interns developed and completed projects in food security, justice, and access during the summer.

One of the most promising aspects of campus agriculture projects as model of an ecological perspective is its potential to strengthen place attachment. Commitment to the farms is a direct result of participation, empowerment, self-organization, and student leadership designed as part of the farm internships. The social-spatial attachment serves as a key process for positive socialization that would be expected to influence behaviors such as food choices. Research suggests place attachment fosters care and concern for a place that is associated with pro-environmental behavior (Daryanto and Song 2021; Scannell and Gifford 2010; Stedman 2002; Vaske and Kobrin 2001). If campus agriculture projects are able to strengthen students' socio-spatial place attachments, the effects of these farms and gardens could have an impact beyond food choices to a range of other pro-environmental behaviors.

The campus farms also instill a sense of self-efficacy or internal locus of control. This type of experiential education provides students with the opportunity to practice pro-environmental actions to incorporate into behaviors. With increased urbanization and industrialization of agriculture, students often have few opportunities for direct contact with nature and first-hand experience in humans interdependence on nature. In the words of a participant of Hellermann's (2017) case study of a garden at New York City College of Technology, "We are urban kids ... we don't really have much nature in our lives" (p. 658). By learning to farm and garden through experience students have the skills and confidence in their abilities to carry these skills and knowledge off the farm and into their careers and lives. None of the Yale

Farm or PEAS Farm students came from a farming background, however, a majority of students expressed desire and intention to either farm or garden for a living or as lifestyle.

Study results also support the notion that experiences on campus agriculture initiatives prompt pro-environmental behaviors. I argue that through attention to sustainability, community building, systems thinking, interdisciplinary learning, and value-based pedagogy as opposed to strictly access provided the motivation to impact students' behaviors and behavioral intentions. While experiences at the campus agriculture projects motivated pro-environmental and social behaviors specific to farming, food, and the more-than-human community at the farms, participating students did not report an increase in behaviors beyond food, farming, or the more-than-human community at the farms. Findings illustrate specific altruistic environmentally and socially responsible behaviors are motivated by specific corresponding knowledge, skills, awareness, concerns, cognitive beliefs and connection to nature, and especially attachments of place.

8.8 Conclusions

Colleges and universities are positioned to lead the paradigm shift between anthropocentrism and ecocentrism necessary to prepare students to integrate sustainability into their lives and career. Through broadening agriculture in undergraduate education campus agriculture projects can and do play a role in providing students with knowledge, skills, and emotional connections to a place needed to address what the American College and University Presidents' Climate Commitment (2014) described as, "critical, systemic challenges faced by the world in this new century" (para. 3). Through attention to sustainability initiatives and pedagogies, campus agriculture projects distinctively impact students' relationship to place, food, and nature. Both Leopold (1968) and Bailey (1911) envisioned the unique opportunity agriculture could play in teaching ecology, ethics, and shifting the human/nature relationship. Furthermore, integrating agriculture-based learning across disciplines bestows agricultural knowledge and experience to "a diverse set of experts and actors, from scientists and engineers to regulators and policymakers" (National Academy of Sciences 2009, p. 2) needed to address the relationship between climate change and agriculture as called for the National Academy of Sciences.

Campus agriculture initiatives along with community gardens and urban farms have become places to change the world by addressing environmental and social problems in traditional agriculture, community dynamics, hunger, and food justice (Solnit 2012). As examples of urban agriculture, Yale Farm and PEAS Farm demonstrate environmental and social sustainability practices and alternative view of cities, agriculture, and nature. The two farms also offer direct learning experiences in nature often inaccessible in urban areas.

This study suggests key implications for practice. First, both campus agriculture projects operated with an ecological and alternative agriculture paradigm that value locally adapted diverse systems, long-term outcomes, decentralization, independence, community, and nature intrinsically. Campus farms and gardens that can embrace value-based pedagogy with a focus on interconnections and community offer a model of an ecological worldview for students. Second, students, especially at the PEAS Farm are given leadership and responsibility for the operation of the farm; this along with a focus on community building increased feelings of ownership and place attachment.

However, more research is needed to understand the intellectual, emotional, behavioral, and physical objectives and outcomes of campus agriculture projects, especially as they exist outside land grant colleges of agriculture. Campus agriculture projects represent a commitment of resources—financial, physical, and human—by colleges and universities to an activity that is traditionally the terrain of agricultural schools and land grant universities. Such investment of resources requires programs provide and meet valued learning objectives and outcomes important to the administration and the overall mission of an institution. Without research demonstrating the positive effects and value of campus agriculture projects on students, that faculty, staff and students the persistence of campus agriculture projects may not continue through budget renewals, as well as faculty, staff, and student turnover.

More research is needed to understand the outcomes of all reported learning goals, and outcomes, including in-depth studies at a more diverse and larger sampling of campus agriculture projects, a more integrated and tested model of place attachment, and environmentally responsible behaviors at campus agriculture projects to further understand the emerging intersection occurring between higher education and campus agriculture projects. The long-term effects of the school and campus agriculture projects have yet to be seen. It is unknown how students' behaviors, beliefs, and perceptions of and connections to nature are affected in the longer term. As Barlett (2011) wrote, "This is a critical moment for academic engagement with food" (p. 102). Assessments of campus agriculture projects are needed for their continuance and support.

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Chapter 9
An Overview of Urban Agriculture Youth Programs in Major Cities of the U.S. and the Integration of STEM Curriculum and Activities

Tara Pisani Gareau and Alex Moscovitz

Abstract The purpose of this study was to learn the extent to which urban agriculture projects are incorporating youth STEM education by providing resources or programs to teach project-based learning related to STEM subject areas into their operations and typify them based on their programs. The top 35 most populated cities in the United States were searched for organizations with both urban agriculture and K-12 youth education components. The 40 organizations that met the criteria were then typified by the programs they have and evaluated for their incorporation of STEM education into their operations. Nineteen of the organizations were determined to have programs that had STEM curriculum integrated into their program; 16 organizations did not have specific STEM goals in their educational programs but did have STEM related activities; the minority of organizations (five) had neither STEM goals nor STEM related activities. Merging urban agriculture projects with STEM learning is a logical step because these organizations provide educational resources and empowerment that can help students succeed in school. Further research is needed to determine the educational outcomes of these programs, but their contribution to youth STEM education should be considered.

Keywords Urban agriculture · Urban farm · Community garden · STEM curriculum · Engagement · Motivation · Expectancy-value theory

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9.1 Introduction

Technological innovation is a driver of economic growth and it depends on a highly competent workforce that has been academically trained in science, technology, engineering, and math (STEM) (U.S. Congress Joint Economic Committee 2012). U.S. students' academic achievement in STEM lags behind other industrial countries (DeSilver 2017) and the largest achievement gaps in STEM are among racial groups. The Nation's Report Card for 2015 shows a 33, 34, and 35 point difference in average science scores between Black and White students in 4th, 8th, and 12th grades respectively, with only slight reductions in the gap for 4th and 8th graders since 2009 (National Assessment of Educational Progress 2015). Disparities in teacher expectations, resource access, and course rigor are just some of the factors that contribute to the achievement gap (National Research Council 2011). The STEM academic achievement gap extends to aspirations (ACT 2017) and realizations of STEM careers (Wang 2012; National Center for Science and Engineering Statistics [NCSES] 2019), which limits opportunities for wealth generation and quality of life for marginalized students (Reardon 2011). The U.S. educational system needs to explore new ways to spark interest, motivation, and engagement in STEM areas and to close the achievement gap among Black and White students so that there is equal access to STEM learning and careers. We suggest that urban agriculture programs aimed at youth empowerment is one such pathway.

This chapter elucidates the largely unrecognized roles that urban agriculture programs (UAPs) play in fostering student engagement in STEM learning. We identify and review 40 UAPs in 35 US urban cities and typify them by their main approach to working with youth. We posit that UAPs, which incorporate STEM curriculum in their programming, stimulate interest and engagement in STEM.

9.1.1 Theoretical Framework

STEM achievement gaps come as no surprise to educators who have spent any time in the U.S. school system. The authors of this chapter have encountered reluctance and downright fear of science and math courses among college students. Theorists claim that we answer questions about who we are such as, *am I a science or math person?*, during adolescence (Adams et al. 1984; Eccles 2009; Erikson 1980). Social networks both inside and outside the academic classroom influence identity development during adolescence (Eccles and Roeser 2011; Wang and Degol 2016). We are specifically interested in the ways that these outside classroom social networks of support and co-learning can shape interest in STEM.

Theorists agree that engagement is critical for academic success (Li and Lerner 2013; Wang and Peck 2013). An engaged learner has high quality and frequent interactions in learning activities and is motivated to learn (Skinner and Pitzer 2012). Experiential learning activities tend to be higher quality interactions because they use heuristic techniques and active modes of learning where students have a chance to practice what they learn and gain mastery over skills. According to Connell (1990) motivation to learn relates to deep psychological needs for competence, autonomy, and relatedness. Expectancy-value theory suggests that adolescents make choices about which activities to engage in based on how likely they are to feel competent and successful in that activity (Eccles 2009). Pulling these ideas together, our central premise is that UAPs that integrate STEM curriculum into their activities may have high levels of engagement and thus learning of STEM concepts because by their very nature UAPs are relational to participants, use experiential activities to teach new knowledge and skills, and often focus on youth empowerment, which increases one's sense of autonomy.

9.1.2 Garden Learning

Gardening as environmental education provides different forms of engagement for children. Studies and activities can include designing, planting, and maintaining gardens or hydroponic systems; harvesting, preparing and sharing food; working cooperatively in groups; and learning about plant biology, soil ecology, and food and nutrition. Gardens are also canvases for creative expression through art, poetry, and literature. Alice Waters, founder of the Edible Schoolyard Project, has been a leader in the development of the edible education field. The Edible Schoolyard Network shares edible curriculum resources for educators for a wide range of subjects for K-12, college, and adult education. Studies show that growing food makes children more likely to eat fresh fruits and vegetables or express preference for those foods (Lineberger and Zajicek 2000; Libman 2007).

Research on school gardening programs has shown that garden education can lead to a growth in soft skills such as positive social and emotional skills, healthy eating and nutrition, and positive attitudes towards learning. Third to fifth grade students who participated in a one-year gardening program experienced a significant increase in self-understanding and ability to work in groups compared to non-participating students (Robinson and Zajicek 2005). Williams and Dixon's (2013) review of 48 studies on direct academic outcomes of garden-based learning reveals that third to fifth graders are the most common grade levels assessed in these studies. Although evidence of a community based garden internship program suggests that students in higher grades may also benefit by increases in maturity, responsibility, and interpersonal skills (Hung 2004).

Research shows that science scores also improve when students participate in gardening programs (Dirks and Orvis 2005; Klemmer et al. 2005; Smith and Motsenbocker 2005; Williams and Dixon 2013). Fifth grade students in Temple, Texas who participated in school gardening activities demonstrated significantly higher scores on science achievement tests than students who had a curriculum without garden experiences (Klemmer et al. 2005). Gardening programs in Indiana and Louisiana also had a positive effect on science achievement scores for students involved in the program in comparison to students not involved (Dirks and Orvis 2005; Smith and Motsenbocker 2005). The mechanisms behind gardening effects on academic performance have been linked to improved nutrition and physical health through the program (Hollar et al. 2010; Bell and Dyment 2008), hands-on learning that is relevant to students' lives and fosters inquiry (Habib and Doherty 2007; Jagannathan et al. 2019) and increased social and emotional health (Habib and Doherty 2007; Robinson and Zajicek 2005).

Not all schools, especially ones in urban centers, have access to land, rooftops, or greenhouses on school property or qualified staff to manage food production in these spaces. To take advantage of garden-based curriculum to increase soft and hard skills, UAPs can help fill a gap.

9.1.3 The Rise of Urban Agriculture Programs

Urban agriculture projects in major cities across the United States have grown as the local farm movement has gained momentum, and as issues of community food security have come to the forefront of social and political concern (Rogus and Dimitri 2015). Health and nutrition advocates, community economic development organizers, and environmentalists are joining with community gardeners, university extension services, and emergency food distributors to form coalitions on behalf of urban food security (Brown and Carter 2003). Organizations have initiated programs to increase access to fresh, local produce in disadvantaged communities experiencing food insecurity (Block et al. 2012).

Urban communities are separated along lines of race and class with many disadvantaged neighborhoods experiencing inadequate access to healthy, nutritious foods. These "food deserts" lead to social, environmental, and health concerns (Raja et al. 2008). Rates of food insecurity are disproportionately higher in Black and Hispanic households (Coleman-Jensen et al. 2020). Concomitantly, food deserts may have vacant lots or neglected parks that can be exploited for increased food production or green space revitalization. According to the Brookings Institution, an average of 15.4% of land in 70 U.S. cities is deemed vacant along with 2.6 abandoned structures per 1000 urban residents, with the highest rates of vacant land and structures in the south (Pagano and Bowman 2000). Many UAPs aim to increase food access and revitalize communities, by setting up shop in disadvantaged communities, where there are opportunities to utilize vacant lots for food production. A case study of Philadelphia shows that there is a positive spatial correlation between UAPs and communities with high rates of poverty and hunger (Meenar and Hoover 2012). A study of low-income youth in New York City found that participation in extracurricular activities, especially in a community or athletic setting, had a positive effect on students' grade point average (Schwartz et al. 2015). Thus, UAPs have the potential to both increase food security in poor neighborhoods and increase recruitment of adolescents into STEM fields, by offering hands-on STEM curriculum. The question though, is how wide-spread and involved is STEM education in UAPs?

9.1.4 Purpose and Research Questions

The purpose of this study was to describe how urban agriculture organizations, independent of schools, are contributing to youth education, and in particular their level of engagement with STEM curriculum. Given the diversity of UAPs in the U.S., a secondary objective was to develop a typology of UAPs based on how they interact with students. Our three research questions were:

1. Are different types of UAPs more integrative of STEM development goals or activities for youth?
2. In what ways are UAPs engaging youth in STEM education?
3. Does participation in UAPs increase interest in STEM?

9.2 Methods

9.2.1 Urban Agriculture Program Selection

UAPs included in this review were selected on the basis that they include a component of urban farming or gardening and programs that engage with K-12 youth. Urban farming or gardening can range from a small garden or a hydroponic lab to a full-scale operating farm located within city limits. A youth program includes any program that involves youth participation in activities at a garden or farm. Youth participation may take the form of one-time visit field trips, seasonal camps, and monthly or weekly interactions during class or after school. UAPs that operate outside of schools but are connected to youth by the resources they provide such as garden construction, teacher workshops, and curriculum building were included in this study. We also included employment programs where students are paid for farm work but also may engage in workshops and group projects. We excluded from this study schools that have constructed their own gardens for classroom use and organizations that service only one school. This is with the intention to focus on organizations that are not currently well recognized and assessed for their impact on STEM education.

To select UAPs, we searched the internet and literature of the 35 most populated cities (see the results section for a list of the cities and organizations) using the search terms, “urban agriculture,” “urban farms,” “urban garden,” “youth,” and “education.” We viewed the websites of the UAPs for their missions and programs to determine if they incorporated youth programming into their operations. We came up with 40 UAPs that fit our criteria.

9.2.2 Website Review

We combed through each UAP website, which typically includes a purpose statement, programs, events, and employment opportunities. Some also contained annual reports or other publications that we reviewed. We recorded data on how each organization engaged with youth, which we used to typify the organizations. We also looked for programming and curriculum that was science, math, or technology related.

9.2.3 Survey Instrument and Procedure

In addition to our website review, we developed a survey instrument to collect more specific information to use for case studies. Our survey and follow-up phone interview questions and informed consent procedure were reviewed by Boston College's Office of Research Protections (Table 9.1). Due to the low risk nature of the questions, we were granted an exemption from Institutional Review Board Review in February of 2015 in accordance with 45 CFR 46.101 b(2). We sent the program coordinators or directors of the 40 UAPs the electronic survey via email. We followed up with a second and third email for those who did not respond. Eighteen percent of the organizations ($N = 7$) returned a completed survey. Follow-up phone interviews were conducted with three programs to elaborate on responses.

9.2.4 Qualitative Data Analysis

From the information available on UAPs' websites, we typified each organization based on whether their interaction with students was via employment (EMP), enrichment (ENR), a resource for schools (SR), or a combination of those (Table 9.2). Each organization was also evaluated to determine if it directly integrated STEM goals and curriculum or indirectly integrated STEM learning and interest through related activities. We considered UAPs to integrate "STEM curriculum" if they explicitly included goals of educating youth in STEM fields or implemented standards-based STEM lessons. We classified programs as "STEM related activities" that involve youth in informal lessons of science topics: ecology, plant biology, hydrology and climate, animal husbandry, sustainable agriculture, nutrition, food systems, marketing, engineering, and math. Generally these programs do not state that they are specifically targeting STEM goals. Rather, STEM learning may be an indirect outcome of their activities due to their relationship with STEM topics.

Table 9.1 Questions Included in an Electronic Survey Sent to UAPs via email and Used in Follow-up Phone Interviews

Electronic survey
1. What year was the program established?
2. What is the program's funding source?
3. What is the program coordinator's training? Please detail the level of education and background.
4. Who are your students?
5. How often are students engaging with the urban agriculture program?
6. Does the mission of your organization include a goal of training program participants in STEM?
7. Does your program involve training of STEM educators in K-12 public schools?
8. How often do students engage with the following activities? (not at all, occasionally, frequently)
(a) Determining how much of each crop to grow.
(b) Determining fertility applications.
(c) Testing water or soil pH.
(d) Hydroponic system design, installation, or maintenance
(e) Marketing
(f) Animal care
9. Are there other program activities where participants would be applying STEM skills? Please, explain.
10. How would you describe participants' interest in STEM activities at the beginning of the program (low, medium, or high)
11. How would you describe participants' interest in STEM activities at the end of the program (after graduation)?
Follow-up interview questions
12. Could you please describe your program for me? (what are the program's objectives? How do you recruit students? Is there a curriculum you use?)
13. Please describe what methods you use to educate the students in your program. What activities do your students partake in that develop STEM skills?
14. Do you see any increased interest in STEM by the students? (elaborates on question 6)
15. Does your program impact the student's performance in school? Is there evidence of this?
16. What do the graduates of your program go on to study?
17. Do you plan to change/develop your program at all? If so, how?
18. Would you consider applying for funding aimed at improving STEM skills?
19. What would you like your program to look like in 5 years?

9.2.5 Urban Agriculture Program Typology

Youth enrichment programs (ENR) are school or farm based. The organization hires educators to run programs at the urban farm or school garden for field trips and programs outside of school hours. The amount of time youth spend at the farm or garden can vary from a morning or afternoon field trip to an extended time period. However, in all these programs, youth participants engage in hands-on lessons in

Table 9.2 Urban Agriculture Program Types and Typology

Program Types	Typology
Youth enrichment	ENR
Youth employment	EMP
School resource	SR
Youth enrichment + school resource	ENR-SR
Youth employment + enrichment	EMP-ENR
Youth employment +enrichment + school resource	EMP-ENR-SR

agriculture, ecology and nutrition. Field trips typically involve school teachers bringing their students to the urban farm or garden where they are taught a lesson by a staff member and participate in farm activities. Youth enrichment programs outside of school hours include after-school programs, garden clubs, seasonal camps or internships/apprenticeships.

Youth employment programs (EMP) are paid jobs where youth help to operate the farm or agriculture project, learn about the process of growing and selling food, and build leadership skills. Students in these programs gain a foundation in agricultural marketing, engineering, communications and social media, managing or computer skills. They also may be educated in community organizing, food justice, and environmental stewardship.

School resource programs (SR) are administered through an organization that contracts with schools to build gardens, greenhouses, or labs for schools or communities to serve as learning facilities. School resource programs may also train teachers on how to integrate a school garden with school curriculum. Some school resource programs also have educators available to conduct lessons in classrooms or gardens for students and teachers.

9.3 Results

9.3.1 Urban Agriculture Youth Programs in Major US Cities

Of the 35 cities we searched, 25 contained organizations that matched our criteria for selection. Searches on Jacksonville, Columbus, Charlotte, Dallas, Fort Worth, El Paso, Oklahoma City, Louisville, and Fresno did not reveal any projects or organizations that fit the criteria for selection. In the 25 cities researched, 40 organizations were found to have UAPs that engage with K-12 youth (Table 9.3).

Table 9.3 Urban Agriculture Youth Programs by City, Typology, and Level of STEM Integration

City	Organization	Typology	STEM Curriculum	STEM Related Activities
Albuquerque	Erda gardens	ENR		X
Austin	Sustainable food center	ENR-SR		X
	Urban roots	EMP-ENR		X
Boston	The food project	EMP-ENR-SR	X	
	City sprouts	EMP-ENR-SR	X	
	Green dragons	ENR-SR		X
	Green City growers	ENR-SR	X	
Chicago	Growing power	EMP-ENR-SR		X
	Windy City harvest	EMP		X
	Plant Chicago	ENR-SR	X	
Denver	Denver urban gardens	SR	X	
Detroit	Earthworks urban farm	ENR		X
Houston	Urban harvest	ENR-SR	X	
Indianapolis	Indy urban acres farm	ENR		
Las Vegas	Vegas roots	ENR		
Memphis	Green leaf learning farm	ENR		X
Milwaukee	Growing power	EMP-ENR-SR		X
Nashville	Hands on Nashville	ENR-SR		X
New York	Red hook farms	EMP-ENR-SR	X	
	Battery urban farm	ENR-SR	X	
	New York sun works	SR	X	
Philadelphia	Bartram's garden	ENR		X
	Urban stead	ENR		X
Phoenix	Tiger Mountain foundation	EMP		
Portland	Zenger farm	ENR	X	
Sacramento	Soil born farms	ENR-SR	X	
San Antonio	Local sprout	ENR	X	
San Diego	Humane smarts	ENR		X
	UrbanLife farms	EMP		
San Francisco	Produce to the people	EMP		
	The garden project	EMP	X	
	Urban sprouts	EMP-ENR-SR	X	
San Jose	Veggielution	ENR-SR		X

(continued)

Table 9.3 (continued)

City	Organization	Typology	STEM Curriculum	STEM Related Activities
Seattle	GRuB	EMP-ENR		X
	Tilth Alliance	ENR-SR	X	
Tucson	Tucson Village farm	ENR-SR	X	
Washington D.C.	City blossoms	ENR-SR	X	
	Common Good City farm	EMP-ENR-SR	X	
	Washington youth gardens	EMP-ENR-SR	X	

Note. STEM curriculum signifies that the STEM goals are explicitly part of program goals and incorporate STEM related activities. While organizations classified as STEM Related Activities engage in activities that we considered within STEM

Note. See Table 9.2 for typology meaning

[a]Growing Power (Milwaukee and Chicago branches) and Produce to the People are no longer operating

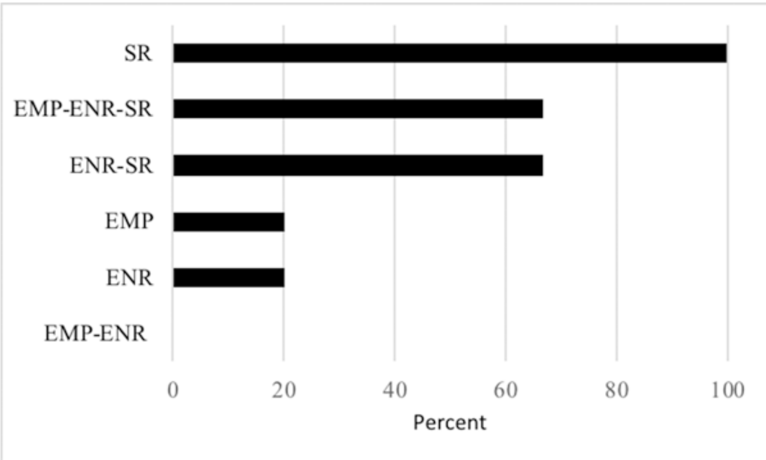

Fig. 9.1 Percent of UAP types that incorporate STEM curriculum

9.3.2 *Types of UAPs that Integrate STEM Curriculum into their Youth Program*

Urban Agriculture Programs typified as solely SR ($N = 2$), providing schools with resources for student learning or teacher training, were most likely to integrate STEM curriculum goals into youth programs (Fig. 9.1). The nature of the school resource model is to use a garden or hydroponic system to learn or reinforce curriculum from the classroom. SR organizations provide or recommend curriculum for the teachers to use in the classroom that makes use of the school resource. For example, NY Sun Works' creates greenhouse labs and trains their teachers using a recommended curriculum that they have developed. It's notable that 67% of UAPs typified as EMR-EN-SR and ENR-SR used STEM curriculum, which may be driven by the SR programming.

Only 20% of UAPs typified as EMP or ENR integrate STEM curriculum in programming (Fig. 9.1). None of the EMP organizations responded to the survey, but San Francisco's The Garden Project mentioned on their website that they use a STEM curriculum for their students. The Garden Project has their students participate in environmentally-based math and science classes along with the employment program. Windy City Harvest focuses its education efforts in sustainable urban agriculture and has some STEM learning activities alongside its core work in food systems and nutrition education as the students work in all aspects of production as well as marketing.

9.3.3 Common STEM Topics and Approaches Used by UAPs

We found that UAPs are engaging youth in STEM in a variety of ways. Organizations using STEM curriculum and STEM related activities are introducing student participants to a number of topics in their youth programs. Figure 9.2 illustrates the frequency with which each topic is taught across the organizations selected for this study. The most common STEM curriculum taught by UAPs is nutrition. Sixty percent of the organizations include lessons and activities to encourage familiarity with fruits and vegetables and teach students the components of a healthy diet. Nutrition is often taught along with cooking or vegetable tasting activities. About a quarter of the organizations teach topics of food systems, meaning how food is produced,

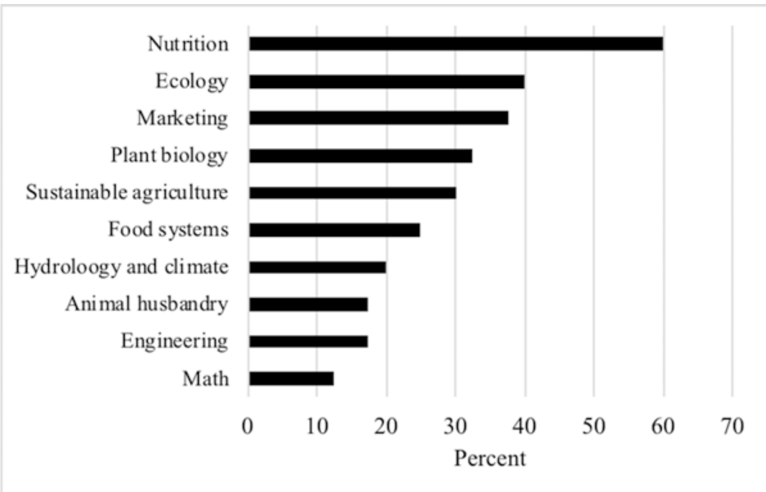

Fig. 9.2 STEM related topics taught by urban agriculture programs in major US Cities

processed, and distributed locally and nationally. While teaching their students food systems, many organizations describe teaching topics of social justice and food sovereignty. Tucson Village Farm has a STEM-based agricultural literacy program in which students learn food production, harvesting and processing of food on the farm along with the science behind processing soft drinks and fast food.

About 40% of the organizations involve ecology curriculum into their programs. The most common ecological processes taught were pollination, decomposition, predation, parasitism and trophic interactions of the farm and surrounding ecosystem. One popular method of teaching ecology is through interactions in the compost bins and soil. Activities involving composting and soil drainage demonstrations can teach students about the organic and inorganic components of soil, the importance of decomposers, and nutrient flow through systems. Another topic often included in educational programming is plant biology, or botany, which includes subtopics of plant structure, reproduction, growth, photosynthesis and respiration. A third of the programs include lessons or activities to teach plant biology by conducting growth rate experiments and identifying plants and their structures. City Sprouts lessons uses strawberry plants to teach sexual and asexual plant reproduction and math skills via measuring and charting plant growth.

Organizations with access to local watersheds, wetland ecosystems, or weather stations incorporate these resources into their curriculum on hydrology and climate. For example, at Battery Urban Farm, high school students conduct water quality tests to determine pH, nitrate levels and more in the Hudson River Estuary.

Math topics are taught only by a few organizations through curriculum and activities: Green City Growers, New York Sun Works, The Garden Project, GRuB, and the Battery Urban Farm. These organizations teach math topics through activities including planting plans, taking soil and plant measurements (pH and growth), and calculating yield statistics. At the Battery Urban Farm program participants measure spacing for seeding and transplanting, and track plant and oyster growth. Thirty-seven percent of the organizations involve a marketing component to their programs which involves math skills. Students weigh and measure produce, appropriately price produce based on costs of production, and sell the produce at farmers markets or to their school community. At GRuB, students in the employment program learn how to determine the appropriate amount to harvest and how to divide it up between CSA (community supported agriculture) boxes by weight, and then sell it at the market.

Engineering curriculum was most likely integrated into programs that use hydroponics or aquaponics as controlled environment agriculture allows for opportunities to design and build the planting system and water and nutrient delivery. At NY Sun Works' greenhouse labs, students in grade 6–12 participate in a unit called "Hydroponic Games" in which they design, construct, and evaluate an original hydroponic system. The students must also develop their operations manual, test and maintain the system, and sell its produce. In Plant Chicago's Materials Reuse lab, students engage in an engineering challenge to build a planting system from discarded plastic bottles.

Seven organizations cite that their students participate in animal husbandry activities. Students engage in hands-on activities tending to farm animals (i.e., feeding chickens or milking goats) or caring for fish in aquaponic systems. Animal health, nutrition, and space requirements are common animal husbandry topics.

About a third of the programs specifically cite teaching the more holistic concept of sustainable agriculture. Urban Roots and Common Good City Farm, The Food Project, Zenger Farms and Hands-on Nashville provide sustainable agriculture workshops for their youth employees or participants. Plant Chicago is unique in its emphasis on using a circular economy model for food production where fish and vegetables are produced with zero waste and renewable energy and its alignment of activities with Next Generation Science Standards. In The Plant's original aquaponic system, fish were fed a combination of spent grain from the onsite brewer, fly larvae that decompose kitchen waste, and algae from a bioreactor; fish waste provides the nutrients for plant growth; plants filter the water that then gets recycled; and food waste from an onsite commercial kitchen fuels the anaerobic bio-digester that turns the turbine that generates electricity to power lights and pumps for the aquaponic system.

9.3.4 Does Participation in UAPs Increase Interest in STEM?

Eighty-six percent (6 out of 7) of the organizations surveyed reported an increased interest in STEM among graduates of the program, while 14% (1 UAP, NY Sun Works) reported high interest from beginning to completion of the program. This measure is based on the organizations' internal evaluations. One organization described this increased interest as arising from a realization that science is connected with food. Other impacts reported include improved eating habits, social skills, self-advocacy, collaborative work, and problem solving as well as increased interest in nature and environmental stewardship. However, the surveyed UAPs did not report a process for assessing participants' gain in STEM knowledge due to particular urban agriculture programming.

9.3.4.1 Case Study: Washington Youth Gardens, Washington DC

Founded in 1971, Washington Youth Gardens is one of the oldest UAPs in this review and what we consider to be a model of how UAPs can provide valuable extracurricular experiences that spark interest and engagement in STEM and can be strategic about who they reach. We typified Washington Youth Gardens as having employment, enrichment, and resources for schools (EMP-ENR-SR). It was one of the only UAPs that includes STEM in its mission, "we want to enrich science learning." School garden coordinators co-teach hands-on garden science education to K-12 educators at their main demonstration garden on the grounds of the

U.S. National Arboretum. The Program Manager at the time, Charla Wanta, had this to say about Washington Youth Gardens' work with disadvantaged youth:

> We work with whole schools for our School Gardens Partnership program and look for ones where over half of the students qualify for free and reduced price lunch. We see another 2,000 students in our field trip program. Nearly 80% of those students also happen to come from schools with more than half the students qualifying for Free and Reduced Price Lunch.

In response to the question, what do students most like, Charla replied:

> They most enjoy tasting fresh produce from the plants, touching and closely examining worms and insects, feeling the hot compost pile, cooking, planting seeds, weeding, (if they are under 3rd grade), and harvesting. Basically anything that does not involve sitting or writing.

When asked about curriculum use and needs, Charla had this to say:

> We have written some of our own, but we also draw from a number of different sources, such as Life Lab and the Food Project. We continue to need a good, hands-on indoor curriculum that helps students be ready for the STEM learning they do in the garden during the growing season.

9.4 Discussion

Urban farms and gardens are formative spaces for youth where they gain confidence in their skills and develop a social network that fosters cooperative learning (Wang and Hofkins 2020). Urban agriculture programs, important for enhancing the well-being of vulnerable populations (Allen et al. 2008; Dyg et al. 2020), are also fertile environments to engage youth in STEM learning. In our review of 40 UAPs, we learned that nutrition is the most common STEM topic incorporated into K-12 programming. Food is instantly relatable to students. Alice Waters built the highly acclaimed The Edible Schoolyard Project on the idea that students will eat food that they grow and she was right! At Washington Youth Gardens, tasting food from the garden is one of the most enjoyed activities of program participants. Beyond the gratification of tasting the fruits of their labor, adolescents also relate the urban farm and garden to the food security of the larger community. All but one of the survey respondents said that program participants engage in marketing activities, which often includes preparing CSA boxes and selling produce at the farmers' market where adolescents can interact with community members. Relatedness is an important motivator for engagement in an activity (Connell 1990) and it is clear from our study that UAPs do a very good job at using relatedness as a motivator for youth engagement.

But how much do youth participants of UAPs engage in STEM curriculum and related activities? We found that almost half of the UAPs use STEM curriculum in their programming and less than half engage in STEM related activities without a curriculum. Although it is important to note that these numbers are based on our website review and survey. It is possible that UAPs are doing a lot more in STEM education but are not reporting it. The program coordinator for Washington Youth Gardens mentioned that they make use of curriculum resources developed by the Life Lab (https://lifelab.org/store/free-downloads/) and The Food Project (thefood-project.org/curriculum/), although we found that their STEM resources are geared mostly for a K-5 audience. As noted by Charla Wanta, there is a need for curriculum that can be used indoors when the outdoor gardens are not growing. For the adolescent to adult audience, we highly recommend *Teaching Organic Farming and Gardening: Resources for Instructors*, a free publication of the Center for Agroecology and Sustainable Food Systems (Miles and Brown 2005). CASFS uses the curriculum to train apprentices in their Ecological Horticulture certificate program. Another option for the winter season is developing an engineering, water chemistry, and plant biology curriculum for hydroponic or aquaponic systems, which function indoors year-round. New York Sun Works developed 80 lesson plans per year divided between K-5th, 6-8th, 9-12th grade levels, covering the mandated science standards while using hydroponic and related technology (https://nysunworks.org/education/curriculum/). Plant Chicago offers an aquaponics workshop focused on water chemistry– "Using our aquaponics system as a field site, students use the scientific method to test water for various levels of ammonia, nitrites, nitrates, and phosphates. Explore what makes "healthy" water for fish, plants, and humans!" Notice how that last sentence uses a relatedness approach to recruit participants who might not see the value in learning about nitrogen.

Results from our survey indicate that participation in UAPs increases student interest in STEM activities over the course of the programs. Building interest in STEM during adolescence, when questions, such as who am I and who do I want to become, are being explored, is essential for STEM identity formation (Eccles and Roeser 2011; Wang 2012), which in turn is a precursor to choosing a STEM vocational pathway. Expressed or measured interest in STEM is correlated with higher levels of college preparedness for STEM subjects (ACT 2017). The UAP model that develops and nurtures interest in STEM is especially important for first generation college bound students from a racial/ethnic minority group and low-income family, who are sixteen times less likely to be ready for STEM courses in college (ACT 2017). The expectancy value theory predicts that if students perceive that they are less likely to be successful at STEM, they are less likely to pursue it as a field (Eccles 2009). The statistics on diversity in STEM fields (NCSES 2019) lend support to this theory.

This study reveals an important contribution of all UAPs is that of nurturing the scientific mind. From the Washington Youth Gardens program, we learn that students like to touch plants, closely examine worms and insects, feel the heat coming off of a compost pile, and experiment with cooking. The urban farm, garden, hydroponic, or aquaponic system offers limitless opportunities for exploration and experimentation. Scientific inquiry that can be answered through investigation is at the heart of the "Practices" dimension in the Next Generation of Science Standards (NGSS 2020).

9.5 Future Research

More research is needed to examine whether UAPs with STEM curriculum and activities (e.g., designing a hydroponic system) have a positive effect on science and math achievement scores in high school and students' intention to pursue STEM fields in college. Longitudinal research that tracks youths who participate in UAPs with STEM curriculum on their major choice in college would provide much needed quantitative measures of impact. Also important to understand is how UAPs outside of schools compare to UAPs that co-create programs with schools, to know if investment should be put towards after school programs and field trips or school gardens and greenhouses. Are there advantages or disadvantages to using outside organizations for farm or garden-based learning? Advantages of using outside organizations may include increasing the chances of a successful and productive garden with employees experienced in agricultural production techniques as well as an increase in access to land resources. On the other hand, UAP educators may not be well trained in delivering STEM curriculum, and therefore unable to properly connect the garden-based lessons to science and math standards. If true, school districts could support continuing education for UAP program coordinators in the area of STEM education.

We found that there was no online national directory of UAPs. In addition to being helpful for a follow up study, a UAP directory would be useful to programs for advertising their presence and sharing information and resources. A UAP directory would also be useful to communities and schools for finding potential partners or collaborators.

Given the rise of UAPs in food insecure communities and the widening socioeconomic gap in STEM education, future studies on alternative methods of youth education are needed. In this study we found that many UAPs are actively using STEM curriculum in their outreach to youth, while many others may be indirectly influencing STEM development through activities that utilize science and math for food production, marketing, and consumption. Beyond integration of STEM curriculum, UAPs help improve the healthy eating habits and physical activity of their students that have been shown to directly influence STEM performance in school (Hollar et al. 2010). Yet UAPs exist outside of the domain of the school system, where their teaching approaches are rarely informed by state standards or evaluated for effectiveness. STEM programs and UAPs have historically functioned separately, yet clearly there are opportunities for integration of the two, with the benefit of producing synergistic effects. Youth from disadvantaged communities could potentially be recruited into STEM through UAPs, reducing the achievement gap (Ray et al. 2016), while UAPs could benefit from more recognition and funding from STEM sources.

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