Review of Educational Research
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REVIEW OF EDUCATIONAL RESEARCH published online 27 February 2013

DOI: 10.3102/0034654313475824

Review of Educational Research
Season XXXX, Vol. XX, No. X, pp. xx–xx
DOI: 10.3102/0034654313475824

Impact of Garden-Based Learning on Academic Outcomes in Schools: Synthesis of Research Between 1990 and 2010

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What is the impact of garden-based learning on academic outcomes in schools? To address this question, findings across 152 articles (1990–2010) were analyzed resulting in 48 studies that met the inclusion criteria for this synthesis. A review template with operational coding framework was developed. The synthesis results showed a preponderance of positive impacts on direct academic outcomes with the highest positive impact for science followed by math and language arts. Indirect academic outcomes were also measured with social development surfacing most frequently and positively. These results were consistent across programs, student samples, and school types and within the disparate research methodologies used. However, a common issue was lack of research rigor as there were troubling issues with incomplete descriptions of methodological procedures in general and sampling techniques and validity in particular. Recommendations for more systematic and rigorous research are provided to parallel the growing garden-based education movement.

Keywords: garden-based learning, academic outcomes, school gardens, environmental learning.

Since the early 1990s, school grounds previously covered with asphalt or grass have instead increasingly become sites for growing school gardens. This resurgence of interest in school gardens over the past 20 years has resulted in the establishment of thousands of school gardens across rural and urban areas in the United States of America. Schools in California, Colorado, Florida, Illinois, Iowa, New York, Ohio, Oregon, North Carolina, Texas, and Vermont, among other states, have aligned subject area standards with newly designed garden curricula (Blair, 2009; Klemmer, Waliczek, & Zajicek, 2005a; Ozer, 2006; Williams & Brown, 2012). Simultaneously, garden curricula sprouting in districts, schools, and state education departments are designed for various grade levels to meet subject standards, particularly for science, mathematics, language arts, nutrition, geography, literature, and health science, along with skills acquisition. In recent years, with First Lady Michelle Obama (2012) joining children from local public schools in planting and harvesting organic vegetables at the White House, the school garden movement in the United States is becoming validated and reenergized. Furthermore, garden-based learning is at the convergence of two overlapping strands of public interest.

The first strand centers around obesity, health, and food insecurity. There is heightened interest in teaching students how to grow food, and school grounds are considered prime places for local food production and garden-based learning (Azuma & Fisher, 2001; Birch, 1990; The Edible Schoolyard, 2009; Ozer, 2006; P. J. Morgan et al., 2010). The following trends give a sense of urgency to this interest: all-time high childhood obesity rates (Eisenmann, Gundersen, Lohman, Garasky, & Stewart, 2011; Harrison et al., 2011; Niklas, Yang, Baranowski, Zakeri, & Berenson, 2003), waves of salmonella and *E. Coli* outbreaks, and the increase in Type 2 diabetes among children (Hedley et al., 2004; Vivian, Carrel, & Becker, 2011).

The second strand is fueled by the No Child Left Inside Coalition. Louv's (2005) bestseller, *Last Child in the Woods: Saving Our Children From Nature-Deficit Disorder*, has spurred the formation of a large national Children and Nature Network (2009) with a sense of urgency to offer children outdoor spaces to play and experience nature. As an antidote to the No Child Left Behind Act of 2001, seen as narrowly defining curriculum and restricting children, a No Child Left Inside Coalition (2009) has emerged. School gardens are seen as common denominators for children to gain *outdoor* learning experiences on school grounds.

Given these trends and the national interest in gardens at school sites (Hayden-Smith, 2006), the school garden movement and garden-based learning appear to be set fixtures in our educational institutions. A survey of the extant literature shows that specific curriculum/subject links are made with science, language arts, mathematics, social studies, and writing. Studies also show that school gardens have a multitude of purposes, including (a) personal, social, physical, and moral development that also addresses self-concept, self-esteem, and motivation (Bowker & Tearle, 2007; Dirks & Orvis, 2005; Hendren, 1998; O'Brien & Shoemaker, 2006; Robinson & Zajicek, 2005; Sheffield, 1992; Simone, 2003); (b) positive environmental attitude and empathy (Berenguer, 2007; Dirks & Orvis, 2005; Skelly & Zajicek, 1998; Waliczek & Zajicek, 1999); (c) increased food literacy and healthy eating habits (Canaris, 1995; Koch, Waliczek, & Zajicek, 2006; Lineberger & Zajicek, 2000; Morris, Neustadter, & Zidenberg-Cherr, 2001; Parmer, Salisbury-Glennon, Shannon, & Struempler, 2009; P. J. Morgan et al., 2010); and (d) school bonding, parental involvement, and formation of community (Brink & Yost, 2004; Brunotts, 1998; Cutter-Mackenzie, 2009; Mayer-Smith, Bartosh, & Peterat, 2009; Waliczek, Logan, & Zajicek, 2003).

Although the vast array of topics covered and increased interest in garden-based pedagogy are laudable, there is need for evidence about the extent to which garden-based learning meets *academic* outcomes if school gardens are to gain legitimacy. Since gardens are on school grounds, there needs to be justification for their academic value. Hence, the overall goal of this exploratory study was to determine what the landscape of research indicates about the impact of garden-based learning on academic outcomes. A synthesis of existing research was undertaken with a view to identify, select, and analyze the knowledge base of academic outcomes of school gardens to help educators, policymakers, and other stakeholders understand whether gardens are effective in improving academic learning.

What Is Garden-Based Learning?

Garden-based learning is an instructional strategy that utilizes a garden as an instructional resource, a teaching tool. “It encompasses programs, activities and projects in which the garden is the foundation for integrated learning, in and across disciplines, through active, engaging, real-world experiences” (Desmond, Grieshop, & Subramaniam, 2002, p. 7). There is proliferation of garden programs and curriculum, including the Boston Schoolyards Initiative, the Common Roots Program in Vermont, Denver Urban Gardens, the Garden-Based Learning Program at Cornell, the Learning Gardens Laboratory in Portland, the Life Lab Science Program at Santa Cruz, the San Francisco Green Schoolyard Alliance, the Edible Schoolyard in Berkeley, the Garden Initiative in Chicago, Urban Harvest in Houston, the Junior Master Gardener programs, 4-H Youth garden programs, and the National Wildlife Federation Schoolyard Habitat Program across most states (Broda, 2009; Houghton, 2003; Williams & Brown, 2012). Although each program is unique and distinctive based on its locale, all engage school children and youth with experiential and hands-on learning.

Method

Conceptual Framework for Research

In a recent article in *Review of Educational Research*, Suri and Clarke (2009) presented a new framework of “methodologically inclusive advancements in research synthesis” (MIRS) methods. Going beyond the traditional positivist approaches to meta-analyses, they developed a methodology that we used, as it is conceptualized by distilling and synthesizing ideas, theories, and strategies. Their theoretical approach to advancing research syntheses is appealing because it builds connections. As garden-based learning research tends to be interdisciplinary, we believe MIRS provided the best match for this research synthesis. Furthermore, in *Synthesizing Research: A Guide for Literature Reviews*, Cooper (1998) stated,

> Research syntheses focus on empirical studies and seek to summarize past research by drawing overall conclusions from many separate investigations that address related or identical hypotheses. The research synthesist hopes to present the state of knowledge concerning the relation(s) of interest and to highlight important issues that research has left unresolved. (p. 3)

As with all exploratory research, we did not have a hypothesis going into the process. The trends emerged in the analysis. We used a wide net to identify empirical research between 1990 and 2010 that examined the impact of garden-based learning on academic performance from the primary grades through the end of high school (12th grade). We used descriptive rather than parametric tools, “paying close attention to details before invoking more technically involved procedures” (Howell, 2002, p. 4). Not only is garden-based learning new, but the research is relatively new and limited. Hence, we gathered extant research in garden-based learning. We selected studies for detailed analysis based on a set of criteria and analyzed the results along the lines of positive, negative, or no impact, and we summarized their findings and trends.

Search Process

Although gardens have been part of the school landscape in the United States from time to time since the late 19th century, and were particularly popular during World War I and World War II, for our review we chose studies from 1990 to 2010 since much of the recent momentum for establishing school gardens started in the early 1990s and we were able to cover databases until mid-2010 as a cutoff point. The 48 studies that are reviewed resulted from a three-phase process we followed for the identification, selection (elimination or inclusion), and analysis of studies.

Studies were selected if they met the following criteria: (a) There was garden-based curriculum, (b) academic outcomes were measured, (c) exposure consisted of a minimum of an hour at least every 2 weeks, (d) there was connection with schools, and (e) assessment measures were specific to the age group being studied. These criteria were developed after we had randomly reviewed 20 publications of garden programs prior to undertaking Phase 1 of the search process and were also based on pilot site visits to school gardens in eight states undertaken by the primary author (Williams & Brown, 2012). We were mindful not to let our own interest in garden-based learning as a pedagogical tool bias the process by establishing coding protocols that emerged as an iterative process while reviewing a sample of studies in the first phase of the review, since our intentions were to find out what research tells us about the academic difference that school garden programs make and to disseminate research knowledge in order to shape both practice and policy in garden-based learning.

Phase 1: Search process to access studies. In the first phase we did a search of electronic databases and journals: Academic Search Complete (EBSCO), Agricola (EBSCO), Biological and Agricultural Index Plus, BioOne, Child Welfare League of America, ProQuest Dissertations & Theses Abstracts Online, Education Full Text, Environmental Science and Pollution Management, ERIC (EBSCO and U.S. government interfaces), Google Scholar, GreenFILE (EBSCO), HortTechnology, informaworld, JSTOR, PsycINFO, and Web of Science (SocSciCitIndex). We queried each database separately rather than use a meta–search engine in order to have a clear record of the source of results, a procedure we followed throughout the research. In formulating the query terms, we used a text editor that allowed word wrapping to be disabled. This assured accurate pasting into the database search windows without line breaks or any unseen symbols typically generated by word processors. Based on the research question, three major search parameters were developed: (a) garden-based education, (b) academic achievement, and (c) evaluation. The most elegant, simple, and effective search strings were developed. Following standard search process, the final search terms were as follows, separated by the Boolean term “AND”:

- garden or (garden-based learning) or (school garden) or (green school yard) or (green school ground) or horticultur*
- academic or (academic achievement) or (academic effect) or (academic outcome) or (academic performance) or (academic skill) or (standard test) or (test score) or outcom*
- (program evaluation) or (evaluation research).

We found that grouping the terms resulted in fewer duplicate sources, eliminating extraneous articles without jeopardizing the final results. For example, we used the term *academic achievement* instead of *academic* and *achievement* by themselves. Several search terms were eliminated because they were found to be contained in a shorter final search. We tested this by adding terms, then comparing the results. For example, when we added the term *math*, it gave rise to no additional results when compared to the results from the previously described second search term. Furthermore, we did not need to list individual direct or indirect variables because they emerged from the simple search terms used. We excluded from our search terms those that did not add to the outcome of the searches: *knowledge, science, motivation, attendance, engagement, literacy, academic efficiency, program effectiveness, academic impact*, and *academic measure*.

In performing the queries, we used "apply related terms" but found that it did not result in additions. Also, we eliminated many terms that were rendered redundant with the use of a "wildcard" to make searches more efficient. For example, *competenc** was effective in the search for *competence, competency*, and *competencies*. Dissertations and Theses Abstracts and JSTOR had limits to the number of terms that could be used. For instance, JSTOR could only take three wildcards, which necessitated modification as follows:

- garden* or (garden-based learning) or (school garden) or (green school yard) or (green school ground)
- academic* or (academic achievement) or (academic performance) or (standard* test) or
- (test score) or outcome or (program evaluation) or (evaluation research).

As we were progressing through the search, on the recommendation of the research librarian, we used RefWorks primarily because it allowed for online collaboration from any computer by the two investigators as well as other researchers if they were to be added at a later date. RefWorks permitted backups and exportation of citations into multiple formats, including EndNote and CSV (comma separated values) delimited text files. Next, we used Zotero to acquire references from Google Scholar, informaworld (where Applied Environmental Education & Communication, among others, is housed), and HortTechnology. Published books on the topic were utilized for their reference sources to hand trace further relevant studies. After collecting the citations into RefWorks, we traced and eliminated any duplicate articles that resulted from overlaps in the databases, resulting in 235 citations.

Phase 2: Preliminary analysis of studies and fine-tuning. The citations were next color coded: neither pertinent nor relevant to our synthesis (blue), relevant to garden-based education in general but not pertinent to our synthesis (yellow), or directly pertinent to our synthesis (green). For instance, if an article had the term *garden* in the name of a school or even a city such as Garden Grove, California, but did not use garden-based learning, it was considered neither pertinent nor relevant and marked blue. Articles were considered relevant to garden-based learning but not pertinent and marked yellow if (a) they dealt with garden programs that were based in the community with no explicit connection to schools and/or student learning, (b) they were commentaries on garden-based learning, (c) there was no "treatment" of a garden, or (d) there was no research component.

Abstracts of all articles (including journals, dissertations, theses, and reports) were read by the primary author to determine which ones were empirical studies of school-based garden programs. If abstracts were unclear, then the full articles were read. The second author randomly checked 20% of the abstracts; before proceeding, we discussed discrepancies mostly to gain clarity and accuracy over the coding. In keeping with Suri and Clarke (2009), as an emergent synthesis design, we attempted to keep our approach open, raise questions of each other, explore possibilities, and stay in dialogue. Nevertheless, independent coding of the rest of the articles was undertaken next by the second author. Overall discrepancy between the authors for 21 (9%) articles was minor, bordering on green and yellow coded articles. Each discrepancy was discussed to reach consensus. After eliminating the blue and yellow ratings, 152 articles remained. A matrix was developed to classify and catalog all 152 unduplicated articles in a garden-based learning database we created based on reviewing the abstracts and several full-length manuscripts as samples. The two authors then filled in the matrix to further refine the search.

We used a compendium of variables from previous readings of the articles as well as the headings from the matrix. The categories (column headings) for analysis in the matrix were modified after the first 35 articles were read at random. Articles often resulted in population of several columns in the matrix. The emerging list of categories included author, date, title, school/district, grade, school demographics, student demographics, research design, data collection, learning outcomes, and subjects covered (e.g., science, math, language arts, social studies, writing). After a few reviews, it became clear to us that we also needed universal categories such as "direct academic outcomes" and "indirect academic outcomes," which were added to the matrix. Any differences in deciding whether to include or exclude an article were discussed until consensus was found.

In order to include the articles in the next phase of the synthesis, we asked the following questions: (a) Is the study empirically based, (b) are there pertinent research questions, (c) is the methodology described, (d) is research evidence provided, (e) are links made between garden and school/curriculum/subjects, and (f) are outcomes measured? The caliber of research became critical during our review as we examined each study further for the following characteristics: clear statement of intentions, problem, setting, and arguments; coherent framework of theory, methodology, validity, analysis, and conclusions; detailed information about the study context, methods, and sources of data; well-defined and articulated sample; presentation of an adequate data set; description of data collection methods; findings that emerged from the research process; and conclusions that referred back to the original framework.

As an initial assessment, the authors reviewed each article independently and rated it on a 1 to 10 scale; the greater the relevance to the research question, namely, examining the impact of school gardens on academic learning, the higher the score on relevance. Furthermore, studies with a higher quality of research and writing received higher ratings. Based on aforementioned categories, studies that reported an impact on indirect academic variables (e.g., discipline, bonding, social skills) but did not measure direct academic impact (e.g., test scores, grades, GPA) were scored no higher than 7 if written clearly. We operationalized direct academic variables as subjects including science, math, language arts, writing, and social studies.

Apart from the national urgency for improvement in science, language arts, math, and writing, another reason for the focus on direct academic outcomes is the relative standardization of assessments for these subjects when compared to indirect variables. Both investigators reviewed all articles, with surprisingly close results. None of the ratings were more than 2 points off the other investigator's ratings. Although 38 out of 152 had slightly differing scores, these studies were re-read and the scores were discussed to reach consensus. For the next phase, only those studies rated 6 or higher (i.e., above the mean) were included, as the overall pool of articles was weak in research methodology and the distribution resulted in a natural break between the ratings of 5 and 6, resulting in the inclusion of 52 studies. Four were dropped because they were dissertations or theses that were subsequently published in a peer-reviewed journal already in this set of studies. These procedures resulted in 48 studies for final review.

During the search process, we found two peer-reviewed articles (Blair, 2009; Ozer, 2006) and one literature review/report from the United Kingdom (Dillon, Rickinson, Sanders, Tearney, & Benefield, 2003) that were syntheses of garden-based and/or farm-based education that we examined in depth but did not include in our database for this synthesis since they were not empirical studies about garden-based learning. Blair (2009) reviewed U.S. studies related to children's gardening that resulted from 12 quantitative and 7 qualitative studies with a view to explore "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" (p. 33). In her review, which was limited in its criteria for selection and not solely focused on academic outcomes, she found positive results. Her outcomes included science achievement (5 studies), food and nutrition (4 studies), environmental attitude change (2 studies), and self-esteem and life skills (2 studies).

Ozer (2006) reviewed 10 studies, 4 of which overlapped with Blair (2009), that explored the relationship of school garden programs to youth development and health outcomes, but this review did not include an analysis of academic outcomes. Finally, Dillon et al. (2003) reviewed studies in the United Kingdom that addressed children's knowledge of and attitudes toward food, farming, and the countryside. Although not entirely related to our synthesis, this report served as a useful resource in developing guidelines for the template that we discuss in Phase 3. In our database, we included the original sources of articles in these reports if they met the criteria. All three syntheses were critical of the limited number of research studies and also the weak methodology in research they were able to find. These syntheses of research convinced us that our present review spanning two decades was comprehensive and also distinctive in its focus on academic outcomes of garden-based learning.

Phase 3: Design of template and analysis of studies. After the matrix was developed and populated and the list of articles was narrowed to 48, a template was designed and

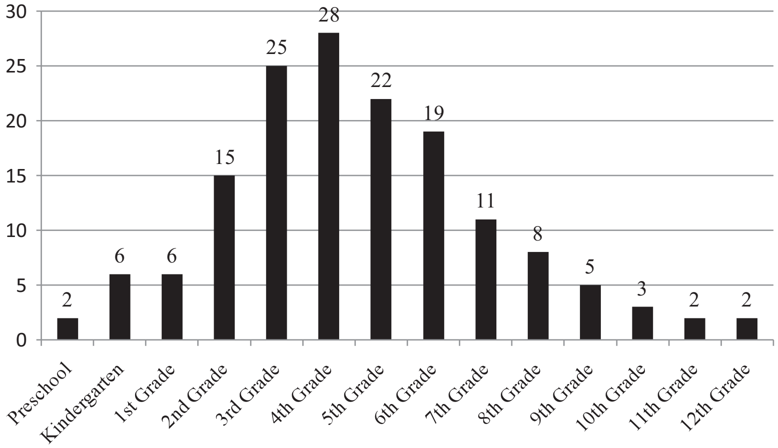

Figure 1. *Studies by grade level.*

developed (see Appendix A) to analyze each article, using Dillon et al. (2003) as a guiding skeletal framework. The final template was the result of multiple iterations involving consensus exercises between the two researchers. Each of us independently reviewed 15 articles at a time and then met to discuss our ratings and any divergences as well as reach consensus before going on to the next 15.

The data from the template were entered into an Excel spreadsheet directly from the 48 templates using the categories enlisted in the template. Once data were verified, an SPSS database was developed from the headings and variable types (numeric, string, etc.) used in the spreadsheet. These data were then imported into SPSS. Variable names and labels were developed to mirror the template, and missing cases labels were developed where appropriate. Also, new variables were developed from original data to enhance statistical analyses. For example, a study that indicated "Grades 1–3" resulted in positive dummy variables for first, second, and third grades. The results of all additional variables and transformations were verified on a case-by-case basis and computations performed according to generally accepted techniques in educational and sociological research.

Results

In Appendix B in the online journal, we summarize the 48 studies that met the criteria and present their overall findings, research design, and programs. Because there were multiple measures, multiple grade levels, and multiple outcomes in many of the studies, the totals often exceed 48, as seen in the tables presenting the analyses of the data.

Samples and Grade Levels

Of the 48 studies reviewed, 32 examined multiple grades and 16 looked at a single grade only. In those cases where age was mentioned, for comparative purposes we recorded the corresponding grade. Figure 1 presents the studies by grade level: Nearly half comprised of third, fourth, and fifth grades. The least studied grades were preschool and Grades 10–12. When we analyzed the sample size, we found that 44 of the 48 articles designated the individual student as the unit of analysis, 3 studies looked at the performance of the school as a whole, and 1 study queried teachers only. Of the studies, 57% had a sample size of fewer than 200 students. Of the 11 studies with a sample size less than 100, more than 50% had samples of less than 50.

Outcomes of Garden-Based Learning

The studies looked at direct or indirect impacts of garden-based learning on academic performance. Twenty-five outcome categories were reported, with most articles reporting more than one outcome (see Table 1). Twenty-two of the 48 studies measured the impact of garden-based learning directly on science, math, language arts, writing, and social studies. Several of these also measured indirect or other impacts; 26 articles did not measure any direct impact but measured indirect academic outcomes, and there were additional outcomes ("other") in the articles related to growing food, healthy eating, and physical activity, for example.

Of the studies with direct academic outcomes, 15 (38%) measured science outcomes, followed by language arts (11, 28%), math (10, 25%), writing (3, 8%), and social studies (1, 3%). Of the 40 assessing direct learning outcomes, 33 (83%) found positive effects, 1 (3%) found a negative effect, and 6 (15%) indicated that learning was unchanged after the program. Science had the highest proportion of positive effects, with 14 (93%) of the 15 resulting in positive effects. In one study, using a sample of 647 students in Grades 3–5 in seven elementary schools in Temple, Texas, Klemmer, Waliczek, and Zajicek (2005b) found that "science achievement of students who participated in a hands-on school gardening program was higher than that of students who did not participate" (p. 448). They concluded, "Hands-on, constructivist learning serves as the main idea behind school garden programs. Gardens can serve as living laboratories in which students can see what they are learning and in turn, apply that knowledge to real world situations" (Klemmer et al., 2005b, p. 452).

Furthermore, 80% of the direct academic outcomes in mathematics and 72% in language arts had positive outcomes. Two of three measures were positive for writing, and the only study that examined social studies found a positive effect. Of the 170 reported outcomes, 140 (82%) were positive, 3 (2%) reported negative effects, and 26 (15%) indicated no impact. The curricula for science and math were recorded as most frequently connected to gardens, and these varied widely across studies. Soil chemistry, plant taxonomy, plant parts, flower dissection, water properties, seed germination and variety of seeds, insects and other wildlife, ecology and environmental horticulture, and insects and diseases represent a partial list of science themes presented in the research studies. In mathematics, experiential learning covered themes in geometry, algebraic equations, probabilities, data analysis, and measurements.

Positive outcomes were often attributed to direct, hands-on experiences that made classroom learning relevant. As Castagnino (2005) reported in her study, third-grade students "developed observation skills and applied them in other classroom activities; improved descriptive and scientific vocabulary; demonstrated understanding of the scientific method; . . . and explored connections between

TABLE 1
Frequency and percentage of academic outcomes with impact

	Positive impact (row %)		No impact		Negative impact		Total
Direct academic outcomes							
Science	14	(93)	1	(7)	0	(0)	15
Language arts	8	(72)	3	(27)	0	(0)	11
Math	8	(80)	1	(10)	1	(10)	10
Writing	2	(67)	1	(33)	0	(0)	3
Social studies	1	(100)	0	(0)	0	(0)	1
Subtotal	33	(83)	6	(15)	1	(2)	40
Indirect academic outcomes							
Social development	10	(77)	3	(23)	0	(0)	13
Nutrition knowledge	8	(73)	3	(27)	0	(0)	11
Self-concept	6	(60)	4	(40)	0	(0)	10
Attitude toward academics	9	(100)	0	(0)	0	(0)	9
School bonding	4	(67)	1	(17)	1	(17)	6
Curiosity and wonder	4	(100)	0	(0)	0	(0)	4
Life skills	4	(100)	0	(0)	0	(0)	4
Problem solving	4	(100)	0	(0)	0	(0)	4
Motivation	3	(100)	0	(0)	0	(0)	3
Attendance	0	(0)	2	(100)	0	(0)	2
Discipline	2	(100)	0	(0)	0	(0)	2
Study habits	1	(100)	0	(0)	0	(0)	1
Subtotal	55	(80)	13	(19)	1	(1)	69
Other outcomes							
Attitude toward gardening	14	(100)	0	(0)	0	(0)	14
Environmental empathy	10	(77)	2	(15)	1	(8)	13
Growing food	11	(92)	1	(8)	0	(0)	12
Nutrition attitudes	8	(80)	2	(20)	0	(0)	10
Healthy eating	5	(83)	1	(17)	0	(0)	6

(continued)

TABLE 1 (contineud)

	Positive impact (row %)		No impact		Negative impact		Total
Locus of control	1	(50)	1	(50)	0	(0)	2
Moral development	2	(100)	0	(0)	0	(0)	2
Physical activity	2	(100)	0	(0)	0	(0)	2
Subtotal	53	(87)	7	(11)	1	(2)	61
Total	141	(83)	26	(15)	3	(2)	170

science and writing" (p. 40). However, another study that showed statistically significant differences found that "fifth graders learning from traditional curriculum techniques achieved higher Math TAKS scores and Science achievement scores" when compared with those participating in garden programs (Pigg, Waliczek, & Zajicek, 2006, p. 264). The researchers concluded that since other studies have shown positive effects, "further research needs to be conducted on school garden programs and their influence on the academic success of students" (Pigg et al., 2006, p. 264).

Thirty-six studies assessed garden-based learning's effects on indirect academic outcomes. Most articles assessed more than one outcome, resulting in 69. Of these, 55 (80%) were positive, 1 was negative (1%), and 13 (19%) were neutral. In a study measuring the overall impact of a school gardening program on environmental attitudes and locus of control among third through fifth graders using a youth gardening program, Aguilar, Waliczek, and Zajicek (2008) concluded that "no statistically significant differences were found on either variable in comparisons of experimental and control group responses" (p. 243). They added, however, that students from both groups exhibited positive environmental attitudes. Among the indirect academic outcomes, social development was the most commonly assessed (13), and 10 (77%) resulted in positive effects.

Only one study found negative impact on any indirect variable, in this case, school bonding. The lowest ratio of positive findings was in self-concept (60%). In a study of 528 students in Grades 2–8 in eight schools in Kansas and Texas, Waliczek (1997) found that the garden program had a "statistically negative effect on adolescents' attitude toward school" (p. iv). She explained that "this could have been due to the timing of the post-test instrument at the end of the school year, or factors such as some students involved were concerned with 'getting dirty' at school" (Waliczek, 1997, p. iv). However, this study also indicated that girls had more positive attitudes toward school than boys. As seen in Table 1, in the synthesis, the effects on several of the indirect outcome measures were 100% positive, including motivation, curiosity and wonder, discipline, study habits, problem solving, life skills, and academic attitudes.

Of the other outcomes reported beyond direct and indirect academic learning, 53 (87%) were positive, 1 (2%) was negative, and 7 (11%) indicated no effect. Fourteen studies measured the impact of garden programs on attitudes toward gardening, and all 14 resulted in positive effects. Two measures of environmental attitudes (environmental empathy and locus of environmental control) were also assessed. Of the 15 examinations of these attitudes, 11 (73%) yielded positive effects, including 10 of the 13 studies (77%) that looked at environmental empathy. Thirteen of the 16 (81%) examinations of nutrition measurement found positive effects, as did 11 of 12 (92%) outcomes on growing food. Both studies that looked at the impact on morals found positive results. Likewise, the 2 studies that measured the outcomes on physical activity found positive outcomes.

Year of and Place of Publication and Methodology

Dates and places. Thirteen (37%) of the 48 studies were completed in the 1990s, and 35 (73%) were in the 2000s, with 20 (42%) being conducted between 2006

TABLE 2
Frequencies of research by school demographics and type of schools

School/district descriptors	Number of studies (n = 48)	%
Ethnicity		
> 50% non-White	5	10
≤ 50% non-White	0	0
Not reported	43	90
Socioeconomic status		
Low	15	31
Medium	3	6
High	0	0
Not reported	30	63
Public/private		
Public	33	69
Private	0	0
Both	3	6
Not reported	12	25

through 2010, suggesting a recent increase in research interest in the topic. Although we placed no restriction on where the research took place, almost 79% of the studies took place in the United States, with the others taking place in Australia, England, India, Kenya, and Wales.

Type of study. Of the studies, 50% were quantitative only, whereas 13 (27%) were mixed-methods, and 11 (23%) were qualitative only. We defined quasi-experimental as research that had a pre- and posttest of the effect of the garden program but without randomization of assignment to the sample and experimental groups. The majority (69%) of the research designs were quasi-experimental. Eight studies (17%) were descriptive, 4 were case studies (8%), 2 were participatory research projects (4%), and 1 was an action research project (2%). Thirty-three of the 48 articles (69%) addressed validity issues.

Description of samples. Limited information was provided on school demographics, and information on ethnicity and socioeconomic status were not reported in 90% and 63% of the studies, respectively. Additionally, none of the studies reported overall gender information when discussing schools. Only 36 studies reported the type of school, and 33 (69%) of these were described as public schools. Three studies (1%) involved students from both public and private schools (see Table 2). The mean number of students in the studies was 225 students (Mdn = 178, SD = 178, $5 \leq N \leq 654$; see Table 3). Nineteen studies used experimental and control groups, and control groups were substantially smaller than experimental groups.

Program description. Appendix B in the online journal highlights, by study, the range of programs offered. It was not unusual for garden programs and redesigned schoolyards to serve multiple functions (Williams & Brown, 2012), such as growing food, connecting students to nature and the outdoors beyond the four walls of

TABLE 3
Student samples by experimental and control groups

	Total students	Experimental group	Control group
Mean	225	161	96
Median	178	113	74
Mode	127	306	57
Standard deviation	178	135	72
Range	649	452	272
Minimum	5	9	12
Maximum	654	461	284

the classroom, making a variety of disciplines—particularly science—relevant through hands-on learning, developing environmental stewardship, enhancing the symbolic significance and aesthetics of life in its many forms right on the school grounds, educating for nutrition and health, and bringing balance to students' lives.

Among the most frequently studied programs were those designed and offered by Master Gardeners, known as the Junior Master Gardener program (13, 27%); Schoolyard/Wildlife Habitat programs including those developed by Learning Through Landscapes and the National Wildlife Federation (6, 12%); Project GREEN, a garden resources for environmental education program (4, 8%); and the national 4-H programs offering grade-level structured gardening curricula adaptable locally (3, 6%). In addition, there was a wide range of programs specifically designed for a school or a school district: Gardening Angels, Greener Voices, Heritage School Garden, Multicultural School Garden, Youth Farm Market Project, and Youth Garden Program, among others.

Nutrition and health programs were also explicit designs in seven (15%) of the studies. Field trips were undertaken to teach students specific subjects through gardening and were connected to curriculum in the classroom. Examples of these types of programs included Louisiana's Coastal Roots program, the Brooklyn Botanic Gardens, and Pittsburgh Civic Gardens program. Given the sample size for the studies analyzed, incomplete demographic information, and the vast variety of gardens and programs, often with more than one direct and indirect academic goals and outcomes, it was not possible to assess relationships to grades, gender, and themes.

Discussion

One important finding of this review deals with the grade levels and school settings being studied by current research. Nearly half of all studies were conducted with third, fourth, and fifth graders, although it is not clear if garden-based curricula are concentrated at these grade levels. Although the research reported is useful to academics, practitioners, and policymakers in these grades, it points to the need for research in the grades largely excluded from research that examines the impact of school gardens on academic outcomes. Furthermore, nearly half of the studies had a sample of 175 or less. A bifurcated research strategy looking at both the micro as well as macro levels of garden-based learning—small groups as well as school and district levels—would be useful, since gardens, like gymnasiums and laboratories, affect the whole school.

Findings on Academic Impact

The main goal of this review was to report on recent research on the impact of garden-based learning on academic outcomes of subjects such as science, language arts, mathematics, writing, and social studies. Since many of the studies also provided data on a number of related outcomes, we analyzed these additional outcomes and categorized them under indirect academic outcomes as well as other related outcomes. The indirect academic outcomes were included because they offer information on the impact of garden-based learning on the entire learning experience of participating children and youth. The results of the studies indicate strong and frequent positive impacts in all areas studied. The results of the studies show overwhelmingly that garden-based learning had a positive impact on students' grades, knowledge, attitudes, and behavior. These positive impacts prevailed for nearly every outcome group, including the elementary, middle, and high school levels, with positive impacts of 85%, 83%, and 91%, respectively, although the number of studies at the high school level was the lowest. The preponderance of overall positive findings is important since research methodologies of the 48 studies were found to be highly eclectic. These findings speak to the potential of garden programs in benefitting academic and academic-related outcomes.

Although practitioners, administrators, and policymakers may find the direct academic outcomes to be of primary interest, the totality of effects from the indirect and other effects form what appears to be a systematic structure of positive impacts on many different levels for students exposed to school gardens. These range from self-concept to motivation and life skills to environmental attitudes. However, there were few robust measures clearly delineating many of these outcomes.

Criticism of Research Rigor

There were several weaknesses in the studies that emerged from this review, related primarily to issues of sampling and validity. Although random assignment to experimental groups is frequently impractical in educational research, there was ample opportunity to address sample groups that were not found in many of the studies. For example, gender and socioeconomic status were reported in a low proportion of the studies. Sample ethnicity was mentioned only in 33% of the studies and only 46% mentioned gender. Moreover, none of the studies mentioned socioeconomic status in other than a cursory manner and with enough specificity to allow us to examine the impact of this variable. Similarly, only five studies provided demographic information on the ethnicity of the school population.

In the process of searching for studies that met the criteria for this review, we found that validity was seldom explicitly addressed. In the final pool of 48 articles, only 33 (69%) mentioned validity at all. Several studies referred to validity and reliability of the scores for the standardized tests utilized as an academic outcome, but none of the studies mentioned threats to construct validity, content validity, criterion validity, or reliability. Nor was any explicit mention made of experimental validity. In several of the articles that mentioned validity, the authors listed as affirmative those studies that talked about aspects of validity (e.g., when the control group and experimental group were claimed to be generally similar).

Finally, one of the major challenges in synthesizing research such as this is in locating bias, especially bias from those advocates passionate about the subject matter. Researcher bias is important to acknowledge. Those who both work and perform research in garden-based learning tend to be passionate advocates of the pedagogy, as was evident in many of the studies; yet the limitations that bias poses for research were not acknowledged. This field needs to begin to engage in deliberate, thoughtful, and critical analysis of their work.

Conclusion and Future Research Directions

In general, the body of research on garden-based education lacked focus and clarity given the myriad outcomes reported. Although the growth of school gardens, garden programs and activities, garden curriculum, and garden-based learning is laudable, the movement falls short in that there has not been a parallel focus on rigorous research to understand the academic learning outcomes in a systematic manner. School garden programs will likely continue to be invigorated since there is broader acknowledgement among educators and policymakers alike about obesity and health issues affecting children and youth. With increasing interest comes accountability. We call for well-designed studies to disseminate research knowledge that can inform the field, as there is a growing need to systematize knowledge of garden-based learning. Clustering similar kinds of garden programs/models across schools, districts, and states might support investigations of their effectiveness, especially if large-scale longitudinal studies are undertaken.

The template we developed for this research (see Appendix A) provides a framework for future research on garden-based learning related to research methodology, sample demographics, reliability, validity, analysis, and the like. Furthermore, this review has policy implications on two levels: (a) instructional and curricular integration of school gardens and (b) focusing the discourse of garden-based learning on academic outcomes. This synthesis found a preponderance of positive academic outcomes especially in science, math, and language arts, giving credence to gardens serving as instructional and curricular means for covering academic content. Hands-on learning has been shown to be an important component in promoting positive attitudes toward learning (Klemmer et al., 2005b), and involving children in experiential learning is also found to help promote higher-level learning (Waliczek et al., 2003). Results from this synthesis support the idea that for some students, gardening may be an effective tool to supplement, enhance, or complement existing traditional curricula.

However, these results also indicate that garden instructional activities may need more curricular development and integration with particular subject areas if they are intended to improve academic performance. Perhaps garden-based learning could serve as one venue to advance the recent interest in education reform promoting Science, Technology, Engineering, and Mathematics (STEM) initiatives (National Science Foundation, 2010) and for career prospects in horticulture, landscape design, and architecture, as well as food, nutrition, and health. Yet, these outcomes necessitate an agenda that measures learning outcomes. This synthesis demonstrates the need for equal attention to rigorous research if garden-based learning is to gain credibility within and beyond the garden advocacy groups and include the broader education community.

Appendix A

Garden-Based Education Outcomes: Research Studies

Review Template

<table>
<tr><td>DATE OF REVIEW (d/m/yr)</td><td></td></tr>
<tr><td>NAME OF REVIEWER</td><td></td></tr>
<tr><td>REFERENCE
primary author, date, title
(place “x” in box)</td><td><table><tr><td></td><td></td><td></td><td></td><td></td><td></td></tr><tr><td>article</td><td>thesis</td><td>dissertation</td><td>book</td><td>conference paper</td><td>report</td></tr></table></td></tr>
<tr><td>RESEARCH GOALS</td><td></td></tr>
<tr><td>OVERALL SCHOOL/ DISTRICT FEATURES</td><td><table><tr><td>school name/ district:</td><td></td></tr><tr><td>city:</td><td></td></tr><tr><td>state:</td><td></td></tr><tr><td>features:
(size, rural/urban, diversity, etc.</td><td></td></tr></table><table><tr><td></td><td></td><td></td><td></td></tr><tr><td>public</td><td>private</td><td>magnet</td><td>charter</td></tr></table></td></tr>
<tr><td>SAMPLE</td><td><table><tr><td>grade:</td><td></td></tr><tr><td>age:</td><td></td></tr><tr><td>race/ethnicity:</td><td></td></tr><tr><td>gender:</td><td></td></tr><tr><td>total sample size:</td><td></td></tr><tr><td>experimental:</td><td></td></tr><tr><td>control:</td><td></td></tr></table></td></tr>
<tr><td>CONCEPTUAL/ THEORETICAL FRAMEWORK OF THE PROJECT/ TREATMENT</td><td></td></tr>
<tr><td>TREATMENT
Name of Program</td><td><table><tr><td></td><td></td><td></td></tr><tr><td>formal</td><td>informal</td><td>integrated</td></tr></table></td></tr>
</table>

(continued)

Appendix A (continued)

TREATMENT DURATION

duration: weeks/months/years	
start/stop dates:	
summer term:	
academic year:	

RESEARCH METHODOLOGY

qualitative	quantitative	mixed method

experi-mental	quasi-experimental	action research	participatory/ ethnographic	historical	research synthesis

case study	descriptive	longitudinal	other (list)

DATA COLLECTION

survey	interview	observation	secondary data	other (list)

VALIDITY MEASURES

yes	no

MAIN FINDINGS

OUTCOMES

academic	growing food	wildlife enhanceme nt	healthy eating	personal development	moral/ethical development

social development	formation of community	physical activity/play	vocational	other (list)

(continued)

Appendix A (continued)

<table>
<tr><td>DIRECT ACADEMIC LEARNING OUTCOMES BY SUBJECTS (e.g., test scores)</td><td>
<table>
<tr><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>science</td><td>math</td><td>language arts</td><td>writing</td><td>other (list)</td></tr>
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Specify/Describe:</td></tr>
<tr><td>GENERAL ACADEMIC OUTCOMES</td><td>
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<tr><td>GPA</td><td>attendance</td><td>other (list)</td></tr>
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Specify/Describe:</td></tr>
<tr><td>INDIRECT ACADEMIC LEARNING OUTCOMES</td><td>
<table>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>self-concept</td><td>self-esteem</td><td>self-confidence</td><td>interpersonal</td><td>motivation</td><td>enthusiasm</td></tr>
</table>
<table>
<tr><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>discipline</td><td>respect for others</td><td>environmental empathy</td><td>school bonding</td><td>study habits</td><td>problem solving</td></tr>
</table>
<table>
<tr><td></td></tr>
<tr><td>other (list)</td></tr>
</table>
</td></tr>
<tr><td>KEY CONCLUSIONS</td><td></td></tr>
<tr><td>REVIEWER’S INTERPRETIVE VIEWS/FINDINGS</td><td></td></tr>
<tr><td>RELEVANCE/ RATING</td><td>
<table>
<tr><td>(low) 1 2 3 4 5 6 7 8 9 10 (high)</td><td></td></tr>
</table>
</td></tr>
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Note

This article is based upon work supported by a grant from the Spencer Foundation to the first author. Any opinions, findings, conclusions, or recommendations are those of the authors and do not reflect the views of the Spencer Foundation. The authors thank Sarah Beasley for library help, Lauren Young for assistance with initial research ideas, and James Williams for editing support. The authors also thank the editors and reviewers for their thorough feedback on an earlier version of this article.

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