

Article

Taiwan Roadkill Observation Network: An Example of a Community of Practice Contributing to Taiwanese Environmental Literacy for Sustainability

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Abstract: Citizen science has become a major source of scientific research in recent years. Many studies have concluded that citizen science projects not only contribute to the sciences but also considerably improve the scientific and environmental literacy of participating volunteers (citizen scientists). A dynamic citizen science project can accomplish goals that benefit society but it is difficult to establish, operate, and maintain a citizen science project. This paper reports a case study and examined the most famous citizen science project in Taiwan, the Taiwan Roadkill Observation Network (TaiRON), with the viewpoint of a community of practice learning theory. Community of practice theory is widely used in education and business management research and is an important framework for knowledge exchange and dissemination. Through content analysis, observation, and interviews with the moderator of the TaiRON project, this study explored how its internal operations reflected the principles of community of practice theory. The results indicated that TaiRON members developed a set of shared working methods and jointly completed certain actions. All participating members possessed in-depth knowledge or enthusiasm with respect to their specific focus areas, enabling them to meaningfully contribute to work on specific topics. The three major elements of a community of practice—domain, community, and practice—should be aligned with the community’s purpose and action. We discovered that the TaiRON citizen science project was consistent with the elements of the theory of community of practice. In particular, the establishment of TaiRON was enabled by scientific and technological advances; therefore, this paper discusses the characteristics of virtual communities of practice. Moreover, TaiRON contributed to raising the public’s environmental literacy. This paper reports pilot research concerning citizen science operations and may stimulate related future research.

Keywords: citizen science; communities of practice; environmental literacy; citizen scientist; Taiwan Roadkill Observation Network

1. Introduction

Citizen science projects are one of the major recent trends in scientific research. By harnessing the power of the public to perform large-scale collection of scientific data, citizen science presents an effective approach to investigate, monitor, and conserve Ecology; examples include the monitoring and removal of non-native species, conducting urban bird surveys, studying coral reef fish, and astrology [1–4]. Taiwan is home to many citizen science projects, such as Breeding Bird Survey

Taiwan, Taiwan Amphibian Conservation, Airboxes, Terrestrial Snails in Taiwan, and Taiwan Roadkill Observation Network (TaiRON).

In addition to contributing to scientific research, citizen science is a means to promote science and environmental education [5–7]. Scientists and participants communicate and engage in field research when working on a project together, which raises the scientific knowledge and science or environmental literacy of the participants—citizen science projects present an attractive means for scientists to connect with the public.

This paper examines TaiRON as a citizen science case study. The TaiRON project maintains a simple record of roadkill incidents, which entails photographing and uploading pictures and geographic locations of the roadkill to an internet database. It derives its scientific value from the extensive collection of records it comprises. Since its founding on 8 August 2011, TaiRON's membership has grown to roughly 15,000 members. Its original ecological data collecting mission has expanded to encompassing conservation activities that have achieved major success. TaiRON thus exemplifies a successful citizen science project. For example, in 2013, a rabies case was discovered in Taiwan—the first since 1961—and it caused considerable panic among the public. However, after examination of Formosan ferret-badger (*Melogale moschata*) specimens collected by TaiRON over the years, it was discovered that rabies had persisted in Taiwan in that species for years. The discovery of this vector of a potential rabies epidemic prompted the government to give more attention to interspecies disease transmission between humans and animals and to adopt certain policies in response. The vital role played by TaiRON in monitoring for rabies to thwart an epidemic opened the eyes of major domestic and foreign experts in epidemic prevention to the power and the value of the TaiRON citizen scientists.

Another case was in 2014, some citizen scientists discovered birds that died from unknown causes near an agricultural area. In the following year, TaiRON cooperated with National Pingtung University of Science and Technology and engaged citizen scientists to collect bird carcass. The volunteers collected 250 bird corpses for laboratory tests, which confirmed that the bird deaths were attributable to the pesticides used on crops. This prompted the Taiwanese government to restrict pesticides, and the Bill of Pesticide Management amendment, establishing a pesticide control system, was passed after the third reading in the Legislative Council. It included a one-year buffer period that expired on 26 December 2016. Since then, the 3500-odd pesticide stores across Taiwan have had their products regulated under the law.

How TaiRON community operated is also interesting. The member started with 12 people in 2011 and increased to 14,873 recently (Figure 1). Thus, in our article, we try to discuss with a theory “community of practice”. The theory of community of practice is discussed to a participation process that is committed to a common area and formed by a group of learners is the core concept of community of practice theory [8–10]. We hoped to know if participants of TaiRON follow the core elements of community of practice, or how the new comers turned into the core members. We will review the community of practice in detail in next section.

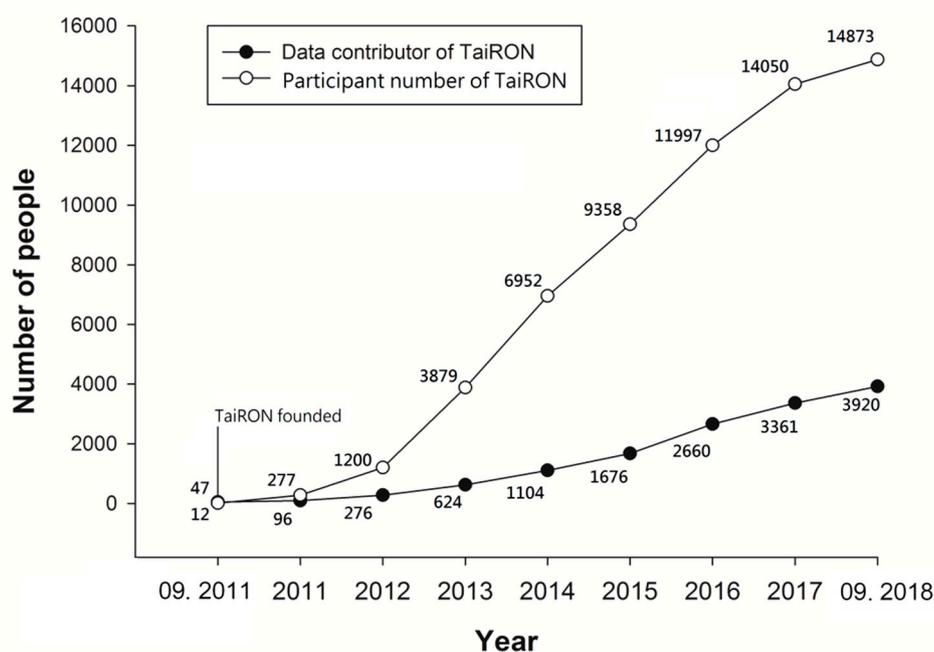


Figure 1. The evolution of the number of participants in time.

TaiRON's contributions to Taiwan's environment and society are exemplified by the two cases detailed in the preceding paragraphs. Having demonstrated the organization's value, this paper next addresses two questions:

- (1) Whether TaiRON's operational model is essentially consistent with the theory of community of practice, and
- (2) Whether, and to what extent, TaiRON has contributed to the dissemination of environmental knowledge among its volunteers and the general public.

These questions will be discussed in the following paragraph.

2. Literature Review

2.1. Citizen Science

Definitions of citizen science vary slightly by region. In America, citizen science is mainly led by scientists and uses the power of volunteers to conduct large-scale standardized data collection [5]. In Europe, citizen science has a more humanistic hue and typically concerns social science research, which is undertaken to raise public awareness and knowledge, adopting a philosophy of science approach to engage citizens in discussion and policy formulation [11]. Restated, one could say that citizen science in America is typically science-oriented and involves data collection, analysis, and cooperation with scientists whereas the typical European model views citizen science as a powerful and engaged community for policy work. Judging from the collected projects featured on the "Introduction to Citizen Science" website, the citizen science programs in Taiwan tends more toward to the American view of citizen science; however, some community-based discussion groups and groups that seek to reconstruct the traditional knowledge of indigenous tribes are also referred to as citizen science in Taiwan. The present author contends that the most fruitful approach entails a combination of these approaches. From an educator's perspective, Krueger and Shannon (2000) define citizen science as a process that enables a wide range of people to participate in scientific research [12].

Because scientific research might be wide-ranging and large in scale, citizen science has become one of the most vital paths for undertaking scientific research. It also offers participants the opportunity for self-improvement and for contributing to society [13]. Citizen science generates benefits for

individuals and society. Citizen scientists can monitor ecological phenomenon [14,15] and contribute to the removal of alien species [1,16], which benefits society. Participating in citizen science can increase the critical-thinking skills of volunteers [17] and enhance their social capacity [13], which are personal benefits. Because participants forge close connections with scientists during onsite investigations and project implementation, a volunteer's participation in the process of project planning can enhance their scientific knowledge as well as scientific and environmental literacy [5,18–20]. Participants are also empowered to influence policy [13,21]. The benefits of citizen science can be classified into four categories (Table 1): benefits to the scientific community, benefits to volunteers, benefits to the education community, and benefits to society.

Table 1. Four Levels of Effects from Citizen Science (adapted from Raddick et al., 2009) [13].

Beneficiary	Benefits
Scientific Community	<ol style="list-style-type: none"> 1. Quick collection of extensive data 2. Having an extensive body of data increases the likelihood of having collected particularly germane information 3. Quick and accurate analysis of extensive data 4. Simulation parameters can be explored quickly 5. Occasional novel discoveries
Volunteers	<ol style="list-style-type: none"> 1. Have fun 2. Connect with the society and community 3. Participate in real science
Education Community	<ol style="list-style-type: none"> 1. Communication with scientists 2. Acquire more scientific knowledge 3. Experience scientific practice 4. Opportunity to change a scientific attitude
Society	<ol style="list-style-type: none"> 1. Strengthens the relationship between scientists and the public 2. Improves scientific cognition of the general public

The learning process and outcome of participation in citizen science and how knowledge is constructed and acquired from such participation has been less well studied [17]. Nevertheless, the prominent roles of science and technology in society, increasing scientific literacy among the general public, and heightened environmental awareness have caused increasing numbers of people to care about the environment and recognize how Ecology influences their lives. The internet has also facilitated friendship formation among individuals with interests in the same scientific topics. Thus, citizen science has thrived on the basis of convenience of the internet. Despite the benefits to individuals and society, most scientists are primarily concerned with the data collected by citizen scientists rather than the citizen scientists themselves. The author assumes that this is attributable to the much greater difficulty of analyzing data concerning human participants in citizen science than in analyzing the hard data collected by those participants. However, understanding the participants in citizen science is also worthwhile; therefore, this study explores the human side of citizen science, including the operations of citizen science projects.

2.2. Community of Practice

The community of practice theory was proposed by Lave and Wenger in 1991. A participation process that is committed to a common area and formed by a group of learners is the core concept of community of practice theory [8–10]. Participating in a community of practice is an old phenomenon, but acquiring knowledge and learning from participation are new aspects of the concept. Various forms

of communities have always been organized within human societies to share practical experiences; cave-dwelling ancestral tribes discussed hunting around the campfire, guild members discussed trade in the middle ages, street gang members share techniques for living at the margins of society, and engineering trade groups discuss the latest design principles—in all these examples, which are a few illustrations of the myriad possible examples, the fundamental aspect of participation in the community is learning [8].

The study of a citizen science “community” has rarely been undertaken. A citizen science community requires a careful composition of various elements to be successful. A community of practice entails an informal group in which members share issues of common concern, develop a shared working style, and complete certain specific actions. The participating members have deep knowledge of or enthusiasm for their specific issues, and these community members adopt various personal roles and have various experiences. Members do not necessarily meet every day, but they typically communicate in some form, such as via the Internet, because they find value in communicating with each other. Communities of practice exist everywhere, and most citizens belong to at least one of them, whether at school, in the family, at work, or through membership in an interest group [22]. Members tend to learn the essentials of their work and activities through communities of practice, and the setup is similar to an apprenticeship [10]. Although they have always existed within human communities, communities of practice have become a topic of interest for research because research into “knowledge management” is now undertaken much more systematically, and a community of practice can be categorized within that research field. Knowledge is the basis for success in society today. Therefore, engaging in strategic management of communities of practice is a practical method for knowledge management; knowledge management treats knowledge as an asset and seeks to manage it similar to other assets that are systematically managed in a corporation [22]. Wenger et al. (2002) identified three core elements that comprise a community of practice:

1. **Domain:** A domain of knowledge is a key component of a community of practice. Community members must discuss the core values of their community; such as issues of concern, organizational strategies, and the desired effect from community activities.
2. **Community:** In pursuing a categorical interest, the development of the community must be focused, organized, and nurtured. For example, community members should follow the community’s guidelines, support the emotional development of community members, participate in the community’s activities, or seek to deploy an operational method in a community to maintain the community’s vitality and growth.
3. **Practice:** To maintain its inclusion in the field of knowledge, the community must constantly participate in or develop various relevant activities. Activities can help the community to effectively acquire knowledge resources and inherit knowledge. Community members can learn from their practice.

Although a community of practice is established to serve its specific purpose, Storck and Hill (2000) contended that members of a community should enjoy autonomy, which affords all community members the space for open discussion and group learning [23]. Because of the members, community interaction, communication, and development become major mechanisms for the creation, sharing, and dissemination of knowledge. The main implication of a community of practice is that it promotes the sharing of knowledge—a major benefit to the community. Because communities of practice afford the opportunity for members to connect with all other members, membership in the community provides enough time and space to establish relationships with others, and the focus is on common topics of interest; these factors generate the conditions that promote knowledge sharing [24]. This knowledge sharing is noneconomic in nature; nevertheless, it is not only for personal interest but also for sustaining and developing the community. Embedded knowledge in the community is seen as owned by all members, maintained by the community, and available as the basis for discussion and collaboration. Knowledge is the key asset of the community [25].

Wenger et al. (1998) proposed a social theory of learning and outlined four main necessary preconditions for integrated social participation [10]:

1. Humans are social—this is the core concept of this learning theory;
2. Knowledge is valuable for work and other tasks and activities;
3. People are motivated to seek knowledge to understand causes and participate in activities;
4. Ultimate meaning—our experiences and actions are the final outcome of learning.

Wenger et al. (1998) believed that the most critical aspect of learning is that people must learn through social participation; participation is not simply “doing something” but also includes ascribing meaning to explorations and participation in action [10]. Social learning theory integrates elements concerning social participants and those concerning the process of learning knowledge; these elements are described as follows:

1. Meaning: How we understand whether the actions we undertake are valuable within the larger context of our life and society.
2. Practice: The sharing of history and social resources, structures, ideas, and the ability to continue participating in joint actions.
3. Community: An organization or business should define its goals, and members should buy-in to those goals.
4. Identity: Learning changes the individual, and we can examine how a personal history is created and altered in the context of a community.

Many citizen science communities use virtual organization or community platforms to communicate and engage in discussions because their members are spread over a large survey area; a virtual platform is also more convenient and may incentivize scientists to participate in it [26]. This virtual setup is called a virtual community of practice or a mobile practice community [27,28]. Members of the virtual community interact on the internet or platforms such as discussion boards or news communities [27,29], and in a mobile community of practice, participants use mobile phones to communicate with the community or conduct work in the community. An online community is more challenging for new members. Many participants in the online community are not necessarily members of the physical community, and because participation in the community's activities is not on a fixed schedule, it becomes difficult to receive formal training. Wenger (2001) undertook a community-oriented technology survey that revealed numerous online and virtual practice communities and concluded that although the forms of these communities may vary, their ultimate goal is to exchange knowledge through identifying and solving problems, establishing a vision, and establishing a common knowledge base [28].

Another key concept in community of practice theory is legitimate peripheral participation. This concept holds that in communities of practice, new members gradually move from the periphery to the center of the community. This process begins with simple work; for example, a new member observes the working practices of the experienced members of the community [30]. Lave and Wenger (1991) argued that the knowledge and ability acquired specifically from participation in a community of practice by learners have value and significance; if learners can take the initiative and learn community knowledge, they will gain a deeper understanding of the acquired knowledge shared by the community and their community's culture [30]. Therefore, studying the learning process of new members of citizen science communities also warrants research. How a member transitions from a peripheral member to a core member and the various roles a member inhabits at various stages of integration in the community during the transition are also worth discussing.

Community of practice theory has been widely used in research concerning corporate communities, education communities, and hobby communities [31–34], but no practical community study has been conducted concerning citizen science communities. Therefore, this study is a pilot study that clarifies new perspectives and charts a path for subsequent research on citizen science

projects. Besides, we also wanted to know how the citizen science projects raise the public through the communities of practice.

3. Materials and Methods

3.1. Participation Observation

This study used participatory observation as one method of data collection. The authors conducted most direct observations by participating in TaiRON's online community, attending the annual meeting and trainings, and interacting with core members. Because social phenomena are dynamic and social actions and cultures vary according to person, time, place, and object, participatory observation is a fundamental research method in the social sciences [35]. After analyzing and comparing the observed data with community of practice theory, one TaiRON core member and one expert or scholar conducted data tests to improve the validity of our conclusions. Participatory observation is a method through which a researcher can get close to the research object. Researchers immerse themselves in the subjects of research. Through participatory observation, a researcher comes to clearly understand the research subject's terminology, communication patterns, behaviors, and actions. However, something that needs to be noticed about the method is that the validity of results from participatory observation must be tested. This study used the analyst's triangulation method to compensate for this deficiency.

3.2. Content Analysis

Data content analysis was another method used in this study. One of the authors of this study is the moderator of TaiRON. He provided first-hand information regarding TaiRON, for example, its organizational vision and architecture. In addition, TaiRON's internal operating model was analyzed through examination of TaiRON's accumulated survey data, relevant reports of results, and information appearing on the official website. Because TaiRON has made major contributions to Taiwanese society, numerous interviews and reports concerning core members, the families of citizen scientists, and other relevant topics have been conducted and were available for examination.

3.3. Unstructured Interviews

We conducted unstructured interviews with Mr. Lin. Mr. Lin is the moderator of TaiRON now and also is a research assistant in the Endemic Species Center. He founded TaiRON and still continues promoting the roadkill citizen science. The main interview content concerned the operation and management of the entire citizen science community. After the interview, we converted the text into a verbatim script and coded it according to the categories of communities of practice, legitimate peripheral participation, and dissemination of knowledge. The interview was conducted on 26 March 2017. The series code would be (Mr. Lin, 26 March 2017).

4. Results

This study was a pilot study because community of practice theory has been developed in various respects since 1991, but here, for the first time, we examined the core theory with respect to a citizen science project (TaiRON).

4.1. Analyzing TaiRON in Light of the Four Principles of Social Theory of Learning

The four main elements of social learning theory are as follows: (1) humans are social; (2) knowledge is valuable for work and other tasks and activities; (3) people are motivated to seek knowledge to pursue careers and participate in activities; and (4) our experiences and actions are the final outcome of learning and generate ultimate meaning.

The four preconditions and related observations from this study of TaiRON are displayed in Table 2.

Table 2. Four preconditions and related observations of this study.

Element of Community of Practice Theory	Observation Concerning TaiRON
(1) Humans are social	TaiRON is a fully interactive community in which members confer to identify dead species on roadside, discuss ecological issues, and jointly participate in conducting surveys.
(2) Knowledge is valuable for work and other tasks and activities	The knowledge provided by each person is valuable; for example, the species that each person specializes in are not the same, and therefore a membership with various specialties is of considerable value for collectively determining the type of species that a dead animal is.
(3) People are motivated to seek knowledge to pursue careers and participate in activities	Members hope to learn to recognize species through acquiring environmental knowledge by communicating with each other, and this knowledge can help members participate in the investigation.
(4) Experiences and actions are the final outcome of learning from which we assemble the ultimate meaning of our activities	* In addition to completing surveys, volunteers also hope to see TaiRON contribute to policymaking. Therefore, members are inspired to learn within the community and constantly improve their abilities to collect more accurate information. In addition to enhancing their own abilities, members hope to contribute to society.

We conclude that TaiRON meets the four preconditions of a community of practice. The assemblage of knowledge is critical for the community because revealing the roadkill problems depend on the information that is gathered from investigations and shared among the members. Various members are experts in a wide variety of fields, and members can contribute to the group's collective knowledge of amphibians, reptiles, arthropods, mammals, birds, and the particular species' within these groups. The carcass of dead animals at the roadside are often difficult to recognize. Thus, citizen scientists must possess a broad base of knowledge to make identifications; however, if an animal cannot be recognized, members can exchange knowledge through discussion to identify the species.

4.2. Three Core Elements of Community of Practice Theory and TaiRON

The three core elements of community of practice theory are domain, community, and practice. Domain is an important aspect of a community of practice. Community members must discuss the core values of their community. The aims of the community must be within the domain, and the development of the community must be accordingly focused, organized, and nurtured. The practice element highlights that a community must continually interact in the field of knowledge, and a community must continue to participate in or develop various activities. Practice can help the community effectively acquire knowledge resources and inherit knowledge. Community members can also learn through practice (Table 3).

Table 3. Core elements of community of practice theory and TaiRON's vision.

Three Core Elements of the Community of Practice Theory	Analysis of the Research Data (Source: TaiRON's Official Website)
Domain	<ol style="list-style-type: none"> 1. Citizen science. 2. Improve identification of roadkill. 3. Environmental education. 4. Promote respect for wildlife.
Community	<ol style="list-style-type: none"> 1. Members begin participate in the roadkill recording activity, implement environmental education activities, and promote the concept of ecological conservation. 2. Hold annual meetings and follow the related regulations.
Practice	<ol style="list-style-type: none"> 1. Propose ideas, experimental designs, data collection projects, engage in analytic discussion, and participate in cooperative work. 2. Through analysis of a large set of data collected at a section of road with a severe roadkill problem, TaiRON identified the most dangerous seasons and threatened species, and advocated for an improved road design or the addition of wildlife corridors, fences, or other facilities to reduce the considerable number of dead wildlife killed because of the development of domestic roads and traffic volume.

With respect to domain, TaiRON has four core values, which are shared by its members. Participants are willing to invest time and effort to collect citizen science information related to these four core values. Regarding community, TaiRON organizes several events each year to promote the relationships between its members. For example, more than 200 people attended the 2014 TaiRON annual meeting. They might not all meet one another, but events such as annual meetings give members the opportunity to collectively communicate, discuss the knowledge in the community, and attend topical seminars [36]. In addition, related rules are clearly established to govern members' behavior. For example, it is forbidden to directly disclose the location of dead animals, especially rare or endangered species in the community to prevent the appearance of opportunistic hunters. Practice is evident in the implementation of the survey and the discussion of policy. Members can learn from actual situations and convert the knowledge into practical actions. Mr. Lin commented:

"Participants can achieve a deeper level of communication when they engage in the citizen science recording project. Then, during the discussion concerning the dead animals by the roadside, if the participants share an opinion and we realize that is a good topic, we responded to the commenting member after the discussion. In so doing, we satisfy their desire to express their ideas and concepts." (Mr. Lin, 26 March 2017)

4.3. Legitimate Peripheral Participation and TaiRON

The creation of a community is bound to involve newcomers, but how they transition from being peripheral newcomers to core players or old timers is of interest for every community of practice. How a member is converted into a core player typically depends on some contextual factors. For example, the core role and who plays it may vary depending on the project and expertise of the members. We can use some cases of TaiRON to prove that this phenomenon has occurred in the community.

The moderator of TaiRON described how newcomers join TaiRON:

"Participants discovered that there were so many animals near their homes that they had never seen before and never would have seen but for participation in the organization. They only saw the dead. Many people would reflect on this afterwards, and contemplate the human activities that lead to roadkill. Subsequently, they became very involved, and they

started looking for friends to join too. Slowly, the number of people in TaiRON increased.” (Mr. Lin, 26 March 2017)

From this, we conclude that TaiRON has many legitimate peripheral participants, and new participants are continually joining the organization. How they deepen their involvement is beyond the scope of this study. However, we do know that many experts in various fields are active within the community:

Mr. Lin stated, “the most interesting thing about citizen science is that many experts are active in our community, and they offer their expertise and share ideas and suggestions when we encounter problems.” (From the Reporter News, 27 December 2016)

Many members of TaiRON have various specialties. Therefore, when a problem related to any academic specialty occurs, a member from within that professional community can step forward and assist the organization at the appropriate times. For instance:

“Even members in the United States—in New York—provided suggestions and assistance on an initiative to develop an app for us to use to maintain records.” [37]

Members who were originally peripheral participants were able to apply their expertise with respect to this project to assist TaiRON and became core participants of this project.

From these experiences, it is evident that legitimate peripheral participation occurs in TaiRON. However, this study observed that TaiRON’s legitimate peripheral participation may be more complicated than typical of a community of practice. This is because the knowledge level encompassed by the activities of TaiRON is very wide. Moreover, the talents across various professional fields in the community are quite diverse; thus, the legitimate peripheral participants are in constant flux.

4.4. Improvement of Environmental Literacy for Sustainability

TaiRON’s citizen science community has contributed greatly to the dissemination of environmental and scientific knowledge. However, it has not always gone smoothly.

“TaiRON has become widely known in Taiwan. Five years ago, if you mentioned the roadkill group, no one would know what it was. Everyone would be very puzzled, and say things like, why did you get into this kind of thing? People would think that it was a group of freaks.” (Mr. Lin, 26 March 2017)

However, eventually, many newspapers and magazines began to report on TaiRON’s contributions. Till now, TaiRON has been mentioned 271 times by social media such as Environmental Information Newsletter, China Times, Taiwan Animal News, Apple Daily, The Reporter, ETtoday, etc. Almost all the Taiwanese news were included. The frequency of the TaiRON’s news was approximately 50 times per year in recent 3 years. Besides, the TaiRON’s information sometimes presented in the magazines regarding the nature or environmental education such as Nature Conservation Quarterly, Green Teacher, and so on. A member of TaiRON, Ms. Chin, told her own experience to Mr. Lin:

“After joining TaiRON, everyone treated me as a pariah and blocked me out because they would see pictures of dead animals on their Facebook feed. Many people were unnerved, but later, they came to understand that concern for the death of these animals was not some weird and horrific preoccupation—this realization was helpfully assisted by media reports of our activities. People came to realize that the dead animals are a critical signal of a problem in the environment, and that all our health could be endangered.” (Mr. Lin, 26 March 2017)

Thus, many people began to care about and pay attention to the matter of roadkill through exposure to the work of TaiRON. Media attention also increased the awareness of many environmental issues, and many people began to gradually pay attention to environmental issues because of news

reports. In the past, concern for environmental issues typically did not extend past small groups of environmentalists. But now, because of projects like TaiRON's citizen science, concern is able to spread out from core groups of concerned citizens to reach a broader segment of society.

"I think the roadkill group is quite different because it is addressing a problem across all the species, and it involves diseases, pesticides, and safety issues. Everyone in the group has a very special background. Most of the 10,000 people are not specialists in ecology or wildlife biology, and largely come from a diverse variety of social strata." (Mr. Lin, 26 March 2017)

The roadkill citizen science participants began to pay attention to the ecological environments near their homes, and began to express concern whether engineering projects nearby were ecologically friendly.

"Apart from joining a community of like-minded people, our members began to observe the environment to determine if there were any problems near their own homes. For example, is there a place where many trees were suddenly felled? After the felling, animals would have no place to hide, so they would run out into the road and often be crushed to death. Or, if there is a road that has a design problem that has become a major thoroughfare, then traffic becomes very busy and hazardous to the animals." (Mr. Lin, 26 March 2017)

We can conclude from these experiences that TaiRON has made an indelible contribution to improving the environmental literacy of the general public.

5. Discussion

On the basis of the preliminary research of this study, we can conclude that the TaiRON citizen science project is an example of a community of practice. In other studies, people rarely used communities of practice to discuss the organization of a citizen science project. Citizen science projects are often goal-oriented, and the domain of the communities of practice are the core values of the project. Methods of communication, the sense of belonging among members, and the rules to be followed are all part of the community. Practice mainly concerns how each citizen science project conducts surveys and translates data into policies. According to the results of this study, it appears that not only TaiRON but several citizen science communities are in line with the operating model of a community of practice. The exchange of knowledge occupies the central position in each citizen science project, informing both action and policy, and thus such projects can be understood through the theoretical lens of community of practice.

The community was the main target of analysis in this study. Therefore, the "individual" members of the community were left uninvestigated. Therefore, the individual's activities within the community, the role of legitimate peripheral participation, and other individual-based knowledge learning were not explained in detail in this paper. However, the author's future research is to examine the participants in the community in light of the community of practice theory. In the future research, the author will fill in the details missing from this paper to create a holistic view of how the individual and community interact within a community of practice.

TaiRON's website communities met many of the criteria proposed by Wenger (2001) such as: member identification, asynchronous discussion boards, chat, instant messages, document folders, calendar of events, administrative console, activity analysis, and management tools. In the current generation, virtual communities of practice have become one of the main sites of knowledge exchange. Therefore, research on virtual communities is also a subject worthy of discussion in the future. Mr. Lin commented:

"All of a sudden, Facebook became popular, and some people began to rummage into their cabinets to pull out slides and photos taken ten years ago, or two decades ago—as long as it was road killed! Then, they uploaded it Anyway, Facebook is free. If it fails, we have no loss or stress." (Mr. Lin, 26 March 2017)

The information age has had a very profound impact on TaiRON. Presently, most of Taiwan's citizen science projects have established virtual communities. Bonney et al. (2014) published an article in the journal *Science* entitled "Next steps for citizen science" that concluded that more extensive, larger scale, and more diverse data has been collected in recent years because of technology [38]. The trend appears to be for citizen science to combine science and technology.

TaiRON has played a major role in improving public environmental literacy. It has managed to widely disseminate environmental information to the people of Taiwan, which has increased public awareness and sensitivity to environmental issues. These are the indispensable outcomes of all citizen science projects: the promotion of public environmental literacy and the encouragement of more sustainable development. However, a problem we are still trying to deal with is that only a small population of participants contributed to most of the data in TaiRON (Figure 2). Ways to promote people to engage our program would be our further study.

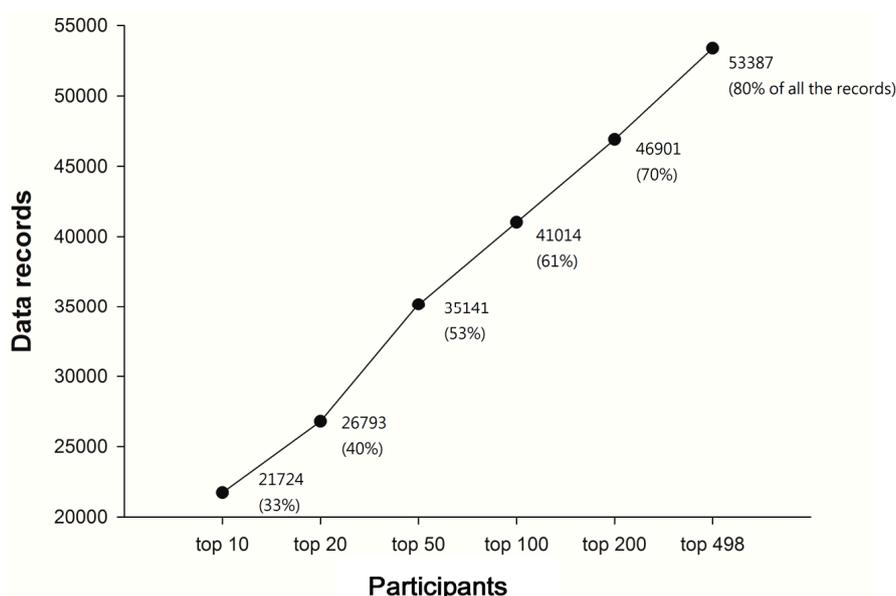


Figure 2. The relationship of the participants and the roadkill data records.

Citizen science describes a multifaceted community. The term "citizen science" has only been widely used in the last 30 years, which means that research concerning citizen science is still at a nascent stage. Nevertheless, it appears that citizen science is an excellent tool for spreading knowledge and promoting scientific and environmental literacy. Most vitally, citizen science has proven itself capable of making an indelible contribution to society.

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