Eurasian Journal of Science and Environmental Education
2023, 3(1), 17-23
ISSN 2672-863X (Online)
https://www.ejsee.com/
Review Article
OPEN ACCESS

The order of garden-based learning from science education to STEM education

Filiz Gulhan [1]*

[1] Ministry of National Education, Istanbul, TURKEY
***Corresponding Author:** flzgulhan@gmail.com

Citation: Gulhan, F. (2023). The order of garden-based learning from science education to STEM education. *Eurasian Journal of Science and Environmental Education*, 3(1), 17-23. https://doi.org/10.30935/ejsee/13040

ABSTRACT

In this review study, the inclusive potential that emerges when garden-based learning, which has long been considered within the framework of science education in the literature, is handled within the framework of STEM has been examined. The research calls for addressing garden-based learning in relation to STEM education. In particular, he suggests that digital tools and landscape architecture elements related to the integration of the engineering discipline into the garden can be mentioned, permaculture design can be applied, and wall gardens can be made in narrow spaces. STEM suggests that there is a need for teacher training for garden-based learning and that this can be achieved especially through collaborative work. In addition, it argues that STEM garden-based learning practices can turn into a nature mobilization beyond a teaching practice, by associating gardening studies with other school stakeholders, as well as integrating the disciplines in STEM with a purpose.

Keywords: garden-based learning, school gardening, science education, STEM education, interdisciplinary

Received: 03 Feb. 2023 ◆ Accepted: 05 Mar. 2023

INTRODUCTION

In education, it is very important to go out of the classroom, to experience something, to learn through life activities. Environmental education creates productive research-practice areas (Ardoin et al., 2020). School gardens are considered as "open-air laboratories" for children (Ozer, 2007). Leading educational thinkers such as Comenius, Dewey, Montessori, Pestalozzi, and Rosseau described and suggested garden-based teaching in their studies (Desmond et al., 2004). The beginning of the 20th century in the USA saw the rise of the school gardening movement (Lavrinoviča, 2021). School gardens and garden-based learning have gained popularity again in recent years (Cramer & Ball, 2019). In addition to the educational results of environmental education, environmental problems, the effects of which we have felt more in recent years, are also effective in this.

When the literature is examined, it is seen that the studies on the garden-based education approach focus on two main headings: The effects of garden-based education on academic development and the effects of nutrition programs on students' knowledge, skills and attitudes towards fruit and vegetable consumption (Tasci et al., 2021). School gardens were started mainly to involve children in nature, not to improve vegetable consumption (Huys et al., 2017). Sustainable school garden practices are successful in enabling early children to learn about the environment, to develop their awareness of healthy living and to eat healthy (Putnam, 2015).

Gardening students improve their overall academic performance, increase their interest in learning, and have positive effects on their general behavior and emotional and social health (Papadopoulou et al., 2020). Studies show that school garden practices increase students' nutritional knowledge and awareness in primary education, and have positive effects on sensory awareness, imagination, compassion, patience, self-discipline, persistence, motivation, academic success, teamwork skills, positive behavior, attention span, pride in success and sense of place reported effects (Klein, 2012). Eugenio-Gozalbo et al. (2020) examined the garden-based learning activities of students from different levels. In the early stages, preschool and primary education, it has been reported that gardens provide an atmosphere of emotion and motivation, encourage the establishment and reinforcement of simple cause-effect relationships, and improve children's artistic expression. They stated that in secondary and university education, activities involving the educational experience in gardens, enrichment and diversification in all available elements (cultivation styles, irrigation elements, tools, crops, trees, and animals) significantly improve students' knowledge. They reported that school failure significantly decreased, the dropout rate decreased, and their skills, self-esteem and self-confidence improved significantly in at-risk students who did garden-based practices (Ruiz-Gallardo et al., 2013). Ohly et al. (2016), when they examined the studies on the subject, they stated that groups of students who were not successful in classroom activities especially benefited. These results show that garden-based learning has positive cognitive, affective and behavioral outcomes.

Despite the positive effects of gardening on student health and academic performance, garden-based learning also encounters resistance from school administrators and teachers (Cramer & Tichenor, 2021). The use of school gardens as a teaching environment is not as common as it is thought, and teachers have various barriers based on time, support and knowledge (Poole, 2016). Cramer and Tichenor (2021) stated that their focus group discussions with teachers who practice garden-based teaching ended with the following question: "What would you recommend to teachers who want to do gardening with their students?" The answer is often, "Just do it!" Huys et al. (2017) in their focus group discussions they experienced facilitating factors (e.g., adaptability of the garden, having a person in charge of the garden) as well as various barriers (e.g., initial difficulties, care during summer holidays and integration into the school curriculum) and suggested some solutions (e.g., external organizations and parents, expanding the garden) and motivating factors for children (e.g., colorful plants, use of gloves).

When Williams and Dixon (2013) examined 48 garden-based learning studies published between 1990 and 2010, they stated that direct academic outcomes were obtained with the highest positive effect for science, followed by mathematics and language arts. They also stated that indirect academic results most frequently and positively support social development. When the results of school garden practices between 2000 and 2015 were examined, Urey (2018) stated that it had a positive effect on the development of academic performance, the development of healthy living skills, and the development of individual and social skills. In the current literature, school gardening is characterized by its role in improving students' learning and achievement, environmental attitudes, health and food behaviors, internal skills and emotional well-being, and social bonds (Lavrinoviča, 2021). Theoretical research on school gardening is still not well formed, as the distribution of research activities is uneven and the concept itself is still seen as innovative (Lavrinoviča, 2021).

GARDEN-BASED LEARNING AND ITS RELATIONSHIP WITH SCIENCE EDUCATION

The most common subject related to gardens is science (Tasci et al., 2021). In addition, the most common positive effect is seen in science education (Williams & Dixon, 2013). Priyayi et al. (2020) concluded that this approach can be an alternative model in science learning, based on the positive attitudes of students and teachers who apply garden-based education towards science. Gardens are real-life contexts suitable for science teaching, where students experience the field and develop both their scientific knowledge and observation skills (Eugenio-Gozalbo et al., 2020). Students' experience of participating in garden-based science activities predicts their participation in science class, science learning, and academic identities in science (Williams et al., 2018). K-12 science educators stated that they do original, hands-on activities that increase their sense of belonging, competence, and autonomy in science (Riggs & Lee, 2022).

There are many studies showing that using gardens as a teaching-learning context improves students' performance in experimental sciences (Monferrer et al., 2022). Fisher-Maltase (2013) stated that students' science content knowledge improved with school garden-based learning. Wells (2015) reported that the knowledge of garden-based students about science increased compared to the control group. Kos and Jerman (2019) showed that school gardening activities improve academic outcomes and children's attitudes towards vegetable consumption. Skinner et al. (2018) stated that when they observed the garden-based activities of secondary school students, there was an increase in their success in learning science in the garden and in other basic subjects (mathematics and social studies) taught in the garden, and their participation in science lessons increased. Riggs (2020) reported that students' science-self perceptions and their perceptions of their participation in science improved with interesting gardening activities in science lessons. Yildiz (2021), in her research where she conducted informal science teaching in the garden with primary school students, stated that the environmental awareness of the students improved, and they performed the activities lovingly and having fun. Lloyd and Paige (2022) stated in their case study that they taught gardening to primary school students in an Australian school and stated that engaging children in gardening gave them the opportunity to see the world as a whole, learn about science concepts, and also address local issues such as organic food production.

STEM EDUCATION WITH GARDEN-BASED LEARNING

STEM an approach that expresses a reform in teaching by considering the fields of science, technology, engineering and mathematics in an integrated way (Bybee, 2013; Katehi et al., 2009; Kelly & Knowles, 2016; Sanders, 2009). STEAM education, which includes the art (A) add-on, is handled with a structure that increases the emphasis on creativity (Bequette & Bequette, 2012; English, 2017; Watson & Watson, 2013). STEM education, which has been developing in the evolutionary process of science education, especially in the last 20 years, encourages a holistic view with its interdisciplinary perspective. With this trend towards mathematics, technology, engineering, and beyond these, STEAM and social studies and art, new hybrid fields of study have emerged. Although the study of nurseries is often linked to science education, it also requires understanding of economics, mathematics, geography, ethics, language, politics and other subjects, and is interdisciplinary in nature (Miller, 2007).

Garden-based learning is in a structure that can be easily associated with mathematics. Wagner and Fones (1999) brought together children, families, undergraduates and teachers in the garden discoveries program with natural sciences and mathematics in the garden. Lucero (2021) stated that working in the classroom garden with activities focused on design and sewing during an after-school program for a semester provides opportunities for young children to engage in mathematical experiences, mathematical reasoning, and mathematical identity development. Monferrer et al. (2022) made a call to action encouraging the interdisciplinary nature of these two issues in the context of school gardens.

In a case study investigating the role of design in garden-based education, Zuiker and Riske (2021) conducted an analysis of garden-based learning in a USA fifth grade classroom (10-11 years) who implemented a project-based gardening curriculum. They arrived at themes related to content and context, to harmonize curriculum and gardens, and to design for curiosity. This research is important in terms of emphasizing the design elements in the garden.

Children can also learn social lessons by absorbing nature in garden-based learning. They become aware of a garden community and that everything depends on sun, water, air and soil and their role in their community (Klein, 2012). Inwood and Sharpe (2018) stated that many art teachers turn to their schoolyards as a fertile space for inquiry, creativity and display, offering a welcome alternative to the four walls of a traditional classroom. Therefore, garden-based learning can be associated with many fields and lessons, thus enriching it. School-based breeding grounds support students' participation in STEM learning through authentic agricultural pursuits (Ingram & Keshwani, 2021). Hands-on, experiential, inquiry and project-based gardening activities to learn several themes at once (physical activities, literature, art, history, information and communication technologies (ICT) practice, citizenship education, entrepreneurship, economics, history, culture and even career guidance) available (Lavrinoviča, 2021). Bae et al. (2021) added culture and art, language and literature to the disciplines of science and mathematics in the garden-based learning program they developed for the Ecuadorian Sierra Region. With a collection of garden-based lesson plans and activities, they have made a number of recommendations for schools wishing to implement garden-based learning. For example, planting vegetables may include (Lavrinoviča, 2021): "planting, maintenance and harvesting (horticulture) activities (biology, cleaning, and chemistry), knowledge of soil and irrigation (geography, physics), planting beds (mathematics, physics, and economics), decorating the school area (design and art), garden projects, copywriting, and marketing for the school website (ICT and literature), fundraising (entrepreneurship), planning tools and materials (entrepreneurship/management), distribute tasks and share different roles (career planning), cooking and sharing with parents (community building, cleaning, and chemistry), waste management and circular economy knowledge (geography and biology), doing physical exercises outdoors (sports), and of species and localities (history and geography)."

Ingram and Keshwani (2021) conducted a survey of Nebraska schools to characterize existing school-based cultivation areas and identify challenges limiting garden-based STEM learning. It confirms the use of school-based training grounds for STEM education from kindergarten to grade 12, especially in science. They noted that opportunities for technology and engineering experiences are currently limited and additional professional development support is needed to expand garden-based STEM learning efforts.

EXAMPLES OF GARDEN-BASED STEM EDUCATION RESEARCH

In this section, as a review research, examples from related research are given without being subjected to systematic analysis. Studies examining the effects of garden-based learning based on STEM elements on students are as follows: Urey (2013) determined that the science-based and interdisciplinary school garden program was effective on students' science academic achievement and attitudes. He also emphasized the in-service training needs of teachers regarding out-of-class activities. Selmer et al. (2014) aimed to show how statistical literacy can be initiated at the upper primary level through integrated science-mathematics teaching in an authentic context. They applied project-based learning focusing on a farmer's market project and school gardening, expanding seed germination and related experiments through growing crops and selling at a local farmer's market. Although these two studies did not use the abbreviation STEM since they were conducted before the era when STEM education became widespread, they applied activities that combine more than one discipline as content. Stubbs and Myers (2015) investigated STEM integration into three Florida high school agriculture programs. As a result of the research, they stated that STEM student achievement could be increased with agricultural education, they reliably integrated science and technology at high levels, but engineering and mathematics concepts were less consistently integrated between cases. Sahin et al. (2016) enabled students to grow and grow plants and sell the product in the market in STEM projects in three different socioeconomic regions. It was observed that the students' interest in natural life increased and they were able to earn their own money, and this situation increased their motivation at school. Kwack and Jang (2021) developed a STEAM Program using classroom wall gardens. Primary school students participating in the "plaster pot wall garden", "pluggable LED wall garden", "coffee pack wall garden", and "hanging wall garden" programs have shown increased interest in science, a high level of understanding and participation, and helping them connect with other subject areas specified.

Studies examining the effects of garden-based learning based on STEM elements on teachers are as follows: Kelley and Williams (2013) used teacher professional learning communities for sustainability and implemented STEM in learning gardens in low-income schools. They stated that school gardens provide a rich learning environment for both teachers and students by adopting experiential, integrated and collaborative learning. Graves et al. (2016) conducted a case study with two primary school teachers and two STEM coordinators to implement and evaluate a horticultural-based curriculum. Teachers made curriculum decisions based on their confidence in teaching herbs, the accessibility of curriculum materials, their perceptions of the compliance of courses with academic science standards, and time constraints. They stated that professional development was provided in the horticultural-based curriculum for both teachers and STEM coaches. Turner et al. (2021) implemented a garden-based STEM education program. They used technacy type theory to frame the interdisciplinary learning domains: Science (the hypothesis testing literacy skills); technology (digital microscopy and robotics); engineering (food systems and biotechnology literacy), and mathematics (data collection and statistical literacy). The findings showed that teachers benefit from development of effective strategies that lead to successful outcomes in interdisciplinary teaching and learning, and improve their confidence, knowledge and skills regarding the implementation of a STEM program in primary school classrooms.

Among the garden-based learning practices with STEM content, the project-oriented studies that deal with multiple stakeholder groups are as follows: Putnam (2015) integrated the sustainable garden program she developed within the scope of the thesis with STEM education and shared the plans on a website. Guasti and Niewint-Gori (2018) in a pilot research project on the use of a hydroponic conservatory in preschool and primary school in peer workgroups collaborating with others in a laboratory activity to gather information from the experimental setup and using this information to develop a theory inferred from observed events practices they participated in. Fisher (2018) advanced design and engineering learning, problem solving in a project to make vegetable gardens using programmable microcontrollers (e.g., Arduino and Raspberry Pi), sensors, switches, relays, LEDs, and LCD screens to incorporate technology into school garden programs and automate systems stated that they can inspire their skills and critical thinking. In the nova hydroculture project, partnerships between universities, associations and public K-12 schools in the USA were realized. NHP involves building hydroculture gardens with food crops (such as tomatoes, peppers and strawberries). Hydroculture gardens are not only great opportunities to learn about STEAM but have turned into a collaborative and interactive experience for everyone involved (Schmitt Lavin et al., 2022).

CONCLUSION AND RECOMMENDATIONS

In this research, it has been tried to reveal the current potentials of research in which school gardens are used as learning spaces for STEM education. School learning gardens provide an easily accessible entry point for teachers and children to learn important concepts and skills in an integrated, holistic way while connecting with the natural world (Kelley & Williams, 2013). Schoolyards offer opportunities to study natural and built environments simultaneously, bringing together learning from science, literacy, and the arts, and appealing to students' diverse learning preferences (Inwood & Sharpe, 2018). This research is by Monferrer et al. (2022) supports the call to bring science and mathematics together in the context of schoolyards, and Zuiker and Riske (2021) extends this call to STEM education, while supporting calls to expand environmental education research through design. It argues that garden-based education, which has been examined within the framework of many different disciplines, especially science education discipline, can reach a more advanced structure with STEM education.

There are inadequacies in the literature on associating garden-based education with engineering. There are very few studies that focus on these areas. A lack of computer technology training and limited use of agricultural technology and engineering (automatic irrigation, weather stations, and solar panels) have been found in relation to cultivation areas (Ingram & Keshwani, 2021). Stubbs and Myers (2015) stated that they integrate science and technology at high levels reliably, but the fields of engineering and mathematics are not sufficiently integrated. For the integration of the engineering field, studies based on digital skills (Fisher, 2018; Turner et al., 2021) can be carried out, as well as design-based activities such as landscape architecture (Gulhan & Sahin, 2016).

Permaculture design can be done to highlight the design dimension in garden-based STEM applications. Permaculture reinforces the values of resourcefulness, management and sustainability through its practices with certain principles, built on the ethics of interacting with the environment in a mutually beneficial way (Praetorius, 2006). Permaculture education: in addition to raising awareness of children, it can support children in many areas such as providing them with aesthetic feelings, providing physical activity opportunities, supporting their social and emotional development, increasing their academic (especially science and mathematics) success, and increasing their tool use (rake, shovel, etc.) (Caglar Kabacik & Deretarla Gul, 2021). In this respect, permaculture design applications can be recommended for STEM education. In cases where the gardens of the schools do not have enough space, narrow areas can be evaluated. As in the research of Kwack and Jang (2021), wall gardens can be made with various types of pots.

Teachers are the mainstay for garden-based teaching practices (Blair, 2009). Therefore, both pre-service and in-service teachers need more training to use horticulture effectively as a teaching tool (Blair, 2009; de Alba, 2019; Ingram & Keshwani, 2021; Rosenthal, 2018; Rye et al., 2012; Urey, 2013). Gray et al. (2022) suggest that teachers should come together and find ways to combine science and art so that schoolyards can be used as an effective learning environment that supports creativity. It is very important for teachers to carry out collaborative work for STEM-based garden-based teaching practices (Graves et al., 2016; Kelley & Williams, 2013; Schmitt Lavin et al., 2022).

There are also views that associate garden-based learning with other stakeholders beyond the student-teacher relationship. de Alba (2019) suggested that all stakeholders support the focal point of the garden and that the positive effects of school gardens be shared with stakeholders. They advocated that garden-based learning within the scope of curriculum-based formal learning should be extended to non-formal education and included in public education (Cramer & Ball, 2019). Educational research on environmental protection highlights the importance of focusing on local issues, partnerships and action (Ardoin et al., 2020). Gardenroots: A citizen xcience project (2015) increased their intrinsic motivation, self-efficacy, knowledge and satisfaction by engaging citizens in gardening practices (Sandhaus et al., 2019). In order to increase parental involvement, parents can be explicitly included in the school garden programs by organizing activities for families in the garden, allowing students to bring garden products home for tasting or cooking, or giving students homework that requires family participation (Ozer, 2007). Ohly et al. (2016) similarly stated that participation in local communities and the integration of gardening activities into the school curriculum support success. Perhaps the greatest contribution of garden-based learning to the world debating sustainable development may be to solidify a path to ecological literacy (Desmond et al., 2004). Another conclusion that can be drawn from this is that stakeholders can be combined for a purpose, as in the logic of integrating disciplines in STEM. In this respect, STEM garden-based learning applications will be able to turn into a nature mobilization beyond a teaching application. Finally, suggestions for those who want to conduct research on garden-based STEM education are, as follows: It has been stated that in studies that systematically analyze research on garden-based learning, sufficient evidence cannot be obtained from quantitative research, while qualitative studies are descriptive of the situation and report a wider range of effects (Blair, 2009; Ohly et al., 2016; Ozer, 2007). It may be helpful to focus on research examining qualitative and in-depth effects.

Funding: The author received no financial support for the research and/or authorship of this article.

Ethics declaration: Since this study is a literature review, it does not require any ethics committee approval.

Declaration of interest: The author declares no competing interest.

Data availability: Data generated or analyzed during this study are available from the author on request.

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