Applied Environmental Education & Communication

ISSN: 1533-015X (Print) 1533-0389 (Online) Journal homepage: http://www.tandfonline.com/loi/ueec20

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To cite this article: Andrew Jon Schneller, Casey A. Schofield, Jenna Frank, Eliza Hollister & Lauren Mamuszka (2015) A Case Study of Indoor Garden-Based Learning With Hydroponics and Aquaponics: Evaluating Pro-Environmental Knowledge, Perception, and Behavior Change, Applied Environmental Education & Communication, 14:4, 256-265

To link to this article: http://dx.doi.org/10.1080/1533015X.2015.1109487

Published online: 11 Dec 2015.

Applied Environmental Education & Communication, 14:256–265, 2015

ISSN: 1533-015X print / 1533-0389 online
DOI: 10.1080/1533015X.2015.1109487

A Case Study of Indoor Garden-Based Learning With Hydroponics and Aquaponics: Evaluating Pro-Environmental Knowledge, Perception, and Behavior Change

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This article reports on a mixed methods evaluation of an indoor garden-based learning curriculum for 5th and 6th graders which incorporated aquaponics and hydroponics technologies. This study provides a better understanding of the extent to which indoor gardening technologies can be used within the formal curriculum as an effective teaching tool. Treatment group students showed statistically significant improvement in environmental knowledge scores as well as higher overall scores on environmental preservation, and in some instances, a commitment to practicing pro-environmental behaviors. Unexpected findings were found in relation to the extent to which students with learning disabilities excelled within the pedagogical design.

INTRODUCTION

Teachers throughout the United States are teaching interdisciplinary environmental education topics as well as Common Core State Standards and Next Generation Science Standards through garden-based learning (Hirschi, 2015). The pedagogy provides a framework for learning about food production systems, biology, botany, ecology, nutrition, composting, soils, food waste, globalization, food justice, medicinal plants, and native/invasive species, among others. Current research on garden-based learning has shown positive outcomes related to increases in healthy eating, environmental knowledge, as well as pro-environmental

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attitudes and behaviors (Aguilar, Waliczek, & Zajicek 2008; Bazzano, 2006; Blair, 2009; Dirks & Orvis, 2005; Karsh, Bush, Hinson, & Blanchard, 2009; Klemmer, Waliczek & Zajicek, 2005; Libman, 2007; Smith & Motsenbocker, 2005; Somerset & Markwell, 2009). Garden-based learning can be taught without having to leave the school grounds, and outside (utilizing school gardens) during warmer months. However, many school calendars do not coincide with months when outdoor gardening is possible (May through September). As such, teaching experiential garden-based learning through the use of indoor aquaponics and hydroponics systems could provide a surrogate framework for introducing students to sustainable food systems and community environmental issues (Carver & Wasserman, 2012).

Current research addresses the outcomes of hydroponic systems on the work adjustment skills of Korean students with mental retardation (ByungSik, SinAe, & KiCheol, 2012), and the logistics of building aquaponics and hydroponics systems in elementary and high school shop, science, and agriscience classrooms (Handwerker, 1990; Johanson, 2009; Paul, 2011; Peckenpaugh, 2001). However, Carver and Wasserman (2012) provided the only instance of evaluative research that documented positive knowledge and attitudinal outcomes of teaching biology, chemistry, and sustainable food production (with high school students) through building and maintaining indoor hydroponic systems.

Aquaponics, or the combination of aquaculture and hydroponics, is emerging as a teaching tool throughout the country, and has the potential to enhance interdisciplinary science education (Hart, Webb, & Danylchuk, 2013). Because aquaponics simultaneously grows edible plants and raises fish in a closed-loop system, the technology can increase the availability of food, thus addressing food security. Aquaponics is scalable and flexible, as small–medium size systems require minimal space and maintenance. Hart and colleagues (2013) measured the use of aquaponics systems in schools across North America. While no student outcomes were reported, the authors interviewed 10 educators using a system in a formal classroom (K–12 and higher education), within the past 5 years. Authors found three categories encompassed the reasons for aquaponics incorporation in classrooms: (a) applicability to academic subjects Science, Technology, Engineering and Math education (STEM); (b) benefits of hands-on, experiential, and integrated learning; and (c) connections to food, agriculture, and global trends. Challenges included technical difficulties and logistical restrictions due to school settings (Hart et al., 2013).

PROGRAM DESCRIPTION

Professors and students from an upstate liberal arts college, and a teacher from a local independent school, designed and implemented an experiential environmental education curriculum for a combined class of fifth and sixth graders, who maintained and studied three indoor hydroponic and aquaponics systems.

Indoor Garden-Based Learning Lessons

Twelve 1-hr lessons were taught weekly (for 12 weeks) to treatment group students. Lessons fit the independent school's guiding theme of the year, "Plants." Lessons were developed by faculty and students in an upper division environmental education course, and included a sampling of pre-existing lessons, for instance, "Food Miles: Where does my food come from?" developed by Hoyler (2012). Four guiding themes were utilized to structure the curriculum: Aquaponics, Hydroponics, Composting, and Food Systems (see Table 1). These four broader topics incorporated eight detailed lessons: (a) causes behind bioregional watershed problems; (b) exploring the physical environment, including flora, fauna,

Table 1
Indoor garden-based learning curriculum: Four overarching themes and underlying teaching topics

Aquaponics	Hydroponics	Composting	Food systems
pH and water quality	Photosynthesis	Composting	Organic and local foods
Nitrogen cycle	Indoor grow lights	Vermicomposting	Conventional food systems
Water testing	Pesticides	Soil health	Globalization
Closed-loop systems	Plant production tech.	Decomposition	Food justice
Symbiosis	Nutrients (N,P,K)	Worm anatomy	Food Miles
Fish production tech.	Hypothesis formation	Fertilization	Medicinal plants
Ammonia	Lab manuals	Food production	Native and invasive species
Species mortality	Healthy eating	Solid waste mgt.	Watershed health

and ecosystem relationships; (c) adopting pro-environmental behaviors: composting, vermicomposting, waste reduction, mindful consumerism, gardening; (d) plant literacy; (e) exploring global industrial and sustainable agricultural systems, and food justice; (f) local food systems and farming in the bioregion; (g) scientific literacy: hypothesis formation, data collection, and lab manual reporting; and (h) building and maintaining hydroponic and aquaponic technologies in the classroom.

All materials were provided free of charge by the college's Environmental Studies Program and Heliospectra, an LED indoor grow lamp manufacturer. Materials included (but were not limited to) custom stands, three fluorescent lighting hoods, one LED lighting hood, one 50-gallon fish tank, three water pumps, lightweight expanded clay aggregate, grow trays, water testing equipment, hydroponic liquid nutrients, seeds, and fish. Treatment students, their teacher, a janitor, college students, and a professor worked collaboratively to transport, design, and construct three custom indoor grow systems. Treatment students were responsible for planting seeds and fish, observing and recording plant and fish growth, feeding fish; and monitoring pH, temperature, and nutrient levels in the systems. The lessons included lectures, group discussions, and hands-on learning. The curriculum was designed to immerse students in aquaponics and hydroponics agricultural technologies and food-related projects that provided opportunities for students to grow and eat their own food. The curriculum was designed to incorporate the Inform, Assimilate, Apply learning model (Johnson & Manoli, 2008). For example, during the pH and Water Quality lessons the "Inform" portion included lectures, discussions, and note taking. The "Assimilate" portion involved hands-on activities to measure pH from community water sources, and the "Apply" portion was completed to determine appropriate pH levels for constructing and maintaining hydroponic and aquaponic systems. Students completed in-class labs, maintained lab manuals, and were assigned homework and take-home projects.

METHODS

The purpose of this research was to: (a) contribute to the growing body of research that addresses the outcomes of garden-based learning on various attributes of participants, and (b) contribute to the better understanding and documentation of innovative environmental learning pedagogies that depart from traditional didactic teaching styles. We addressed this by answering the following research questions:

- What are the environmental knowledge, perception, and behavioral outcomes of an indoor garden-based learning curriculum taught to adolescents?

- To what extent do adolescents participating in garden-based learning become more aware of environmental issues facing their community?
- What aspects of the experiential indoor garden-based learning curriculum do students find most influential in affecting their experience?

Participants

Two upstate New York schools participated in this study during the 2015/2016 school year. The quasi-experimental design (Creswell, 2003) incorporated a treatment group of 15 fifth and sixth graders attending an independent school (a combined science class of 10 and 11 yr. olds), while the control group of 17 fifth graders attended a private school in a nearby community; the control and treatment groups were demographically matched. The treatment group participated in indoor garden-based learning, all knowledge pretests and posttests, the pretest and posttest "2-MEV" scale (Bogner & Wiseman, 1999), and focus groups and interviews. The control group did not receive any of the garden-based learning curriculum, but did receive all of the pretest and posttests. Other participants included a sampling of treatment group parents and the primary school teacher, all of whom received semistructured interviews or participated in a focus group.

Environmental Knowledge Instrumentation

We developed a 21-item environmental knowledge evaluation tool[1] that was pilot tested with public school fifth grade students unrelated to our treatment or control groups. The test incorporated multiple choice, fill in the blank, and open-ended questions. The knowledge instrument was also later edited for clarity and content in accordance with the guidelines suggested by Creswell (2003).

Environmental Perception Instrumentation and the 2-MEV

We utilized a robust and multidimensional measurement scale called the Model of Ecological Values (2-MEV), which describes environmental attitudes contributing to an individual's Preservation (P) *and* Utilization (U) values (Bogner & Wiseman 1999, 2002, 2006). Wiseman and Bogner (2003) espouse that the higher order values of preservation (P) and utilization (U) are uncorrelated; preservation is "a biocentric dimension that reflects conservation and protection of the environment" and utilization is "an anthropocentric dimension that reflects the utilization of natural resources" (p. 787.). "The 2-MEV was specifically designed to tap the environmental values of children" (Schneller, Johnson, & Bogner, 2015, p. 2).

Johnson and Manoli (2008) utilized (and further validated) the 2-MEV scale to investigate changes in the environmental perceptions of a sample population of adolescents. The researchers administered pretests and posttests to the adolescents, using scores from The Environment Questionnaire (TEQ). The TEQ consists of 16 Likert questions broken into five categories: intent of support, care with resources, enjoyment of nature, human dominance, and altering nature. Johnson and Manoli found the 2-MEV to be valid and reliable (2008).

Control and treatment group respondents were given 40 min to complete both of our testing instruments in their school classrooms.

[1]This tool also included open-ended questions regarding student pro-environmental behaviors. Answers to these qualitative components were not included in the knowledge test scores. In terms of instrument reliability, the Cronbach's Alpha in the current sample at pretest was .64 (and could not be calculated at posttest due to numerous items with zero variance).

Both groups received the pretests at the beginning of the Spring 2015 semester. The same test was administered posttreatment to both groups at the end of the Spring 2015 semester. The change in student knowledge and perception between groups (control vs. treatment) was tested using a mixed design analysis of variance (ANOVA). This analysis allows us to determine whether the treatment group demonstrated greater improvement in knowledge and attitudes from pre to post than the control group.

Qualitative Instrumentation and Content Validity

The researcher and students from the college created semistructured interview questions for the focus group and individual student and parent interviews. The instrument was designed to incorporate the life-history technique (Bertaux, 1981) to better understand the extent to which the program affected the life of the learner.

Students were interviewed by the researcher and college students using a semistructured interview style. Interviews with students, parents, and the teacher took place at the independent school, and were audio-recorded and coded for thematic trends (Creswell, 2003).

Qualitative Reliability and Validity

This study incorporated source triangulation through data collection from students, parents of students, and their teacher. One interview was conducted with the teacher of the course. We interviewed two parents (individually) and facilitated one parental focus group postcurriculum (with three parents) in order to verify the student self-reporting and to uncover if, and how, these students were impacting their families (Serow, 1997). Validity of the findings was further addressed through methods triangulation (Creswell, 2003), incorporating digital photography, participant observation, the facilitation of one precurricular and postcurricular student focus group (with the same seven students on both occasions), as well as individual semistructured interviews precurricular and postcurriculum with eight treatment group students, one week after the curriculum finished.

FINDINGS

Environmental Knowledge

The treatment and control groups did not differ significantly at baseline on environmental knowledge, $t(30) = 1.83$, $p = .08$, $d = .65$. A mixed design ANOVA with condition (treatment, control) as a between-subjects factor and time (pre, post) as a within subjects factor revealed main effects of time, $F(1, 29) = 87.91$, $p < .001$, $\eta^2_{\mathrm{p}} = 0.75$ and condition $F(1, 29) = 31.93$, $p < .001$, $\eta^2_{\mathrm{p}} = 0.52$, which were qualified by an interaction of condition by time $F(1, 29) = 51.65$, $p < .001$, $\eta^2_{\mathrm{p}} = 0.64$. To evaluate this interaction we evaluated pretest versus posttest scores separately for each group. Consistent with study hypotheses, results revealed that in the treatment condition scores improved significantly from pretest ($M = 11.40$, $SD = 3.05$) to posttest ($M = 18.97$, $SD = 1.45$), $t(14) = 12.54$, $p < .001$, $d = 3.17$. In contrast, scores from pretest ($M = 9.84$, $SD = 2.63$) to posttest ($M = 10.84$, $SD = 3.27$) did not significantly change in the control condition $t(15) = 1.47$, $p = 0.16$, $d = .34$ (Fig. 1).

Environmental Perceptions: 2-MEV

The treatment and control groups did not differ significantly at baseline on perceptions of environmental utilization $t(30) = 0.19$, $p = .85$, $d = .07$. Environmental utilization was evaluated with a mixed design ANOVA with

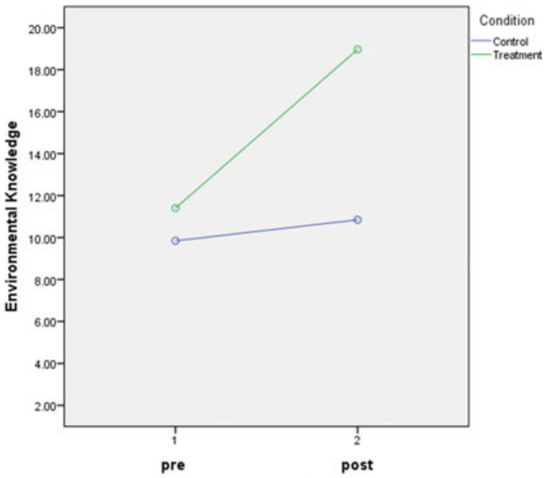

Fig. 1. Change in environmental knowledge according to condition.

condition (treatment, control) as a between-subjects factor and time (pre, post) as a within subjects factor. Results revealed that there was no main effect of time, $F(1, 30) = 0.14$, $p = .72$, $\eta^2_p = 0.005$ or condition $F(1, 30) = 0.16$, $p = .69$, $\eta^2_p = 0.005$. The interaction of condition by time was also nonsignificant. $F(1, 30) = 1.47$, $p = .23$, $\eta^2_p = 0.05$. Evaluation of the pretest descriptive statistics suggests these non-significant effects may be explained by a floor effect at baseline for this measure. That is, treatment and control group average scores were 2.22 and 1.97 respectively, where a utilization score under 3.0 indicates a low preference for environmental utilization.

The treatment and control groups did not differ significantly at baseline on perceptions of environmental preservation $t(30) = 1.33$, $p = .19$, $d = .47$. Environmental preservation was evaluated with a mixed design ANOVA with condition (treatment, control) as a between-subjects factor and time (pre, post) as a within-subjects factor. Results revealed that there was no main effect of time, $F(1, 30) = 0.67$, $p = .42$, $\eta^2_p = 0.02$. A main effect of condition $F(1, 30) = 8.0$, $p = .008$, $\eta^2_p = 0.21$ was observed indicating that, across time points, participants in the treatment condition ($M = 4.25$, $SD = .42$) had higher scores on environmental preservation than participants in the control condition ($M = 3.82$, $SD = .44$). The interaction of condition by time revealed a nonsignificant trend, $F(1, 30) = 3.25$, $p = .08$, $\eta^2_p = 0.10$.

Pro-Environmental Environmental Behavior Change

Interviews showed that treatment group students were practicing, on average, four pro-environmental behaviors before curriculum implementation, and seven afterwards. The quantity of pro-environmental behaviors within the control group did not increase. It was most common for treatment group students to have begun composting as a new environmental behavior. Precurriculum, only one student reported composting their food scraps, while postcurriculum, 13/15 (87%) of treatment group students began composting at home and/or at school. The second most common pro-environmental behavior change mentioned postcurriculum was gardening. At precurriculum, 3/15 (20%) of students gardened, while afterwards, 9/15 (60%) listed gardening as a pro-environmental behavior that they were practicing at home or at school. Interviews showed that students were particularly engaged with the unit addressing the environmental, economic, and logistical differences between industrial agriculture and organic agriculture. For instance, precurriculum, students did not mention "sustainable eating habits" as a pro-environmental behavior, whereas postcurriculum, half of students reported that they "were trying to eat more local and organic foods" (Student). Other pro-environmental behaviors reported postcurriculum only, included: only taking as much food on my plate as I need; buying local foods; stop using pesticides; creating aquaponics and/or hydroponics systems at home; planting flowers; fishing for fish (instead of purchasing); decreasing paper and plastic bag usage;

vermicomposting at home; and utilizing reusable containers.

The teacher reported a change in student pro-environmental behaviors regarding composting. Prior to the curriculum the school tried classroom composting, but failed due to lack of student interest. However, during and postcurriculum: "Some of the students have been asking me, 'where the compost is.' They seem more likely to want to compost their food waste in the classroom." The teacher described instances where students were internalizing knowledge and thinking critically: On a field trip the teacher was surprised when the students started questioning why their prepared lunch included paper bags and plastic water bottles: "Students were mildly outraged and persistent in questioning why we were doing this, not taking no for an answer regarding why they had to use nonreusable bags and plastic water bottles, and why we couldn't compost." Students applied what they had learned from the curriculum and translated it to action. Parents also discussed changes in student pro-environmental behaviors at home:

> The biggest change I've noticed is we're growing worms in his bedroom right now. He's vigilant about watering and feeding them and keeping them moist, and he understands the whole cycle. (Parent)
> He has been asking when I get meat, that we make sure it's grass fed, he always checks with me and says "What kind of meat did you get . . . local?" He's trying a few more things. (Parent)
> We have a compost bin that we haven't touched it in a year and she's interested in resuming that now. She was really interested in the whole concept of worm castings and how it's fortifying the plants. (Parent)

Intergenerational Learning

The first emergent theme identified related to instances of intergenerational learning. Of the 15 students interviewed postcurriculum, 13/15 (86%) said they discussed the curriculum with their families. Students explained to their families how aquaponic and hydroponic systems function, with some students bringing parents to the school to explain the technological process.

The second emergent theme related to the benefits of the hands-on components. When students were asked about teaching preferences, 12/15 (80%) explained that they preferred hands-on experiential pedagogy:

> I liked all of the things we did just because it was really interactive and hands-on, because then you're not just sitting, and learning, and learning. . . . (Student)
> I liked how there's a big process. We had to put in the pebbles, then the water, then the fish, and the most fun part is that we saw that it actually works. The plants are growing! (Student)
> It was really interesting to see, because I've never thought about fish being in a tank and what happens to their waste. It was interesting to see how their waste could be used to help grow plants. (Student)
> He understands the nitrogen cycle better and easier by having the whole system setup. The project made it much easier. He's a visual and auditory learner, so that [the hands-on components] brought it all together for him. So definitely, there was learning that took place, and things that he internalized based on what he told me at home . . . and now we're growing worms in his bedroom. (Parent)

During interviews and focus groups 13/15 (87%) of students said that they were most influenced by the discussion of "food issues:"

> My whole life we've gotten local or organic foods, but I never knew really why. I didn't know about the conventional and organic and local food, and the differences between them . . . that was a helpful lesson for later in life. (Student)
> I've been thinking about the "Food Miles" [lesson] more. I've been more aware when I buy stuff, of what I buy, and where it is from. (Student)
> She does question more. She questions food . . . she's become more aware of that and more curious. (Parent)

Two more emergent themes were identified through student interviews and focus groups, related to collateral learning and self-efficacy. Table 2 presents representative student responses to provide further insights into the four (total) thematic outcomes that were identified.

Table 2
Representative student quotes by theme

Intergenerational learning	Collateral learning	Self-efficacy	Learning preferences
I told my parents about the aquaponics system, about how it circles around and what's good for the plants and fish. They thought it was a really cool idea.	I imagine if it [environmental learning] was fun here, it will be fun to continue in middle school.	I understand the environment more now, so I feel more like an environmentalist.	I think science was probably one of my least best subjects. I understand it a lot more just in the way it's been taught in this class.
I showed my brother the composting [instructional] paper and he was really interested.	I want to go to college for something that has to do with writing and nature.	I'm getting chickens!	I definitely like it a lot more than a lecture. It's fun to move instead of sitting in the same spot. It's a different way of doing it that doesn't always feel like learning.
I talked to my brothers about the aquaponics system.	I'm interested in the invasive and native plants and I want to explore which plants are, and which plants aren't, and why.	I could definitely see myself playing that kind of role, I could get more into it [being environmentally conscience].	With the hands-on stuff I kind of learned better with it, and then I could say 'Oh, I realize that . . . you know . . . I get this now!'
I talked to my family about how maybe we should grow some more organic foods so we don't have to pay for it . . . like maybe apples, or we can grow vegetables . . . my dad and I are talking about making a list.	*Food Miles* was a helpful lesson for later in life, so you have the choice what to buy, you have the pros and cons.	Well before [this class] we didn't really compost much. But now that we talked about it, we do it all the time, and anything that we can compost, we do.	I like the hands-on because you get to prove whether your hypothesis was right or wrong, and it's interesting to see how things come out in the end.

Unexpected Outcomes

Since using aquaponic and hydroponic technologies to teach garden-based learning is fairly unexplored, with little existing research on the outcomes, we report several unexpected outcomes. Once the aquaponic and hydroponic systems were operational, the teacher reported that students began using their free time to voluntarily check on the systems. Students were the first to know if something went wrong. For instance, in March all of the aquaponics fish died. To the detriment of the fish, this offered a teachable moment: six students crowded around the tank offering hypotheses. Students discovered that the aerator had been unplugged (by a substitute teacher). They agreed that without the water cycling through the system, neither plants nor fish could survive. Through this macabre event it became evident that students understood the environmental factors contributing to organism mortality and the relationship to the technology.

When designing the curriculum we did not take into account that we would be working with two students with learning disabilities. Both the teacher and a parent noted that the garden-based experiential components provided students with Attention Deficit Hyperactivity Disorder an opportunity to better understand complex concepts:

> I have students with a variety of learning styles and learning abilities. The hands-on aspect was an equalizer. The kids who have trouble learning, and for the kids who are super advanced, they're all having the same discussions. There's more collaboration and

engagement and it contextualizes what they're learning. (Teacher)

My child is learning disabled, so the visual and hands-on is better. He wasn't telling me what happened in math or English class, he was telling me about this project. In that sense I noticed changes in his work. (Parent)

CONCLUSION

As an extension of an outdoor garden, indoor classroom-based aquaponics and hydroponics technologies have the potential to bring the natural world into the classroom, while encouraging the use of experimentation and hands-on learning. We found statistically significant advances in the treatment group's environmental knowledge scores compared to the control group. There is inconclusive evidence as to whether indoor garden-based learning results in changes in environmental perceptions. While we found evidence for greater overall environmental preservation attitudes in the treatment group, the change in these attitudes relative to the control group was not statistically significant. Further, given evidence that the assessment of environmental attitudes may have been constrained by floor (utilization) and ceiling (preservation) effects, future research conducted with similar pedagogical advents may consider evaluating larger samples.

Our qualitative findings revealed that the treatment group's pro-environmental behaviors and knowledge of environmental issues increased. Treatment group students (as well as parents and the teacher) reported that various aspects of the curriculum were effective for student learning, specifically, the experiential and hands-on design of the classroom projects, designing and maintaining the aquaponics and hydroponics technologies, composting and vermicomposting, and discussions addressing food systems and consumerism. Also noteworthy were the unexpected benefits for students with learning disabilities, and as similarly reported by Dirks and Orvis (2005), a high degree of intergenerational learning at home.

As reported by Hart and colleagues (2013), an indoor garden-based learning curriculum utilizing aquaponics and hydroponics can be implemented in public school classrooms if teachers have the flexibility to participate in nontraditional pedagogies. Barriers to school implementation include the need for extra time, lack of financial, equipment, and spatial resources, lack of administrative support, and the constraints of teaching to the state testing standards. Despite the fact that this research was facilitated through an independent school setting, we believe that indoor garden-based learning is flexible enough to be integrated into a public school classroom; experiential indoor garden-based learning activities can be designed and integrated into pre-existing curricular units which are currently being used to prepare students for state testing.

Although we found aquaponic and hydroponic technologies to be effective teaching tools for an indoor garden-based learning curriculum, more research in this field is necessary. This study adds to the handful of findings, including those of Hart and colleagues (2013) who found aquaponics to be an effective teaching technology for the application of experiential math and science curricula, and for making connections to food systems and globalization. Future research should assess outcomes when the technology and curriculum is implemented in a public primary school with different social and administrative climates and those that require greater adherence to Common Core State Standards and Next Generation Science Standards.

REFERENCES

Aguilar, O. M., Waliczek, T. M., & Zajicek J. M. (2008). Growing environmental stewards: The overall effect of a school gardening program on environmental attitudes and environmental locus of control of different demographic groups of elementary school children. *HortTechnology, 18*(2), 243–249.

Bazzano, A. L. (2006). The high cost of not consuming fruits and vegetables. *Journal of the American Dietetic Association*, *106*(9), 1364–1368.

Bertaux, D. (1981). *Biography and society: The life history approach in the social sciences.* Beverly Hills, CA: Sage.

Blair, D. (2009). The child in the garden: An evaluative review of the benefits of school gardening. *The Journal of Environmental Education*, *40*(2), 15–38.

Bogner, F. X., & Wiseman, M. (1999). Towards measuring adolescent environmental perception. *European Psychologist*, *4*(3), 139–151.

Bogner, F. X., & Wiseman, M. (2002). Environmental perception of pupils from France and four European regions. *European Journal of Psychology of Education*, *17*(1), 3–18.

Bogner, F. X., & Wiseman, M. (2006). Adolescents' attitudes towards nature and environment. *The Environmentalist*, *26*(4), 231–237.

ByungSik, J., SinAe, P., & KiCheol, S. (2012). Improving work adjustment skills in students with mental retardation using hydroponics program. *Korean Journal of Horticultural Science and Technology*, *30*(5), 586–595.

Carver, J., & Wasserman, B. (2012). Hands-on hydroponics. *The Science Teacher*, *79*(4), 44.

Creswell, J. W. (2003). *Research design: Qualitative, quantitative, and mixed methods approaches.* London, UK: Sage Publications.

Dirks, A. E., & Orvis, K. (2005). An evaluation of the Junior Master Gardener Program in third grade classrooms. *HortTechnology*, *15*(3), 443–447.

Handwerker, T. S. (1990). Model program on hydroponics and aquaculture. *United States Department of Agriculture - Yearbook of Agriculture* (pp. 152–154). National Agricultural Library. Retrieved from http://naldc.nal.usda.gov/naldc/download.xhtml?id=IND20402432&content=PDF

Hart, E., Webb, J., & Danylchuk, A. (2013). Implementation of aquaponics in education: An assessment of challenges and solutions. *Science Education International*, *24*(4), 460–480.

Hirschi, J. S. (2015). *Ripe for change: Garden-based learning in schools.* Cambridge, MA: Harvard Education Press.

Hoyler, E. (2012). *Food miles: Where does my food come from?* Shelburne Farms' Sustainable Schools Project. Retrieved from http://www.sustainableschoolsproject.org/curricula/food-miles-lesson.

Johanson, E. K. (2009). Aquaponics and hydroponics on a budget. *Tech Directions*, *69*(2), 21–23.

Johnson, B., & Manoli, C. C. (2008). Using Bogner and Wiseman's Model of Ecological Values to measure the impact of an earth education programme on children's environmental perceptions. *Environmental Education Research*, *14*(2), 115–127.

Karsh, K., Bush, E., Hinson, J., & Blanchard P. (2009). Integrating horticulture biology and environmental coastal issues into the middle school science curriculum. *HortTechnology*, *19*(4), 813–817.

Klemmer, C. D., Waliczek, T. M., & Zajicek, J. M. (2005). Growing minds: The effect of a school gardening program on the science achievement of elementary students. *HortTechnology*, *15*(3), 448–452.

Libman, K. (2007). Growing youth growing food: How vegetable gardening influences young people's food consciousness and eating habits. *Applied Environmental Education and Communication*, *6*(1), 87–95.

Paul, C. (2011). Gompers' science curriculum. *Practical Hydroponics and Greenhouses*, *116*, 15–18.

Peckenpaugh, D. J. (2001). Classroom hydroponics. *Green Teacher*, *65*, 20–25.

Schneller, A. J., Johnson, B., & Bogner, F. X. (2015). Measuring children's environmental attitudes and values in northwest Mexico: Validating a modified version of measures to test the Model of Ecological Values (2-MEV). *Environmental Education Research*, *21*(1), 61–75.

Serow, R. C. (1997). Research and evaluation on service-learning: The case for holistic assessment. In A. S. Waterman (Ed.), *Service-learning: Applications from the research* (pp. 13–24). Mahwah, NJ: Lawrence Erlbaum Associates.

Smith, L. L., & Motsenbocker, C. E. (2005). Impact of hands-on science through school gardening in Louisiana public elementary schools. *HortTechnology*, *15*(3), 439–443.

Somerset, S., & Markwell, K. (2009). Impact of a school-based food garden on attitudes and identification skills regarding vegetables and fruit: A 12-month intervention trial. *Public Health Nutrition*, *12*(2), 214–221.

Wiseman, M., & Bogner, F. X. (2003). A higher-order model of ecological values and its relationship to personality. *Personality and Individual Differences*, *34*(5), 783–794.