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Evaluating a Community-Based Citizen Science Project: Attitude as a Key Mediator of Behavior Intention Toward Biodiversity Conservation

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Abstract: Community-based citizen science plays a vital role in biodiversity conservation by engaging the public in scientific research while fostering environmental awareness. This study evaluates a citizen science project conducted in the Taoyuan Algal Reef (TAR) region of Taiwan, focusing on participants' motivations, learning outcomes, and their relationship with behavioral intentions toward biodiversity conservation. Despite a small sample size, our findings provide valuable insights into the effectiveness of such initiatives. Learning and self-achievement emerged as the primary motivators for participation, with social interaction playing a secondary role. Using the structural equation model (SEM), we confirmed that attitude serves as a critical mediator between knowledge, sense of place, and behavioral intention. This supports the Knowledge-Attitude-Behavior (KAB) model, emphasizing that knowledge acquisition fosters attitudinal shifts that ultimately drive conservation behavior. Moreover, place-based learning was identified as a key component in strengthening participants' sense of place and ecological awareness. Our findings suggest that aligning citizen science initiatives with participants' motivations enhances engagement and long-term conservation efforts. Additionally, ongoing community monitoring not only contributes to scientific data collection but also empowers local communities in environmental decision-making. This study highlights the broader educational, social, and ecological benefits of community-based citizen science and underscores the need for systematic evaluations to optimize its impact.

Keywords: citizen science evaluation; motivation; learning outcome; algal reef; structural equation model; conservation behavior intention

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1. Introduction

To achieve nature-positive goals by 2030, understanding biodiversity baselines is essential. Citizen science has emerged as a valuable tool for scientific research, particularly in regions where data collection is challenging or costly. It has contributed to various fields, including ecology, conservation, astronomy, and public health [1]. Citizen science involves collaboration between the public and scientists in conducting research, monitoring environmental activities, collecting data, interpreting results, and disseminating new findings [2,3]. This data supports basic scientific research and management purposes [3–5].

Moreover, citizen science offers a learning environment for participants [6,7]. Numerous studies have demonstrated its positive impact on public engagement with the environment and science, enhancing environmental and scientific literacy [6,8–10]. It has also gained prominence as an environmental education approach in conservation biology [11]. Ultimately, its key contribution to biodiversity conservation lies in fostering behavior change [12,13].

Maintaining a citizen science project or community is challenging. Understanding participant motivation is crucial for effectively managing these projects [14,15]. Insights into participant motivation can also aid in recruiting new members, enhancing satisfaction, and encouraging continued involvement [16]. However, motivations vary depending on the type of citizen science project. For example, Hsu and Lin (2021) found that participants in a roadkill citizen science project were primarily motivated by learning and self-achievement [15]. Larson et al. (2020) reported that contributing to science and conservation was the main motivator for participants in the Audubon Christmas Bird Count, with this motivation strengthening as engagement increased [17]. Motivation is dynamic, evolving with participation levels and project alignment with personal interests [15,18]. Additionally, motivation is a key driver of learning and can influence learning outcomes [19,20].

Evaluating learning outcomes has become increasingly important for citizen science program managers to assess participant growth, project impact, and core values [21]. However, such evaluations are often scarce due to the need for resources, time, and expertise in social science research methods [22]. Learning outcomes in citizen science vary by project type but commonly include scientific knowledge, inquiry skills, sense of place, attitudes, interests, competencies, and pro-environmental behavior [23–27]. For biodiversity-focused citizen science, a critical learning outcome is influencing participants' behavior toward biodiversity conservation, aligning with long-term sustainability goals [28,29].

Human behavior change toward environmental sustainability is influenced by various factors. Initially, the Knowledge-Attitude-Behavior (KAB) model was widely used to predict behavior [30–32]. However, many studies highlight the limitations of linear behavioral predictions, emphasizing the complexity of human behavior [32,33]. Consequently, more comprehensive models have been developed to explain environmental behavior mechanisms, considering psychological factors such as beliefs, locus of control, norms, and behavioral intentions [34–37]. Nonetheless, Phillips et al. (2018) argued that causal relationships between these factors and behavior are underexplored in citizen science learning outcome research [22].

This study focuses on a community-based citizen science project in Taiwan to evaluate participant motivation and learning outcomes. Specifically, we aim to explore the following: (1) the primary motivations for participants in this citizen science project; (2) the main learning outcomes of participants; (3) the relationship between motivations and learning outcomes; and (4) the factors that directly or indirectly influence behavior intention.

2. Materials and Methods

2.1. Background

The citizen science community was established in the Taoyuan Algal Reef (TAR) area of Taiwan, home to the world's largest intertidal algal reef ecosystem [38]. The initiative emerged in response to the Taiwanese government's goal of achieving zero nuclear power generation by 2025, which involved plans to construct two liquefied natural gas (LNG) storage tanks and related infrastructure near TAR. This proposal sparked significant debate within Taiwanese society, with some advocating for sustainable development and others emphasizing environmental preservation. In 2021, a national referendum was held, but the proposal to halt the LNG project was rejected [39].

Before and after the referendum, diverse perspectives emerged from the public and nearby communities. Although these viewpoints were valuable, local residents recognized their limited knowledge of the algal reef and its surrounding environment. In response, the government identified the need to enhance local environmental awareness through scientific knowledge. To address this, they commissioned our research team to develop a community-based citizen science program in partnership with the local community, aiming to provide a comprehensive understanding of the TAR.

The development of the citizen science community followed the nine-step framework proposed by Bonney et al. (2009) [6]. This study focuses on the final step, "evaluation", to assess the program's effectiveness. The process of creation, negotiation, and collaboration involved in establishing this citizen science initiative is detailed in Table 1. People who participate in citizen science can be considered part of the citizen science community. Although the participants may change over time, approximately 20 to 30 people can be classified as members of our citizen science project.

Table 1. Development process of community empowerment for the citizen science project in the community surrounding the Taoyuan Algal Reefs.

Event Date/ Event Theme	Overview of Event Objectives	Summary of Results	Overview of Participants
2 May 2022 Communities' Leaders' Consensus Meeting	Leaders from neighboring communities near the algal reefs gather for visits and discussions on citizen science design to reach a consensus.	Only one community expressed willingness, but further development plans need to be determined.	Participants include leaders from different communities, key members of our team, and scientists (approximately 10 participants).
18 June 2022 Community Consensus Meeting	A consensus meeting was held to establish a citizen science project focused on algal reefs. The meeting aimed to discuss scientific issues and community needs further, and also included sharing experiences from successful citizen science projects in other locations.	The community expressed the belief that understanding coral reef ecology would greatly benefit the community and therefore expressed a desire to focus the investigation on algal reef ecology.	Participants included local leaders, residents, representatives from public agencies, members of the research team, and community leaders from other locations, totaling approximately 20 participants.
13 July 2022 Site Visit for Investigation Location	In response to the community's desire to focus the investigation on coral reef ecology, our team conducted a site visit in the buffer zone of the algal reef.	After careful consideration, we identified a suitable location near the Taoyuan City Animal Protection Education Park for the investigation.	The site visit involved local volunteers and members of the research team, with approximately 5 individuals participating.

Table 1. *Cont.*

Event Date/ Event Theme	Overview of Event Objectives	Summary of Results	Overview of Participants
30 July 2022 Pre-Survey Training	To ensure participants have foundational knowledge of algal reef ecosystems and related organisms before the field survey, and to maintain their enthusiasm for participation, this preparatory course was organized.	The session included sharing knowledge about algal reef ecosystems and organisms and explaining the operational procedures planned for August 14.	The training involved external lecturers, scientists from our team, and citizen science participants (approximately 20 participants in total).
14 August 2022 First Field Survey (Summer)	The first citizen science field survey was conducted, supplemented by a brief introduction to foundational knowledge of algal reef organisms, survey procedures, and a post-survey experience-sharing session.	The participation of diverse stakeholders allowed for a deeper understanding of algal reefs and a review of any shortcomings in the initial survey process.	The event included external lecturers, citizen science participants, and scientists from our team (approximately 20 participants in total).
29 October 2022 Second Field Survey (Autumn)	The second citizen science field survey was conducted.	The results from the first survey were presented to the participants, followed by the second round of field investigation.	Participants included citizen science volunteers, team members, and scientists (approximately 20 participants in total).
8 January 2023 Third Field Survey (Winter)	The third citizen science field survey was conducted.	The results of the second survey were presented to participants, followed by discussions on algal reef ecology and the third round of field investigation.	Participants included citizen science volunteers, team members, and scientists (approximately 30 participants in total).
12 March 2023 Fourth Field Survey (Spring)	The fourth citizen science field survey was conducted.	The results of the third survey were presented to participants, followed by the fourth round of field investigation and a summary of the annual project.	Participants included citizen science volunteers, team members, and scientists (approximately 20 participants in total).

2.2. Evaluation of Participants in Citizen Science

In this study, we employed a mixed-methods approach to investigate participants' motivations for participation and their learning outcomes. Quantitative research was utilized for its ability to measure, calculate, and analyze quantifiable aspects and their relationships, thereby providing a systematic understanding of the phenomena under investigation [40]. Conversely, qualitative research offered in-depth, detailed, and long-term insights through interactive engagement between the researcher and participants, leading to a more comprehensive interpretation of the complexity and richness of their experiences [40].

2.2.1. Quantitative Research

The questionnaire was developed based on existing citizen science research, utilizing the framework from Hsu and Lin (2021) [15] for the motivation dimension and Hsu and Lin

(2023) [41] for the learning outcome dimension. Notably, the sense of place subdimension within the learning outcomes was specifically designed for this study. The questionnaire comprised several main dimensions, including basic demographic information, motivation (self-achievement, learning, leisure, physical, and social), and learning outcomes (knowledge, attitude, behavior intention, and sense of place). All dimensions (except for demographic information) were measured using a Likert scale, with "strongly agree" = 5 and "strongly disagree" = 1 as the measurable values. Reliability tests for each dimension were conducted using Cronbach's alpha, as shown in Table 2.

Table 2. The dimensions and items of the questionnaire used in this study.

Main Dimensions	Subdimensions	Items	Cronbach's Alpha
Demographic Information		What is your gender? What is your actual age? What is your educational level? How many times have you participated in this survey?	N/A
Motivation	Self-achievement	I can contribute to ecological conservation. I can satisfy my interest in marine life.	0.61
	Learning	I can gain a better understanding of the scientific research process. I can get to know more marine creatures in algal reefs. I can learn more about the natural ecology of coastlines. I can acquire new scientific knowledge.	0.64
	Leisure	Because I don't have much going on usually, I participate to fill my time. Joining the surveys made me feel relaxed.	0.78
	Physical	I can receive souvenirs. I can receive reputations.	0.97
	Social	My family is very supportive of my participation in the surveys. Because my friends invited me to join together.	0.74
Total dimension of motivation			0.81
Learning outcomes	Knowledge	After participating in this project, I got to know many new species. After participating in this project, I learned more ecological knowledge. After participating in this project, I learned the methods of ecological investigation.	0.73
	Attitude	Participating in this project made me realize that Taiwan's natural ecology faces severe impacts. After participating in this project, I believe there is still a lot of effort to improve ecological conservation in Taiwan. After participating in this project, I believe that every natural environment holds its own significance.	0.73
	Conservation Behavior intention	By participating in this project, I will proactively care about issues related to natural ecology and conservation. If there are visitors illegally entering protected areas, I will take the initiative to advise them. I am willing to continue participating in investigations related to algal reefs.	0.61
	Sense of place	By participating in this project, I have become increasingly familiar with the natural environment of my hometown. After participating in this project, my determination to protect the environment of my hometown has increased. After participating in this project, I have grown to love the environment around the algal reefs.	0.76
Total dimension of learning outcomes			0.87
Total questionnaire			0.86

Participants were invited to complete the questionnaire through the project's social media community (Line group). The Line group consisted of 39 members, excluding our research team and documentary filming crew, with an estimated 30 active participants as of 20 May 2023. A total of 18 valid questionnaires were collected, representing 60% of the estimated participant population. Since we did not require everyone to complete the questionnaire, we respected their choice to participate in the survey voluntarily. The demographic information is presented in Table 3.

Table 3. Demographic information of participants, presented as frequencies and percentages.

Attribute	Items	*n*	%
Age	≤30	6	5.6
	31–40	1	0.9
	41–50	3	2.8
	51–60	3	2.8
	≥61	5	4.6
Gender	Female	11	10.2
	Male	7	6.5
Occupation	Student	3	2.8
	Freelance	6	5.6
	Retired	3	2.8
	Service industry	3	2.8
	Public sector employee and related to the environment	3	2.8
Education	High school	3	2.8
	Bachelor's	10	9.3
	Master's/Doctor	5	4.6
Join Times	≤2	8	7.4
	3	7	6.5
	4	3	2.8

To explore differences in motivations and learning outcomes, the Kruskal–Wallis rank sum test and Dunn's post hoc test were employed, as the data did not follow a normal distribution ($p < 0.05$, Shapiro–Wilk normality test). Given the community-based nature of this citizen science project and the consequently small participant population, the sample size for the questionnaire survey was expected to be low. Therefore, a significance level of $p < 0.1$ was adopted for this study.

Kendall's rank correlation was conducted for each subdimension to examine the relationships between motivations and learning outcomes. Due to the limited sample size, a significance level of $p < 0.1$ was also applied for these analyses.

Partial Least Squares Structural Equation Modeling (PLS-SEM) was applied using the plspm package in R 4.4.3 [42] to examine the relationships among latent variables related to learning outcomes and their influence on behavioral intention. Four latent variables were defined: Knowledge, Attitude, Sense of Place, and Behavioral Intention, with the corresponding items listed in Table 2. Due to the limited sample size, bootstrapping with 5000 resamples was conducted to evaluate the significance of the path coefficients, thereby enhancing the robustness of the model's parameter estimates. The analysis was performed with a maximum of 5000 iterations and a convergence tolerance of 1×10^{-5}.

This approach allowed for the exploration of complex relationships among the latent constructs, providing insights into the underlying mechanisms influencing learning outcome dynamics. A path matrix was developed to specify the hypothesized relationships among the latent variables, assuming a lower triangular structure with the following hypotheses (Figure 1):

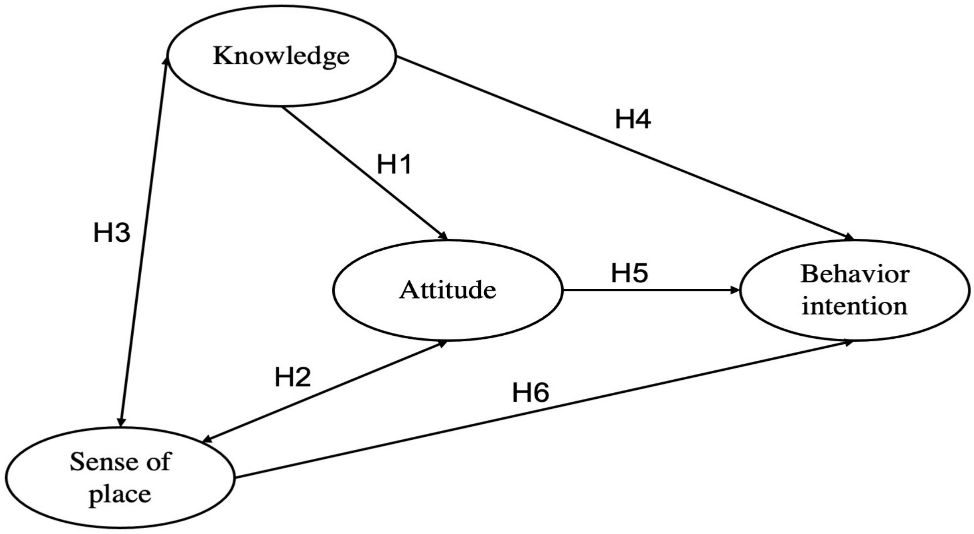

Figure 1. The structural equation model and the path hypotheses of this study.

H1: *Knowledge directly influences Attitude.*

H2: *Attitude and Sense of Place are bidirectionally or directly related.*

H3: *Sense of Place and Knowledge are bidirectionally or directly related.*

H4: *Knowledge directly influences Behavioral Intention.*

H5: *Attitude directly influences Behavioral Intention.*

H6: *Sense of Place directly influences Behavioral Intention.*

Reflective measurement models were specified for all constructs, with observed variables serving as manifest indicators for their respective latent variables. The inner model path coefficients and outer model weights (loadings) of latent variables on observed variables were estimated. Model fit and predictive accuracy were evaluated using the Goodness-of-Fit (GoF) index, with the following interpretation: GoF ≥ 0.36 indicates high goodness of fit, GoF ≥ 0.25 indicates medium fit, and GoF ≥ 0.10 indicates low fit [43].

2.2.2. Qualitative Approach: Semi-Structured Interview

After completing the surveys for all four seasons, we conducted semi-structured interviews with the participants. A total of 10 individuals (33.3% of participants) took part in the interviews. Their demographic information is presented in Table 4. The primary purpose of these interviews was to explore participants' motivations for participation and their learning outcomes. Additionally, the insights gathered will guide future adjustments to the project, ensuring its sustainable operation.

Table 4. Demographic information of interviewees from semi-structured interviews.

Subject Code	Age	Educational Background	Current Occupation
L-1	60–65	Graduated High School	Retired, part-time tour guide and farmer; Core Member of the Community Development Association
L-2	25–30	Bachelor's degree	Employee at the Community Development Association
F-1	60–65	Bachelor's degree	Substitute Teacher at an Elementary School
F-2	40–45	Bachelor's degree	Substitute Teacher at an Elementary School
F-3	40–45	Master's degree	University Assistant, High School Teacher
F-4	65–70	Bachelor's degree	Retired, Former Real Estate Agent
F-5	60–65	Bachelor's degree	Accountant
S-1	20–25	High School Graduated	Undergraduate student
S-2	20–25	High School Graduated	Undergraduate student
S-3	20–25	High School Graduated	Undergraduate student

Although the semi-structured interviews followed a general outline, the researchers probed deeper when interviewees provided meaningful insights related to the research theme. The interview outline for this study included the following topics:

1. Personal Information Collection
    a. Could you please provide your full name?
    b. Which age range do you fall into?
    c. What is your educational background?
    d. What is your current occupation?
2. Motivation for Participation
    a. How did you first learn about this project?
    b. What initially motivated you to participate?
3. Learning Outcomes
    a. What did you learn the most from participating in this project? Why?

For qualitative analysis, we employed an open coding approach, known for its flexibility in describing data compared to structured methods. This was followed by axial coding to organize the data into categories related to motivation and learning outcomes. Furthermore, we enhanced the quantitative findings by including detailed insights into participants' motivations and learning outcomes throughout the project.

3. Results

3.1. Motivation

3.1.1. Quantitative Analysis of Motivation

The results indicated a significant difference in participants' motivations ($p < 0.001$, Kruskal–Wallis test). Self-achievement and learning emerged as the strongest motivations (Figure 2), followed by social motivation, leisure, and finally physical motivation as the lowest (Figure 2). The p-values for the pairwise comparisons between these dimensions, obtained from Dunn's test, are presented in Table 5.

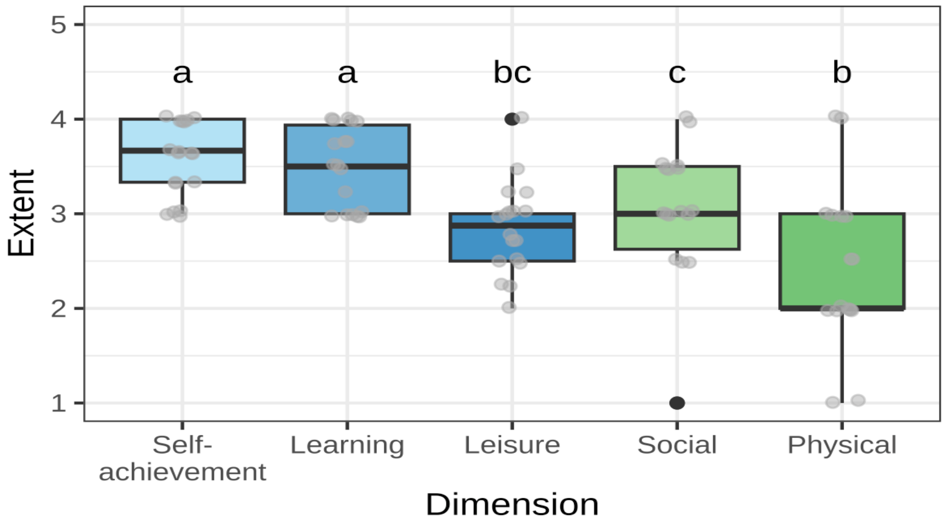

Figure 2. Differences in motivation across dimensions. Different letters indicate significant differences.

Table 5. Post hoc comparison results between dimensions using Dunn's test (* < 0.05; ** < 0.01; *** < 0.001).

Dimension	Dimension	*p*-Value
Self-achievement	Learning	0.35
Self-achievement	Leisure	<0.001 ***
Self-achievement	Social	0.006 **
Self-achievement	Physical	<0.001 ***
Learning	Leisure	<0.001 ***
Learning	Social	0.02 *
Learning	Physical	<0.001 ***
Leisure	Social	0.16
Leisure	Physical	0.12
Social	Physical	0.014 *

3.1.2. Qualitative Analysis of Motivation

The results of the qualitative analysis on motivations for participation revealed four main categories: 'Learning', 'Self-achievement', 'Social mission', and 'Social motivation' (Table 6).

Among these, "Learning" and "Self-achievement" were the most prevalent, with nine participants (75%) citing each of these motivations and eight participants (66.6%) mentioning both. This was followed by "Social mission", cited by five participants (41.6%). These findings align with the results from the quantitative analysis.

The "Social mission" category was not explicitly classified in the quantitative result. However, during the interviews, several participants expressed concerns about the environment and a desire to "do something" for the community or the environment. Therefore, this category was specifically highlighted. These participants were motivated not only by personal learning but also by a purpose beyond themselves—they wanted to contribute to improving the environment and society.

Table 6. Qualitative analysis of participants' motivations for participation.

Interviewee	Motivation	Description
L-1	Learning, Self-achievement, Social Mission	1. Wanted to learn survey methods to address the lack of ecological data in the community: "To promote environmental education or conduct ecological surveys, we need supporting data. . . When engaging in community building and ecological surveys, without systematic learning, we can't achieve meaningful results. We need someone to guide us a few times until we master it ourselves for long-term sustainability". 2. Aimed to use collected data to create new educational programs: "After gathering species data, we can develop new courses or explore historical knowledge by consulting elders about local names, which can inspire future project proposals".
L-2	Learning	Primarily motivated by work, with an element of curiosity: "Mainly for work. But participation in evening surveys wasn't mandatory for me, so part of it was also due to curiosity, as there are few opportunities to join nighttime activities".
F-1	Learning, Self-achievement, Social Mission	Loves the ocean, cares about the environment, and wants to enrich personal knowledge: "Initially, I had no connection to ecology, but I later realized how beautiful Taiwan's oceans are, which sparked my interest. . . I learned about marine ecology through The Society of Wilderness and started documenting intertidal zones, so I decided to participate in this citizen science project".
F-2	Learning, Self-achievement, Social Mission	Wants to contribute to marine conservation and enrich personal knowledge: "As a guide, giving incorrect information misleads others, especially about marine life, which I'm least familiar with. I was eagerly waiting for this type of course. . . I want to contribute to marine conservation and participate in future surveys".
F-3	Self-achievement, Social Network	Previously helped the community design educational materials and wanted to learn scientific survey methods this time: "I helped Yongxing Community design the 'Millennium Love of Algal Reefs' educational plan, which is still in use. Now, seeing this professional survey, I wanted to join and learn the scientific approach while connecting with others in the group".
F-4	Learning, Leisure, Self-achievement, Social Mission	Enjoys nature, cares about environmental issues, and wants to enrich personal knowledge: "It's fun to explore the ocean—I love nature. I didn't know what algal reefs were before. . . As a guide, it's essential to keep learning to provide accurate information. The more knowledge, the better".
F-5	Learning, Self-achievement	Wants to understand the local environment and enrich personal knowledge: "As a guide, I need to know what's here and the general environment. . . I've always been curious about the ecosystems in the core, buffer, and sustainable use zones".

Table 6. *Cont.*

Interviewee	Motivation	Description
S-1	Learning, Self-achievement	Simply interested in learning more about the environment.
S-2	Learning, Self-achievement	Interested in environmental education and wants to understand citizen science: "I wanted to see the process of citizen science from scratch, which is why I committed to participating fully".
S-3	Learning, Self-achievement, Social Mission	Interested in learning about citizen science and enriching personal knowledge: "I took a geography course that discussed the algal reef issue, which made me curious. . . I've been interested in citizen science and the topic of algal reefs, so I joined this project. I might pursue work related to citizen science in the future, as environmental education ultimately aims to foster environmental citizenship".

3.2. Learning Outcome

3.2.1. Quantitative Analysis of Learning Outcomes

The quantitative analysis revealed no significant differences among the dimensions of learning outcomes ($p = 0.81$, Kruskal–Wallis test) (Figure 3). Although no single dimension stood out as the highest, the median values for all dimensions were above 3, indicating that most participants perceived positive learning outcomes across all dimensions through their involvement in this citizen science project (Figure 3).

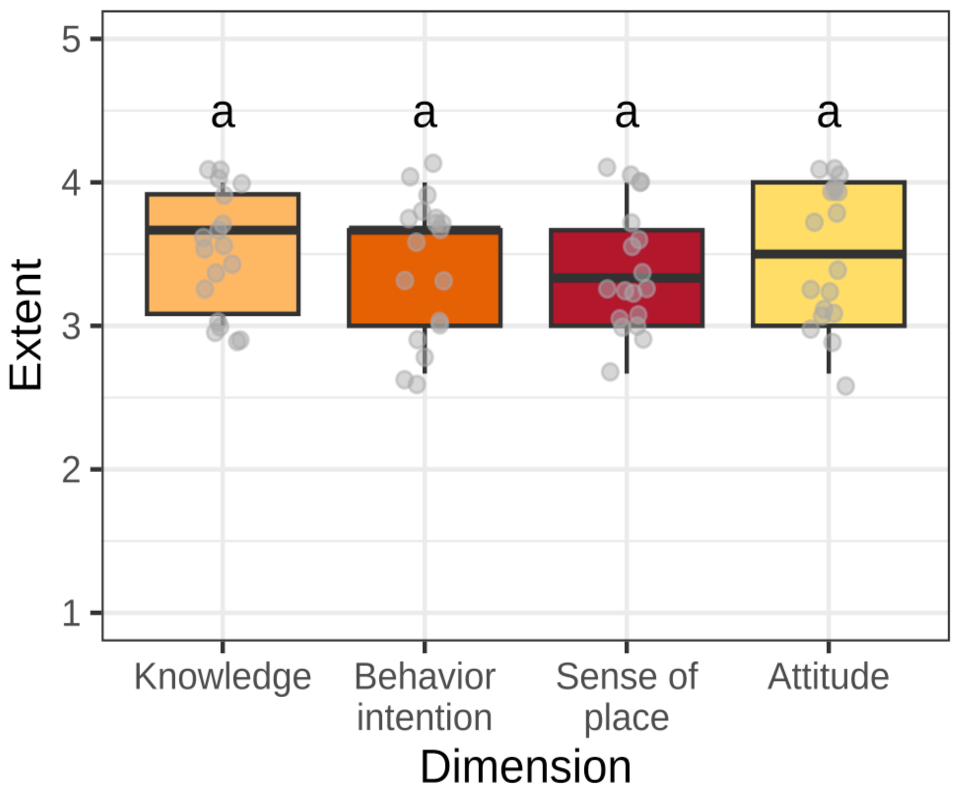

Figure 3. Differences in learning outcomes across dimensions. Different letters indicate significant differences.

3.2.2. Qualitative Analysis of Learning Outcomes

The quantitative questionnaire analysis revealed significant learning outcomes in the dimensions of "Knowledge", "Attitude", "Behavioral intention", and "Sense of place". From the qualitative interviews, the learning outcomes in the "Knowledge" dimension were particularly prominent.

Participants primarily acquired "Biological Knowledge" and "Survey Methods", with eight participants (66.6%) gaining biological knowledge and seven participants (58%) learning survey methods. Notably, six participants (50%) reported learning both. Additionally, "Scientific Perspectives" and "Project Design" were mentioned by two participants (16.6%) each.

Regarding "Survey Methods," participants' learning experiences could be categorized into two aspects: (1) the operation of the "Survey Process" and (2) "Sampling Methods." Some participants were particularly impressed by the quadrat sampling technique (Table 7).

Table 7. Qualitative analysis of participants' learning outcomes.

Interviewee	Motivation	Description
L-1	Survey Methods, Biological Knowledge	Using citizen science to learn about things, how to conduct surveys, and how to generate data. Placing the sampling points and generating big data is valuable. Also, I got to learn about many species. Identifying species using field guides and accumulating a database was the greatest gain.
L-2	Survey Methods, Biological Knowledge	(I learned about) the process of citizen science. I had heard of the term before but didn't understand the details until Professor Chen's explanation. During the field survey, Brother Luen-ji shared species identification tips. Also, the session on crabs was quite informative. Learning about how other communities conduct surveys and the challenges they face was also relatable to our community.
F-1	Survey Methods	(I learned) survey methods! I'm someone who learns from diverse sources. Some methods in this project were new to me, and the teaching style was different from what I've experienced in other environmental education programs. I can integrate these methods into my teaching.
F-2	Scientific Perspectives,	I learned the most from Professor Chen. His words were very philosophical. I loved his teaching style and his presence. I'm grateful for this project. It was very meaningful since many ecology courses require formal training, but here we had access to experts like Professor Chen.
F-3	Biological Knowledge, Scientific Perspectives	I learned about algal reef species, but I need to verify the accuracy. I also learned how to conduct surveys using simple methods. The lectures on coastal changes and Professor Chen's viewpoints, as well as feedback from peers, were also insightful.
F-4	Biological Knowledge	There's so much to learn. I didn't know much about crabs before. I've learned about environmental and political issues through three years of training, but biological knowledge is limitless.

Table 7. *Cont.*

Interviewee	Motivation	Description
F-5	Survey Methods	I learned from professional instructors and gained expert knowledge. Previously, I would just take photos without collecting data. There was no guidance. Now, I understand systematic data collection.
S-1	Biological Knowledge	(I learned the most about) species found in the algal reefs.
S-2	Project Design, Biological Knowledge, Survey Methods	I learned how to identify key points when designing educational materials. The project taught me that it's important to focus on visible species that the public can easily observe. I also learned about species and survey methods. This was my first time conducting a coastal survey.
S-3	Project Design, Biological Knowledge	It's really challenging to maintain a project, especially when it involves the whole community. It was impressive to see how the survey methods and schedule were designed to be accessible to the public. I learned a lot about project design and got to know many species that I wouldn't normally encounter.

As for "Scientific perspectives" and "Project design", these outcomes went beyond the initially anticipated learning objectives of the project, reflecting more personal growth for the participants. In terms of "Scientific Perspectives", some participants were inspired by one researcher's view on the unity of humans and nature, which gave them new insights and feelings about the natural environment (F-2, F-3). For "Project Design", two student participants (S-2, S-3), who are interested in environmental fields and engaged in environmental education, observed and learned about project design methods through their involvement in the study (Table 7).

3.3. Relationship Between Motivation and Learning Outcome Dimensions

According to the results of Kendall's rank correlation analysis, out of 20 correlations (5 dimensions of motivation × 4 dimensions of learning outcomes), only 3 showed significant positive associations: learning with sense of place ($p = 0.06 < 0.1$), leisure with behavioral intention ($p < 0.05$), and social motivation with behavioral intention ($p = 0.08 < 0.1$) (Figure 4).

3.4. Structural Equation Model Revealing Influential Factors for Behavioral Intention

The result revealed that our model's goodness of fit is 0.5, which indicates high goodness of fit ($\geq$0.36). In the path, knowledge and sense of place significantly influenced attitude. For the behavior intention, only attitude significantly influenced behavior intention, indicating attitude was the crucial mediator between knowledge, sense of place, and behavior intention toward conservation (Figure 5).

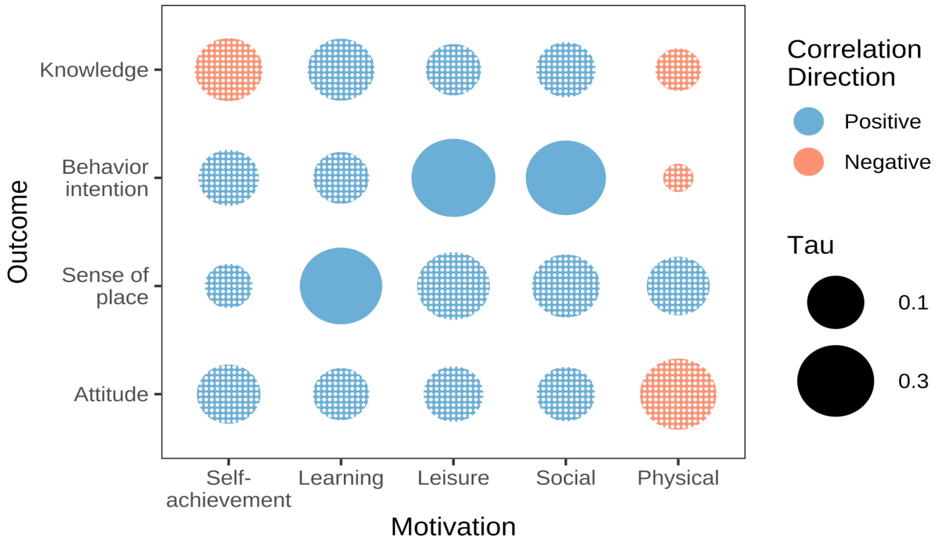

Figure 4. Kendall's rank correlation analysis between motivation and learning outcome dimensions. Solid circles indicate significant correlations, with blue representing positive and orange representing negative associations. The size of the circles reflects the relative correlation coefficients (Tau). The circles with white bullets indicate that there is no significant relationship between the variables.

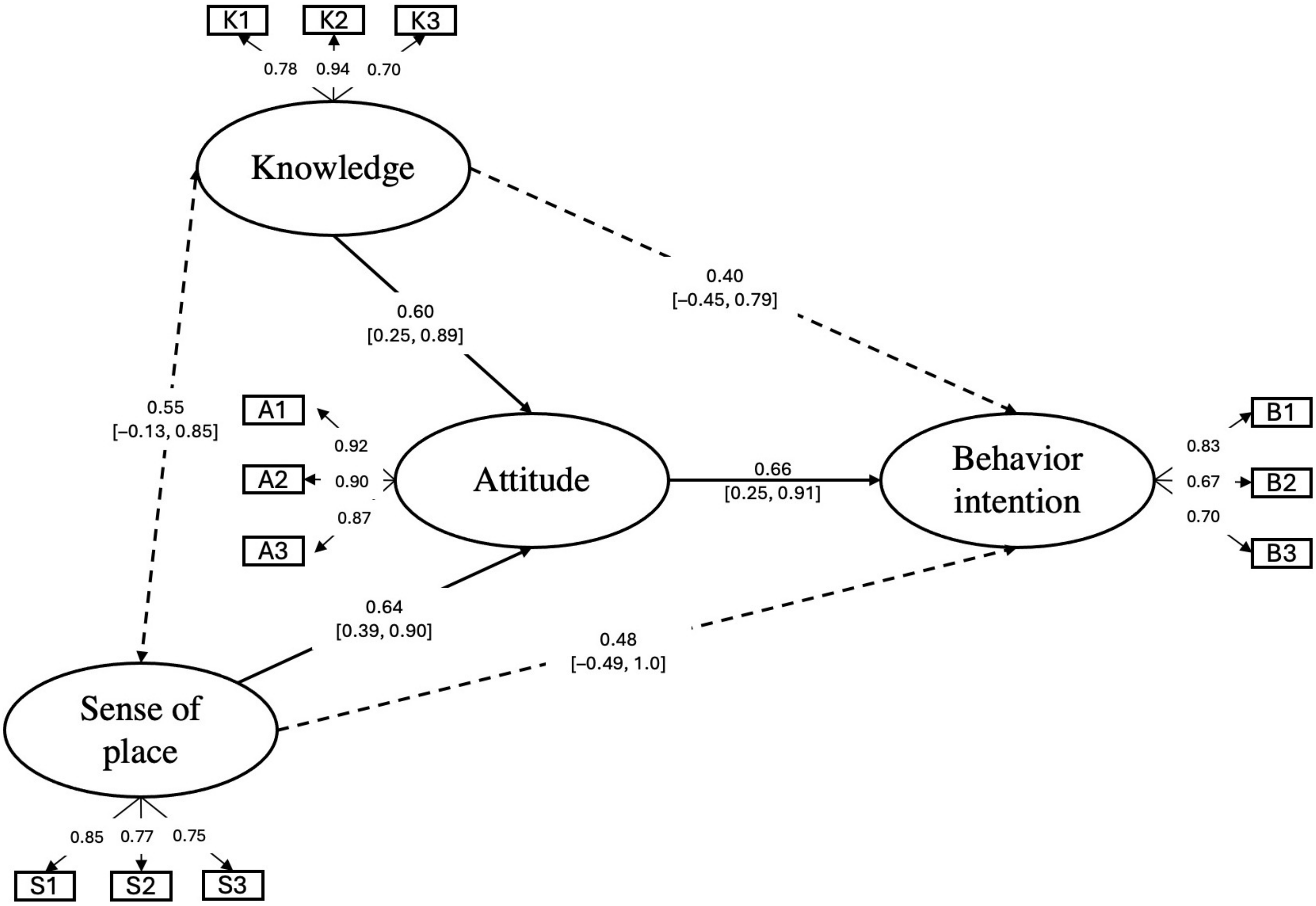

Figure 5. Structural equation model for behavioral intention developed in this study. The number on each path represents the path coefficient, while the value in brackets indicates the 2.5th and 97.5th percentiles of the confidence interval. If the interval includes 0, the path is not significant. Solid arrows denote significant paths, whereas dashed arrows indicate non-significant paths.

4. Discussion

Our research evaluated a community-based citizen science project in the Taoyuan Algal Reef (TAR) region of Taiwan. Although the sample size was relatively small, it provided valuable insights into biodiversity conservation. Therefore, we encourage all small citizen science communities to conduct evaluations to ensure alignment with project goals and to provide feedback for management [21]. This study specifically focused on evaluating participants' experiences, while evaluations of the generated data and its ecological significance have also been completed and are currently under journal review. MacPhail and Colla (2020) identified delays in disseminating outcomes as a major barrier to citizen science development [44]. Given that our participants recently completed a two-year continuous survey, we believe our evaluation is timely and relevant for publication.

Motivation plays a crucial role in retaining participants' engagement in citizen science initiatives for biodiversity conservation [16,45]. Regarding participation motivation, most participants cited self-achievement and learning as their primary reasons for joining the project. Learning appears to be a particularly strong motivator for participation in citizen science projects. For instance, Domroese and Johnson (2017) found that the primary motivation for participants in the Great Pollinator Project was their interest in learning about bees, followed by their desire to contribute to science [46]. Similarly, Hsu and Lin (2021) reported that participants in a roadkill citizen science project joined primarily to learn how to identify animals and understand the mechanisms for preventing roadkill [15].

In this study, we define self-achievement as the desire to contribute to nature and fulfill personal interests. This dimension was also a strong motivator for participation in some citizen science projects, particularly those related to scientific curiosity or conservation efforts [47]. Although social interaction was not as important as learning and self-achievement in our study, it still received a score above 3 on the rating scale, indicating that participants generally acknowledged its significance. This finding aligns with results from an avian citizen science project in South Africa, where social interaction was also found to be an important motivator [14]. In contrast, motivations related to leisure (recreation) and tangible rewards (such as gaining reputation or receiving gifts) were not as prominent in this project, though they have been identified as key motivators in other studies [48,49].

Participation in citizen science projects can be considered a form of informal education [50]. Regarding learning outcomes, our study did not find significant statistical differences among dimensions. However, all dimensions received a median score above 3, indicating that participants generally perceived gains in knowledge across multiple aspects. Qualitative analysis further revealed that understanding scientific processes and species identification were particularly important learning outcomes (Table 7). This is consistent with findings from Perry et al. (2021) [51] and Peter et al. (2021) [52], who reported that species identification knowledge and skills were major learning outcomes for participants in biological citizen science projects. Although our quantitative analysis did not show significant differences among learning dimensions, the qualitative data suggest that knowledge gain was a predominant outcome. We attribute this to the fact that dimensions such as attitude and sense of place are more abstract and therefore less frequently mentioned by interviewees.

In terms of the correlation between motivations and learning outcomes, three significant relationships emerged. A strong motivation for learning was associated with a higher sense of place, suggesting that individuals who were eager to learn also sought a deeper understanding of their local environment. Our project can be regarded as an example of place-based learning, which involves not only acquiring locally relevant knowledge and skills but also deepening one's connection to a place [53]. Another correlation was observed between leisure motivation and behavioral intention; we suggest that participants' relaxed and stable emotional states while engaging in the project facilitated pro-environmental behavior change [54]. Additionally, high motivation for social interaction was correlated with strong behavioral intentions, which can be linked to subjective norms—the idea that peer influence exerts social pressure, encouraging behavior change [36]. While correlation does not imply causation, these relationships suggest interdependencies rather than mutual exclusivity [55,56].

One of our key findings is that structural equation modeling (SEM) confirmed that attitude serves as a mediator between knowledge, sense of place, and behavioral intention toward biodiversity conservation (Figure 5). Our results support the classic Knowledge-Attitude-Behavior (KAB) model, which posits that knowledge influences attitudes, which in turn shapes behavior [32]. However, we found that sense of place did not directly influence behavioral intention; instead, attitude mediated this relationship (Figure 5). Similarly, Lo et al. (2019) found that satisfaction mediated the relationship between sense of place and pro-environmental behavior, with satisfaction functioning as an attitudinal factor, aligning with our findings [57]. Based on our results, we conclude that attitude change is the most critical factor in fostering behavioral change.

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