Citizen Science and Urban Home Gardeners' Attitudes Toward Gardening

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Abstract. Citizen science is a participatory research method that enlists community members as scientists to collect data at a scale that would not be possible for researchers on their own and in research contexts that are difficult for researchers to reach. Although the contribution of citizen science to scientific data collection is well-known, a new area of research investigates the impact that citizen science programs have on the citizen scientists. Gardening can support healthy dietary patterns, food access, and food system resilience in urban communities. Leveraging home gardening can be a good way for cooperative extension and community groups to support the health and wellbeing of their community members. However, to reap the health and community benefits of gardening, individuals need to adopt the behavior of gardening. In this study, researchers from University of Florida conducted a home gardening citizen science program between Mar 2022 and Jul 2022 for the purpose of assessing whether participating in a citizen science home gardening program increases the likelihood of participants' future home gardening. Researchers used a matched pretest and posttest evaluation design to assess whether participation in this program affected the citizen scientists' (n = 112) beliefs, attitudes, and perceptions of home gardening. Citizen science program participants improved their attitudes and beliefs about home gardening but had limited improvement in their self-efficacy about home gardening after participation in the program. A 1-year follow-up survey found that program participants had adopted new gardening behaviors and reported benefits of participating in the program beyond gardening. These results highlight the value of citizen science to facilitate intentions to home garden and show the importance of information and program support to ensure the success of program participants.

Citizen science is a participatory research method that allows researchers to collect data at a scale and breadth that would not be possible if the data collection had been limited to research teams (Ebitu et al. 2021). Citizen science is also an apt methodology for collecting data in real-world conditions and locations where researchers may not have access (Pollard et al. 2017). There are a variety of different types and scales of citizen science programs ranging from large-scale, long-term, highly structured programs to small community-led programs to address local issues (Hajibayova et al. 2021). The prevalence of citizen science as research methodology has become so large that the methodology itself—its types, purposes, and impacts—has become an area of inquiry with its own academic journal, professional association, and conferences focused specifically on the methodology of citizen science rather than the data that are collected via the methodology (Bonney et al. 2016; Hajibayova et al. 2021; Phillips et al. 2019; Wiggins and Crowston 2011).

One new area of inquiry is examining how collecting data in citizen science programs affects participants (Price and Lee 2013). Some research has focused on whether participation in citizen science increases scientific knowledge or scientific literacy (Bonney et al. 2009, 2016; Brossard et al. 2005; Shirk et al. 2012). Other research has sought to understand whether citizen science programs change participants' attitudes and behaviors (Hajibayova et al. 2021; Price and Lee 2013; Severin et al. 2023). Most research of the impacts of participating in citizen science has focused on whether participation in environmental and natural resource citizen science programs affects participants' attitudes and behavior related to conservation (Severin et al. 2023; Wiggins and Crowston 2011). To a lesser extent, research of the impacts of participating in citizen science has focused on what have been called "personal outcomes," which include topics such as whether citizen science contributes to development of new skills, improved mental health, connection to nature, or a sense of community (Peter et al. 2019; Shirk et al. 2012).

Participation in citizen science improves attitudes of participants, including attitudes about science (Berndt and Nitz 2023; Price and Lee 2013), the environment (Chase and Levine 2018), and proenvironmental behaviors (Severin et al. 2023). Citizen science also increases scientific knowledge (Ballard and Belsky 2010), scientific thinking (Trumbull et al. 2000), and knowledge related to the topic of citizen scientists' data collection (Jordan et al. 2015; Peter et al. 2019; Price and Lee 2013; Severin et al. 2023). Citizen science programs related to conservation and environmental monitoring increase intentions to engage in conservation behaviors (Severin et al. 2023; Toomey and Domroese 2013). In addition to science or research related topics, citizen science can have positive impacts on health, well-being, satisfaction, and the feeling of connection to other people and to nature (Peter et al. 2021).

Citizen science has been identified as a valuable research methodology for urban agriculture (Pollard et al. 2017) and has been used previously in home gardening research. For example, Sykes et al. (2021) used citizen science to conduct a large, multiyear, statewide project with many plant species to create a foundational dataset that helped guide vegetable selection in Tennessee. Similar to the approach of most other citizen science projects, the study focused primarily on the data collected by project participants (Sykes et al. 2021). However, research describing the effects that participating in garden-based citizen science has on participants is lacking.

Researchers using citizen science methodologies rely on participants to volunteer their time, energy, and resources to collect data that can help the researchers answer questions. Often, citizen scientists collect these data without receiving any compensation or appreciable benefit. Without their participation, these types of studies would be impossible. Because the aforementioned research has found that participation in citizen science studies can affect knowledge, attitudes, and behavior of participants, it is worth assessing whether participation in a citizen science study can have the effect of increasing knowledge, attitudes, and skills related to gardening that will ultimately help people to garden in the future and receive the benefits from gardening. If participating in citizen science research on home gardening provides benefits to participants, then it can be seen as a mutually beneficial enterprise in which both the researchers and citizen scientists receive something of value. In this vein, future citizen science activities could be used as interventions to help support behavior change using active participation rather than more traditional education programs that engage participants as passive recipients of knowledge.

Gardening has many benefits to individuals, households, and communities. Community gardens can create community cohesion or support social connections (Alaimo et al. 2016; Firth et al. 2011). Gardening also provides opportunities for education and skill-building (Fusco 2001). Gardening has positive effects on both mental and physical health by providing opportunities for physical activity, reducing stress, and increasing connections with nature (Brown and Jameton 2000; Okvat and Zautra 2011; Sommerfeld et al. 2010). Additionally, there has been extensive research of the benefits of gardening to food and nutrition outcomes (Garcia et al. 2018). More than half of community gardeners meet the national recommendations for fruit and vegetable consumption as compared with only 25% of non-gardeners (Litt et al. 2011). In addition, participating in community gardening increases fruit and vegetable intake not only of the gardener but also other household members—adults who live with a community gardener are more than three times more likely to consume fruits and vegetables at least five times per day (Alaimo et al. 2008). Community gardeners perceive that gardening helps them eat more fruits, vegetables, organic, fresh, and traditional food (Tackie et al. 2014). Research of home gardening specifically has been limited because of its lack of public accessibility and visibility, and because of the great variations in scale, location, and type of growing methods used in home gardening (Taylor and Lovell 2014).

The theory of planned behavior (TPB) has been used widely to understand and predict individual behavior in public health and consumer research over the last four decades (Ajzen, 1985; Fishbein and Ajzen 1975). According to TPB, intentions to perform behaviors both precede and predict individual behavior, and intentions are a product of a specific set of beliefs and attitudes. Namely, intentions are a product of behavioral beliefs (beliefs about the behavior and its likely outcomes), attitudes about the outcomes of the behavior, normative beliefs (beliefs about what others think about the behavior), and control beliefs (beliefs about how easy or difficult it would be to engage in a behavior) (Ajzen 2020).

Although there have been previous studies using TPB in relation to gardening and citizen science, they have focused on other types of programs, audiences, and intended outcomes. For example, TPB applied to youth gardening programs found that attitudes were most predictive of behavior changes of boys and girls, but control beliefs were associated with behavior changes of only girls (Lautenschlager and Smith 2007). In the case of community gardeners' intentions to adopt safe gardening practices, behavioral beliefs about certain practice as well as control beliefs were found to influence community gardeners' behavior (Hunter et al. 2020). Behavioral beliefs about ecosystem services have been found to have direct positive impacts on attitudes, normative beliefs, and intentions to participate in urban community gardens (Wu et al. 2022).

Because of its prevalence and utility in behavior theory, TPB has been applied to the field of citizen science in several ways. It has been used to understand why people would be willing to participate in citizen science programs (Martin et al. 2016), perceptions of participants in citizen science programs (Cigarini et al. 2022), individual and organizational support for citizen science programs (Van Buskirk et al. 2023), and factors that predict scientists' use of citizen science as a type of public engagement with science (Poliakoff and Webb 2007). One extensive review article used TPB as an organizing framework to understand the barriers and incentives to participating in citizen science that have been identified in the literature (Wehn and Almomani 2019).

Although there is extensive literature regarding the effects of gardening, particularly community gardening, as described, there is limited research regarding what types of programs or activities increase the likelihood of people gardening in the future. Unlike studies that have examined the behavioral and attitudinal impacts of gardening, the purpose of this study was to assess whether participating in a small-scale, home gardening citizen science program affects participants' beliefs, attitudes, and intentions to home garden in the future. This is the first study to use TPB to examine the behavioral impacts of participating in a home gardening citizen science study.

Methods

This study was conducted in Alachua, Broward, and Orange Counties in Florida between Mar 2022 and Jul 2022, and it was approved by the University of Florida institutional review board (IRB no. 202102778). All three counties are classified as dense urban metropolitan, or micropolitan areas by the United States Census

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Bureau (US Census Bureau 2020). Program participants were recruited with the support of commercial and residential horticulture extension agents in each county. Interested Florida residents completed an initial sign-up form. Two-hundred people were selected to participate in the program based on answers to questions on the sign-up form. Specifically, the research team gave priority to limited-resource participants who were identified by whether someone in their household had received food assistance during the last 12 months (e.g., Supplemental Nutrition Assistance Program). In addition, because most people who registered to participate were experienced gardeners, the research team selected participants who indicated that they had limited experience with gardening.

Although the purpose of the study described in this article was to assess whether participating in a small-scale, home gardening citizen science program affects participants' beliefs, attitudes, and intentions to home garden in the future, the citizen scientists ($n = 180$) collected data for a project to assess how differences in experiences in growing plant products—such as whether the level of gardening involvement required, time to harvest, or number of challenges experienced—affect home gardeners' preferences and successes with growing plants started at different stages (Perez-Lugones et al. 2023). The citizen scientists conducted an experiment growing tomato (*Solanum lycopersicum*) plants at three different stages of maturity from seed, a transplant in a 4-inch container, and a plant in an 8-inch container with at least one green fruit ≥1 cm. Tomato was selected as the crop for this experiment because it is the most popular home gardening vegetable plants in the United States and found in 86% of home gardens (National Gardening Association 2014). All materials required to conduct the in-home experiments were provided to project participants, including a detailed protocol and instructions to grow each plant. For the citizen science data collection, participants recorded data on the dates they sowed seed, transplanted, and started and stopped harvesting from each plant, and on the number of mature and immature fruit that each plant produced. Additional details regarding the citizen science materials, methods, and results of the tomato citizen science study can be found in the work by Perez-Lugones et al. (2023).

Participant engagement was maintained through monthly online meetings via video conferencing software (Zoom Video Communications, Inc., San Jose, CA, USA) and regular participation in a social media community page (Meta, Menlo Park, CA, USA). The monthly online meetings occurred during the evenings to increase the likelihood that people who work during the day would be able to attend. These online meetings connected citizen scientists within their respective communities and across counties and provided opportunities to troubleshoot challenges and update participants about the progress of the experiment. The social media page, entitled Citi-Sci: Growing Food for Science, not only served to connect citizen scientists through the exchange of knowledge between participants of differing experience levels but also provided visual updates through photographs of the participants' progress. This aspect of the program was met with consistent engagement, with 129 active users making more than 300 posts. The posts garnered 750 comments and nearly 3000 reactions from participants, with up to 99 participants engaged during 1 d. The group served as a valuable tool for promoting community interaction. In addition, program participants were invited to attend two optional family and consumer science lessons about home food preservation, food safety, nutrition, and reducing food waste, which were delivered live via video conferencing software in Jun 2022, and uploaded to the social media community page so that it could be available to people who could not attend the lessons live.

INSTRUMENTATION. The program used a pretest and posttest format, followed by a 1-year follow-up survey. Surveys were completed via an online survey platform (Qualtrics XM, Provo, UT, USA). Both the pretest and posttest included questions about participants' attitudes, beliefs, and intentions about home gardening. The pretest collected demographic data, and the posttest collected data related to the program participants' satisfaction with the plants and the program, as well as their needs and preferences related to program delivery.

The pretest and posttest survey questions about the participants' attitudes, beliefs, and intentions about home gardening were constructed based on TPB (Ajzen 2020). To assess program participants' attitudes about home gardening, we used a 5-point semantic differential scale for seven sets of bipolar descriptors (e.g., 1 = harmful, 5 = beneficial; 1 = overall bad, 5 = overall good). The responses regarding gardening beliefs were measured using a 5-point Likert scale (1 = strongly disagree; 5 = strongly agree). There were four questions about their behavioral beliefs. Specifically, they were asked whether they believed that home gardening would help them improve where they live, eat more fresh fruits and vegetables, connect with nature, and improve their mental health. There were questions about their normative beliefs and subjective norms, including whether their family or friends think they should home garden, and whether people important to them value home gardening or would approve of them home gardening. For perceived behavioral control, we asked whether they believe home gardening is easy or convenient, whether they had the resources they need to home garden, and whether they were confident they could home garden. Finally, we asked whether participants would make an effort to home garden or plan to home garden in the future.

Five-point Likert scales were also used to collect responses regarding participants' satisfaction with aspects of the program (1 = very unsatisfied; 5 = very satisfied), including producing food, contributing to science, connecting with other citizen scientists, and the time required to participate in the program and take care of the plants. Responses were measured using a 5-point Likert scale (1 = very unsatisfied; 5 = very satisfied). Real limits were set a priori for the interpretation of responses as follows: 1.00 to 1.49 = very unsatisfied; 1.50 to 2.49 = unsatisfied; 2.50 to 3.49 = neither satisfied nor unsatisfied; 3.50 to 4.49 = satisfied; and 4.50 to 5.00 = very satisfied. Regarding the difficulty of participating in the citizen science activities, such as acquiring project materials, understanding project instructions, and recording project data, responses were measured using a 5-point Likert scale (1 = very difficult; 5 = very easy). Real limits were set a priori for the interpretation of responses as follows: 1.00 to 1.49 = very difficult; 1.50 to 2.49 = difficult; 2.50 to 3.49 = neither easy nor difficult; 3.50 to 4.49 = easy; and 4.50 to 5.00 = very easy. Regarding the perceived usefulness of additional support or activities in the program, such as receiving more guidance about the project or more opportunities to collaborate with researchers, responses were measured using a 5-point Likert scale (1 = not at all useful; 5 = extremely useful). Real limits were set a priori for the interpretation of responses as follows: 1.00 to 1.49 = not at all useful; 1.50 to 2.49 = slightly useful; 2.50 to 3.49 = moderately useful; 3.50 to 4.49 = very useful; and 4.50 to 5.00 = extremely useful.

A 1-year follow-up survey was distributed in Jun 2023 via an online survey platform. The survey assessed whether people had adopted practices or behaviors related to the program, including whether they increased well-being, bought more plants to grow at home, adopted recommended gardening practices, or started a home garden. Responses were measured using a 5-point Likert scale (1 = strongly disagree; 5 = strongly agree). Participants were also asked to share qualitative data about how their experience with the citizen science program affected their lives. An inductive–deductive open coding approach was used to code the qualitative data. Responses were coded thematically to reflect the anticipated responses and, as researchers coded, they allowed for simultaneous inductive interpretation of emergent themes (Saldaña 2021).

Statistical analysis. Analyses of the quantitative data were performed using statistical software (IBM SPSS Statistics version 24; IBM Corporation, Armonk, NY, USA). Descriptive data were calculated for all program participants. Statistical tests were used to assess changes in program participants for whom we were able to match pretest and posttest data. The internal reliability of the garden attitudes scale questions was calculated using Cronbach's α, and the standard consistency score for a scale to be considered reliable was ≥ 0.7 (Nunnally 1978). The seven items comprising the garden attitudes scale had a high degree of reliability for both the pretest ($\alpha = 0.92$) and the posttest ($\alpha = 0.87$). The Shapiro-Wilk test was used to assess the normality of the data. The results of the Shapiro-Wilk tests showed that the data were not normally distributed; therefore, we used nonparametric methods (Shapiro and Wilk 1965). The two-sided Wilcoxon signed-rank test ($P < 0.05$) was used to compare the means of the two matched samples before and after the program.

Results and discussion

Most participants (82%) who enrolled in the program reported having space for gardening in their backyard (Table 1). More than half (54%) had patio space for gardening, and just less than half (43%) gardened in their front yard. Most program participants were somewhat or very experienced gardeners (72%). Like other studies seeking to assess the behavioral impacts of participating in citizen science, our study also had the issue of program participants having high levels of knowledge and positive attitudes toward the activity when they joined the program (Chase and Levine 2018; Severin et al. 2023). The majority (84%) of the study population had a college degree, and just less than half had a graduate or professional degree (43%). Most members of the study population did not have children living in the home (61%). The study had a fairly even spread of participants in different age groups; however, half (50%) of the program participants were between 30 and 49 years of age. Although the research team sought to enroll participants with limited resources, the majority of program participants (85%) had not received food assistance during the 12 months before the beginning of the program. This paralleled the experience of other citizen science research projects that tried to assess changes in participants' attitudes and behaviors in that there is a narrow range of individuals who self-select into participating in citizen science projects who tend to be more educated and affluent and have high levels of interest in science and positive attitudes about the environment before enrolling in the citizen science programs (Chase and Levine 2018; Domhnaill et al. 2020; Pateman et al. 2021). There have been calls for researchers to make an effort to expand the range of citizens who participate in these projects (Chase and Levine 2018; Pateman et al. 2021).

A large proportion of participants (38%) collected the program materials and completed the pretest but did not complete the posttest. There was no significant difference in demographic data—by county, gardening experience level, or income level—for people who did and did not complete the posttest. Other studies of how participating in a citizen science program affects behavior and attitudes have had difficulty collecting complete posttests from participants (Price and Lee 2013). In our study, the lack of response could have been attributable to participants with waning interest in the project or dropping out of the program, for example, because of finding the program to be too burdensome or struggling to keep the plants alive. Additionally, witnessing the successes of other participants may have influenced feelings of satisfaction, self-efficacy, and overall success. Future programs should seek to ensure ongoing engagement with participants to maintain participation throughout the study period (Table 1) (Reynolds et al. 2020). For programs implemented via extension, this ongoing engagement could be supported by master gardener volunteers. Although it was communicated that failure to bring all stages of plants to maturity was not a means for dismissal from the project or the results, participants whose plants died might have felt a lack of necessity to share their results. Emphasizing the importance of collecting all results in participatory research and the use of incentives to finish the postsurvey may improve this aspect.

As with other citizen science studies [e.g., Price and Lee (2013)], our program participants' attitudes about home gardening were significantly more positive after the program according to six of seven questions and the attitudes scale (Table 2). Gardeners experienced significant increases in all four of

Table 1. Personal and household characteristics of citizen science program participants.

Variable	No.	%
Location available to garden (n = 180)		
Backyard	147	81.7
Patio	98	54.4
Front yard	78	43.3
Windowsill	46	25.6
Other	22	12.2
Garden experience level (n = 167)		
Very inexperienced	11	6.6
Somewhat inexperienced	18	10.8
Neither experienced nor inexperienced	18	10.8
Somewhat experienced	96	57.5
Very experienced	24	14.4
Education level (n = 180)		
Did not complete high school	1	0.6
High school diploma or test of general education development	3	1.7
Some college, technical or vocational training	25	13.9
Associate's degree	15	8.3
Bachelor's degree	58	32.2
Graduate or professional degree	78	43.3
Sex (n = 179)		
Male	32	17.9
Female	147	82.1
Children living in the home (n = 180)		
Yes	71	39.4
No	109	60.6
Received food assistance within last 12 months (n = 180)		
Yes	25	13.9
No	153	85.0
Do not know	2	1.1
Age range (years) (n = 179)		
18–29	9	5.0
30–39	45	25.1
40–49	44	24.6
50–59	26	14.5
60–69	35	19.6
70 or older	20	11.2

their behavioral beliefs toward home gardening—that it would help them improve where they live, eat more fruits and vegetables, connect with nature, and improve their mental health (Table 3). Thus, this research documented changes in beliefs in a household context that had been previously identified by research focused on community gardening (Alaimo et al. 2016; Hale et al. 2011; Kortright and Wakefield 2011; Krishnan et al. 2022). Participants had the greatest improvements in their normative beliefs about home gardening, with three of four normative beliefs being significant ($P <$ 0.001) (Table 4). The monthly meetings and social media community page encouraged program participants to interact with each other, which may have contributed to the significant increases in the participants' perceptions of other people's support for home gardening, as would be expected from the TPB theoretical framework (Ajzen 1985).

Program participants experienced significant improvements in their behavioral intentions related to home gardening, with respondents indicating that they plan to home garden in the future and that they will make an effort to home garden. Program participants did not have significant improvements in control beliefs and perceived behavioral control (Table 5). A person's control beliefs are related to how easy or difficult a behavior is and whether they perceive that they have the skills and resources available to them to perform the behavior (Ajzen 1985). Other studies focused on knowledge and attitude changes from participating in citizen science have similarly found decreases in certain types of knowledge or attitudes as a result of participating in the project. Researchers have suggested that these results could have occurred because participating in the citizen science project helped participants realize just how much more they still have to learn even though many appraised themselves as being highly knowledgeable

Table 2. Citizen science program participants' attitudes toward gardening before and after the program (n = 112).

	Attitudes (1–5 scale)				
	Pretest		Posttest		
	M	*SD*	M	*SD*	*P*[i]
1 = Overall bad; 5 = Overall good	3.71	0.59	4.53	0.72	**0.003**
1 = Unimportant; 5 = Important	3.62	0.82	4.46	0.96	**0.002**
1 = Worthless; 5 = Valuable	3.61	0.89	4.65	0.89	**<0.001**
1 = Undesirable; 5 = Desirable	3.60	0.94	4.20	0.95	0.061
1 = Useless; 5 = Useful	3.59	1.00	4.35	1.06	**0.026**
1 = Harmful; 5 = Beneficial	3.57	1.09	4.64	0.50	**0.005**
1 = Not a priority; 5 = High priority	3.37	0.80	3.92	0.90	**<0.001**
Attitudes Scale	4.40	0.66	4.58	0.52	**0.021**

[i] Statistically significant at $P \leq 0.05$.

Table 3. Citizen scientists' behavioral beliefs about home gardening before and after the program (n = 112).

	Behavioral beliefs (1–5 scale)[i]				
	Pretest		Posttest		
	M	*SD*	M	*SD*	*P*[ii]
Home gardening will enable me to:					
Improve where I live	3.22	0.89	3.63	0.93	**0.004**
Eat more fresh fruits and vegetables	3.55	0.66	3.91	0.83	**0.025**
Connect with nature	3.59	0.67	4.09	0.75	**<0.001**
Improve my mental health	3.68	0.54	3.94	0.78	**0.029**

[i] 1 = strongly disagree; 5 = strongly agree.
[ii] Statistically significant at $P \leq 0.05$.

Table 4. Citizen scientists' normative beliefs about home gardening before and after the program (n = 112).

	Normative beliefs (1–5 scale)[i]				
	Pretest		Posttest		
	Mean	*SD*	Mean	*SD*	*P*[ii]
My family (or relatives) think I should home garden	3.21	0.72	3.62	0.95	**0.005**
My friends think I should home garden	3.26	0.75	3.71	0.87	**<0.001**
People who are important to me approve of my home gardening	3.73	0.45	4.33	0.66	**<0.001**
The people I care about value home gardening	3.53	0.65	4.10	0.76	**<0.001**

[i] 1 = strongly disagree; 5 = strongly agree.
[ii] Statistically significant at $P \leq 0.05$.

or skilled at the beginning of a program (Price and Lee 2013).

Program participants were satisfied with all aspects of the program (Table 6). Many participants had difficulty with insect pests and keeping their plants alive, which could have negatively impacted their perception of how difficult home gardening is or feelings of self-efficacy for home garden. For example, the mean score for how difficult it was to keep the plants alive was neither easy nor difficult based on the real limits we set for interpreting the data (Table 7). Similarly, citizen scientists indicated that participating in the monthly video conferencing software meetings—which could have helped people address issues with their plants—was neither easy nor difficult. Gardening programs could facilitate perceived behavioral control by ensuring that all program participants have the support they need to grow the plants, keep them alive, and address pest issues. Program participants indicated that having more instructions or opportunities to collaborate with researchers would have been useful (Table 8).

Most of the participants who attended the two optional family and consumer sciences sessions (n = 16) reported that they increased their knowledge of home food preservation methods (75%), food safety practices for home food preservation (75%), ways to reduce food waste (81%), and ways to incorporate fresh produce into their eating plan (69%) (Table 9). Because one important benefit of gardening is increasing access to healthy food (Garcia et al. 2018; Smith and Harrington 2014; Tackie et al. 2014), more formal inclusion of nutrition, cooking, and food preservation courses in a citizen science program would likely have positive impacts on participants' vegetable consumption. In addition, those courses could increase the enrollment of participants with limited resources (Table 1) who may be specifically interested in home gardening for

Table 5. Citizen scientists' perceived behavioral control and behavioral intentions before and after the program (n = 112).

	Perceived behavioral control and intentions (1–5 scale)[i]				
	Pretest		Posttest		
	Mean	*SD*	Mean	*SD*	*P*[ii]
I will make an effort to home garden	3.67	0.54	4.03	0.81	**0.014**
I plan to home garden	3.64	0.57	3.93	0.93	**0.029**
I am confident that I can home garden	3.53	0.74	3.65	1.09	0.375
I have the resources to home garden	3.39	0.74	3.63	0.98	0.062
Home gardening is convenient	2.92	0.85	3.10	1.03	0.054
Home gardening is easy	2.75	0.93	2.88	1.01	0.191

[i] 1 = strongly disagree; 5 = strongly agree.
[ii] Statistically significant at $P \leq 0.05$.

Table 6. Citizen scientists' satisfaction with aspects of the citizen science gardening program (n = 118).

	Perceived satisfaction (1–5 scale)[i]	
	Mean	*SD*
Producing food	4.39	0.93
Contributing to science	4.37	0.86
Time required to participate in the citizen science project	4.38	0.88
Time required to take care of the plants	4.27	1.04
Connecting with other citizen scientists	3.69	1.06

[i] 1 = very unsatisfied; 5 = very satisfied.

Table 7. Program participants' perceptions of the difficulty of aspects of the citizen science gardening program (n = 118).

	Perceived difficulty (1–5 scale)[i]	
	Mean	*SD*
Acquiring the project materials	4.59	0.78
Understanding citizen science project instructions	4.46	0.90
Recording data	4.34	0.90
Keeping plants watered	3.91	1.10
Using social media to engage with other citizen scientists	3.92	1.20
Keeping the plants alive	3.45	1.10
Participating in monthly zoom meetings	3.25	1.40

[i] 1 = very difficult; 5 = very easy.

the purpose of improving access to fresh fruits and vegetables for themselves or of their families (Siegner et al. 2018).

Based on the 1-year follow-up survey, the largest changes reported by participants (N = 73) were adopting practices to conserve natural resources, increasing well-being, buying more plants to grow at home, and adopting recommended gardening practices (Table 10). The finding that the lowest number of people started a garden was likely attributable to the fact that our population, as with many citizen science programs, had a study population with many highly experienced home gardeners who already had home gardens (Table 10).

The qualitative data from the 1-year follow-up survey revealed that the program affected participants in a number of ways. The primary themes emerging from the data were as follows: increased knowledge, skill, confidence, and interest in gardening; adoption of new gardening practices; improvements in mental and physical health; social and community impacts; and increased interest and appreciation for science and research.

Table 8. Program participants' perceptions of the usefulness of additional program support or activities in the citizen science gardening program (n = 118).

	Perceived usefulness (1–5 scale)[i]	
	Mean	*SD*
More guidance or project instructions	3.35	1.14
More opportunities to collaborate with researchers/community members	3.23	1.18
More guidance on how to collect and record data	2.69	1.23

[i] 1 = not at all useful; 5 = extremely useful.

Most reported impacts that the citizen science program had on participants' lives related specifically to home gardening. Participants discussed knowledge and skills that they gained in the program and how they have used it, including starting plants from seed, identifying the correct location for plants in their garden, monitoring for pests, and using correct fertilization techniques. They discussed having increased interest in gardening, confidence about gardening, and curiosity about plants. For example, one participant said the following:

"I have had a mango (*Mangifera indica*) tree on my property since I first bought the property in 2018. However, I have been more diligent about researching the variety, examining for pests and bugs, recording progress, and comparing this year's yield to last year's and pruning practices. This has all been since participating in the study. I probably would not have gone to these measures without my engagement in the study and what I learned. Thank you to the scientists for that."

Participants also discussed having increased confidence in growing plants and an increased willingness to try to grow new plants. Participants noted that they shared their knowledge and confidence with others. For example, one participant said, "I encourage friends and family to try home gardening and also feel I have some additional advice for them due to what I learned and the experience I had." Another said, "With the newly found confidence in growing my own food and the techniques learned I am growing my own garden and sharing how-to with friends." Other participants mentioned sharing plants or produce they have grown with their friends and colleagues.

Participants also discussed a variety of social, mental, and physical benefits. For example, one participant said the following:

"This program gave me the confidence to plan and start my own garden, helped my depression and anxiety immensely, and has really changed my mind set on growing my own food. I now feel equipped to try growing new fruits and vegetables. My whole family is immensely grateful for this experience."

Table 9. Knowledge gained by citizen science program participants who attended family and consumer science extension program (n = 16).

Knowledge topic	Perceived knowledge gain (1–5 scale)[i] Mean	*SD*	No.	%
Increased knowledge of home food preservation methods	4.19	0.83	12	75
Food safety practices for home food preservation	4.13	0.81	12	75
Ways to reduce food waste	4.25	1.13	13	81
Ways to incorporate fresh produce into my eating plan	4.06	1.18	11	69

[i] 1 = strongly disagree; 5 = strongly agree.

Table 10. Behavior changes of citizen science program participants 1 year after the program (n = 73).

	Behavior change (1–5 scale)[i] Mean	*SD*
Adopted a practice to conserve natural resources	4.10	1.15
Increased well-being	4.03	0.96
Bought more plants to grow at home	3.97	1.30
Adopted a recommended gardening practice	3.79	1.38
Eat more fresh fruits and vegetables	3.77	1.07
Purchase more local produce	3.66	1.17
Started a home garden	3.60	1.53

[i] 1 = strongly disagree; 5 = strongly agree.

Another participant said the following:

"I began a health and weight loss journey last May 2022. Since then, I have lost 50 lb and at 67, I am the healthiest of my life! Gardening and healthy eating certainly helped my wellness journey. I encourage friends and family to try home gardening and also feel I have some additional advice for them due to what I learned and the experience I had."

These quotations highlight the following multiple benefits that a citizen science program can have: building knowledge, attitudes, and skills related to home gardening, and social, physical, and mental health benefits beyond the specific objectives of the study or the data collected for the citizen science project.

Limitations and future research. The research team was interested in enrolling populations with limited resources in the program to assess whether citizen science can be effective at increasing home gardening in populations that typically have difficulty accessing fresh fruits and vegetables. It is often difficult to enroll populations with limited resources in research studies because they may not be able to devote the time required to participate in a program, or they may not have internet access to attend online meetings. Future programs could be more successful at enrolling populations with limited resources by providing programs in person or with limited time commitments. In addition, for populations with limited resources, particularly those who are interested in health and nutrition, a citizen science program that focuses on cooking and nutrition as a part of the overall program objectives and informational activities may have better enrollment and, if the participants are successful gardeners, increase fruit and vegetable consumption among populations with limited resources (Lu et al. 2021). Because this project only evaluated people participating in the program, there was no control group to compare the results. The attrition between the pretest and posttest limited the researchers' ability to identify why people did not complete the program or assess the effects of the potential response bias associated with the participants who did complete the posttest.

Conclusions

Participating in a citizen science program focused on home gardening was found to improve attitudes and beliefs about home gardening. According to TPB, these changes in beliefs and attitudes increased the likelihood that program participants will home garden in the future. In this study, the most significant increases were found in participants' normative beliefs—beliefs about how supportive other people are about home gardening. Future citizen science programs can leverage the impact of the program on normative beliefs by creating opportunities for program participants to interact more with each other and share information about the program with their friends and families. The more limited impact on self-efficacy and perceived behavioral control highlighted the importance of ensuring that programs address factors that will support participants' success in home gardening, particularly by providing information, tools, and resources that will make them perceive home gardening as easy to accomplish and believe that they would be able to overcome challenges associated with growing their plants.

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