Growing Garden-Based Learning:

Mapping Practical and Theoretical Work through Design

Environmental Education Research

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Biographical Note

Dr. Steven Zuiker is a learning scientist in the Mary Lou Fulton Teachers College at Arizona State University. His research is broadly based on the notion that ideas are only as important as what we can do with them. Learning environments, like school gardens and video games, as well as research findings, like scholarly journal articles, can each be both useful and used to create value in scholarly, educational, and local communities. Dr. Zuiker's research agenda explores how to design activities, resources, and projects that interconnect classrooms and schoolyards, digital video games and real-world activities, and ultimately, educational research and educational practice.

Amanda Riske is a math educator in the Mary Lou Fulton Teachers College at Arizona State University. Her research …

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Abstract

Echoing calls to expand environmental education research through design, this study explores the role of design in garden-based education and illustrate its contributions towards practical impact and theoretical insight. Design can explicate and map conjectures about resources, tasks, roles, and other supports for learning and teaching then, in turn, can be teste to illuminate how these supports operate together. Design, as such, focuses holistically on examining systems of activity. To these ends, case study method organizes analysis of garden-based learning in a US fifth-grade classroom (ages 10-11) that enacted a project-based gardening curriculum. Findings develop threes themes about designed supports: relating content and context; aligning curricula and gardens; and designing for curiosity and wonder. Discussion considers the role design plays in organizing, enhancing, and ultimately growing garden-based learning as well teaching and learning in environmental education more broadly.

Keywords: design-based research, garden-based learning, case study

Introduction

Garden-based learning (GBL) in schools typically organizes environmental education around campus-based plots (e.g., Malone & Tranter, 2003). Of course, organizing plots for classes also entails integrating gardens into schools. Gardens and schools, however, do not simply integrate themselves. Each is an intentionally designed context, embodying, reflecting, and sometimes also resisting human thought and action (Cole, 1996; De Landa, 1997; Pickering, 1995). Therefore, as schools integrate gardens, they confront wide-ranging questions about how either to enlist and adapt well-designed gardening curricula or to design curricula themselves. In this way, the goal of integrating gardens into schools can be viewed as a series of design decisions, including where to locate the garden, when and how to involve students, who maintains it, and what goals and aims GBL should pursue. As designed spaces, both schools and gardens are malleable, changeable, or reconfigurable and thereby open to new possibilities, including the very ways each is integrated into the other. At the same time, both schooling and gardening embody constraints and limitations that often temper efforts to transform them. To build on prior discussion of the role of design in environmental education in general and GBL in specific, this paper develops a case study of designing GBL within school settings in order to examine the role design plays in organizing, enhancing, and ultimately growing teaching and learning in environmental education.

Focusing on the content of teaching and learning in relation to its context is obviously important to environmental educators in light of what is known about how people learn (NRC, 2000; 2018). Content-context relations are increasingly important as a practical matter too because the number of school gardens are growing. One annual sampling of schools in the United States suggests that the number of school gardens doubled between 2006 and 2013

(Turner et al., 2014). More recently, USDA (2015) censuses in 2013 and 2015 established 42% growth over two years. Noteworthy evidence of growth is also practically important because the 7,100 schools with gardens that responded still remains a small fraction of total schools. Therefore, while the trend suggests a more concerted use of school campuses for gardening, it also underscores the value of enhancing GBL to further accelerate growth.

Focusing on content and context in relation to each other entails new opportunities and challenges for environment education research (Rikinson, 2006). As we argue below, lines of inquiry into GBL generally underspecify the process of learning as well as what, beyond a garden, is designed to support learning (e.g., Cobb et al., 2003). (Specifying garden-based teaching processes and supports also matter but in service to a robust argument this study concentrates on learning only.) We contend that characterizing the process of learning and how it relates to intentionally designed features can accelerate efforts to understand, enhance, and grow GBL.

To these ends, the article first presents activity systems as a theoretical lens for organizing the case study then enlists the same lens to critically examine insights into designing GBL. Against this backdrop, we present a case study of GBL in order to interrogate one designed approach then discuss the complementary role of design research (i.e., Cobb et al., 2003) to the longer standing roles of contemporary research design on GBL.

Activity Systems: A Theoretical Lens for Understanding When Is Garden-Based Learning

Our work is grounded in socially-, relationally-, and culturally-oriented theories of learning (Case, 1996; Greeno et al., 1996) in which individuals remain units of concern but activities are units of analysis. In a discussion of science education, McDermott and Webber

(1998) suggest asking not what is science (i.e., content) or where is science, (i.e., context), but rather when is science. Asking when science occurs rather than what constitutes science or where science is located presumes opportunities emerge in through experience and real-time interaction with other people and the environment. These learning and teaching moments are most powerful when they “overlap systematically with the lives of the children” (p. 323). We embrace this question “when is garden-based learning?” (GBL) here, shifting the focus of analysis to moments, lessons, and whole units of integrative activities in environmental education. We therefore broadly ask *when* is garden-based learning (GBL) before *what* should be learned or *how* it should be taught (underscoring our analytical focus on learning). In this way, we focus on what kinds of activity count as scientific and as environmental education and, equally important, counted by whom and with what consequences (Esmonde, 2017). In turn, the analysis below locates and analyzes GBL in social interaction as it systematically unfolds in activity over time.

Activity systems include observable social interactions (e.g., tasks, projects), artifacts of these processes (e.g., notes or drawings, garden beds), and what is designed to support them (e.g., science journals, driving questions; Greeno & Engeström, 2014). By analyzing interactions, artifacts, and designed supports in relation to one another in this study, socio-cultural theory accounts for patterns and functions among activities in school gardening systems. Illuminating these patterns and functions contributes to process-oriented understanding of learning (as well as gardening) that can inform an iterative approach to improving designed supports for learning processes (Sandoval, 2014). However, focusing on processes raises questions of when (and under what conditions) school gardening gives rise to learning opportunities (McDermott & Webber, 1998). To answer questions about *when* is GBL therefore entails tracing how activity unfolds in time and space, which we discuss further in the data analysis section below.

Integrating Gardening and Schooling for Learning

Integrating GBL with schooling is a longstanding agenda. Miller (1904) observed over a century ago that gardening in schools “is not a new phase of education, but an old one gaining the recognition and support its importance merits” (p. 3). Nevertheless, integrating gardening into schooling, then as now, reflects enduring tension between evolving opportunities and persistent challenges. We review general aspects of GBL in order to better resolve practical and theoretical challenges that accompany these efforts.

Characterizing What Garden-Based Learning Efforts Involve and Accomplish

Integrating GBL with schooling is a non-trivial foundation in order to provide learning opportunities in and with gardens. The practical wisdom of garden leaders illustrates this point. A survey of over 400 garden leaders across the United States suggests that, when gardening and schooling can be integrated, substantive students experiences increase (Burt et al., 2019). At the same time, integrating gardening with schooling is multi-faceted; that is, it involves much more than GBL. For example, inquiry into 21 successful school gardens in New York City suggests that a well-integrated school garden is “a maintained garden, at or near a school, is primarily used as a learning environment to create meaningful experiences for students, is a valued part of the school’s culture, and is sustained over time” (Burt et al., 2017a, p. 1518). While student learning experiences are obviously key, integration entails a broader scope with multiple facets beyond learning and teaching at the classroom level.

Given that schools and gardens do not integrate themselves, it is key to broaden the scope of GBL in order to understand what gardening and learning, together, specifically involve. A robust example of designing that illustrates this broader scope beyond teaching and learning is the Garden Resources, Education, and Environment Nexus (GREEN) tool. Burt et al. (2017a) developed the GREEN Tool in order to identify and characterize four different domains that guide garden integration efforts in schools. We also contend that these domains can serve as a useful foundation for exploring the work of design in research on GBL. Therefore, we briefly describe these domains in anticipation of the roles they play in the case analysis below.

The domains specified in the GREEN tool are resources and support; the physical garden space; the school community; and student experiences. The model also maps out a progression of components for each domain in order to communicate how to begin and where to go next. For example, the student experience domain includes six components. It begins with (1) establishing curricular connections then progresses to (2) time spent in the garden and the (3) activities completed during that time. Time spent on activities, in turn, gives rise to (4) engagement then (5) tasting and (6) additional learning. Altogether, the model identifies nineteen different components across four separate, domain-specific progressions, underscoring the complexity and coordination that precedes, accompanies, and follows GBL.

Importantly, the GREEN tool domains serve as a useful foundation for exploring design because all four domains operate in relation to one another. “Schools may continually move through the [four domains], addressing new components as the school and garden evolve” (Burt et al., 2016, p. 11). Each domain relates to the others, mutually supporting school gardening. As such, integrating gardening and schooling for learning is non-trivial; it is an achievement over time, not at launch; it involves interdependent continua, not multiple binaries. Integrating therefore reflects evolving system of relations among domains. As a foundation for understanding GBL, these relations suggest that school gardening from one school to the next can be viewed as complex and varied systems of integration activities.

Insofar as mapping the domains and components of an integration model illuminates what GBL involves, then mapping valued outcomes begins to illuminate what GBL can accomplish. To this end, Diaz et al. (2018) successively surveyed garden leaders in the US state of Florida in order to resolve consensus outcomes. Many of the 38 outcomes generated through this study align with the integration model above. For example, with respect to the student experiences domain, one consensus outcome is that teachers develop knowledge and skills for cross-curricular integration, which aligns with the curricular connections component. Meanwhile, some consensus outcomes extend beyond what is explicit in the model such as students sharing knowledge about gardening. For the purposes of this review, these two illustrative outcomes demonstrate productive overlap (and establish a degree of methodological triangulation) between a model and a set of outcomes for GBL. However, Diaz et al. also contend that consensus outcomes like the two examples above enable researchers and practitioners to reason from ends back to means or, said differently, to design backwards from outcomes to inputs.

The work above by Burt, Diaz, and their respective colleagues begin to illustrate how design can clarify the nature of both challenges and opportunities associated with GBL. They also reflect a longstanding tradition of collaborative and participatory research. At the same time, our own work resonates with a research challenge in medical education (McKenney & Reeves, 2020) as well as this journal to consider how "the development of future environmental learning research might well benefit from a consideration of ideas such as design experiments and [development and research]" (Rickinson, 2006, p. 452). Such a consideration, according to Rickinson, involves reconceptualizing educational research topics like GBL in terms of design science rather than either social or natural sciences. Design science seeks to illuminate connections and more deeply link theoretical and practical work around the complex development goals associated with GBL and other environmental education topics (e.g., Budwig, 2015). The final sub-sections of this review therefore consider current research in integrating gardening and schooling for learning in relation to this research challenge.

Understanding How Gardening Organizes Learning, and Vice Versa

Integrating schooling and gardening organizes activity systems through which students interact with a local ecology and encounter the natural world. The ideas of ecology and nature, however, are embedded in wider activity systems that reflect cultural norms and, often, ahistorical experiences with a campus, school community, and neighborhood (e.g., Nabhan & Trimble, 1994). The complex relationships between ideas and places resonate with enduring tensions between the content of academic learning and the contexts in which learning academically unfold. Echoing our theoretical perspective, we do not ask what or where is GBL, but rather when is GBL. Asking when enables us to explore how and why opportunities to garden create learning and teaching moments that add up to lessons and units (e.g., Lemke, 2000). Asking how and why recognizes not only that content and context remain inextricably tangled up in one another but that garden-based activities can systematically intersect with the everyday experiences of children (i.e., McDermott, & Weber, 1998). This review of GBL argues that research wrestles with these same tensions, albeit with limited consideration of design (e.g., Rickinson, 2006).

Foremost, learning with school gardens remains promising. A comprehensive review of research summarizes “a preponderance of positive impacts on direct academic outcomes” (Williams & Dixon, 2013, p. 211). At the same time, the review also expresses two critical concerns. First, the selected studies, as a whole, lack methodological focus and clarity. And second, the curricula featured in the reviewed studies may be underdeveloped and weakly aligned with academic areas. Viewed through the lens of activity systems, this latter concern about curricula suggests that the relationship between academic outcomes and curricular structures and processes is underspecified, incomplete, or both.

In relation to this review, Wells et al. (2015) conducted a randomized controlled trial that addresses methodological concerns raised by Williams and Dixon (2013). The study punctuates prior research, resolving modest, statistically significant learning gains attributable to a GBL intervention (Wells et al., 2015; cf. Klemmer et al., 2005). At the same time, the curriculum for the study also underscores the aforementioned concerns about curricula. Specifically, the study enlists individual lessons drawn from ten different curricular models. The trial therefore reveals that GBL in general works but not how any of the ten models contributed to the intervention. It is equally noteworthy that these concerns reflect an enduring challenge (i.e., Williams & Dixon, 2013).

In a review of health and development outcomes associated with GBL, Ozer (2007), much like Williams and Dixon (2013), concludes that "beyond investigating whether school garden programs are effective in influencing relevant health and social outcomes, it is critical to study how and why these effects might be achieved" (p. 861) Likewise, in a broad review of the benefits of school gardens, Blair (2009) concludes that "researchers and educators should pay attention to how they design the garden and the learning experience in the garden" then elaborates that "gardens require embedded support mechanisms that lighten the teacher's burden" (p. 35). These separate reviews of research on GBL arrive at similar conclusions: scholarly literature documents promising results on valued outcomes but underspecifies reliable guides for designing curricular processes and programs. By extension, if research demonstrates that GBL works, then it can also reliably communicate how gardening curricula enable GBL to work well and, further, inform ongoing efforts to enhance how it works (i.e., Rickinson, 2006). This suggests that research into GBL, collectively, is addressing a primary challenge—demonstrating that GBL can enhance learning and other valued outcomes—without also generating insight into how particular programs or curricula achieve these outcomes or how a particular program might be integrated into teaching and learning.

Designing for Garden-Based Learning

Empirical studies can report not only what students do and learn in gardens, but also how resources, structures, and practices support and enhance learning. These garden-based activity systems include not only the tools provided (e.g., water hoses, environmental probes) but also the tasks that shape how learners use tools (e.g., watering plants, optimizing irrigation). They can also report the kinds of roles that students assume (e.g., observer, investigator) as well as expectations for how they enact these roles (e.g., noticing, problematizing). Developing and describing well-designed educational experiences illuminate how, for example, curricula enable gardens to be the teacher (e.g., Larson, 2015; Hyun & Marshall, 2003) or enable learning to emerge from actions and discussions among youth (e.g., Rahm, 2002) while also recognizing that learning to observe phenomena with a disciplinary framework "requires supportive learning environments and tools" (Eberbach & Crowley, 2009, p. 53). Well-designed GBL experiences that connect theoretical and practical work can therefore be challenging.

Designing for garden-based learning entails activities unfolding along multiple timescales. Garden experiences are brief activities that unfold from moment to moment as tasks position individual students to engage with real-time garden phenomena (e.g., Rahm, 2002). Garden experiences are also a longer process of noticing that unfolds from week to week as discussion activities position small groups to make sense of a changing setting in terms of focal concepts (e.g., Eberbach & Crowley, 2009). They are also a season-long process that unfolds from month to month as gardening projects position whole classes to explore how to grow tasty food (e.g., Zuiker & Wright, 2015). These three examples illustrate different timescales in order to characterize GBL in terms opportunistic moments of interest-driven exploration, discretely framed observations aligned to disciplinary frameworks and standards, and sustained projects anchored to driving questions. They also illustrate that integrating learning among campus plots and classrooms occurs in multiple, and sometimes wide-ranging, ways. The case study of designing for GBL below can begin to explore whether and how to advance concerted design efforts in environmental education.

Locating Practical and Theoretical Agendas in Garden-Based Learning Design

While GBL design may remain underspecified, it is still possible to locate practical and theoretical work around design. Two examples illustrates this point. As one example of locating design in practical work, the student experience domain featured in the GREEN tool reviewed above (Burt et al, 2016) maps out a practical sequence for organizing GBL. As a basic design for learning, the student experience domain specifies a progression of six components associated with the physical and social environment (see Figure 1 below).

[figure 1 near here]

A conjecture underlying the GREEN tool is that incorporating more components from the student experiences domain will foster deeper integration between schooling and gardening. We argue that the GREEN tool therefore serves as a design framework. It systematically incorporates insight about enduring problems of practice that can support practical impact.

Design may also serve to locate implicit theory working in this progression. Drawing on Figure 1, student experiences in a garden minimally entail curricular connections, or “the relationship, relevance, and fit of the garden with state-mandated learning objectives, aims, and goals for students in a particular grade or class" (Burt et al., 2018, p. 852). With more time and varied activities, student experiences incorporate the garden to a greater degree. Finally, learning opportunities beyond curricula fully integrate the garden into student experiences. In particular, learning opportunities contrast curricular connections because they entail "learning facilitated by the garden that is unrelated to mandated curriculum or learning standards" (Burt et al., 2016, p. 10). With respect to the literature on GBL reviewed above, the student experience domain generally recognizes the need for curriculum development and alignment; it emphasizes curricular connections as minimally necessary for integrating GBL into student experiences then specifically focuses on additional, often implicit components. Taken together, these practical and implicit theoretical details translate GBL into design, specifying six general design features (i.e., student experience components).

In contrast to the integration framework featured in GREEN tool, a second example locates design in theoretical work. Ozer (2007) provides a conceptual model of school garden programs that relates program components (e.g., hands-on education) to proximal and distal effects (e.g., topical learning, conservation practices). While the model links general learning features to outcomes, each feature remains independent; they can be readily combined but whether, and how, a particular combination is also integrative (and not merely additive) is underspecified. As such, the model can resolve component understanding but deeper insight may be necessary to guide design or inform refinements to processes or programs.

In sum, these examples illustrate practical and theoretical work, respectively, associated with GBL, but neither addresses how features relate to one another or might lead to valued outcomes. In turn, features and components apart from the systems and contexts in which they operate constrains efforts to localize or optimize them in a particular school or district. That is, insofar as a productive and consequential GBL is not one-size-fits-all, then design is a means of enabling iterative refinements that approximate a tailor-made experience, one that systematically intersects the everyday lives of youth (cf. McDermott & Weber, 1998). The remainder of this article therefore presenting a case of GBL that seeks to make progress on efforts to locate both practical and theoretical work in design.

Methods

This qualitative case study (Stake, 1995; 2005) examines garden-based learning (GBL) in schools. Because the study reflects a socially co-constructed context among the authors, teacher, and students, the focus of the case emerged as the study unfolded. We focused on student learning but did not otherwise predetermine or bound the focus (e.g., Wells et al., 1995). In this sense, the study represents research into an emergent but ultimately specific and well-defined case of student learning that explores how design can support GBL.

Curriculum

The case derives from the enactment of an elementary school environmental science curriculum (Zuiker & Wright, 2015) that organizes project-based learning around the everyday settings and practices of gardening. Project activities support learner-centered, collaborative design as manifested, first, in the initial construction of garden plot and then iterative refinements thereafter. These activities evolve across four general phases—scheduling, planning, monitoring, and harvesting. In this way, projects position students as designers who are responsible for growing tasty food. They work to develop, improve, and enjoy a garden plot, enlisting physical and informational resources (e.g., hoses and irrigation schedules) as well as conceptual tools (e.g., soil moisture). They also work to document and understand gardening by means of visual observations comparisons over time using digital photography and measurements. Projects therefore involve design but also refinement informed by unfolding phenomena (e.g., yellow leaves, muddy soil). In this way, the curriculum can explore ideas about ecosystem dynamics in relation to general concepts like systems and patterns and specific practices like asking questions and interpreting data that align with the Next Generation Science Standards (e.g., NRC, 2011; 2013) developed for United States elementary schools and resonate with standards elsewhere (e.g., ACARA, 2015; Hazelkorn et al., 2015).

As the plot grows into a garden, students actively construct observations and negotiate open-ended situations in relation to present and possible designs. These learner-generated designs serve to recruit and transform practices and resources associated with both gardening and science. Gardening, in sum, is a sympathetic medium for the study of authentic engagement with complex environmental systems where learner-generated design positions students as active agents of inquiry rather than as passive objects of instruction.

Participants

Nineteen fifth-grade students (10-11 years old) and their teacher, Mrs. Green (all names are pseudonyms), enacted the curriculum in their urban school classroom and campus in the southwest United States across one semester. Mrs. Green is an experienced educator with multiple years as a classroom teacher and district curriculum developer. She identifies as American Indian and is a member of a US southwest indigenous nation. Meanwhile, the majority of her students identify as Latinx or Black; therefore, the class like the vast majority of students in the school come from non-dominant communities. The families of all participating students live near the school campus and all students can walk to school each day, establishing uncommonly small geographical boundaries for the school community. However, many families also experience food insecurity, compounded by limited access to fresh, unprocessed groceries within the same geographical boundaries. Importantly, the school principal recognizes and values the physical proximity of families to the school and prioritizes school gardening as a way of linking the school campus with the surrounding neighborhood. The warm desert climate, meanwhile, enables Mrs. Green and other teachers to organize two gardening cycles during the 9-month academic year. The case below considers the second, spring semester cycle .

In relation to these classroom and school-wide gardening agendas, I (Zuiker) was in the third year of an ongoing partnership with the principal and seven teachers. The partnership is a mutual effort to organize and improve GBL during school hours and for school-community engagement during evenings and weekends. Emphasizing mutual effort focuses insights and innovations around their relevance to practice (Gutiérrez & Penuel, 2014) and sustainability under existing conditions (Penuel & Gallagher, 2017). Mrs. Green and I worked closely to support the fifth grade enactment. She and I reviewed and optimized each session plan together beforehand and briefly reflected on session enactments together afterwards. I also judiciously participated in later sessions as an informal teacher's aide, answering questions posed by students and occasionally posing questions in order to make their thinking visible.

Data Generation

The fifth grade class participated in sixteen project-based gardening sessions over four months, totaling 18 instructional hours across 12 classroom and 10 garden sessions. I (Zuiker) observed all sessions and participated in 8 sessions, documenting (a) session activities via multiple digital video and audio recordings (approximately 50 total hours) as well as (b) individual actions via digital photographs of learner-generated artifacts produced in relation to these activities (e.g., notebooks entries, material changes to garden plots).

Data Analysis

Interaction analysis (IA; Jordan & Henderson, 1995) organized a qualitative examination of social interaction among students and between students and the teacher. IA examines what counts as knowledge among participants when students interact with each other, consistent with our theoretical orientation and the question "When is GBL?" As an analytical framework, IA considers what is relevant and consequential to participants (Hall & Stevens, 2015); it also provides an ongoing check in analyses of youth, minoritized populations, and less powerful others that run the risk of producing deficit accounts of their perspectives and practices when the systematic intersections with individual and community assets can be more productive and relevant (e.g., McDermott & Weber, 1998).

IA proceeded sequentially in order to characterize project-wide participation as it unfolded in time, from one activity to the next and from one session to the next. As a data transformation and reduction strategy, IA involves content logging. We therefore segmented sessions into component activities and further divided these activities into episodes of social interaction (e.g., teacher's question and student responses); importantly, segmenting reflects the emergent order of social interaction and does not necessarily map onto the designed intentions that a teacher or curriculum (e.g., lesson plans). As an analytical technique, IA methodically examines sessions, activities, and episodes in order to enhance both the range and precision of observations. IA attends to the materiality of gardening activities, the conceptually and physically tooled environment, and the ways learners use them. To inform the case report below, content logs organized general, relational annotations using contiguity-based connecting strategies (Maxwell & Miller, 2008). "Contiguity-based relations … involve juxtaposition in time and space …; their identification involves seeing actual connections between things, rather than similarities and differences" (p. 462). Analysis therefore links and juxtaposes social interaction across sessions, activities, and episodes.

In this study, annotated content logs advance a progressive analytical focus that arrives at six key episodes connecting learning across time and space. The analytical goal of this effort is to examine how the physical design of schools gardens and educational design of GBL programs organize opportunities for sensemaking and knowledge building. In effect, gardens affords many powerful forms of learning but design organizes what knowledge counts and who can count it. Drawing on activity systems as a theoretical lens, we examine not only what learners bring but also what gardens do. We, therefore, employ the idea of affordances to sharpen the focus of analysis. Affordances are "actions that the context offers up to the individual" (Jornet et al., 2016, p. 296); with gardens as with classrooms, contexts afford many possibilities but not all actions are equally probable because learners may not recognize them. In this sense, perception is a form of action. IA therefore interrogates learning (and teaching) processes as socially designed systems of action among individuals (i.e., students, teachers, parents) and environments (i.e., classrooms, campus gardens, homes). As such, social interaction with gardens demands questions about "when is GBL?" because relations among individuals and contexts remain dynamic and evolving. The case study below, therefore, examines a designed curriculum, the social interactions among students, and the actions that a school garden offers up using the theoretical lens of activity systems.

Findings

This section contextualizes then analyzes an illustrative episode from a fifth grade classroom community that implemented the Connected Gardening curriculum with their school garden plot across one semester. The goal of examining this episode as case is to illuminate garden-based learning (GBL) in relation to design and, therein, elaborate existing efforts to locate curricular design for GBL in both the practical and theoretical work of design.

Context of the Case

The partner teacher, Mrs. Green, adopted a project-based approach to gardening though close collaboration with her colleagues, principal, and me (Zuiker). The project-based curriculum therefore served as the primary activity system, which includes observable social interactions, artifacts, and what is designed to support them. Within this system, the fifth graders themselves assumed responsibility for planning, monitoring, and harvesting one of the nine 36 square-foot garden plots on their school campus. The driving question guiding their work was “how can our garden grow tasty food?” Their project responsibilities positioned all 19 students as not only the owners of their garden plot but also its authors. As designers, the students shared one common goal: growing tasty food together. Their responsibilities therefore involved wide-ranging design decisions that included selecting seeds, scheduling planting and irrigation, monitoring and interpreting visible markers of garden conditions, measuring and interpreting environmental indicators of garden conditions, and, ultimately, raising questions about unresolved social and technical tensions (e.g., salsa versus pizza garden; how much and how often to water soil). Typically, students also identified and made sense of unexpected outcomes (e.g., yellow leaves, muddy soil) in order to improve their design decisions (e.g., modify the irrigation schedule). The project involved regular visits from classroom to garden in order to tend the plot, to observe and document plant and soil health, and to determine what action to take.

Importantly, the fifth graders and their garden project were not alone. Seven classes assumed responsibility for most other plots and three school families managed the final plot; each plot included a sign indicating its owners and designers (e.g., Mrs. Green’s Fifth Graders).

Given multiple gardens growing in parallel, each class project generated comparative insights for the others while sometimes provoking competition among classes and always engendering awe and humility when assessing the flourishing family plot. The many projects unfolding in the school garden, therefore, not only enabled youth to author the campus materially and conceptually through their plot designs but to do so relationally along with seven other classes and some school families. As such, individual classroom garden projects cannot be divorced from the multi-class and family garden program.

Case Narrative

In relation to our consideration of DRB and design in the research literature on GBL, this episode analysis involves two arguments. First, it seeks to establish that the activity of all three participants--Jose, Mrs. Green, and Domingo—maps onto all but one design component in the GREEN tool's student experience domain (Burt et al., 2017a). This resonance affirms the practical work reflected in Burt et al. (2016) integration framework. Second, the case analysis engages in theoretical work to explicate a theory at work in student experiences domain. This explication illustrates an alternative integration flow. Equally important, in illustrating this point it also illuminates interplay between practical and theoretical work that is at the heart of design and its potential contribution to GBL and environment education research.

The specific case we present to advance this argument emerged from analysis of social interactions among students and with Mrs. Green as the project unfolded across four months. We considered peer interactions during small group activities, teacher-student interactions during whole-class activities, and Mrs. Green's opportunistic visits to some peer groups during various activities. The episode that we focus on occurred during the third of ten garden visits. Student small groups are observing germinating seeds and, in particular, distinguishing plants with fibrous and taproots as their teacher, Mrs. Green, circulates among them. In Table 1 below, she shares an observation with students examining a row of watermelon then several students respond. A student named Jose notices a watermelon flower and raises a question that Mrs. Green and a peer named Domingo address.

[table 1 near here]

This episode is a common phenomenon during school garden activities. Students observe their plot and notice aspects that are new or different; meanwhile, the teacher facilitates the process by formulating probing questions, therein fostering deeper engagement. Jose responded to one such probe by raising a pointed question—"how come it's growing flowers"—that becomes the focus of a discussion. For her part, the teacher, Mrs. Green, engaged Jose with an open question then guiding questions that attempt to make a curricular connection to a classroom lesson on plant anatomy. While Jose and Domingo each shared relevant prior experience, the discussion ends without a curricular connection when Mrs. Green shifts to another group.

The episode is not only familiar but also illustrative because it maps onto most key components of the GREEN tool's student experience domain. Specifically, the planned focus on roots constitutes a curricular connection; the episode is from the third of ten garden activities over four months, establishing moderate to high time spent in the garden; as part of a project-based curriculum, activities involve hands-on gardening related to an academic focus on root systems; and finally, Jose and Domingo's engagement reflects an interest-driven discussion beyond the planned curricular goals. Consolidating these points, Figure 2 below summarizes how the episode maps onto the student experience domain.

[figure 2 near here]

The remainder of the analysis draws on the theoretical notion of affordances introduced in the data analysis section above in order to examine the role of design. To do so, we consider how the episode informs an alternative mapping of the components of the student experience domain. Specifically, we consider learning opportunities as complements to curricular connections rather than a culmination of them. This alternative begins to enlist design in order to expand and refine the student experience domain and serves to highlight GBL as a design challenge rather than as separate practical and theoretical challenges. The analysis progresses across three subsections that consider (a) relating content and context; (b) aligning curricula and gardens; and (c) fostering curiosity and wonder.

Relating Content and Context

Drawing on the notion of affordances presented in the analytical framework, the episode demonstrates how experience relates content (and content-related outcomes) and context to one another across activities, therein building connections over time. In this way, social interaction makes sense of and builds knowledge with gardens not only in real-time discussion but over time too (Jornet et al., 2016). This is evidenced by the fact that all three participants in the conversation reach back in time to recruit prior experiences into this episode. Foremost, Mrs. Green recruits the aforementioned flower anatomy lesson in her efforts to guide Jose towards relevant resources for answering his question. Meanwhile, both students recruit personal experiences: for Domingo, a conversation with a different teacher and, for Jose, contributions to his mother's home project. It is also noteworthy that neither student recruits prior lessons despite Mrs. Green's guiding questions. Thus, in asking when is learning, then the students rendered systematic interactions with their everyday lives (outside of school) while also rendering these lessons inert.

The episode also demonstrates how experience relates content and context to one another during activities, affording connections simultaneously in real-time. For this reason, experience is not only an unfolding sequence of interaction but also a simultaneous series of competing influences in each discrete moment (Jornet et al., 2016). The visit afforded Jose an opportunity to notice watermelon plants among other garden features, observe a watermelon flower closely, and, in this case, ask “how come it’s growing a flower,” all within the span of several seconds. Jose’s direct experiences with the garden plot, in turn, give rise to questions and comments during the episode that imbue the same watermelon flowers with deeper significance. Together, these characterizations of the episode highlight that student experiences are a confluence of both the sequential influence of unfolding interactions and the simultaneous influence of what learners and the garden contribute in each discrete moment. They also highlight that activities can be purposefully designed for content-oriented curricular connections but inevitably remain open to unintended, serendipitous context-oriented learning opportunities as well. School gardens are among many authentic sites that afford interplay between content and context.

At the same time, insofar as gardens can foster interplay between content and context, then the episode also illuminates the challenges of fostering this interplay during real-time student experiences. Mrs. Green first employs open questions and then direct, leading questions but neither links a lesson to the flower for the students. First, she revoices Jose’s question “I wonder why they are growing flowers”, ratifying it as a topic for discussion, then seeks to make visible Jose’s thinking, asking “Why? Do we know why?” These general techniques are consistent with project-based approaches that seek to foster and engage student questioning in order to capitalize on interest-driven inquiry. Domingo responds by expanding the topic to bolting plants then Mrs. Green narrows it again by asking a focused, closed question about a plant anatomy classroom lesson. While the question seems to lead him towards content, Jose relates the flower to his mother's project. In this way, the discussion does not connect prior lesson content with an emergent, context-oriented student question, thus not capitalizing the invitation that Mrs. Green's question presents.

The episode also illuminates a second, fleeting moment of interplay between content and context. Mrs. Green's open questioning prompts Domingo to recount a conversation with another teacher about flowering radish plants. Domingo's response establishes, first, that he and the garden each contributed to a learning opportunity with another teacher and, second, that he reflects on this conversation in order to contribute this learning opportunity (e.g., Clancey, 2008). The episode highlights simultaneous influences on participations, including the home project that Jose recalls, the conversation that Domingo recalls, and the lesson that Mrs. Green recalls. The episode, therefore, illustrates how engagement with garden plants can enlist prior experience to co-construct understanding through discussion, albeit without forging interplay between the context and content, underscoring more challenges between aligning curricula and gardens.

Aligning Curricula and Gardens

The illustrative episode in Table 1 also lends insight into the designed relationship between curricula and gardens. In this instance, aligning curricular topics and garden phenomena proved challenging for two reasons. First, despite Mrs. Green's guiding questions, Jose's question remained dissociated from a relevant, prior lesson. Said differently, despite alignment, the discussion did not link a learning opportunity to a curricular connection. There is no obvious explanation for this dissociation but one contributing factor may be the four-week span of time between the lesson on flowers and the question about flowering watermelon. This suggests that the designed relationship between curricula and gardens may include aligning or coordinating a curricular progression with garden progress.

As a second challenge, Domingo's contribution about vegetable flowers afforded a learning opportunity that could have built upon the same prior lesson. The topic of the earlier lesson focused exclusively on fruit flowers. While pollinated flowers yield tasty fruit in watermelon, flowering vegetables like radishes yield a bitter taste (i.e., bolting). In turn, the contrasting significance of flowering fruit and vegetables are themselves affordances for monitoring and harvesting a garden plot. This reflects that the well-known fact that the intended design or curriculum-as-planned underdetermines and underspecifies all that unfolds during an implementation or curriculum-as-lived. The relationship between curricula and gardens is not predetermined by design but contingent upon relationships and situational mechanisms that underscore the need for flexible and adaptive designs that enable teachers to modify a local, tailor-made implementation. Domingo's contribution underscores that curricular connections are a necessary foundation but not a constraint of what authentic physical and social environments afford.

Designing for both Curiosity and Wonder

The opportunities and challenges of relating content and context and aligning curricula and gardens discussed in the episode above not only strongly resonate with components of the GREEN tool's student experience domain but also illustrate how design relates the framework to theories about how people learn. The episode illustrates how the learning opportunities and curricular connections components mutually reinforce one another and hold the potential to enhance student experiences. Yet, striking resonant tones between content and context and between curriculum and garden is non-trivial. Foremost, the curricular connection component is a pre-condition for establishing and ultimately sustaining gardens in schools. By the same token, reciprocity between curricular connections and learning opportunities may be a pre-condition for designing systems of learning and teaching (e.g., Rogoff et al., 2016). To understand more than if GBL works, it is also important to understand how and why it is working. Therefore, through the lens of design, this episode serves to problematize how these twin components relate to the flow of the student experience domain.

Figure 1 above suggests that learning opportunities follow from curricular connections rather than accompany these connections. As a means of envisioning a more complementary flow, it is useful to consider how students and curricula contribute to learning and teaching systems. To this end, Opdal (2001) contrasted curiosity and wonder within education. Curiosity is engagement driven by an existing frame typical in curricula. Examples of such frames include disciplines like ecology, topics like flower anatomy, and practical pursuits like growing tasty food. Curiosity therefore relates to what is already well-defined, if not altogether standardized like a flower diagram in a science textbook. Meanwhile, wonder is engagement driven beyond existing frames such as when something strikes a learner as peculiar or perhaps strange akin to Jose's question above. "Wonder is also consistent with a certain uneasiness towards the given, an inkling that there is more to it than tradition admits, and that this more can be investigated" (Opdal, 2001, p. 331). Wonder can therefore be a gateway to critical and creative engagement. Curiosity and wonder may be the double-face of student experience domain, resolving curricular connections and learning opportunities as opposite sides of interest-driven engagement.

With respect to the episode, Jose's interest appears consistent with wonder because his contribution to the unfolding conversation is a connection between school and home, between complementary projects in his family and in his class. Meanwhile, Domingo's interest is consistent with curiosity and his contribution is a connection between the significance of flowering among edible plants. Finally, Mrs. Green's engagement appears oriented towards student curiosity and directly facilitating connections between context and content, between the garden and the curriculum. With respect to the GREEN tool (Burt et al., 2017a), curiosity and wonder each foster interest-driven engagement, enlisting curricular connections and learning opportunities to cultivate rich student experiences. More broadly, design agendas enable scholarship to better illuminate how and why designed activity systems mediate and produce outcomes and, in turn, how teachers and schools can adapt the varied physical and social environments of school gardens in order to optimize engagement as an interplay between formal curricula and informal learning opportunities.

Discussion

By interrogating our own work in relation to one practical framework for designing well-integrated school gardens (i.e., the GREEN tool), our case study illustrates how design can productively account for both practical impact and theoretical insight. Specifically, the case serves to problematize a progression of six components that contribute to student experiences with school gardens (see Figure 1). In this section, we argue that problematizing like this is common, productive, and generative. It can create value and insight in environmental education research.

Efforts to problematize and continuously improve curricula and programming in environmental education are not new. For example, Ozer (2007) observed that "there are multiple pathways by which school garden programs may potentially strengthen the healthy development of students [...] while strengthening qualities of the school and the relationship of the school to the family and broader community" (p. 859). There is not a single optimal trajectory but rather multiple, competing pathways. Problematizing and continuously improving, however, are rarely reported in terms of design. In light of the underspecified evolutions of these pathways, design provides a lens and a toolkit through which to map designed features and supports (e.g., activities, roles) and, equally importantly, assumptions about how features work together systematically inside and outside classrooms. Design can illuminate how GBL operates towards practical impact. It can also resolve theoretical insights that account for why different GBL pathways can arrive at productive and complementary outcomes.

Research in environmental education can likewise expand to enlist not only research design but design research (see also Rickinson, 2006). When studies explicate designed supports and illuminate how these supports mediate learning, environmental education not only situates disciplinary content into environmental contexts (e.g., Greeno et al., 1996), but entangle content and context in the everyday lives of youth. These entanglements afford questions like "when is science?" (McDermott & Weber, 1998) and insights into systematic intersections with the everyday experiences of students. Our case study illustrates how the complex interdependencies underlying these entanglements can expand the scope of garden-based learning from discretely bounded, formal curricula to its deeper integration into classroom and schools and wider integration into neighborhoods and communities.

Expanding environmental education in the direction of design also enables researchers to adapt and optimize design features for other contexts and with other programs. For example, our case highlights how interplay between curricular connections and student interests can surface curiosity and wonder as resources for GBL. Translating these points back into designs for GBL entails productively framing this interplay. The GREEN tool's student experiences domain provides a starting point and our case one evolution of it. Figure 3 below communicates how the components of the student experiences domain might be reorganized to communicate this interplay.

[figure 3 near here]

Figure 3 relates learning opportunities directly to curricular connections and enlists two-way arrows to communicate its reciprocal influences on all aspects of student experiences. This alternative flow communicates that curricular connections remain a primary structure, but without a one-way influence on students experiences. Curricular connections, therefore, remain in dynamic relation to the unfolding experiences of youth participants. This reorganization of the GREEN tool illustrates how reporting design can create value and new insight. It contributes to both ongoing practical and theoretical work, and productively frames and navigates the increasingly dynamic, complex learning landscape in many countries.

In addition to documenting the evolution of curricula and programs, design is also a research toolkit for illuminating emerging (and enduring) principles for designing systems of learning and teaching with gardens (e.g., Barab, 2014). In this way, our case study is not a critique of the GREEN tool but rather an illustration of what Tatar (2007) describes as design tensions. There is a tension between criteria deemed relevant and choices deemed necessary in any design effort. For example, Tatar suggests that ending world hunger is a criterion for which any number of design choices might be plausible but only one or a few can be pursued. The pathways documented in figures 1 and 3 above express similar design tensions. This tension, in turn, enable researchers to explore and articulate principles underlying them.

Exploring design tensions in GBL also enables researchers and practitioners to strike a new balance between thought and action and between vision and agency (cf. Zuiker et al., 2017). Environmental education often concentrates on innovations as interventions. Research intervenes to change what educators do and, in turn, to produce a desired outcome. However, design innovations can also be viewed as ongoing services (see Barab, 2014) that invite researchers and educators alike to optimize a design for a particular setting, in part by responding to the local social and physical ecosystem. Rather than one-size-fits-all interventions, a well-structured invitation recruits multiple stakeholders and cultivates a tailor-made service with greater potential to systematically intersect the everyday lives of youth (cf. McDermott & Weber, 1998). In this way, a focus on design contributes to forms of garden-based learning that are more meaningful and consequential, underscoring its relevance to educational practice (Gutiérrez & Penuel, 2014). It may also prove to be a way of mastering variation, rather than minimizing it. Striking such a balance, however, is not without challenges.

With respect to balancing thought and action, each contributes to design-based research. Each is necessary to transform activity systems on campuses, in classrooms, and within communities. This balance remains a challenge, however, because power relations among researchers, educators, students, and other stakeholders obviously mediate whose thoughts and actions count and with what consequences (e.g., Esmonde, 2017). It is also an opportunity because when researchers think and act with other co-designers, accounts of how and why designs operate can illuminate complex interdependencies. Therein, design-based research expands beyond the limitations of simplified or essentialized portraits (Erickson, 2006) as well as the seductive reductions of factoring assumptions (Greeno, 1997). Many-to-many engagement around design can render more elaborate cases and well-specified design narratives (e.g., Barab, 2014), but introduces another tension.

With respect to balancing vision and agency, a plurality of perspectives can inform the practical and theoretical work of design. Shorter-term events afford thought and action, for example, give rise to a longer-term process of envisioning design and exercising agency to realize it. In other words, thought and action shape events like the episodes in our case or the lessons they were embedded in. Vision and agency, meanwhile, shape activity systems and contexts that can shift questions from "what is science" to "when is science." These shaping influences affirm that designs might be embraced or resisted but always remain open to ongoing negotiation and evolution. Therefore, balancing vision and agency through design also raises questions of whether and when a researcher, educator, student or another stakeholder might affirm, adapt, or abandon particular design supports in order to better realize a shared vision, introducing a final tension between resonance and resilience.

Limitations

While the case study supports arguments about the role of design in environmental education research, it nevertheless remains a single case study and a single curricular design. Focusing on one specific context and one among many designed approaches to GBL inevitably limits the value others may see in the analysis presented. The same limitation proves true of design as well.

At the same time that design seeks to expand perspective on environmental education, it remains inherently perspectival and maintains a set of assumptions that inevitably obscures as much as it reveals. Design is not a panacea but may hold potential to compliment other approaches at work in environmental education research (e.g., Rickinson, 2006). Reflecting on the many, often competing perspectives at work in education, Bruner (1997) observed, "just as depth perception requires a disparity between two views of a scene, so in the human sciences the same may be true: depth demands disparity" (p. 72). Finally, and in relation to the disparities in competing approaches and perspective, the GREEN tool provided a practical foundation for exploring the role of design in GBL in schools because it provides a comprehensive map towards integration but, in balancing multiple components, may restrict the level of detail into learning specifically. Other designs and topics other than GBL for that matter could also serve as foundations for advancing a conversation about the role design plays in the environmental education community.

Future Research

Building on this work, future research can refine or expand designs associated with GBL, using our case study as a foundation. Additional case studies might consider how classroom-level curricular processes relate to school-level programmatic processes. For example, multiple classes gardening in relation to one another affords possibilities that we did not investigate and would likely illuminate mediating influences on learning that operate on different timescales. Similarly, when campus plots enable classes to garden in relation to school families, the scope of design expands, with the potential to illuminate and better understand systematic overlap between school contexts and the everyday lives of students. And as design expands, GBL can productively frame wider relationships between school and everyday practices in families and local communities (Engle, 2011). Integrating gardens with schools and, more specifically, garden beds with school classrooms is already an effort to relate settings to one another and envision a broader landscape through which to design opportunities to learn. Illuminating and understanding key interrelations among different activities, settings, and participants associated with integration efforts is a necessary foundation for ongoing efforts to enhance GBL and teaching.

In this way, research on GBL can better navigate practical and theoretical tensions between learning and use; between content and context; and between knowing what and knowing how (e.g., Greeno & Engeström, 2014; Lave & Wenger, 1991; Vygotsky, 1978). These interdependencies underscore that what counts as knowledge cannot be separated from the activities and situations through which knowledge is produced (Brown et al., 1989).

Conclusions

In this article, a case study of garden-based learning (GBL) examined a focal episode of student experiences with a school garden. The case illustrated how a social interaction between a teacher and her students related content and context to one another as well as how these relations aligned curricula and gardens. As an example of design, the episode serves to affirm the practical work of design already operating in education settings and to expand theoretical work that can inform ongoing efforts to improve learning processes. Specifically, curricular connections and learning opportunities reciprocally influence one another and fuel interplay in systems of teaching and learning (e.g., Rogoff et al., 2016). Connecting practical and theoretical work in this way can enhance GBL and more reliably inform design.

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Table 1. Transcript of Small Group Garden-Based Social Interaction

Mrs. Green:	We got another watermelon coming out right here
Ariel:	That’s a watermelon? I thought it was corn.
Mrs. Green:	Right there, that’s all watermelon right there.
Jose:	How come it’s growing flowers?
Mrs. Green:	Oh I wonder why they are growing flowers.
Domingo:	She ((referring to another teacher)) said, she said that we don’t pick them, then you should not pick them when they grow flowers
Mrs. Green:	Why? Do we know why?
Domingo:	She ((the other teacher)) said, she said that the fruit is not gonna, the fruit or vegetable is not going to taste as good as if you [pick it
Jose:	[Ohhhh I know why the watermelon is growing?
Domingo:	She said this is radish and now it’s growing flowers and if you pick it right now it’s going to come out as a radish, but it is not going to taste as good as a regular radish.
Mrs. Green:	So, let’s think about our ((classroom plant anatomy lesson)) activity, remember when I had us put the plant together? So, what do you think? What was one of the parts from the plant?
((Both students start talking))	
Jose:	This one is growing flowers, the watermelon is growing flowers
Mrs. Green:	Yes

Jose: About a year ago, I was growing watermelon cuz my mom wanted to grow flowers. It is part of the plant because ((inaudible))

Mrs. Green: That is where the fruit and the vegetable grow from. If it doesn't create, if it doesn't grow a flower, is it gonna grow?

Jose & Dom.: No

Mrs. Green: No

Figure 1. GREEN Tool Design for Garden-Based Learning (adapted from Burt et al., 2017, p. 1524)

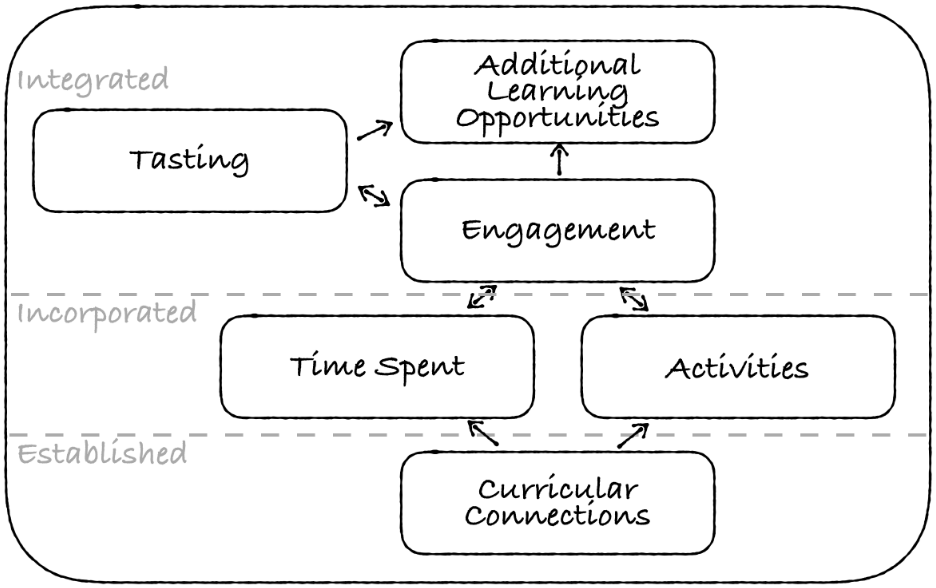

Figure 2. Mapping Connected Gardening onto GREEN Tool Design for Garden-Based Learning

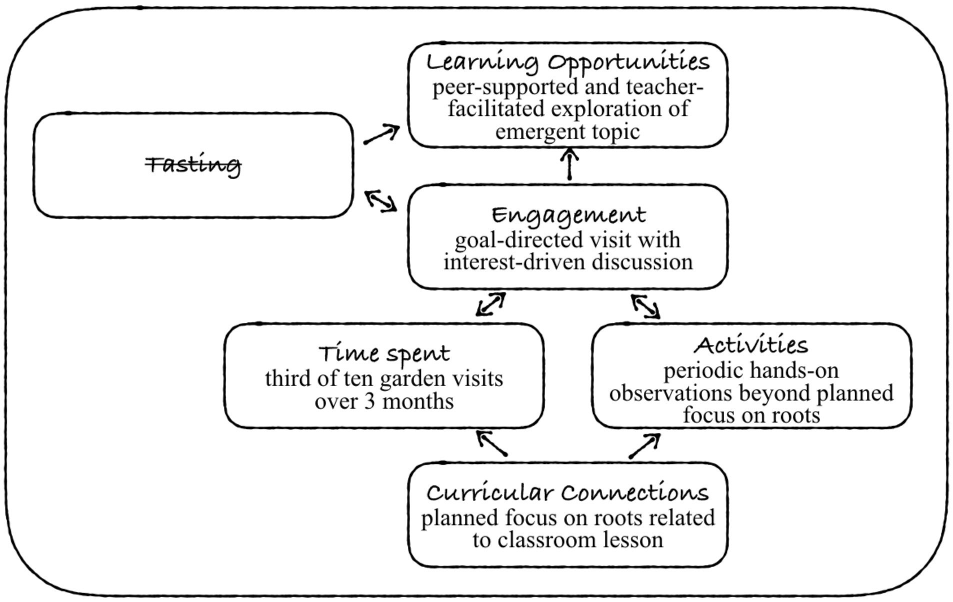

Figure 3. Possible Refinement of GREEN Tool Design for Garden-Based Learning

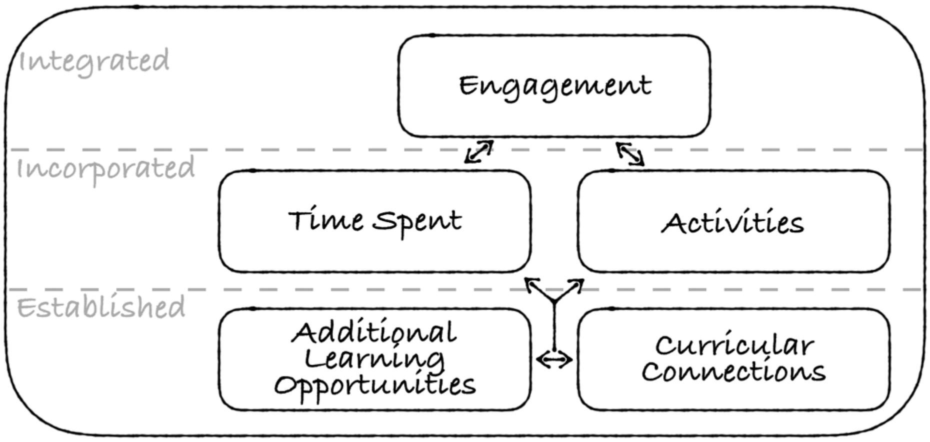

Figure 1. Flow of components comprising the GREEN tool's student experience domain (adapted from Burt et al., 2017a)

Figure 2. Student experience components with descriptions of how the featured episodes reflect them

Figure 3. Alternative flow of components in student experience domain