Research article

Evaluation of School Gardens as a Method of Scaling Up Sustainable Agriculture Technologies

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Abstract Current research on school gardens is primarily focused on improving student nutrition. Less examined is their potential to be agents of knowledge transfer to the wider community. This paper seeks to determine the potential of school gardens as a pathway to scaling agricultural innovations. Literature is reviewed for best practices and recommendations conducive to scaling up agricultural technologies using school gardens. Findings indicated that school gardens have the potential to play a key role in scaling sustainable intensification (SI) technologies. They provide opportunities for knowledge transfer through teacher-student-parent communication. Best practices for scaling through school gardens comprised: including parents in the learning process and upkeep of school gardens; collaboration and commitment among all stakeholders; establishment of hands-on, research-based agricultural curriculum in schools; financial assistance from government or outside organization for startup and upkeep; and establishment of home gardens alongside school gardens. Primary barriers to scaling included: focusing on the 'what' and not the 'how'; social mores and the relationship between parent/child; capacity building for and involvement of school heads, teachers, and parents; lack of social, human, and/or economic capital; and unintegrated commitment and partnership among stakeholders. Identified best practices and barriers are then applied to a case study analysis of a USAID-funded project in Cambodia: Scaling Suitable Sustainable Technologies (S3-Cambodia) project. S3-Cambodia targets youth as an entry point to extend target SI technologies to farm families. The project engages students in experiential learning opportunities by establishing "green labs" at secondary schools. S3-Cambodia is found to already be implementing many of the best practices listed above. Suggestions are made to increase parent involvement in the project and to increase awareness of the challenges that come with a transnational project.

Keywords adoption, scaling, school garden, knowledge transfer, agriculture

INTRODUCTION

School gardens are a well-known tool to develop agricultural education curriculum and food system knowledge within primary and secondary schools worldwide. Current research on school gardens is primarily focused on improving student nutrition and increasing vegetable consumption (Ratcliffe et al., 2011; Schreinemachers et al., 2019; Leuven et al., 2018; FAO, 2004; Ferguson et al., 2019). Less examined is their potential to be agents of food system reskilling and knowledge transfer to the wider community (Cramer et al., 2019). Yet, students have significant potential to be agents of change in their homes and communities. Using knowledge gained through school garden education, students can serve as credible sources of information to their parents on best agriculture practices (Okiror et al., 2011).

School gardens provide a pathway to evaluate new technologies without personal risk. Often, implementation and scaling up of new technologies and innovations is met with apprehension due to fear of the economic, social, and health risks that come with crop failure (Shilomboleni and De Plaen, 2019; Westermann et al., 2019). Understanding the process of and barriers to scaling are not newly developed streams of social science research. Feder and Umali (1993) in their literature review of agricultural innovation adoption during the prior decade detail risk, information availability, credit, and farm size as major factors influencing farmer adoption of new technologies. This understanding of risk severely limits ability to scale new agricultural technologies which seek to improve livelihoods and combat impacts of climate change. Often, scaling is described as either ‘scaling up’ or ‘scaling out’. ‘Scaling up’ can be likened to the act of increasing, often in terms of number, speed, size, etc. On the other hand, ‘scaling out’ refers to the act of expansion, such as the spread of a particular technology to new geographical locations (Wigboldus et al., 2016). This paper will combine the distinction into the phrase ‘scaling up’ which covers the expansion, replication, and adaption of successful technologies, practices, or innovations to reach a greater number of people (Finn, 2012).

Understanding the role of risk in agriculture adoption and scaling is of particular relevance for sustainable intensification (SI) technologies. SI is a method of agricultural production which seeks to balance environmental, economic, and social factors of farming. Zurek et al. (2015) define sustainable intensification as, “production of more food on the same piece of land while reducing the negative environmental impacts and at the same time increasing the contributions to natural capital and flow of environmental services” (p. 24). This has been further expanded to include social issues, economics, and the human condition as non-environmental factors for a balanced application of SI processes (Musumba et al., 2017). Barriers to the adoption of SI technologies include, but aren’t limited to, demographic variables, farm-location characteristics, fiscal capital, information access and human capital, and the occurrence of climate shocks. Often, these barriers vary based upon time and location. For example, Kassie et al (2015) finds the primary barriers of SI adoption in eastern and southern Africa to be, “social capital and networks, quality of extension services, reliance on government support during crop failure, incidence of pests and diseases, resource constraints, tenure security, education, and market access” (p. 400).

This paper seeks to determine the potential of school gardens as a pathway to scaling agricultural innovations, particularly SI technologies. Specifically, it will assess if school gardens are able to limit barriers to adoption such as risk and information availability. Literature is reviewed for best practices and recommendations conducive to scaling up agricultural technologies using school gardens. Identified challenges and suggestions are then applied to a case study analysis of a USAID-funded project on scaling of SI technologies in Cambodia.

OBJECTIVE

Objectives of research are as follows:
- to identify current and historical literature regarding scaling and adoption of agricultural innovation
- to determine the impact of school gardens as a method of scaling up agricultural technologies.

METHODOLOGY

This paper reviewed theoretical and empirical literature on school gardens with a focus on scaling of agricultural technologies and innovations. Literature was found using key word searching through using the University of Tennessee libraries database and Google Scholar (Google Inc., Mountain View, CA, USA). Key words included: ‘adoption’, ‘scaling’, ‘agriculture’, ‘school garden’, ‘knowledge’, ‘transfer’, ‘education’, and ‘sustainable intensification’. Themes and key activities were then drawn from the literature to determine best practices of scaling successful school garden programs. Research gaps and challenges to school garden implementation were determined for each piece of literature and used to determine key barriers to scaling.

Findings were then applied to a case study analysis of the Scaling Suitable Sustainable Technologies (S3-Cambodia) project. S3-Cambodia is a 3-year project funded by the USAID Sustainable Intensification Innovation lab to examine pathways for scaling. S3-Cambodia will advance the capacity and roles of scaling agents in technology diffusion through applied research, technical assistance, curricula development and organizational strengthening. This process will demonstrate the potential for and provide critical information on scaling technology through local, national, and regional networks.

Previous research in Cambodia has identified, evaluated, and promoted SI technologies that addressed gaps within the production systems. These innovations promote the diversification and resilience of smallholder systems by introducing new sources of income and nutrition during seasonal "food gaps," across different agricultural spaces and serving different functions in livelihood strategies. S3-Cambodia will pursue diffusion and adoption of technologies for different user groups. Cambodian youth serve as an entry point to extend target technologies to farm families through experiential learning opportunities in schools by establishing "green labs". Students will receive a combination of hands-on training in SI practices and STEM-based instruction in SI principles. This preparation will culminate in the establishment of student home gardens featuring SI technologies. The process of technology evaluation and diffusion will be supported by applied, participatory research on the agronomic and nutritional qualities and marketing potential. In order to improve the rate of success of S3, it is important to identify previous work in scaling through school gardens and the lessons learned from attempts.

RESULTS AND DISCUSSION

Current and Past Studies regarding Scaling and Adoption of Agricultural Innovation

Based on extensive review of literature on school gardens in various world regions, a list of best practices to assure scaling of agricultural technologies was developed. Additionally, primary barriers to scaling up through school gardens were identified (Table 1).

Inclusion of parents in the learning process and upkeep of school gardens was found to be a key component in assuring a successful and scalable school garden. Active parent involvement increased the likelihood of knowledge transfer from students to parents. Schreinemachers et al. (2017) in their assessment of a pilot school garden program in Bhutan highlighted the positive impact of the program's inclusion of parental involvement throughout the learning process. Parents were involved through land preparation, crop care, material provision, and student advising. Additionally, teachers took the time to visit parents at home and encouraged the use of home gardens. The authors determine the impact to be that parents were highly accepting of the school garden and families increased their knowledge about sustainable agriculture and nutritious food. Along the same lines, Schreinemachers et al. (2019) in their study on school gardens in Burkina Faso involved parents through contributions in determining garden vegetables choice, volunteer garden upkeep, land preparation, and fencing. The authors determined the impact of parental involvement to be that children's knowledge about agriculture, food, and nutrition improved. However, the scope of the study did not directly assess changes in attitudes and behavior of children, teachers, or parents. The authors specifically describe the need for such a component to be included in future study design. Furthermore, barriers to scaling arise if parents are uninterested are unable to commit the necessary time and energy for school garden involvement. This is especially true if a teacher spearheading the school garden effort leaves the school. Ferguson et al. (2019) acknowledge that highly motivated parents/schools are necessary to keep school gardens going on their own if the project leader leaves.

Inclusion of parents in the learning process was directly tied to another identified best practice for scaling – the establishment of home gardens alongside school gardens. The utilization of home gardens to test methods and technologies learned by children in school settings allows for streamlined transfer of knowledge and practices to the parents. This in turn increases usage of new agricultural technologies on a larger scale within households and communities. Calub et al. (2019) in their School-Plus-Home Gardens Project (S+HGP) in the Philippines found that through this methodology, the school gardens became learning laboratories; a place where both students and parents learned about appropriate technologies and practices relevant to sustainable intensification, organic agriculture, edible landscaping, climate change, and the interconnection of food and nutrition. Likewise, Okiror et al.'s (2011) study on school gardens in eight Ugandan schools shows how home gardens allow for the transfer of knowledge from student to parent. The authors find that students were able to effectively pass along their new agricultural knowledge to their parents despite potential barriers such as language constraints, timidness, and social mores. This was accomplished by providing visible examples of agricultural techniques to parents through their home gardens, showing income earned from sale of grown vegetables, and increasing the amount of food eaten at the household level. The likelihood of adoption of these new agricultural practices by parents was improved when inputs (seeds, chemicals, etc.) were provided for home garden projects. Conversely, barriers to scaling arose if parents lacked inputs, household land size was small, or there was a poor relationship between parent and child. Social mores of respect between parent and child could limit youth's confidence or ability to share knowledge with their elder. This phenomenon was found to be a key barrier to scaling in Uganda.

In continuation, child to parent transfer of knowledge is evident in the United Nations University flagship project, network of Regional Centres of Expertise (RCE) on Education for Sustainable Development (ESD) in Cambodia entitled 'RCE Greater Phnom Penh' (GPP). Tabucanon and Mihara (2016) look specifically at the GPP project entitled, 'Promoting Sustainable Agriculture at Kampong Cham Province in Cambodia.' The authors find evidence of transfer of learning through school gardens by incorporating sustainable agriculture and ESD into school curriculum. They highlight that because most students were children of farmers, they were easily able to discuss and test learned SI concepts/practices at home using home gardens/fields. The school gardens, compounded with home garden practice, resulted in increased adoption of sustainable agriculture practices among farming communities in the region. Similarly, Ran et al. (2013) highlight the 'Promoting ESD through Food, Agriculture and Environment Education in Elementary Schools and Rural Communities in Cambodia' project under GPP. While they also acknowledge the positive outcome of ESD to be transfer of knowledge, they also highlight lack of resources as a key barrier to scaling of sustainable agriculture. Many schools in the project lacked adequate buildings, desks, chairs, books, and materials for learning. Additionally, many students are unable to spend necessary time in school due to commitments on their home farms or financial strain forcing them to seek additional employment. Lack of social, human, and/or economic capital can severely impact the ability of a school garden program to contribute to scaling of sustainable technologies.

The implementation of ESD into curricula in Cambodia detailed by Tabucanon and Mihara (2016) and Ran et al. (2013) highlights another identified best practice of scaling: the establishment of hands-on, research-based agricultural curriculum in schools. FAO (2004)'s concept note regarding school gardens calls for the, "integration of school gardening into the curriculum to ensure adequate time is available for school gardening and related teaching activities without compromising the rest of the curriculum" (p. 1). ESD serves as a great example as it is a "holistic and transformational education which addresses learning content and outcomes, pedagogy and the learning environment" (UNESCO, 2019). ESD incorporates SI learning, promotes exploratory learning, and seeks collaborative decision-making learning outcomes. However, ESD is not the only pathway to integrating hands-on, research-based curriculum into schools. Sprague (2016) in her study of opportunities for and barriers to scaling school gardens using the case study of the Edible Schoolyard Pittsburgh project notes the importance that school gardens offer, "dynamic learning experiences via experiential and inquiry-based learning" (p. 18). Remarks from the author's surveys of garden educators and parents both centered around the advantages of experimental learning. In fact, some parents indicated that they had actually sent their child to the particular school because of the school garden curriculum and desired an increased focus on, "outdoor classroom, experimental, inquiry-based learning" (Sprague, 2016, p. 97).

Ferguson et al. (2019) focused on the utilization of action research and inquiry-based learning in the classroom, the garden, and through farmer visits. They highlighted this curriculum approach as a key factor of success for their program scaling agroecology through education in Chiapas, Mexico. Likewise, The Southeast Asian Regional Center for Graduate Study and Research in Agriculture (SEARCA) (2017) also used participatory action research through their discussion of a school and home gardens project in the Philippines. Through the project, "one hundred and twenty-five (125) lesson plans integrating the concepts of nutrition, organic agriculture, climate change mitigation and adaptation, and solid waste management were prepared by Grade 4 and Grade 7 Science, Mathematics, English, Edukasyong Pantahanan at Pangkabuhayan (EPP) (Home

Economics) and Technology and Livelihood Education (TLE) teachers" (p. 2). This resulted in significant sustainable agriculture and nutrition knowledge increase among students and their families. However, important to note is that creating well-established experiential school garden curriculum is a long and tedious process that requires collaboration and patience (SEARCA, 2020).

Building a successful school garden curriculum and then teaching said curriculum is only possible through collaboration and commitment among all stakeholders. Stakeholders include, but are not limited to, teachers, parents, students, school leadership, local government, policymakers, local community members, and research organizations. Without all school garden stakeholders working together, barriers to scaling become paramount. For example, Tabucanon and Mihara (2016) use a multi-stakeholder networking approach in their study and impress upon readers that it produces, "awareness-raising and learning among farmers, curriculum transformation in schools, and implementing the notion of sustainable livelihood" (p. 4). SEARCA (2020) also highlight the necessity of stakeholder collaborations in their briefing of the 'International Conference on School Gardens: Leveraging the Multifunctionality of School Gardens.' The editors describe lack of partnership and leadership between academia, local government, policymakers, schools, parents, and teachers as a key barrier to school garden start-up and maintenance.

Sprague (2016) proclaims that collaboration and commitment among school administrators, teachers, parents, garden coordinators, and community volunteers is necessary for the scaling of an instructional school garden. She introduces the necessity of a reliable system to track levels of stakeholder commitment, capacity, and confidence – dubbed the 3Cs. The 3C approach uses a framework that provides a 3C score that serves as, "a measurement of readiness for change or improvement of a given stakeholder group, arrived at and agreed upon by the stakeholder group" (p.131). Sprague claims this framework serves as a research roadmap with realistic, actionable timelines that do not cause stakeholders to overextend themselves, creating a balanced, scalable school garden system. Similarly, Rositsa and Hernandez (2018), in their comparative case study analysis of three locations for scaling up agricultural technologies, find coalition building between participants, government, and market institutions to be essential for scaling up of innovations. An example of appropriate stakeholder collaboration is seen in SEARCA (2017)'s project report on home and school gardens in the Philippines. The project provided support to the school gardens through partnership with local government and other stakeholders. Local Government Units (LGU) were created to support households in establishing home gardens in pilot schools. This was done to sustain necessary resource inputs and services as well as mainstream the project into LGU development programs.

Concerning resource inputs for school gardens, another best practice of scaling centered around the provision of financial assistance from the government or outside organization for startup and upkeep of school gardens. Many school gardens struggle to maintain the necessary amount of economic capital to run their programs effectively. For example, in 2012, 4-H, a youth centered agricultural program from the US, began a club in rural Ghana that encouraged students to plant hybrid maize seeds donated by DuPont Pioneer. While Pioneer provided the startup costs, the project failed in 2015. Pioneer only provided one round of seeds and additional seeds and inputs (pesticides, herbicides, fertilizers) were simply too expensive for farmers and schools to purchase on their own. The project would have required substantial subsidies in order to be sustainable long-term (Butler, 2014). In Giliberti (2018)'s study on the barriers to adoption and scaling of school gardens he finds that over 50% of agricultural educators surveyed viewed lack of finances as a key barrier to adoption. He suggests the offering of monetary incentives in order to increases rates of school garden adoption. FAO (2004) provides a guideline for minimum budgetary provisions for a national school garden program including start-up costs, teacher preparation and planning costs, and physical input costs.

If fiscal concerns for a school garden program are diminished, more time and attention is able to be given to focus on adequate methods for development and scaling. A key barrier found in literature was focusing too much on the 'what' and not the 'how' of a school garden program (i.e., scaling is not 'one size fits all'). Trying to implement the school garden curriculum without considering social, political, economic, geographic, etc. factors will result in substantial gaps in success (Wigboldus et al., 2016; Glover et al., 2019). Not one of the studies or projects examined for this review used the exact same methodology. Each school garden was situated in a unique geographical, cultural, social, and economic setting that required different tools to address barriers to scaling. To use the same methods of school garden implementation and maintenance in Pittsburgh as in Ghana would make the scaling of agricultural technologies immensely challenging, if not impossible.

Further, a key barrier to scaling was found to be poor capacity building for and involvement of school heads and teachers. At SEARCA's 'International Conference on School Gardens: Leveraging the Multifunctionality of School Gardens', capacity building was a key discussion point with overall issues/challenges section including, "capacity building for school heads, teachers, and parents as part of social and technical preparation to school gardens" (SEARCA, 2020, p. 68). This was often founded in lack of adequate training for teachers and administration working with school gardens. DeMarco (1997) found in his study on factors affecting elementary school teachers' adoption of school gardens into curriculum that teachers' education and knowledge on gardening principals was essential for implementation. However, their knowledge was found to be considerably lacking. In his survey of 236 teachers in the United States, only 18 (8%) indicated that, "their training was sufficient to successfully handle school gardening with their students and no further training was necessary" and 217 (92%) stated they felt additional training was needed. Undertaken 21 years after DeMarco's study, Giliberti (2018)'s study on adoption of school gardens by Agricultural Science teachers in Alabama found almost identical teacher concerns. He found that perceptions of planning, time, incentives, and teaching were key barriers to scaling. If teachers did not feel they had adequate school garden knowledge and training, strategic planning resources, monetary incentive, and/or time outside of the traditional classroom setting, then school gardens were far less likely to be implemented.

Capacity is also a key barrier to scaling outside of the United States as we see in Okiror et al. (2011)'s study on transfer of knowledge from school gardens in Uganda. They find lack of practical skills among teachers and administration support to be key barriers to scaling of school garden knowledge. Limiting factors were listed as: administrative conflicts between teachers and head teacher, negative actions of the school management committee (SMC), inadequate agricultural skills among teachers, and ineffective teachers. Conversely, enabling factors were listed as: teamwork among teachers, supportive school administration, assistance from extension workers, and availability of skilled teachers. Unfortunately, many teachers and administrators in the Global South lack the educational resources and training desired for school garden instruction (Okiror et al., 2020; Ferguson et al., 2019; Tabucanon and Mihara (2016); Comia et al., 2018; Calub et al., 2019; SEARCA, 2017; Schreinemachers et al., 2017; Schrienemachers et al., 2019).

Table 1 Best practices and primary barriers to scaling through school gardens

Best Practices	Primary Barriers
• Including parents in the learning process and upkeep of school gardens • Establishment of home gardens alongside school gardens • Establishment of hands-on, research-based agricultural curriculum in schools • Collaboration and commitment among all stakeholders	• Focusing on the 'what' and not the 'how' (i.e., scaling is not 'one size fits all') • Social mores and the relationship between parent/child • Poor capacity building for and involvement of school heads, teachers, and parents • Lack of social, human, and/or economic capital • Unintegrated commitment and partnership among stakeholders

As such, it is essential to provide capacity building opportunities to educators to assure effective scaling of agricultural technologies through school gardens.

It is of note that a limitation to our review was that while the intended focus was to highlight scaling of agricultural technologies, much literature on school gardens focused on nutrition and food security. While these are important benefits of school gardens, we found literature regarding the knowledge transfer of school gardens to the lacking. However, we were able to pull out the best practices that lead to scaling potential to highlight as tools for future use as well as barriers that would limit a school garden's ability to be used for scaling of agricultural technologies.

Case Study: S3 Cambodia

School gardens have the potential to play a key role in scaling sustainable intensification (SI) technologies. They provide opportunities for knowledge transfer through teacher-student-parent communication. We can apply best practices and address key challenges through analyzing S3-Cambodia. S3-Cambodia seeks to target youth as an entry point to extend target SI technologies to farm families. The project will engage students in experiential learning opportunities by establishing "green labs" at six pilot secondary schools. Students will receive a combination of hands-on training in SI practices and STEM-based instruction in SI principles from Cambodian teachers trained on this topic (Figs. 1, 2). This preparation will culminate in the establishment of student home gardens featuring SI technologies learned in the schools (Fig. 3).

In order to apply best practices and avoid the barriers to scaling S3 will incorporate the findings from the literature. For example, home gardens will be implemented alongside school gardens as a key project activity. It will be done to increase learning and to allow school communities to evaluate new practices before applying them at the field or farm scale. Additionally, hands-on, research-based agricultural curriculum will be developed and applied in the pilot secondary schools. As part of its youth development strategy, the project will work hand-in-hand with the Cambodian Ministry of Education, Youth, and Sport (MOEYS) to develop new 4-H style[1] curriculum and adapt existing curriculum to provide agricultural-based STEM instruction that can be scaled nationally.

Additionally, S3-Cambodia implements the best practice of providing financial assistance to the schools for the startup and upkeep of the school gardens. As a USAID funded project with additional leveraged funds, S3-Cambodia is able to provide the necessary monies to establish green labs, trainings, and necessary inputs. To assure green lab infrastructure and curriculum will be maintained after project close, the project will provide training, supplies, curriculum, and government support to Cambodian educators.

Furthermore, S3-Cambodia will assure collaboration and commitment among stakeholders through adhering to its detailed capacity building plan. This plan includes collaboration and mentorship with project counterparts (CE-SAIN, RUA, UBB[2]), a train-the-trainer program, and direct engagement with end-users. However, it is necessary to be aware of the challenges that may be faced with collaboration of a transnational project funded and directed from the United States but taking place in Cambodia. For example, the COVID-19 pandemic, though unprecedented, has resulted in the stunting of first year project activities because of school closures and travel delays. This was only exacerbated by extreme flooding events in Cambodia during October, 2020[3].

Thankfully, because the project is solely focused on Cambodia and particular regions therein, it is not likely to be hindered by the barrier of focusing on the 'what' and not the 'how'. S3-Cambodia is very context-specific and leverages knowledge from past projects (i.e., 2015-2020 WAgN-Cambodia project[4]) and national partners (CE-SAIN, RUA, UBB).

However, not finalized in the project implementation is parental involvement. As the project moves forward, acknowledging how to incorporate parents into implementation of school gardens should be a key goal. This will be necessary in order to overcome potential barriers such as social mores and the relationship between parent/child. For example, this could be done through welcoming parents to visit the school demonstration plots once a week to view how the SI technologies are working and gain a first-hand understanding of what their children are doing at school, encouraging parent volunteers to help in the green labs, or having parents provide their farms for field visits. Such activities will add to the potential for successful transferring of SI technology knowledge from child to parent.

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[1] *https://4-h.org/about/what-is-4-h/*
[2] *Center of Excellence on Sustainable Agricultural Intensification and Nutrition (CE SAIN), Royal University of Agriculture (RUA), University of Battambang (UBB)*
[3] *https://reliefweb.int/disaster/fl-2020-000212-khm*
[4] *https://smithcenter.tennessee.edu/women-in-agriculture-network-wagn-cambodia-gender-and-ecologically-sensitive-agriculture/*

Fig. 1 Students trimming trees in the wild food plant nursery

Fig. 2 Students propagating wild food plants

Fig. 3 Farmer planting grafted vegetables using conservation agriculture techniques

CONCLUSION

School gardens serve as a useful tool worldwide to enhance student agriculture education and food systems knowledge. This paper addressed a key gap in research on school gardens by reviewing literature to assess their potential to serve as agents of knowledge transfer. While much of current research focuses on nutrition and vegetable consumption, there is literature supporting school gardens' ability to play a key role in scaling agricultural, specifically SI, technologies. Best practices and barriers were identified for scaling through school gardens. The best practices provided plausible opportunities for knowledge transfer through teacher-student-parent communication; the barriers limited these opportunities. S3-Cambodia has strong potential to successfully transfer knowledge of SI technologies from the green labs to the home farm. The project utilizes a significant amount of the best practices identified in literature and has measures in place to avoid the barriers. If parental involvement is increased, project scaling objectives are likely to be met.

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