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Technical Note

Development and Evaluation of a Web Application for Attracting Bees to Your Garden

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Abstract: An online application called BeeGardens was developed for users to quickly access over 85 bee-friendly plants that attract 12 primary bee groups and ways to incorporate these into different landscape designs. The functionality and usefulness of the app was evaluated by students enrolled in two courses: Florida Native Landscaping or Annual and Perennial Gardening, taught in different semesters. Before and after the semester, students were asked to report their perceived confidence to (1) identify bee-friendly plants, (2) identify bee pollinators, and (3) design a bee-friendly garden, using a Likert scale with responses ranging from 1 (strongly disagree) to 5 (strongly agree). Means of pre- and post-test self-reported responses showed a significant confidence gain upon using the BeeGardens online application in both courses. Students in Annual and Perennial Gardening and Florida Native Landscaping were 1.26 and 1.34 times, respectively, more confident in their ability to identify pollinator plants, identify bee pollinators, and design bee gardens after using the web application. These data were consistent with pre- and post-tested means where students were asked to identify three major pollinator plants and three major pollinators using multiple choice response options. Test scores increased by 26.3% and 37.9% in Annual and Perennial Gardening and Florida Native Landscaping, respectively. The majority of students (95.0%) agreed or strongly agreed this learning tool was organized, easy to navigate, and would use it in the future. Since its launch in 2021, BeeGardens has averaged 1201 unique visits per month, revealing its popularity and wide use.

Keywords: distance education; pollinator plants; ecologically friendly landscaping

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1. Introduction

Florida is home to over 300 species of native wild bees, some in critical decline [1]. While public interest in pollinator conservation and pollinator-friendly gardening has increased markedly, a survey conducted by Kalaman et al. [2] revealed a knowledge gap in consumers' ability to identify diverse bee pollinators and the plants that they are attracted to. Online distance education, utilized by 56% of the college student population in the U.S. in 2022 [3], may be an efficient means of educating both student and extension audiences about plants that attract diverse bee pollinators. As such, mobile applications have been shown to be an effective learning tool to help overcome learning gaps in higher education [4]. For example, learners using horticulture-based mobile applications can achieve a variety of goals like designing sustainable landscapes for butterflies [5], identifying plants by family [6], or reviewing important glossary terms in plant propagation [7]. As such, the development and use of a web application specific to bee-friendly gardening could help users identify bee-friendly plants, the bee pollinators they attract, and raise awareness of the critical role bees play in our landscapes.

The purpose of this project was to (1) build a novel mobile application to easily access pollinator plants that attract bees, (2) make this available universally as a no-cost resource for everyone, including instructors, students, extension educators, and master gardener volunteers, and (3) evaluate perceived confidence and tested content knowledge gain from using this teaching tool.

2. Materials and Methods

2.1. Design and Development

The BeeGardens web application was built using a shared library of code (.NET Framework, Microsoft Corp, Redmond, WA, USA) and a relational database management system (SQL Server, Microsoft Corp, Redmond, WA, USA). Once pilot tested, BeeGardens was given a designated domain name (https://ffl.ifas.ufl.edu/bees, accessed on 7 January 2024) and branded with a bee graphic icon. The main page (level 1) consists of five primary tabs ("home", "account", "tips", "resources", and "about") designed to be used on computers or mobile devices. The "home" level-2 tab was built to be used in two different ways. First, users can select the "browse all bees" tab from the main page's dropdown menu to learn more about over 39 native bee species assigned to 12 different major categories (Figure 1). Once a bee category is selected, representative bee images are provided with detailed information regarding their identification features, nesting habitat, behavior, and the plant species they are known to be attracted to. Likewise, users can select the "browse all plants" tab and learn about plant identification, cold hardiness, native status, optimal growing conditions, appearance (type, size, color, form, texture, phenology), and bee species they attract. Second, the bee gardens application can be used to design a bee garden. From the main menu, users can select the "design my bee garden" tab, name their design, enter their Florida zip code (or enter 00000 if unknown), and then choose their desired garden size, light requirements, soil moisture, and plant selection. By using the provided images and sample layouts, users can select which plants from each category (small, medium, and large trees, shrubs, vines, groundcovers, palms, perennials, annuals) they want to add to their design. Once complete, the "my plants" tab can be selected from the main menu and only the chosen plants will appear on a plant list that can be edited, printed, and saved for future use.

In addition to the level-1 "home" tab, the "account" tab was built for an easy way to create a free account. Next, the "tips" tab was built to provide a dropdown level-2 menu containing tips for garden design, selecting plants, buying plants, planting, and maintenance. For example, users can learn what flower types and colors most appeal to bees. The "resource" tab was built to provide links for additional references on pollinator plants, bee gardening, and bee conservation. Finally, the "about" tab was created to provide background information about devices the application can be viewed on, feature highlights, credits for different aspects of its development, and contact information. A tracking software (Google Analytics Inc., Mountain View, CA, USA) was used to monitor BeeGardens usage trends and its number of unique visits.

2.2. Survey Analysis

A pre- and post-test assessment instrument was developed within an online course-management platform that included three questions designed to assess self-reported confidence to (1) identify pollinator plants, (2) identify bee pollinators, and (3) design bee-friendly landscapes (Table 1). The survey then asked respondents to identify images of three different pollinator plants and three different bee pollinators using multiple choice options. The plant species included in this survey were selected based on their popularity and wide promotion for use in pollinator gardens. They included scarlet sage (*Salvia coccinea*), spotted bee balm (*Monarda punctata*), and black-eyed Susan (*Rudbeckia hirta*). The generalist bee species included in this survey were selected for their attraction to a wide range of species and included a European honey bee (*Apis mellifera*), a leafcutter bee (*Megachile texana*), and a sweat bee (*Agapostemon splendens*). Additional questions asked which device

was used to access BeeGardens, how well it was organized, ease of navigation, and how likely it was to be used in the future to access bee gardening information. The resultant questionnaire was administered to students participating in semester-long courses in ORH 4804/5206C Annual and Perennial Gardening (n = 11) and ORH 3815/5817C Florida Native Landscaping (n = 11) via a web course-management system. Both courses had a perquisite of junior standing and were electives. The majority of the students (73%) were majoring in plant science, with the remainder of the students majoring in allied fields such as landscape design, soil and water science, and entomology and nematology. Eighty-two percent of the students identified as female and eighteen percent as male. Items utilized a Likert-type scale, with responses ranging from 1 (strongly disagree) to 5 (strongly agree). Means of each self-reported and tested knowledge questions were calculated for pre- and post-test responses and significant changes for paired data were compared using the Wilcoxon signed rank sum non-parametric test implemented in SAS (version 9.4; SAS Institute, Cary, NC, USA) at $p \leq 0.05$.

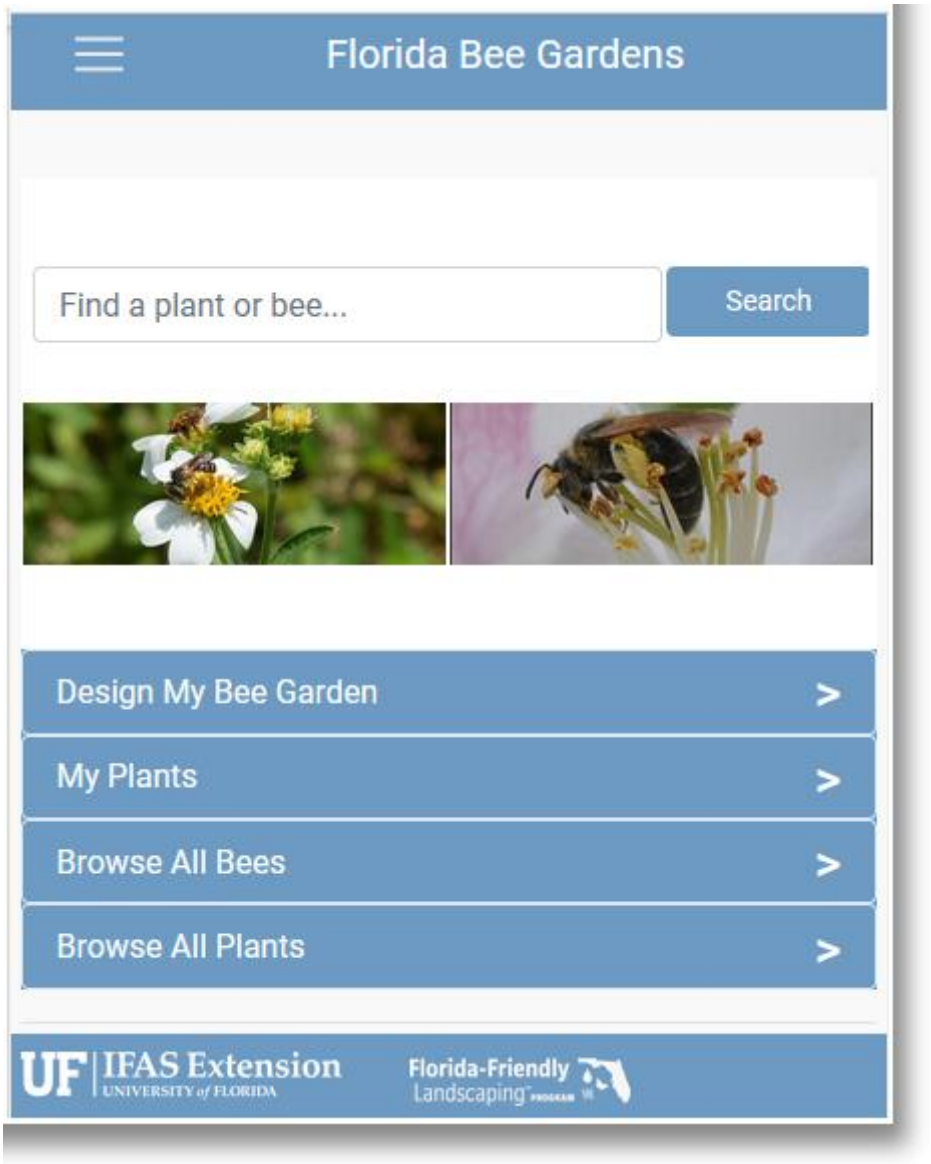

Figure 1. Screenshot of the front page of the bee gardens mobile application (https://ffl.ifas.ufl.edu/bees, accessed on 7 January 2024) built using .NET Framework and SQL Server (Microsoft Corp Redmond, WA, USA) [8]. Users can browse by plants or bees to learn more about them prior to designing their bee garden.

Table 1. Survey questions provided within a course-management system before and after students were assigned to use the bee gardens application. Scale was 1–5, where 1 = strongly agree, 2 = agree, 3 = undecided, 4 = disagree, and 5 = strongly disagree.

1.	I am confident in my ability to identify bee-friendly plants? (0–5 scale).
2.	I am confident in my ability to identify different bee pollinators? (0–5 scale).
3.	I am confident in my ability to design a bee-friendly garden? (0–5 scale).
4.	Name this pollinator friendly plant. (Image provided of scarlet sage). (Multiple choice).
5.	Name this pollinator friendly plant. (Image provided of spotted bee balm). (Multiple choice).
6.	Name this pollinator friendly plant. (Image provided of black-eyed Susan). (Multiple choice).
7.	Name this pollinator. (Image provided of a sweat bee). (Multiple choice).
8.	Name this pollinator. (Image provided of a leafcutter bee). (Multiple choice).
9.	Name this pollinator. (Image provided of a European honey bee). (Multiple choice).
10.	What device did you use to view the mobile bee app? (Check all that apply) (post- test only).
11.	Would you use the mobile bee app again in the future to quickly access bee friendly plants and different bee pollinators? (0–5 scale) (post-test only)

3. Results and Discussion

The results from students' pre- and post- assessments in both courses showed that students had increased confidence in knowledge after using the BeeGardens web application (Table 2). Overall, students in Annual and Perennial Gardening and Florida Native Landscaping were 1.26 and 1.34 times, respectively, more confident in their ability to identify pollinator plants, identify bee pollinators, and design bee gardens after using the web application. Prior to the Annual and Perennial Gardening course, on average students did not have confidence in their ability to identify bee-friendly plants (2.8 on a 1–5 scale), bee pollinators (2.6 on a 1–5 scale), or design a bee-friendly garden (2.6 on 1–5 scale), whereas students in Florida Native Landscaping course were initially neutral or had slight confidence in their ability to identify bee-friendly plants (3.6 on a 1–5 scale), bee pollinators (3.0 on a 1–5 scale), or design a bee-friendly garden (3.9 on 1–5 scale). Upon completing the assignments to use the web application in Annual and Perennial Gardening, students were 1.6, 1.6, and 1.8 times more confident in their ability to identify bee-friendly plants, bee pollinators, and design a bee garden, respectively. Likewise, students in Florida Native Landscaping were 1.4, 1.5, and 1.2, times more in their ability to identify bee-friendly plants, bee pollinators, and design a bee garden, respectively. This increase in knowledge gain when using a web application is consistent with the results of Wilson et al. [8] who reported a 50.0% perceived knowledge gain when plant propagation students used a mobile application for reviewing glossary terms. It is also consistent with the positive learning outcomes of other teaching tools employed in horticulture related classes [9]. For example, Craver and Williams [10] assessed students' learning from producing hydroponic crops for a 6-week module in a greenhouse operations management class. From pre and post surveys, they found experiential learning exercises to significantly increase both lower-level and higher-level learning. Likewise, Miller [11] used a software platform called Genially [12] to create dynamic visual content and interactive components related to geophytes for an online plant propagation exercise. Tools such as these, as well as adoption of virtual reality in education [13], have been shown to not only improve subject matter delivery, but to enhance the classroom experience through creativity, stimulation, interaction, and long-term knowledge gain [9].

Results from pre- and post- tested knowledge of plant and pollinator identification revealed a significant gain in students' mean scores (Table 3). Students had a 26.3% and 38.0% gain in correct responses after being assigned to use Bee Gardens during Annual and Perennial Gardening and Florida Native Landscaping courses, respectively.

Table 2. Students' self-reported pre- and post-test confidence means and difference ± standard error (SE) when using a web application [8] to learn plants that attract bees and different bee pollinators in two courses [Annual and Perennial Gardening (n = 11) and Florida Native Landscaping (n = 11)]. Confidence of knowledge items utilized a Likert scale with responses ranging from 1 (strongly disagree) to 5 (strongly agree) and changes in means were compared using a Wilcoxon signed rank test.

Self-Reported Knowledge Item and Course	Pre-Mean (1–5 Scale)	Post-Mean (1–5 Scale)	Difference ± SE	Significance $p \leq 0.05$
Annual and Perennial Gardening, Spring 2021				
1. Ability to identify bee-friendly plants	2.82	4.45	1.64 ± 0.31	0.004
2. Ability to identify bee pollinators	2.55	4.00	1.45 ± 0.37	0.010
3. Ability to design a bee-friendly garden	2.55	4.55	2.00 ± 0.38	0.002
Florida Native Landscaping, Spring 2022				
1. Ability to identify bee-friendly plants	3.55	4.82	1.27 ± 0.33	0.004
2. Ability to identify bee pollinators	3.00	4.36	1.36 ± 0.43	0.016
3. Ability to design a bee-friendly garden	3.91	4.82	0.91 ± 0.21	0.008

Table 3. Students' pre and post test scores when asked to identify actual images of pollinator-friendly plants and bee pollinators using multiple choice responses. Responses were recorded in two courses taught in different semesters: ORH 4804C [Annual and Perennial Gardening (n = 11) and ORH3815C [Florida Native Landscaping (n = 11)] that utilized a web application to assist in learning [8]. Changes in tested means were compared before and after each course independently using a Wilcoxon signed rank test at $p \leq 0.05$.

Course	Tested Subject Area	Pre-Course Correct Response (%)	Post-Course Correct Response (%)	Difference (%) ± SE	Significance $p \leq 0.05$
ORH 4804C	Plant identification	57.58	96.97		
	Pollinator identification	75.76	90.91		
	Plant/pollinator identification	66.67	93.40	26.30 ± 6.83	0.008
ORH 3815C	Plant identification	54.55	100		
	Pollinator identification	69.70	100		
	Plant/pollinator identification	62.12	100	37.88 ± 7.48	0.002

While the BeeGardens mobile application effectively improved both self-reported confidence and tested knowledge of pollinator plants and bee pollinators, there are some notable limitations of this study that should be considered. Namely, both classes had small sample sizes and thus limited demographic and statistical insight. Further, students' confidence and knowledge were likely influenced by other materials presented during the course, overestimating its impact on learning. A reviewer pointed out that open-ended survey questions or interviews should be conducted to gather deeper insights into students' experiences with the application in future studies. Finally, the authors believe worthwhile effort should be made towards evaluating the use of this application in an extension setting where instruction on how to use the application is followed by a hands-on outdoor garden activity to see its user friendliness and learning impact first-hand.

In closing, BeeGardens was found to be an effective tool for learning about Florida-friendly pollinator plants and the bees they attract. In addition to use by students, it offers a range of applications for diverse audiences such as (1) instructors who use it to supplement their plant identification and landscaping courses, (2) commercial nursery professionals eager to quickly reference diverse types of bee-friendly plants, and (3) extension educators seeking the most current information on plant nomenclature and pollinator gardening. Since its inception in March 2021, this online application has been accessed by over 22,673 unique users from across Florida and beyond. Plans are in place to for the Florida Friendly Landscaping program to update the plant list as needed. Questions or comments about the application are welcome and can be provided using the 'About' tab from the main home screen.

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Data Availability Statement: Data supporting reported results can be requested by contacting the corresponding author. The data are not publicly available due to compliance with data protection regulations.

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