Title:
Science in the Learning Gardens: Engagement and Learning in Sixth Graders from Low-Income Diverse Schools

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Abstract:
This study relied on motivational models derived from self-determination theory to explain how garden-based science activities can contribute to minority students’ motivation and learning in science class and academic identity in science. Participants were 105 sixth-grade students from primarily low-SES families at two diverse urban schools. Students’ reported experiences of engagement (effortful, energized participation) in garden-based science activities predicted their engagement in the science classroom, science learning, and academic identity in science. Moreover, these relationships seemed to be mediated by students’ self-perceptions (feeling autonomous, competent, related, and purposeful). This suggests that the extent to which garden-based activities help promote students’ success in science may depend, in part, on how well these activities foster a sense of ownership, efficacy, belonging, and purpose.

Introduction/Perspectives:
There is growing concern among policy-makers and practitioners alike that, despite demographic trends showing an increasing rate of growth among minority groups, some of these groups (specifically, African-Americans, Hispanics, and Native-Americans) continue to be underrepresented in Science, Technology, Engineering, and Mathematics (STEM) majors in colleges and in STEM careers and professions (PCAST, 2010). Research shows that student disengagement from STEM learning starts early, and that if by eighth grade students lose interest in these subjects, they are less likely to pursue them in higher education (Fraser et al., 2011; Museus, et al., 2011; PCAST, 2010).

A robust body of research also shows the inadequacies of teaching minority students overall, resulting in a widening achievement gap between non-white and white students at all grade levels in schools (Bingham & Okagaki, 2012; Howard, 2010). To address these concerns, scholars have called for culturally relevant curriculum and pedagogy (Atwater, 1994; Babco,
promoting these pedagogical activities learning, and academic identity in science, minority pursuit (Saxton et al., 2014). Pursue develop the students to Ryan, 1985; Skinner, Chi, & the LEAG, 2012). Relatedness, feelings of having activities that are hands fields students’. In light of these Terry, & Hart Blackwell, 2006). Assumptions can lead students to feel whether they settings, where these self perceptions or appraisals, namely, that they are academic contexts related student’s academic identity, convincing minority students that they are “the kind of person” who is needed and who can succeed in science (Saxton et al., 2014; Skinner, Chi, & the LEAG, 2012). Garden-based educational programs show promise as one such meaningful, culturally relevant, real-life, supportive context for promoting students’ engagement and other important academic outcomes (Williams & Dixon, 2013). The “hands-on, heads-on” work promoted by garden-based activities is not only an important ingredient for science learning, but may also shape students’ engagement and enthusiasm for science in the regular classroom. Cumulatively, engagement in the gardens and in science class may serve as an mechanism of personal transformation in a student’s academic identity, convincing minority students that they are “the kind of person” who is needed and who can succeed in science (Saxton et al., 2014; Skinner, Chi, & the LEAG, 2012). Self-determination theory (SDT) suggests that, if students are to develop a positive academic identity for science and to persist and succeed in science, they must first develop a set of self-perceptions or appraisals, namely, that they are competent (or self-efficacious), that they are related (or belong) in science, and that they are autonomous (take ownership) and purposeful in academic contexts (Damon, Menon, & Brock, 2003; Deci & Ryan, 1985, 2000; see figure 1). These self-perceptions may be especially important for minority students in academic and STEM settings, where such students have often been subject to the majority culture’s doubts about whether they are sufficiently “talented” for academic and STEM work. Such societal assumptions can lead students to feel incompetent or unwelcome in science, which can prevent them from developing feelings of ownership, commitment, and identification in these fields (Blackwell, Trzesniewski, & Dweck 2007; Good, Aronson, & Inzlicht, 2003; Oyserman, Bybee, Terry, & Hart-Johnson, 2004; Steele 1997; Walton & Cohen, 2007). In light of these challenges, it is essential to design science activities that foster minority students’ self-perceptions (in order to bolster engagement, learning, and identity with STEM fields), and school gardens offer a supportive milieu in which to do so. Garden-based science activities that are hands-on, high-quality, culturally-relevant and authentic should foster students’ feelings of having what it takes to succeed (competence), being welcome and valued (relatedness), and experiencing science activities as important (autonomy and purpose; Deci & Ryan, 1985; Skinner, Chi, & the LEAG, 2012). These self-perceptions are not only necessary for students to be able to engage and learn in science classes, but also for students to be able to develop the positive academic identity in science (identifying as someone who would like to pursue STEM studies and careers) that will enable them to dedicate their efforts to a STEM pursuit (Saxton et al., 2014). By promoting self-perceptions, science-class engagement and learning, and academic identity in science, minority students’ engagement with meaningful pedagogical activities and supportive contexts in school gardens could serve as a vital means for promoting these students’ membership and success in STEM fields.
Objectives/Purpose:
Critical to advancing science education for minority students is to engage students with real-life issues via academically challenging activities in science in simple yet profound ways. While there are many approaches to advancing science in schools, including sophisticated laboratories and advanced technologies, a growing movement within education has been taking a rather non-traditional approach: engaging students with the school grounds to learn science where school gardens are growing. In low-income schools, often with large percentages of linguistically and racially diverse student populations, these learning gardens have the objective of providing connections to life and learning science in ways not typically addressed (Kelley & Williams, 2013; Williams & Brown, 2012).

This study was part of a larger longitudinal project examining the experiences of racially and ethnically diverse students at two urban middle schools who participated in one such garden-based educational program called Science in the Learning Gardens (SciLG), which is a garden-based curriculum integrated with Next Generation Science Standards (NGSS). Using a set of theoretically-guided survey measures based on SDT (Skinner et al., 2012; Saxton et al. 2014), students provided information about their engagement in SciLG gardening activities, science class, science learning, and their feelings of relatedness, competence, autonomy, and purpose in garden-based and science learning activities. Of special interest was a marker of students’ academic identity as a person who might pursue a career or field of study in science (Saxton et al., 2014), with the notion that the development of this identity might help students persist in their interest and efforts towards a college major in science.

The current study focuses on two research questions: (1) Is students’ engagement in SciLG positively connected to their engagement in science class as well as their science learning and academic identity? And (2) Is engagement in SciLG linked to these positive outcomes because of its positive effects on students’ views of themselves as related, competent, autonomous and purposeful in garden-based and science learning activities?

Research Method:
Students belonged to nine classrooms led by three science teachers in two schools in Portland, Oregon. Parental consent forms were sent to 211 students. We received 129 consent forms; return rate was 61%. Of these, 105 students provided parental consent and participated in surveys in the spring of 2015. Surveys were administered in science classes by trained researchers and volunteers. Students rated their agreement or disagreement with statements about their experiences in the gardens and science class, using a five-point likert-type scale.

Data Sources:
Like many urban school districts Portland Public School (PPS) District, with 48,000 students in Portland, Oregon, continues to struggle with closing the achievement gap between white and non-white students and with its low graduation rate. For this research study, we present data from two highly diverse, Title I schools where all sixth graders take part in garden-based education classes once a week for 50-90 minutes at the learning gardens, supported by graduate assistants from Portland State University, integrating science themes in the garden curriculum with hands-on activities.
Students were 59% female, and were highly ethnically and racially diverse (25% Asian, 2% Black, 26% Latino/Hispanic, 27% White, 18% Multiple ethnicities, 1% other ethnicities). English was not the primary home language for fifty percent of students, which was indicative of the high number of immigrant families at these schools. Parental consent materials were translated into Chinese, Vietnamese, Russian, and Spanish since these were the most spoken home languages. Free and reduced lunch rate averaged at 82.4 percent.

**Measures:**
Study constructs were computed from students’ self-reported agreement/disagreement with statements about their experiences in both the gardens and science class. Negative items were reverse-coded. *Garden engagement* (12 items) and *Science class engagement* (12 items) reflected students’ reports of emotional and behavioral engagement and disaffection (e.g. “I work hard”; “I am bored”) in each domain. *Students’ self-perceptions in the gardens* (23 items) and in *science class* (23 items) reflected their feelings of being autonomous (“I do my work because it is important to me”), competent (“I know how to do well”), related (“I feel like a real part of the gardens”), and purposeful (“by gardening, we help make the world a better place”, “Science can help us solve some of the world’s big problems”). *Science learning* (7 items) reflected students’ reports of what and how much they learned in science (“We learned how to experiment, observe, and measure”, “We learn new things all the time”). *Academic identity in science* reflected students’ reports of being interested in a science career or field (“I am thinking of studying science in college”, “People like me do not get jobs in science”). Measures were adapted from Skinner et al. (2012) and Saxton et al. (2014).

**Results:**
Preliminary analyses showed that students reported generally high levels on all study construct (with means ranging from 3.24 to 3.93 on a 1-5 scale where 5 was high), and that all study constructs showed moderate or strong positive inter-correlations. Tables 1 and 2 show means, standard deviations, and correlations among study constructs.

In our analyses of motivational processes, we first sought to establish whether students’ effortful, energized participation in gardening activities predicted a) students’ engagement in science class, b) reports of learning in science class, and c) academic identity in science. Separate regression analyses showed that, as expected, students’ engagement in the gardens significantly predicted their engagement in science class (β = .53, p < .001, $R^2 = .28$). Thus, students’ effortful, energized participation in the gardens seemed to be a resource for students’ participation in science. Engagement in science, in turn, significantly predicted students’ reports of learning in science (β = .84, p < .001, $R^2 = .70$) and academic identity in science (β = .55 p < .001. $R^2 = .30$). Analyses using Sobel’s test of indirect effects showed significant indirect effects of garden engagement on science learning (β = .58 p < .001) and academic identity (β = .39 p < .001. $R^2 = .30$) through science engagement. That is students’ effortful, energized participation in garden-based activities seems to support students’ learning and academic identity in science indirectly by supporting their engagement in science. Additionally, garden engagement showed a significant direct effect on academic identity in science above and beyond the effect of science engagement. That is, students’ participation in the gardens seemed to support their academic identity in science independently of what happens in science class.
Second, we investigated the processes by which students’ participation in garden activities predicted a) engagement in science class, b) reports of learning in science, and c) academic identity in science. A path analysis was conducted to examine these relationships simultaneously. The model showed good fit. Coefficients for all direct and indirect effects can be found along with model fit statistics in figure 2. We found that gardening engagement indirectly predicted science engagement, science learning, and academic identity in science by way of the gardening self-perceptions. These gardening self-perceptions directly predicted science engagement and self-perceptions, and, in turn, indirectly predicted science learning. That is, gardening seemed to support both students’ effortful, energized participation in science and self-perceptions of being autonomous, competent, related, and purposeful in science, which all supported students’ reported science learning. Gardening self-perceptions also directly predicted academic identity in science, above and beyond the significant effect of science self-perceptions. That is, students’ perceptions of being autonomous, competent, related, and purposeful in the gardens supported students’ identities as somebody who might pursue a STEM field, both directly and by fostering these perceptions in science class.

Significance:
As concern for social justice is growing given the achievement gap among African-American, Native-American, Hispanic students and their White and Asian peers, the growing school garden movement provides an opportunity to engage students in authentic, real-world learning of science and pique their interests in science with holistic garden-based learning (Kelley & Williams, 2013). This study highlighted the role of students’ self-perceptions of being autonomous, competent, related, and purposeful both as mediating pathways by which gardening activities influence science motivation and learning and as direct, formative experiences underlying students’ academic identity in science. As Museus et al. (2011) articulate, there is a sense of urgency to ensure success in school and participation in science fields, particularly for racial and ethnic minority students who have not been successful in science in traditional settings. Our study shows that learning in school gardens can provide one opportunity for different ways of learning science that are engaging and motivating for students’ sense of academic identity.
References


Figure 1. Self-system Model of STEM (Science, Technology, Engineering, and Math) Motivational Development. Adapted from Connell & Wellborn (1991); based on self-determination theory (Deci & Ryan, 1985; Saxton et al., 2014; Skinner & Pitzer, 2012).
### Table 1.
**Means, standard deviations, and measurement properties of study constructs**

<table>
<thead>
<tr>
<th>Construct</th>
<th>No. Items</th>
<th>Crohnbach’s $\alpha$</th>
<th>Mean</th>
<th>Standard Deviation</th>
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<td><strong>Gardening Domain</strong></td>
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<tr>
<td>1. Garden Engagement</td>
<td>12</td>
<td>.85</td>
<td>3.93</td>
<td>.77</td>
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<tr>
<td>2. Garden Self-perceptions</td>
<td>23</td>
<td>.82</td>
<td>3.78</td>
<td>.85</td>
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<td><strong>Science Domain</strong></td>
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<td></td>
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<tr>
<td>3. Science Engagement</td>
<td>12</td>
<td>.92</td>
<td>3.85</td>
<td>.90</td>
</tr>
<tr>
<td>4. Science Self-perceptions</td>
<td>21</td>
<td>.87</td>
<td>3.79</td>
<td>.81</td>
</tr>
<tr>
<td>5. Science Learning</td>
<td>7</td>
<td>.91</td>
<td>3.88</td>
<td>1.00</td>
</tr>
<tr>
<td>6. Academic Identity in Science</td>
<td>7</td>
<td>.90</td>
<td>3.24</td>
<td>1.01</td>
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*Note: $n = 105$. Items were measured on a five-point likert-type scale where 1 = not at all true for me and 5 = very true for me.*

### Table 2.
**Inter-correlations among study constructs**

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<tr>
<td>1. Garden Engagement</td>
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<td>2. Garden Self-perceptions</td>
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<td><strong>Science Domain</strong></td>
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<tr>
<td>3. Science Engagement</td>
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</tr>
<tr>
<td>4. Science Self-perceptions</td>
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<td>.63</td>
<td>.82</td>
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<tr>
<td>5. Science Learning</td>
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<td>.61</td>
<td>.83</td>
<td>.84</td>
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<tr>
<td>6. Academic Identity in Science</td>
<td>.40</td>
<td>.56</td>
<td>.55</td>
<td>.71</td>
<td>.63</td>
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*Note: $n = 105$. All associations significant at $p < .001$.  

Figure 2. Path model of student experiences in gardening and science.

Note: n = 105. Standardized coefficients shown. All tested relationships shown. All associations significant at $p < .001$ except when indicated: $^* p < .05$; n.s. not significant. Model fit information as follows: $X^2(15) = 464.814 \ p < .001$; Root Mean Square Error of Approximation (RMSEA): .019; Comparative Fit Index (CFI): 1.000; Tucker-Lewis Index (TLI): .999.