The Child in the Garden: An Evaluative Review of the Benefits of School Gardening

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ABSTRACT: Although educators widely use school gardens for experiential education, researchers have not systematically examined the evaluative literature on school-gardening outcomes. The author reviewed the U.S. literature on children's gardening, taking into account potential effects, school-gardening outcomes, teacher evaluations of gardens as learning tools, and methodological issues. Quantitative studies showed positive outcomes of school-gardening initiatives in the areas of science achievement and food behavior, but they did not demonstrate that children's environmental attitude or social behavior consistently improve with gardening. Validity and reliability issues reduced general confidence in these results. Qualitative studies documented a wider scope of desirable outcomes, including an array of positive social and environmental behaviors. Gardening enthusiasm varies among teachers, depending on support and horticultural confidence.

KEYWORDS: environmental education, experiential learning, food behavior, school gardens, science achievement, social behavior

Over the last 20 years, school gardening has become a national movement. Texas and California state departments of education and university extension programs have actively encouraged school gardening by providing curricula and evaluative research (Dirks & Orvis, 2005; Ozer, 2007). Also, 57% of California school principals responding to a statewide questionnaire said that their schools had instructional gardens or plantings (Graham, Beall, Lussier, McLaughlin, & Zidenberg-Cherr, 2005). Florida, Louisiana, and South Carolina have had programs that promote school gardening (Culin, 2002; Emekauwa, 2004; Smith & Mostenbocker, 2005; University of Florida, 2006).

Northern states have been slower to become involved, but school gardens are no longer exceptional in cooler climates. In the state of New York, more than 200 schools, 100 teachers, and 11,000 students garden using a state curriculum (Faddegon, 2005). Vermont actively promotes school gardening in partnership

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with the National Gardening Association, which is housed in Burlington, Vermont (National Gardening Association, 2006), and provides demonstration gardens, national newsletters, and teacher education.

Overwhelmingly, gardens (Waliczek, Bradley, Lineberger, & Zajicek, 2000) and gardening curricula target elementary students. Some of the most popular curricula are the 1978 Life Lab K–5 Science Program (LifeLab, 2006); 1990 GrowLab curricula (National Gardening Association, 2006); Texas A&M's Junior Master Gardener Program (Dirks & Orvis, 2005); UC Davis' curriculum Nutrition to Grown On (California Department of Education, 2005; Morris & Zidenberg-Cherr, 2002); and New York's curriculum Kids Growing Food (Faddegon, 2005).

School gardening covers a continuum of efforts to increase the horticultural complexity of the schoolyard, including potted plants, raised beds on asphalt, indoor vermiculture composting, in-ground plantings (Graham et al., 2005), habitat and butterfly gardens, sunflower houses and ponds, composting areas accommodating a school's daily lunch waste (Graham, Feenstra, Evans, & Zidenberg-Cherr, 2004), and a systematic approach to redesign the outdoor space around schools into learning landscapes (Brink & Yoast, 2004). The purposes of the redesigned schoolyard are academic, behavioral, recreational, social (increased sense of belonging, self-esteem, and compassion), political (the schoolyard as a visible community asset), and environmental remediation. Educators and landscape architects used these criteria for the Boston Schoolyard initiative (Corson, 2003) and the Youth and Landscapes program, a collaboration between Denver schools and University of Denver graduate students in landscape architecture to redesign derelict schoolyards (Brink & Yoast).

Schools can move even further afield, as in place-based learning, developing collaborations with rural community partners that aid and facilitate the study of local natural resources (Emekauwa, 2004), or creating partnerships with university forestry departments, city park naturalists, and local businesses to facilitate the study of urban forest ecology (Milton, Cleveland, & Bennet-Gates, 1995). Emekauwa reported that 3 years of place-based learning focusing on local ecology—nature trails, soils, geology, butterfly gardens, and school interactions with community ecological experts—resulted in substantial reductions in unsatisfactory standardized test scores for language arts, math, science, and social studies among fourth-grade students in a poor, rural, 80% African American, Louisiana school district. Lieberman and Hoody's (1998) frequently quoted study reviewed 40 schools in 12 states, comparing classrooms that used the environment as an integrating context for learning with nonintegrating classrooms. Those researchers found that enthusiasm for learning, standardized test scores, and GPAs were higher in 92% of the comparisons—particularly in language arts, social studies, science, math, and thinking skills. The National Environmental Education and Training Foundation (2000) stated that the environment, "from classroom to schoolyard to local nature centers and parks" (p. 7), enables learning that is problem-based and interdisciplinary, with a significant positive impact on achievement.

The specific question that I addressed in this review of the literature is whether a school garden, without causing extensive changes to the schoolyard or integrating broader environmental fieldwork into the curriculum, provides sufficient experiential education to cause measurable and observable changes in student achievement and behavior. Enthusiasm for school gardening is clearly present, but the literature on school gardening's impact on children's learning and behavior comes from many disciplines and has not yet received a thorough, integrative review. My approach is to first give an overview of the rationales for school gardening and then critically examine the evaluative research on school-gardening outcomes.

Rationales for School Gardening

Broadening Children's Experience of Ecosystem Complexity

In earlier eras, Rousseau, Gandhi, Montessori, and Dewey—most notably—promoted school gardens (Subramaniam, 2002). When farms and nature were readily accessible to most children, the goal of school gardens was pragmatic and normative: to teach through experience, to connect children to pastoral nature, and to shape their moral outlook (Bundschu-Mooney, 2003; Subramaniam). School gardening in the United States was originally introduced for aesthetic purposes. It became a national movement first in 1918 and again, with a focus on food production, during World War II, but it waned in the 1950s because of the nation's focus on technology (Subramaniam).

Today's children lack experience with natural ecosystem complexity. In all, 83% of the U.S. population lives in metropolitan areas (U.S. Department of Agriculture, 2006). Thus, pasture or wilderness is no longer the normative standard for experience in nature (Mergen, 2003). Two-worker families who are concerned for the safety of their unattended children must choose close supervision of afterschool and summer playtime. Television, video games, and organized sports have taken the place of unsupervised wandering and environmental exploration (Moore, 1995). As childhood becomes more structured, the places where children must play are open and lack the appeal of intimate spaces grounded in the natural environment (Francis, 1995). City children search out dirt, water, trees, and natural elements and explore and play in the same manner in which rural children do (Mergen), but urban sprawl and environmental degradation reduce the frequency of these city children's positive experiences with natural elements in their environment (Finch, 2004; Kellert, 2002; Orr, 2002). A study of three generations of children in a New York City neighborhood shows a decline in natural areas and an increase in restricted access to the neighborhood and reliance on supervised play (Gaster, 1991). In Gaster's study, schools were considered safe areas. However, typical asphalt-covered or flat green schoolyards were, as they are today, monocultures that minimized environmental complexity.

Whether urban or rural, the landscape in which children find themselves is the staging ground for their imagination, their story, their sense of the world (Mergen, 2003). If formal playgrounds or sports fields delimit many children's natural experiences (Nabhan & Trimble, 1994), well-designed school gardens can readily improve on the complexity of that experience and provide the repetitive access, meanings, and associations needed to create a bond with a place. However, because of the way school gardens are typically interpreted and constructed in our culture, few contain intimate spaces, elements of the wild, or places to dig in dirt. Educators must adjust their norms for neatness, play area supervision, and ease of outdoor maintenance for school gardens to contain areas that are not neatly planted or controlled, thereby making them available for children's imaginative play (Finch, 2004).

Gardens adhering to the principles of biodiversity and organic pest management—containing ponds or recycling streams, trees, and butterfly attractors—would be havens for a wide variety of flora and fauna beyond the crops, flowers, and bushes purposely grown and would demonstrate ecosystem complexity. Gardens that children help to plan allow "close, personal experiences with the earth" (Thorp & Townsend, 2001, p. 349), repeated sensory contact, and interaction with a particular intimately known space, creating confidence in the processes of nature that some researchers believe is necessary for healthy human development (Thorp & Townsend).

Place-Based Learning Clarifies the Nature and Culture Continuum

Personal experience and observation of nature are the building blocks for classroom enrichment (Nabhan & Trimble, 1994). A garden is an environment in miniature, and to be successful a gardener must work in sympathy with nature (Demas, 1979). Gardens ground children in growth and decay, predator–prey relations, pollination, carbon cycles, soil morphology, and microbial life: the simple and the complex simultaneously. Gardens are intensely local. Everything except possibly the purchased plants and seeds are part of the natural local environment. The clouds, rain, and sun, the seasonal cycle, the soil and its myriad organisms, the insects, arachnids, birds, reptiles, and mammals that visit the garden teach about place. Even if some of the weeds, insects, and birds are not native to a place, these immigrant flora and fauna are as locally adapted as the children themselves. *Nature* and *natural* are relative terms that depend on cultural norms and the limits of our own ahistorical experience with place (Finch, 2004; Mergen, 2003; Nabhan & Trimble, 1994). Seeds and gardening styles are the stuff of history, culture, ethnobotany, and literature. Along with English sparrows, starlings, quack grass, and bees, gardening provides another kind of lesson, one about human interaction with the natural world.

Vegetable Gardening Teaches Food Systems Ecology

Anonymous prepackaged food arrives at supermarkets from energy-intensive, polluting, and often obesity-promoting industrial food-manufacturing systems. Researchers have estimated that this system consumes 17–20% of American fossil fuel and that 29% of the food is wasted (Blair & Sobal, 2006; Pollan, 2006). To decrease the threat of the obesity epidemic, children need to broaden their perspective on what foods are edible and to repersonalize food. Gardening in America's northern regions during the school year requires elongating the growing seasons in both spring and fall, thus stretching children's knowledge and taste for cool-season vegetables, particularly for dark leafy greens. Because of our supermarkets' global reach and constant supply of heat-loving vegetables, many cool-season crops remain unfamiliar. For more ecological, local food systems to satisfy year-round vegetable needs, children's tastes in food need to expand beyond the fatty, salty, sweet, and subtropical (Blair, 1996).

School and youth gardens teach "how a plant goes from seed to plate" (Rahm, 2002, p. 175), as one master gardener said. Such gardens introduce young gardeners to local sustainable food systems, as children eat their own produce, compost cafeteria food waste, and connect with adult growers and market gardeners (Graham et al., 2004; Moore, 1995; Morris, Briggs, & Zidenberg-Cherr, 2000). The act of growing food from seeds is exciting, even miraculous; the product is something special to be taken home to share. This sentiment is expressed by Thorp and Townsend (2001) in the following statement:

> [G]ardening changes the status of food for all involved. When one gardens, food can no longer be viewed as a mere commodity for consumption; we are brought into the ritual of communal goodness that is found at the intersection of people and plants. Food that we grow with our own hands becomes a portal for personal transformation. (p. 357)

Exposure to Nature and Gardening in Childhood Shapes Adult Attitudes and Environmental Values

Many authors and researchers believe that today's children lack the exposure to the natural world that shapes environmental values and puts science in context (Bundschu-Mooney, 2003; Finch, 2004; Kahn, 2002; Kellert, 2002; Orr, 2002). Chawla's (1998) review of the qualitative and survey literature found that adults who had significant and positive exposure to nature as children—experiences, often with significant adults, that socialize them to view nature in positive and meaningful ways—were more likely to be environmentally sensitive, concerned, and active. In a sample of teenage natural-resource workers, Vaske and Kobrin (2001) showed that a teenager's identity with a place mediated the relation between dependency on the place and environmentally responsible behaviors.

Active childhood involvement with plants may affect subsequent attitudes and behavior in adults. Blair, Giesecke, and Sherman (1991) found that minority participants—African Americans from the South and Asian immigrants—in community gardening projects in Philadelphia had gardened as children in rural areas. Lohr and Person-Mims (2005) studied metropolitan adults' attitudes toward trees and gardening in relation to their memories of their home surroundings in childhood, their time spent in outdoor places, and their time spent actually performing gardening activities (telephone survey of 112 most populated U.S. cities; response rate = 52%; sample size = 2,004). Active gardening in childhood was the most important predictor of whether trees had personal value in adulthood.

Francis (1995) obtained qualitative interviews from 100 Californian and Norwegian gardeners that explored the significance and meaning of places that they described in their childhood memories of gardens. All of the respondents had vivid memories of favorite private places in gardens that were protected, sheltered, or hidden. Francis wrote:

> Our interviews suggest that garden meaning is a complex ecology of idea, place and action. We found that when children become involved as gardeners or farmers rather than as passive observers of gardens, a deeper significance and meaning is established. Gardens that operated on all levels simultaneously—as idea, place and activity—can become sacred places. (p. 8)

School Gardening: A Broader Effect Than Experiential Education?

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 (Corson, 2003; Kellert, 2002; Mabie & Baker, 1996; Rahm, 2002). Kellert argued that because nature changes rapidly, it attracts and stimulates a child's attention. Naming and categorizing objects found in the particularly information-rich and potentially fascinating natural world facilitates children's capacity to retain information and ideas, a first step in cognitive development, as Bloom's taxonomy of cognition outlined (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956). The experience of nature's detail, whether direct or vicarious, provokes children's need to comprehend and make sense of what they have experienced. According to Kellert, it is "a rich diet for cognitive development" (p. 125), giving ample opportunity for creative inquiry; "strengthening the cognitive muscle we call mind[;] and developing and reinforcing the child's capacities for empirical observation, analytical examination, and evidentiary demonstration" (p. 125).

Although higher order cognitive skills are useful in many areas of life, in schools they are most often a focus of the math and science curricular reform. An overemphasis on factual knowledge has led to weakness in processing skills and critical thinking in the average U.S. student (Culin, 2002; Gibbs & Fox, 1999). South Carolina's statewide school program of butterfly-garden training addressed these science-education deficits through experiential learning that integrated science, math, writing, and social studies. Children stocked the gardens with flowers grown from seed, kept census counts of 27 butterfly and caterpillar populations, tagged migrating monarchs, and interacted with students in Mexican schools (Culin).

Two studies examining the outcomes of experiential learning have shown that it effectively stimulated higher orders of cognition; one of these studies showed that gardening was no more effective than other hands-on agricultural projects as a stimulator. Waliczek, Logan, and Zajicek (2003) evaluated the impact of a 4-hr outdoor hands-on nature program regarding weather, insects, water, and soil on the critical thinking and cognition of 175 second- to fourth-grade students from five New Mexico schools. Researchers interviewed students, teachers, and volunteers about the outcomes by using open-ended questions, and then they classified keywords and phrases as one of the six categories of Bloom's taxonomy of cognition. In all, 87% of respondents used application terminology, 19% used analysis terminology, and 26% used evaluation and synthesis terms such as *problem solving, integrate, plan, test,* and *support.* Mabie and Baker (1996) assessed the impact of two 10-week experiential educational interventions—(a) a school garden project and (b) three discrete in-class projects of seed starting, chick rearing, and bread baking—on the science-processing skills of 147 Hispanic and African American Los Angeles middle school students in comparison with a control science class taught as usual. Qualitative preassessments and postassessments consisted of written and verbal responses to a series of unrelated hands-on cognitive tests. Both treatment groups improved their posttest scores dramatically, showing increases in observational, ordering, comparison, and communication science-processing skills, with neither improvement in the control group nor difference by treatment. From these few studies, researchers can reasonably conclude that experiential learning, rather than gardening per se, improves a child's chances to use higher order cognitive skills.

However, these two types of experiential learning may not be equal in other ways. The difference between a structured discrete experiential learning experience and a long-term involvement in a gardening process resides in the multitude of unstructured learning opportunities that are not in the lesson plan, happen spontaneously and nonhierarchically, and involve students and their adult mentors in multidirectional learning (Milton, Cleveland, & Bennet-Gates, 1995; Rahm, 2002; Thorp & Townsend, 2001). Gardening requires physical labor. Repetitive tasks give ample opportunity for informality, and results happen slowly over a long time. Rahm studied the conversations that 6 African American 11–14-year-old students held with master gardeners and with each other during an 8-week summer youth-gardening project in the Midwest, where young interns prepared the soil, started seeds, nurtured, harvested, and marketed their produce. The project embedded informal science education in gardening conversation that flowed in a natural and organic way, involving, as Rahm stated, "sense making through discourse" (p. 179). As Rahm also stated, "Youth were the creators and not merely the *consumers* of the science curriculum" (p. 180). In addition, as Thorp and Townsend noted, "[A]t the heart of scientific inquiry is good old-fashioned slack-jaw wonder. 'Mrs. Thorp look how big this turnip is!'" (p. 356).

The very qualities that render school gardening a potent and multidimensional experiential-learning experience—being outdoors and involved in hands-in-dirt digging, planting, and cleanup—may render it unpopular with teachers who prefer the safety, predictability, cleanliness, and ease of the indoor classroom.

School-Gardening Studies That Have Assessed Learning Outcomes

Using a questionnaire mailed to 17 school-gardening researchers (76% response rate), Phibbs and Relf (2005) found that the learning outcomes most often studied were health and nutrition (69%), environmental education (EE; 30%), and self-esteem or self-concept (30%). The age groups studied were predominantly elementary (85%) or middle school (38%). The present research also shows that among published quantitative studies, science achievement, nutrition knowledge, and change in food behavior have been most frequently measured, preceding environmental attitude change, self-esteem, and life skills. The intended research subject of qualitative studies is most frequently agricultural education, but the results are much wider in scope.

Quantitative Assessment of the Learning Impact of School Gardening

In all, 12 studies have used quasi-experimental pretest and posttest designs or simple posttest designs to quantify the impact of school-garden participation on children's learning or behavior. The researchers tended to study third- to sixth-grade students. To a lesser degree, the researchers studied general elementary school students; they studied first-grade students only once. Tables 1–4 summarize these research reports and categorize them by specific learning outcome for gardening and nongardening students.

Using a criteria of $p < .05$ for significant results, 9 of the 12 studies revealed a positive difference in test measures between gardening students and nongardening students. School gardening increased the science scores in all reported studies. Gardening improved elementary student preference for vegetables as snacks in Texas (Lineberger & Zajicek, 2000) and California (Morris & Zidenberg-Cherr, 2002). A 12-week gardening intervention increased fruit and vegetable consumption among sixth-grade students in Idaho. However, gardening was no more effective than simple nutrition lessons in conveying nutrition knowledge (Morris & Zidenberg-Cherr). With gardeners serving as their own control, Skelly and Zajicek (1998) reported that the degree of improvement in environmental attitude regarding their gardening subjects was directly related to the amount of outdoor activities experienced in the garden. However, few studies examined the environmental and behavioral impacts of gardening, and those studies' results were mixed.

Out of those studies, three did not meet my criteria of significance, although only one found no significant difference. Mabie and Baker (1996) provided no statistical analysis but reported that gardening groups had higher agricultural achievement scores than did students doing in-class projects. Using significance criteria of $p < .10$, Waliczek and Zajicek (1999) found a small difference in environmental attitude change in relation to school gardening in a diverse sample of 598 Texas and Kansas second- to eighth-grade children. However, the pretest–posttest difference was less than 1%. Given the size of the sample, it is possible that the null hypothesis should have been accepted. A second report using the same sample examined gardening's effect on self-esteem and life skills and showed no significant difference (Waliczek, Bradley, & Zajicek, 2001). Although the participating schools differed in how they handled the gardening experience, Waliczek et al. reported no oversight or monitoring criteria. Those authors mentioned a significant interaction between the variables of school and attitude toward school. On the basis of post hoc comparisons, those authors hypothesized that students had better attitudes toward schools that allowed more individual participation in the garden.

The quasi-experimental designs of the studies in Tables 1–4 have left them open to criticism and the probability of false positives. Rather than randomly assigning classes to a treatment method, in most cases the researchers allowed teachers to volunteer their classrooms for the experimental group. Teachers differ significantly in their training and enthusiasm for gardening (Graham et al., 2005). Enthusiastic teachers are far more likely to volunteer their classrooms and promote positive experiences, biasing a study's results. Dirks and Orvis (2005) reported significant classroom effects in one study of science achievement. They also found ethnicity effects. White students' environmental attitude increased with gardening more than the attitude of African American students did (Waliczek & Zajicek, 1999). The ethnicity of control and experimental groups was inadequately matched in some of these studies. I address methodological issues for improvement of quasi-experimental designs and methods in more depth in the Discussion section of this article.

Qualitative Studies of School Garden Effects

The purpose, research questions, and results of seven qualitative studies of elementary school-gardening projects are presented in Table 5 (triangulated data) and Table 6 (case studies). Methods and research questions vary. The results of several of these studies were discussed earlier in the present article.

Whatever the original intent of these qualitative studies of elementary school gardening, common themes run through each report and are listed below.

1. All seven studies reported that students were delighted and highly motivated by the pleasures of gardening and the opportunity to get dirty outside and were excited by exploratory learning framed in a garden context (Alexander, North, & Hendren, 1995; Brunotts, 1998; Brynjegard, 2001; Canaris, 1995; Faddegon, 2005; Moore, 1995; Thorp & Townsend, 2001).
2. All seven studies reported that students showed improved school attitude and pride in the garden and its produce. The students involved their parents, who became more involved with school. (Alexander et al., 1995; Brunotts, 1998; Brynjegard, 2001; Canaris, 1995; Faddegon, 2005; Moore, 1995; Thorp & Townsend, 2001).
3. All seven studies reported that school gardens had a strong community-building component, promoting teamwork, student bonding, a broader range of interaction with adults, and community

TABLE 1. Quantitative Assessment of Science Achievement in Conjunction With School Gardens

Authors, by date published	Objective	Sample or design	Tools	Results
R. Mabie and M. Baker (1996)	Assess 2 types of activities to improve student knowledge of Ag	Hispanic and African American 5th–6th-grade students from 2 inner-city Los Angeles schools; control group (n = 31), gardening group (n = 56), Ag project group (n = 57) Pre- and posttest	Instrument developed by researchers and tested in a Los Angeles school; Kuder-Richardson 20 reliability = .74 Gardening group: gardened 1 hr per week for 10 weeks Project group: bread baking, chick rearing, and seed germination for 3 days	No statistical analysis reported Gardening groups showed the biggest increase in interest and knowledge of Ag Project group was intermediate in pre- and posttest change between control and gardening group
C. D. Klemmer, T. M. Waliczek, and J. M. Zajicek (2005a)	Develop cognitive test instrument to assess SA gains in conjunction with gardening	3rd–5th-grade students from 7 central Texas schools using state youth-gardening curriculum (N = 657)	Test comprising 40 multiple-choice questions based on Bloom's Taxonomy of Education Objectives	Cronbach's α = .86 overall; .92 for 5th-grade students
C. D. Klemmer, T. M. Waliczek, and J. M. Zajicek (2005b)	Assess effectiveness of school gardens in enhancing SA	Same sample as above (n = 453 in experimental classes; n =194 in control classes mixed in schools) Posttest only	Texas state youth-gardening curriculum given to experimental groups delayed for control Klemmer SA test	SA higher ($p < .001$) for gardening students Only 5th-grade students had sig. dif. ($p < .001$)

L. L. Smith and C. E. Mostenbocker (2005)	Quantify effects of school gardens on SA of 5th-grade students	5th-grade students of African American or multiple ethnicities from 3 inner-city Baton Rouge schools; control (n = 57) and experimental (n = 62) classes in each school Pre- and posttest	Used Jr. Master Gardener Handbook horticulture undergrads gardened with students once per week for 14 weeks Klemmer SA test	Higher SA in gardening students ($p < .05$)
A. E. Dirks and K. Orvis (2005)	Evaluate the impact of Jr. Master Gardener Program on classroom SA	277 students from 11 Indiana schools with few minorities Pre- and posttest	Developed testing tool measuring short-term K&A change	Small but sig. dif. ($p < .0001$) in K&A Significant classroom effect on K&A and school-garden effect on attitude ($p < .0001$)

Note. SA = science achievement; Ag = California food and fiber industry; K&A = knowledge and attitude; sig. dif. = significant difference.

TABLE 2. Quantitative Assessment of School Garden Food and Nutrition Outcomes

Authors, by date published	Objective	Sample or design	Tools	Results
S. E. Lineberger and J. M. Zajicek (2000)	Test garden-activity guide for teachers Measure attitude change toward F&V	111 Texas 3rd–5th-grade students from 5 schools (quasi-experimental) No control group Pre- and posttest	Teachers guide with 34 gardening activities F&V preference questionnaire 24-recall food journals (pre and post)	Increased veg preference ($p < .05$) Fruit preference had no change Increased preference for F&V as snack ($p < .01$) No change in 24-hr recall pre- and posttest
J. L. Morris, A. Neustadter, and S. Zidenberg-Cherr (2001)	Assess feasibility of school-gardening program with 1st-grade students for nutr education and food-behavior change	1st-grade students from 2 California schools matched for location and ethnicity, with ($n = 48$) and without ($n = 49$) school gardens (quasi-experimental) Pre- and posttest	Nutr knowledge score based on food-group recognition Willingness to taste 6 veg, preference, and ability to name	Gardeners had a higher score on food-group identification ($p < .02$) Gardeners more willing to taste veg ($p < .005$) No preference or naming differences
J. L. Morris and S. Zidenberg-Cherr (2002)	Develop and evaluate 9-lesson garden-enhanced nutr-education curriculum	213 California 4th-grade students (control school, NL school, NG school) Pre- and posttest and follow-up	Nutr knowledge questionnaire Willingness to taste 6 veg: carrots, broccoli, spinach, snow peas, zucchini, and	No difference in nutr knowledge between NL and NG sites No difference in willingness

			jicama; rated veg for preference on Likert-type scale 6-month follow-up on preference	to taste veg among sites Compared to others, NG site preferred more veg: snow peas ($p < .05$) and zucchini ($p < .0005$) 6-month follow-up: NG group retained significantly higher preference for broccoli, zucchini, and snow peas
J. D. McAleese and L. L. Rankin (2007)	Assess effects of garden-based nutr education on F&V consumption	122 Idaho 6th-grade students from 3 elementary schools; 2 control schools without gardens and NL school randomly assigned; NG school was a convenience choice because of walking access to a raised-bed garden (nonrandomized) Pre- and posttest	99 students from 3 schools completed 3 pre- and post-24 hr food recalls NL and NG schools' intervention: *Nutrition in the Garden* (12-week horticulture nutr curriculum) NG school also had 12-week hands-on garden-based activities	F&V consumption changed only at NG school where cafeteria servings of both more than doubled ($p < .001$). Vitamins C and A and fiber intake increased at NG school ($p < .016–.001$)

Note. Nutr = nutrition; F&V = fruit and vegetable; veg = vegetables; NL = nutrition lessons only; NG = nutrition lessons plus gardening.

TABLE 3. Environmental Attitude Change in Conjunction With School Gardens

Authors by date published	Objective	Sample or design	Tools	Results
S. M. Skelly and J. M. Zajiek (1998)	Develop an interdisciplinary approach to environmental education using gardens Test treatment difference in EA	Sample is 2nd- and 4th-grade students by class from 4 Texas elementary schools; experimental group (n = 153), control group (n = 84) Posttest only	Project GREEN: developed 33 activities for school gardens Children's Environmental Response Inventory	Sig. dif. in Environmental Response Inventory (p < .001); dose response = score increase with number of outdoor activities Negative age effect (p < .05)
T. M. Waliczek and J. M. Zajicek (1999)	Measure changes in EA with Project GREEN gardening activities	589 2nd–8th-grade students from 7 elementary schools in Texas and Kansas Pre- and posttest design	Project GREEN curriculum Author-created EA scale	Pretest score was 31.45; posttest score was 31.71, t = −1.712 (p < .10) Significant effect of gender and ethnicity

Note. EA = environmental attitude; sig. dif. = significant difference.

TABLE 4. Assessment of School Gardening's Effect on Self-Esteem and Life Skills

Authors, by date published	Objective	Sample or design	Tools	Results
T. M. Waliczek, R. D. Bradley, and J. M. Zajicek (2001)	To determine if Project GREEN curricula positively influenced students' interpersonal relationships and attitudes	598 2nd–8th-grade students in 7 Texas and Kansas schools; gardening children compared with "norming" population for testing instrument Pre- and posttest design	Project GREEN activities for school gardens was used for 6 months (not clear how well teachers carried out gardening activities) The Self Report of Personality Scale for children and adolescents	No sig. dif. between gardening children and "norming" control No significant effect of gardening on experimental group's attitudes or relationships
C. W. Robinson and J. M. Zajicek (2005)	Assess changes in life-skill development of elementary students participating in a 1-year gardening program	281 3rd-, 4th-, and 5th-grade students from 7 Texas elementary schools Pre- and posttest with experimental classes (n = 190) and control classes (n = 91)	Texas Extension Service school-gardening curriculum with teacher training Youth Life Skills Inventory with 3-point Likert-type scale	Small but significant increase ($p < .05$) in scores of gardening children No change in controls but gains in areas of working with groups and self-understanding

Note. Sig. dif. = significant difference.

TABLE 5. Triangulated Studies of Grade-School Gardens Using Qualitative Methods and Analysis

Authors, by date published	Objectives or questions	Sample or research design	Observations or themes
J. Alexander, M.-W. North, and D. K. Hendren (1995)	Pilot study identifying and evaluating short-term effects of master gardener classroom-gardening project	Participating inner-city San Antonio School 2nd- and 3rd-grade students; 3 gardening classes, 2 nongardening controls Observations and interviews with principal, 5 teachers, master gardener, 52 students, and 3 parents	Moral development related to valuable life lessons embedded in gardening Academic learning related to hands-on nature experimentation Gardens engendered parental support, enthusiasm, and involvement Student pleasure, self-satisfaction, teamwork Master gardener critical element as role model Fear of vandalism, protective feelings
C. M. Brunotts (1998)	Evaluation of Pittsburgh Civic Gardening Center's 14-session school-gardening outreach program	Socioeconomically depressed school 150 Kindergarten and 2nd- and 4th-grade students in groups Teachers (open-ended questions); 13% of parents (open- and closed-ended) Methodology was a post hoc adaptation to various problems with pre- and postdesign	Gardening viewed as valuable and effective augmentation of science curriculum, broadening student horizons, and increased parental involvement; gardening increases student excitement about learning, pride, hope, fun, ability to work cooperatively, and taking responsibility; increased observation skills and environmental caretaking Teacher training needed

L. Thorp and C. Townsend (2001)	Phenomenological understanding of the impact of a garden-based agricultural education curriculum on teachers and students in a low-income, multiethnic, midwestern elementary school, K–5 Does gardening improve agency and connection of students to school? Which lessons facilitate learning? Which lessons have barriers or constraints?	Purposive sampling of 5 teachers and 40 students Multiple qualitative methods: interview, conversation, document analysis, and photo elicitation Naturalistic data analysis, refining questions over time	Garden reshaped school culture, creating hope, growth, and community Garden rhythms improved sense of control and place Children experienced "comfort, security, belonging, pleasure and wonder" (p. 357) Garden was a place of self-expression and feeling uniquely present Food took on new, deeper meanings Requires dedicated volunteer
P. A. Faddegan (2005)	Evaluate New York's Kids Growing Food minigrant curricular effects Perceived increase in agricultural literacy; identify other outcomes	Content analysis of final reports, open-ended survey questions with teachers, focus groups with school gardeners, personal interviews (Population > 11,000 students; > 200 gardens)	Most teachers did not fully understand the term *agricultural literacy* and needed more training Gardening's greatest success was improving attitudes toward school, motivation, and enthusiasm in all related subject areas, in particular plants, ecology, and nutrition Garden provided context for experiential learning for core curricular subjects

TABLE 6. Case Studies of School-Gardening Projects and Outcomes (Direct Involvement of Author)

Author, by date published	Place or purpose of garden	Gardening impacts
I. Canaris (1995)	Vermont 1st–4th-grade mixed class worked with organic farmer to develop snack garden and learn where food comes from (2-year teacher retrospective)	Increase in nutrition, food literacy, gardening and math skills, observation and connection to nature Gardening connected the students to the community, stimulating student creativity, recycling, fundraising, and parental involvement
R. Moore (1995)	Berkeley, CA, primary school environmental-schoolyard design project retrospective, a biodesign developed from blacktop over a 10-year period with collaboration from university faculty, students, and an outdoor resource teacher Purposes were to develop an environmental pedagogy where all subjects would be taught through the outdoors and to promote sustainable development values	"Gardens provided the most direct source of children's emotional involvement with living systems. They accommodated every stage of the learning cycle, stimulated by a diversity of flowers and vegetables, constantly changing, interacting with their surroundings, adapting to new circumstances, as children counted, measured, observed, described, interpreted and recorded." (p. 75) "Garden projects had the unique capacity to generate a collective sense of purpose through the shared experience of getting one's hands in the soil. No other activity duplicated such an intimate combination of freedom of expression and discipline." (p. 79)
S. Brynjegard (2001)	Napa, CA, elementary-school garden established by author as AmeriCorps volunteer to promote environmental awareness Interviews with students, parents, and teachers at 3 gardening elementary schools in the San Francisco Bay area Research question: Do children gain unique insights into environmental issues through gardening?	Gardening fosters detailed nature observation leading to mind and heart understanding of natural interactions, identification with and appreciation for living things Gardens need coordinator, whole school support, and unity Children's responsibility and decision making promotes attachment, empowerment, and ownership

outreach (Alexander et al., 1995; Brunotts, 1998; Brynjegard, 2001; Canaris, 1995; Faddegon, 2005; Moore, 1995; Thorp & Townsend, 2001).

4. All seven studies found that school gardens provided a diversity of environmental-stewardship, math, and science-education opportunities: measuring space, observing and experimenting with natural and plant processes, learning about soil improvement, recycling, creatively reusing materials, propagating, germinating, and saving seeds (Alexander et al., 1995; Brunotts, 1998; Brynjegard, 2001; Canaris, 1995; Faddegon, 2005; Moore, 1995; Thorp & Townsend, 2001).

5. Out of the seven studies, four described how vegetable gardens provided holistic food and nutrition education, food-systems thinking, tasting, snacking, cooking dinners, food sales and philanthropy, and good food as reward for good work (Canaris, 1995; Faddegon, 2005; Moore, 1995; Thorp & Townsend, 2001).

6. In addition, four of the seven studies reported that a nonstructured, discovery approach successfully provided the students with opportunities to explore natural phenomena (Brynjegard, 2001; Canaris, 1995; Moore, 1995; Thorp & Townsend, 2001).

7. Four of the seven studies emphasized that school gardens required dedicated, experienced adult volunteers, master gardeners, or paid coordinators to flourish over time (Alexander et al., 1995; Brynjegard, 2001; Canaris, 1995; Thorp & Townsend, 2001).

8. Last, two of the seven studies noted that many elementary teachers were not agriculture-literate and lacked knowledge of basic plant science or plant-growing skills (Brunotts, 1998; Faddegon, 2005).

Four of the seven qualitative studies of K–12 gardening were evaluations of gardening projects that the authors had initiated or were directly involved in. Those studies opened themselves to the danger of overly enthusiastic reporting and biased analysis. However, those authors were also in the best position to unravel the garden–child interactions. Researchers should understand and evaluate such studies as best-case scenarios.

Studies of gardening involving high school students as participants are rare. A review by Sullivan (1999) briefly mentioned a project at a rural health center in Arizona where local high school students and project staff tended a demonstration and community garden next to the health center to provide technical support and encouragement for home gardening in the local area. Then the same high school students provided technical expertise for these new home gardens. Horticultural therapy has been successfully used to increase self-confidence, pride, and self-esteem among troubled youths in Ohio (Hudkins, 1995). However, I found no quantitative and only two qualitative studies connecting gardening with high school students. Although they did not fit the pattern of in-school gardening encountered by researchers in elementary schools, those studies showed innovative ways for using gardening with older students. Lekies, Eames-Sheavly, Wong, and Ceccarini (2006) reported on a New York State 4-H children's garden consultant program in which 7 girls served as consultants to adults in the design of children's school gardens. Those researchers described the process of mentoring those girls through activities and garden site visits to the point where they were competent to assist the adults. The researchers concluded that the mentored girls gained empowerment and self-esteem and provided valuable improvements to the children's garden-design site and garden programming. Krasny and Doyle (2002) conducted qualitative, triangulated research on Cornell University's six-city garden mosaics program, engaging inner-city youth attending summer programs in participatory research with adult gardeners in their communities. Their research included interviews with 4 gardeners, 11 community educators, and 28 predominantly African American and Hispanic 9–16-year-old participants. Youth enhanced their gardening, teamwork, and research skills. They formed learning, helping, and often personal relationships with the gardeners with whom they studied. These studies showed ways to successfully engage high school students in gardening, improving their skills and self-esteem.

Studies of Principals' and Teachers' Evaluations of the Effectiveness of School Gardens

Another approach to evaluating school-garden effectiveness is for researchers to measure (a) principals' and teachers' enthusiasm for gardening as a learning tool, (b) how teachers find gardens useful, and (c) what barriers they perceive in the integration of gardens into the curriculum. Studies of principals or teachers have involved: (a) sending questionnaires to schools or teachers whom researchers identified as garden users, (b) sampling all schools in an area, or (c) identifying schools that have gardens and interviewing teachers in those schools. Approaches (b) and (c) obtain the views of users and nonusers and are reviewed separately.

DeMarco, Relf, and McDaniel (1999) sent a national school-gardening survey to 322 elementary school recipients of a National Gardening Association Youth Gardening Grant. The usable-survey rate was 73%. The researchers did not specify who responded to the questionnaire, but they implied that participating teachers were the respondents and could be potentially biased as grant recipients. Less than 5% of respondents felt that school gardening was unsuccessful at enhancing student learning, and 61% felt that it was very successful at enhancing student learning. Goals for school gardening were academic (92%), social development (83%), recreational (63%), and therapeutic (52%). The subject areas that at least 50% of teachers reported that they taught in conjunction with the school garden were science (92%), EE (83%), mathematics (69%), language arts (68%), health and nutrition (59%), ethics (58%), and social studies and history (51%). DeMarco et al. used cluster analysis to identify those factors most frequently indicated as essential for school-gardening success. These include a person responsible for school-gardening activities, site and materials availability, and support from the principal. Participants selected the factors of *student ownership* and *integration with other subjects* as crucial for school-garden success.

In a similar study of 35 schools and 71 Florida elementary teachers who had entered their gardens in a 1997 University of Florida contest (100% response rate), Skelly and Bradley (2000) found that teachers used gardens for EE (97%), to help students learn better (84%), for experiential learning (73%), and because the teacher had a personal love of gardening (67%). Most teachers were encouraged by their administration (54%). Also, 85% of students spent between 1 hr (68%) and 2–3 hr (17%) per week in the garden, but usually they spent more time on gardening subjects in the classroom (Skelly & Bradley).

California researchers provided three studies of attitudes and perceptions about school gardening in schools where gardens of some type existed but where respondents were not necessarily enthusiastically involved in gardening. Graham et al. (2005) sent a questionnaire by e-mail and by nonelectronic postal service to all California principals (43% response rate). Of those responders, 57% (2,381) indicated that their schools had some kind of garden that grew flowers or vegetables. The gardens ranged from in-ground gardens (69%), to raised-beds gardens (60%), to gardens in pots (46%). Those various forms of gardening opportunities were used primarily for academic instruction in kindergarten to eighth-grade science (86%), environmental studies (64%), nutrition (63%), language arts (62%), and math (58%); and in high school science (74%), environmental studies (54%), nutrition (40%), and agricultural studies (42%). Principals thought that gardens were moderately to very effective in enhancing science education (69%). The factors that most limited combining classroom instruction with gardening were (a) lack of time, funding, staff support, and curricular materials linked to academic standards; and (b) lack of teacher knowledge, training, experience, and interest in gardening.

Graham and Zidenberg-Cherr (2005) used a mailed questionnaire to survey a subset of the fourth-grade teachers at schools that the previous questionnaire indicated had gardens. The response rate was 36% (n = 592). In all, 68% of responders used gardens for instruction. Echoing their principals, these fourth-grade teachers thought that gardens were most important for enhancing academic instruction (72%), but they also thought that gardens effectively enhanced social skills (41%). The percentage of teachers indicating that gardens were moderately to very effective at enhancing specific skills and subjects ranged from 53% for science to only 25% for healthy eating habits. Notable were the number of *no opinion* answers for every category (26–40%) and the high percentages of teachers who felt that gardens were not effective, slightly effective, or only somewhat effective. However, some of the gardens at these schools were minimal, and many grew no food. Like the principals, the teachers indicated that lack of time (67%), lack of teacher interest (63%), lack of experience (61%), and lack of knowledge (60%) were major barriers to using gardening for instruction.

Graham et al. (2004) obtained a 59% response rate to a distributed questionnaire aimed at all teachers (N = 118) participating in Farm to School Connections, a three-school pilot program in Davis, California, that combined school gardens, cafeterias, and classrooms to improve elementary school children's eating habits. These three schools had a garden coordinator (a retired and experienced teacher paid by the state), multiple gardens, farm-to-school salad bars, and school lunch-plate-waste composting projects. These teachers were more receptive to school gardening than were the general sample of California fourth-grade teachers. The percentages of teachers using gardens to teach academic subjects were 90% for science, 71% for nutrition, 64% for language arts, 60% for environmental studies, 59% for health, 57% for agricultural studies, and 56% for math. Perceived barriers were lack of time and lack of curriculum linked to standards, but cited barriers did not include lack of teacher interest, training, or knowledge of gardening.

A major methodological problem with the aforementioned mail-and-distribution studies was non-response bias. Response rates are higher when respondents have a special interest or involvement in the topic of study (Donald, 1960). DeMarco et al.'s (1999) and Skelly and Bradley's (2000) studies of gardening teachers had response rates of 73% and 100%, respectively. Graham et al.'s (2004) study of teachers adequately supported at gardening schools had a 59% response rate. Teachers from schools where gardens were promoted at the state level without perceived adequate attention to time and training had a 36% response rate (Graham & Zidenberg-Cherr, 2005). Unmotivated nonresponders were likely to differ systematically from the responders in variables most critical to interpreting the study results (Ellis, Endo, & Armer, 1970). In the case of those mail-and-distribution studies, teacher and administrator attitudes toward the efficacy of school gardening in terms of learning outcomes was the most critical variable.

Discussion

Research Question and Methodological Issues

The question addressed by this review of the literature is whether a school garden, without educators' either changing the schoolyard extensively or integrating broader environmental fieldwork into the curriculum, would provide sufficient experiential education to cause measurable and observable changes in student achievement and behavior. The results of the reviewed research were positive. In all, 9 out of 12 quantitative studies reinforced the results of Lieberman and Hoody (1998), showing increased science achievement and behavioral improvement in schools that use school gardening as their integrating context for learning. Also, 9 qualitative studies unanimously reported positive learning and behavior effects of school gardening or garden involvement. Mabie and Baker (1996), Rahm (2002), and Waliczek et al. (2003) have shown a positive impact of outdoor gardening or nature programs on higher order cognitive skills. Teacher surveys showed that academic achievement, particularly in the area of science, was the most frequently cited reason for using school gardens. Gardening studies are most commonly performed with third- to sixth-grade students, although researchers cannot say that younger or older children would not benefit.

However, given the methodological problems mentioned previously, the research hypotheses addressed by the qualitative studies cannot be uniformly affirmed. Short-term, quasi-experimental designs are not considered valid or reliable. Systematic biases in data-collection techniques imply that the results reported by the quantitative researchers were most likely more positive than was valid. The quantitative studies I have reviewed suffered from lack of both rigorous sampling procedures and random assignments of control and experimental groups. At least four studies used testing instruments without proven validity.

In designing their studies, future researchers will need to control the previously uncontrolled teacher and classroom effects, ethnicity effects, and nonresponse biases. Teacher attitudes toward gardening, EE, and experiential education should be control variables in any quantitative study where random selection of gardening classrooms is not an option. Use of propensity scores is a way of accounting for the bias inherent in nonrandom assignment to groups, as in these quasi-experimental studies of the effects of gardening on student achievement, attitude, and behavior. Researchers can evaluate teachers and schools on important variables, such as support and enthusiasm for outdoor EE, and a composite score can be used as a control variable to test whether treatment differences maintain their effect when teacher or school effects are constant. However, sample sizes must be large enough for researchers to compare subgroups (Rosenbaum, 1991; Rosenbaum & Rubin, 1983).

Mail surveys suffer from nonresponse bias. Case studies of gardens are often first-person accounts by their initiators. In each case of bias, results may appear more positive than they are in reality. Qualitative results are applicable only to the situation studied and can be used to form a hypothesis, but researchers cannot extend them to other situations. However, there is consistency in the results of the seven reviewed qualitative studies in Tables 5 and 6 from around the United States, which would lead researchers to accept the legitimacy of their findings.

Overall, the methodology in the evaluation of school-gardening programs needs to be much more rigorous. Ozer (2007) suggested a combination of systematic qualitative and quantitative methods emphasizing direct observation because implementation of school gardening cannot be assumed to be uniform, even within the same school. Phibbs and Relf (2005) suggested longitudinal research. Students should act as their own controls, as in McAleese and Rankin's (2007) study. Outcomes should be documented in ways that will affect educational policy toward school gardening and subsequent funding.

Environmental and Social Impacts of School Gardens

From an environmental perspective, school gardens may seem to researchers to be a limited substitute for redesigning the whole schoolyard or for interacting more closely with nearby landscapes. However, Moore (1995) reported that the school vegetable garden was the most feasible pedagogical vehicle for promoting daily environmental learning in his project's fully redesigned schoolyard. In particular, annual vegetable and flower gardens enabled a yearly full start from bare soil. Each year, students could be full participants in designing the garden and the act of regeneration, the regenerative act of embedding tiny seeds in dirt and food-scrap compost, and nurturing those seeds during their transformation into flowers or vegetables. Researchers have frequently commented on how excited children were to put their hands in dirt. Birds, insects, spiders, weeds, and mammalian predators were players in this process, so that the school's environmental complexity flourished. Food production connected students to sensual pleasures, sustenance, and the agri-systems of daily life in and beyond the school. Butterfly, habitat, and pond gardens required less summer maintenance and also provided diverse opportunities for observing natural systems. Educators found that gardens produced the ecological diversity that had been missing from monocultural schoolyards, allowing children to work directly with energy transformation and entropy. A school garden can be a frequent, if not daily, experience, a place owned by the students. With attention, gardens can also create delight and pride and foster the kind of unfettered play that children create in simple hidden spaces (Mergen, 2003). These gardens can be private spots for observing, fostering the imagination, or simply reading among the fava beans (Brynjegard, 2001). Uniformly, the qualitative studies of kindergarten to sixth-grade gardening that are summarized in Tables 5 and 6 showed the following positive behavioral and social outcomes: heightened motivation and enthusiasm, improved sense of self, teamwork, community, and parental involvement. The amount of structure that children encounter in relating to a garden may determine whether they benefit both cognitively and emotionally (Thorp & Townsend, 2001). How much structure is appropriate is an area for further school-gardening research.

Teachers' Need for Support and Training

The teacher and principal are major variables in school-garden success. In particular, more needs to be known about the principal's effect. Major teacher issues are lack of personal interest and limited capabilities, knowledge, and time. Samples of gardening teachers and teachers with adequate gardening support (Graham et al., 2004) were more enthusiastic about the potential of school gardens than were mixed samples of gardening and nongardening teachers (Graham & Zidenberg-Cherr, 2005). Support may come in the form of (a) enthusiastic principals, (b) effective and credible lead teachers who promote school gardening through contagious student excitement rather than through personal power (Vesilind & Jones, 1998), or (c) the semiretirement-lead gardener programs for teachers, such as at the Davis, California, schools (Graham et al.). In Las Vegas, sequential surveys of principals in gardening and nongardening schools regarding potential problems and barriers to school gardening led to the hiring of a community-based instructor to provide training and coordinate the gardening program and the volunteer master gardeners (O'Callaghan, 2005).

Additional studies are necessary on how educators can best remove barriers to implementing and keeping school gardens running. Studies have not addressed school-garden continuity or failure, but they have addressed the lack of teacher preparation for using gardens in instruction. Portillo (2002) reported that elementary teachers with some agricultural training are more likely to use school gardens as a learning tool. Dobbs, Relf, and McDaniel (1998) reported that 98% of the 205 Virginia kindergarten to sixth-grade teachers whom they surveyed wanted to participate in additional gardening training. School-gardening experience and plant science could become a part of teachers' preservice education, so that all teachers can feel prepared to use school gardening as a potent form of experiential education.

Conclusions and Suggestions for Further Research

The results of qualitative, quantitative, and survey research have supported the conclusion that school gardening can improve students' test scores and school behavior. Teachers believe that gardens promote academic instruction. However, methodological shortcomings of the quantitative studies have reduced faith in these results. Gardens can improve the ecological complexity of the schoolyard in ways that promote effective experiential learning in many subject areas, particularly the areas of science, EE, and food education. Researchers and educators should pay attention to how they design the garden and the learning experience in the garden. Both preservice and in-service teachers need more training to effectively use gardening as a teaching tool. Teachers are the mainstay of school gardening. However, gardens require embedded support mechanisms that lighten the teacher's burden.

To improve school-gardening outcomes research, researchers need to (a) use well-designed longitudinal studies that combine qualitative and quantitative elements with appropriate sample design, (b) use validated instruments, and (c) control for teacher and ethnicity effects. More qualitative studies of smoothly functioning school gardens that examine how success is managed and maintained are also necessary. Other productive future research would be (a) studies of reasons for garden failure and (b) reports on creative means of maintaining gardens over time and moving the workload away from teachers. More research would be useful on the level of structure versus self-exploration in a garden that best serves the student's learning needs. Researchers and educators also need to know whether the changes in environmental sensitivity and observation skills reported in qualitative studies of gardening are transient or long lasting, affecting behavior as a child matures.

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