

Title: Developing an Informative Hawaiian Land Snail App

Abstract:

Due to the rise of e-learning, or mobile-based learning, knowledge about nature conservation can be spread and accessed anytime and anywhere. This generation automatically uses e-learning techniques to study with smartphones, and particularly, apps, or self-contained programs designed to fulfill a purpose, are commonly used. Apps have the potential to revolutionize conservation efforts and environmental science due to their easy accessibility and ability to quickly spread knowledge. We are currently in a large biodiversity crisis because many ecosystems are rapidly facing degradation. Specifically, native Pacific island land snails are extremely threatened by extinction, and 90% of the pre-existing 750 have already gone extinct. This study focuses on the development of a Hawaiian land snail app to inform people about the large native snail extinction issue and necessity of conservation efforts as well as generate a filtering method to identify invasive snails. This hybrid app was designed using Adobe XD, coded in HTML, CSS, and JavaScript, and uploaded to the App Store through Monaca. To test the effectiveness of this publicly available app to inform people, I created an eighteen question survey and analyzed data to measure knowledge and attitudes toward Hawaiian land snails. The result of this project is the development of an app which is effective in informing people about the necessity of conservation efforts. Larger implications from this Hawaiian land snail app is that it could serve as the foundation for nature conservation apps for other taxa. Through designing a user-friendly interface and creating a hybrid mobile app that could be used by iPhone users and potentially Android users, I hoped to educate people about fascinating Hawaiian land snails.

Introduction:

Recently, there has been a rise in e-learning toward teaching people about conservation. E-learning is a learning approach that allows for learners to access material anytime and anywhere by using mobile devices like cell phones (Taufiq et al., 2017). This generation automatically uses these techniques to study with smartphones, and it is believed that this will be almost an innate part of the knowledge of future generations (Soto-Martin et al., 2015). Through technology, it is possible to teach the public about the necessity of nature conservation (Joppa, 2015). "Digital conservation" has become increasingly popular because digital innovation has impacted nature conservation (Arts, 2015; van der Wal, 2015). Particularly, apps, or self-contained programs designed to fulfill a purpose, are potentially able to revolutionize conservation efforts and environmental science.

However, this full power hasn't been exploited yet because of the quantity and quality of nature conservation apps (Jepson et al., 2015). For these reasons, this study developed, uploaded, and tested an app with the goal of informing people about the necessity of conservation efforts, specifically toward Hawaiian land snails.

The development of an app about Hawaiian land snails was important to help correctly inform the public about these interesting invertebrate creatures that are underrepresented in conservation management and policies (Yeung et al., 2018). There is a high rate of extinction of native land snails, especially those of the Pacific Islands. Pacific Island land snails hold the most recorded extinctions since the 1500s and also account for 40% of the 743 undocumented animal extinctions (Yeung et al., 2018). One cause of land snail extinction is human interference through habitat alteration and destruction (Solem, 1990). Another cause of the rapid extinction of these native snails can be attributed to fifty-three introduced snails that reside in Hawaii and are invasive in natural ecosystems. Non-native snails are agricultural and horticultural pests which pose a threat to natural ecosystems through competition, predation, and herbivory. They also may carry dangerous diseases like Rat Lungworm (Yeung, 2019). For this project, I worked with Dr. Kenneth A. Hayes and Dr. Norine W. Yeung from the Bishop Museum who wanted me to emphasize these native snail extinction factors through the Hawaiian Land Snails app. They feel that changing people's perspectives of Hawaiian land snails is necessary (Yeung et al., 2018). Our goal of this project was to develop an app with the ability to help people easily identify invasive snails, learn about the severity of the native snail extinction crisis and lack of conservation efforts, learn about the negative effects of non-native snails, gain access to the contact information of Bishop Museum malacologists, and overall have a good user experience while learning about snails in Hawaii.

With the hopes of teaching people in the community about the importance of protecting native Hawaiian land snails, I coded a hybrid mobile application in HTML, CSS, and JavaScript. I developed a mobile application because e-learning is currently an effective learning approach, and apps are potentially able to revolutionize conservation efforts by transforming how humans interact with nature and democratizing access to knowledge about the environment (Jepson et al., 2015; Taufiq et al., 2017). This app was successfully uploaded to the App Store. Then, to see how effective this app is, a questionnaire was sent out to users to test their environmental/conservation knowledge regarding Hawaiian land snails (Dimopoulos et al., 2008). Through developing, uploading, and testing an app about Hawaiian land snails, this study looked at how well apps can inform people about conservation.

Background:

This study looked at how technology can affect nature conservation efforts. The rapid development of technology has produced a new IT-based teaching and learning approach, called e-learning. E-learning is a learning approach involving mobile devices like cell phone, laptop, etc. in which learners can access material anytime and anywhere (Taufiq et al., 2017). Apps, or self-contained programs designed to fulfill a purpose, are easily accessible and often used in this age of e-learning (Sturm et. al, 2018). This generation frequently uses apps on their smartphones, and it is believed that using apps and other e-learning approaches will be almost an innate part of the knowledge of future generations (Soto-Martin et. al, 2015). Recently, there has been a rise in “digital conservation” because digital innovation has impacted nature conservation (Arts, 2015; van der Wal, 2015). Specifically, nature apps can potentially revolutionize conservation efforts and environmental science (Jepson et al., 2015). Through nature apps, we can transform how humans interact with nature and democratize access to knowledge about the environment. However, this power hasn’t been fully used yet because conservationists need to better engage with information engineers, software developers, and potential users (Jepson et al., 2015). Due to the rapid growth of technology, especially in e-learning and conservation, my goal was to design an app to inform the public about Hawaiian land snails.

There have been multiple studies showing the variations in the species diversity of Hawaiian land snails (Cowie, 1995; Solem, 1990). There are over 750 types of land snails that are endemic to the islands. Patterns can be found in these various snails, such as the environments that they live in and their shell shapes and sizes (Cowie, 1995). Before the 1900s, the diversity of native Hawaiian land snails was the most extensive in the world (Solem, 1990). Unfortunately, Pacific Island land snails currently hold the most recorded extinctions since the 1500s and also account for 40% of the 743 undocumented animal extinctions (Yeung et al., 2018). One cause of land snail extinction is human interference through habitat alteration and destruction (Solem, 1990). Human preferences for certain animals have been determined early in human evolution and emerge from early in childhood due to the belief that phylogenetically and behaviorally similar vertebrate creatures are more visually pleasing than invertebrates (Yeung et. al, 2018). Another cause of the rapid extinction of these native snails can be attributed to other snails. Fifty-three introduced or invasive snails reside in Hawaii and are invasive in natural ecosystems. They also may carry dangerous diseases like Rat Lungworm (Yeung, 2019). Invasive snails have identifying characteristics, which is why this study was able to incorporate this information into the app.

There must be a shift in public opinion and perception of land snails to change people's appreciation of land snails and other invertebrates. Conservationists are extremely worried about the lack of awareness regarding this native snail extinction issue. There have been suggestions for the set of actions that are necessary to conserve snails. Particularly, Solem (1990) has proposed a four phase plan to conserve these snails by using museum collections as a baseline, carrying out field surveys, developing ways to protect and expand snail habitats, and revising current systems to prepare for further research. This idea of a four phase plan has been added to by Yeung et. al (2018), as they feel that another phase of changing people's perspectives of land snails is necessary. They suggest that this can be accomplished through methods such as informal education and involvement of citizen scientists (Yeung et. al, 2018). This supports the creation of this snail app, as the sharing of this information could be useful to help inform people about the current situation of land snails.

Information about Hawaiian land snails is readily available to be uploaded into the application. Recently, over the last decade and especially in the past few years, there have been increased efforts to digitize collections of land snail information due to the data that has been made available to the community. Before 2015, the Bishop Museum's four million specimen list was only 15% digitized. Thankfully, there had been funding that was acquired, so attempts to digitize the entire land snail collection have been made, and as of now about 40% has been digitized (Yeung et al., 2018).

Currently, we are in the intersection of the Information Age and Anthropocene, giving technology the potential to help conservation (Joppa, 2015). This study used technology to promote the spreading of the Hawaiian land snail knowledge from the Bishop Museum, and websites show potential to share museum information (Kabassi et al., 2018). However, after deliberation, this study decided on creating an app because of the accessibility of apps on commonly used smartphone devices and its increased usage in the age of e-learning (Sturm et. al, 2018). When created with collaboration between environmental scientists, engineers, and the public, apps are promising for democratizing access to conservation knowledge (Jepson et al., 2015).

Apps that are currently used to raise awareness about conservation through identifying species include iBird and iNaturalist. iBird has simplified the task of identifying birds through creating a downloadable app on smartphones in 2008 (About iBird, 2018). iNaturalist has become one of the world's most popular nature apps that helps to identify the plants and animals through connecting users with scientists and naturalists (About iNaturalist, 2020). In the Hawaiian Land Snails app, users are able to identify non-native Hawaiian land snails by using their identifiable traits, which will hopefully raise awareness about conservation.

To test the effectiveness of the app, participants looked at the app and filled out a questionnaire. Questionnaires are useful in measuring knowledge, understanding, and thinking skills (Dimopoulos et al., 2008). In a questionnaire created in an attempt to test students' knowledge and opinions after using an educational module about sea turtle conservation, four categories were tested: fundamental knowledge, understanding and concern, locus of control, and verbal commitment to conservation. In my study, I tested the criteria from that study using a similar structure with multiple choice, Likert-type, and open ended questions (Dimopoulos et al., 2008).

Collaborating with Dr. Kenneth A. Hayes and Dr. Norine W. Yeung from the Bishop Museum, I designed and engineered an app taking in the needs of both conservationists and potential users. Sturm et. al emphasizes the importance of having a participant-centered approach to the design of apps. Through co-creating and co-designing apps with the needs of participants, or users, in mind, better engagement and learning will be facilitated, as knowledge will be made increasingly accessible and inclusive (Sturm et. al, 2018). With this in mind, I received input from people with a wide range of knowledge about snails to create an informative and understandable Hawaiian land snail app. The purpose of this study was to determine how well apps can expose people to the necessity of conservation, specifically toward Hawaiian land snails, and potentially build the structure for other conservation-related apps.

Methods:

This hybrid app, or a web app put in a native app shell, was written in HTML, CSS, and JavaScript, so it could be viewed on different sized devices. Due to the increased usage and accessibility of apps on commonly used smartphone devices in the age of e-learning, I created an app to inform people about Hawaiian land snails (Sturm et. al, 2018). The specific goals for this app, as outlined by Dr. Kenneth Hayes and Dr. Norine Yeung, consisted of (1) using technology to create a tool to help easily identify invasive snails; (2) informing people about the severity of the native snail extinction crisis and the lack of conservation; (3) informing people about the negative effects of non-native, or invasive, snails; (4) providing access to the contact information of Bishop Museum malacologists; (5) creating a design that enhances user experience. To accomplish these goals, I divided the app development process into four components: design, code, input information, and upload.

First, I designed the app. I used Adobe XD, a design tool for mobile and web apps, to design the layout of the various screens and accomplish my fifth

goal of creating a user-friendly app. By using Adobe XD, I was able to use UI and UX techniques to design and create interactive mock-ups or prototypes.

To code my app, I used Brackets, a text editor, and Google Chrome to preview my app in a web browser while coding it. I coded the features which were in Adobe XD but included a new feature called the “ID Key,” which was a Dichotomous Key Filter hybrid tool to meet the first goal of identifying snails. This tool was the most effective way to help users identify their snail because it incorporated a dichotomous key from the Bishop Museum. The “ID Key” allowed for a user to narrow down/filter all the way to a specific snail similar to a dichotomous key. I coded this tool in JavaScript and created and incorporated arrays and functions to accomplish the objective of filtering out undesired snails and continuing the dichotomous key until necessary. The filter works by starting with an array, and whenever a user clicks on a snail feature they desire in the dichotomous key, the opposite feature gets taken out of the array using the “.filter” function in JavaScript. Additionally, I created an undo button by utilizing the “.push” function in JavaScript. The tool remembers what the user previously pressed, so the user can go back if they make a mistake. Currently, the Dichotomous Key Filter is available for all invasive non-shelled snails, or slugs, and is in the process of being updated with more shelled snail information.

This study included information (K. Hayes and N. Yeung pers. conn.) from the Bishop Museum. Most of the snail information was stored in arrays, specifically 2D arrays that enabled me to keep snail information in an organized manner. The non-native snail data consisted of snail names, photos, and detailed information that the user can access through the dichotomous key filter hybrid as well as the image carousel. There are two image carousels, one for native snails and another for non-native snails, and they are displayed on the app’s home screen as well as their respective information pages. These features help accomplish the second and third goals of teaching about native and non-native snails. Also, using Bishop Museum’s contact information, I designed and coded a contact page to meet the fourth goal of providing access to contact information.

After designing, coding, and inputting the data, I finalized the app and uploaded. Since this app is coded in HTML, CSS, and Javascript, in order for the app to be packaged in its app form, I used Monaca, a cross-platform hybrid mobile app developer that built and prepared my app for distribution on the App Store and Google Play Store. I decided to name the app “Hawaiian Land Snails,” so it could easily be located on the App Store.

Then, after the app was finally developed and uploaded, I tested the effectiveness of the app to teach people about Hawaiian land snails. To test this app, participants looked at the app and filled out a questionnaire. I tested four categories: fundamental knowledge, understanding and concern, locus of control, and verbal commitment to conservation (Dimopoulos et al., 2008). Additionally, I

asked questions that related to the information found on the app as well as questions related to the user-experience and impact of the app. Questions for fundamental knowledge were multiple choice questions asked without aid of the app, testing general snail knowledge. The questions regarding understanding and concern, locus of control, and verbal commitment to conservation categories were Likert-type questions with a scaling from one to five, in which five was the most positive response (Dimopoulos et al., 2008). User-experience questions required participants to identify snails or provide information using features in the app. Additionally, I accepted answers to open-ended questions about what participants learned. These questions enabled me to receive both quantitative and qualitative feedback that helped me recognize if my app effectively educated students about Hawaiian land snails.

Results:

I was able to develop an app about Hawaiian land snails and gather results from a survey testing its efficacy. The Hawaiian Land Snails app consists of features that will be mentioned below which accomplish the app goals created from the desires of Dr. Kenneth A. Hayes and Dr. Norine W. Yeung. These Hawaiian Land Snails app goals include (1) using technology to create a tool to help easily identify invasive snails; (2) informing people about the severity of the native snail extinction crisis and the lack of conservation; (3) informing people about the negative effects of non-native, or invasive, snails; (4) providing access to the contact information of Bishop Museum malacologists; (5) creating a design that enhances user experience.

I created a tool to help easily identify non-native snails by generating a non-native snail identification tool which incorporated the dichotomous key filter that used a set of characteristics provided by the Bishop Museum. Currently, this tool is available to identify non-shelled, non-native snails.

Next, the goal of informing people about the severity of the native snail extinction crisis and the lack of conservation was met by creating a home page, featuring a figure I made on Canva that explains the importance of native land snails. This brief summary of information states the role that native snails play in and how they can affect our ecosystems. Then, I created the native snail page which contains information in two paragraphs about the loss of diversity and the necessity of conservation efforts toward native snails.

Just as I informed people about native snails, I hoped to inform people about the negative effects of invasive snails. I accomplished this goal by creating the non-native snail page, which contains information about why non-native

snails are harmful. The aforementioned dichotomous key filter tool can be accessed from this page.

Then, to meet the goal of providing access to contact information of Bishop Museum malacologists was met by creating the contact page. This page, which was styled in HTML and CSS, contains a photo and information about each of the four malacologists and myself.

Finally, I accomplished the last goal of creating a design that enhances user experience by creating image carousels and a slide-out menu, which are both popular design tools. Currently, the image carousels contain 10 native snail photos and 41 non-native snail photos and information that can be accessed through tapping the photo. The slide-out sidebar is accessible from all main pages of the app and was a UI and UX technique suggested for modern mobile apps.

To test the effectiveness of this app to teach people about Hawaiian land snails, a survey was administered to 5 participants over the age of 18, and the results were as follows. For the user experience questions, I received all “yes” responses, except one “no” response, that participants were able to use the featured tools (Figure 1). Similarly to a study by Dimopoulos et al., I tested four categories: fundamental knowledge, understanding and concern, locus of control, and verbal commitment to conservation (Dimopoulos et al., 2008). First, for the fundamental knowledge category, the two multiple choice quiz questions received 100% correct responses (Figure 1). The following results are based on a Likert-type scale where the most positive score was a 5. Regarding the understanding and concern category, the question about how the snail extinction crisis related to humans received an average Likert scale score of 4.4, and the question regarding severity of the snail extinction crisis received an average Likert scale score of 4.6 (Figure 1). Then, for the locus of control questions, the question about the role that people feel they play in protecting snails received an average Likert scale score of 3.4 (Figure 1). Finally, for the commitment to conservation category, the question about the necessity of snail conservation efforts received an average Likert scale score of 5 (Figure 1).

In addition to multiple choice and Likert-type questions, I posed open-ended questions and here are some chosen participant responses to these questions: “I think this app was good at teaching about Hawaiian land snails, because it was really easy to use. I never knew how many non native land snails there were until I saw the whole list of snails on the app.”; “I have learned that there has been a great loss of diversity and lack of conservation. This app will spread awareness and help people like me realize the importance of this issue.”; “I learned that snails are actually important and vital to our ecosystems.”

Discussion:

With the goal of using e-learning to educate people about conservation, features were added with the intention to help facilitate learning and accomplish the aforementioned objectives: (1) using technology to create a tool to help easily identify invasive snails; (2) informing people about the severity of the native snail extinction crisis and the lack of conservation; (3) informing people about the negative effects of non-native, or invasive, snails; (4) providing access to the contact information of Bishop Museum malacologists; (5) creating a design that enhances user experience.

Through creating the dichotomous key filter, the first goal of using technology to create a tool to help easily identify non-native snails was accomplished. Accessible from the non-native snail page is the non-native snail identification tool, which has a dichotomous key filter to help people learn about what non-native snails may be invading their own backyards and also about why they are so dangerous. This was the greatest change and challenge during this project. This non-native snail identification tool allows for a user to narrow down or filter as far as they can, even all the way to a specific snail using the provided dichotomous key. The user can exit the dichotomous key at any time they desire. I coded this tool in JavaScript, and I created and incorporated functions to accomplish the objective of filtering out undesired snails and continuing the dichotomous key until necessary. Additionally, I utilized more functions to create an undo button, so the user can go back if they make a mistake. I incorporated these features with the intent of making this tool as user-friendly as possible. Currently, the dichotomous key filter tool is available for invasive non-shelled snails, or slugs, and is in the process of being updated with more shelled snail information.

The home page and the native snail page were designed to accomplish the second goal of informing people about the severity of native snail extinction crisis and lack of conservation efforts. When the app is first opened, users are met with the home page that contains information about why native snails are important, as well as brief informative summaries about native (and non-native snails) in Hawaii. I placed this information about native snails on the home page because it is the first interface that appears and gives users their first exposure to the necessity of conservation. The native snail page contains information about why native species are in danger and the necessity of conservation efforts to raise awareness and show the urgency of native snail extinction issues. I created large headings to emphasize the loss of diversity and lack of conservation efforts.

Through the development of a non-native snail page, the third goal of informing people about negative effects of invasive snails was accomplished. The non-native snail page contains information about why non-native snails are harmful to help people understand the severity of the non-native snail issue. I

designed this non-native snail page to help inform people about the negative effects of invasive snails by explaining that they can transmit diseases and contribute to the extinction of native snails.

The contact page contains information about the people involved in the creation of this app and how to contact them through email to accomplish the fourth goal of providing access to contact information. I designed this simple and easy-to-read page containing the biographies and emails of four Bishop Museum malacologists and myself.

Image carousels and a slide-out menu help accomplish the fifth goal of creating a design that enhances user experience. There are two image carousels, one of native snails and one of non-native snails, that can be accessed on the home page as well as on their respective pages. I created these image carousels to allow users to admire the beauty of native land snails, as well as click on non-native land snails to learn about the dangers of them. This tool was designed to show the beauty of native snails and the large number of invasive snails. However, the native snail carousel needs more photos to be more effective and will be updated once more photos become available. Another design tool is the slide-out sidebar menu. I implemented this tool with the hope that it would enhance the user experience. Users are able to access any of the main pages by using the retractable menu that doesn't interfere with app usage. I felt this slide-out menu would be better than a navbar at the bottom of the screen that may be accidentally clicked on while using the dichotomous key filter tool.

Compared to the other conservation apps mentioned earlier, my app serves a similar purpose of identifying species, yet is different. Compared to iBird, which is a downloadable app that was created in 2008 to simplify the task of identifying birds, my app has an identification tool (About iBird, 2018). Our apps are similar in the fact that they can eliminate undesired species by using a filtering method. On the iBird app, however, the identification tool is more similar to an actual filter, where a user can click on a specific criteria, whereas the Hawaiian Land Snails app is more similar to a dichotomous key that has an intentional set order to filtering. Compared to iNaturalist, which has become one of the world's most popular nature apps that helps to identify the plants and animals through connecting users with scientists and naturalists, my app is not very similar (About iNaturalist, 2020). The function of taking a picture and then having scientists identify the creature is not supported on this app as of now. Currently, the method to identify is through the dichotomous key filter.

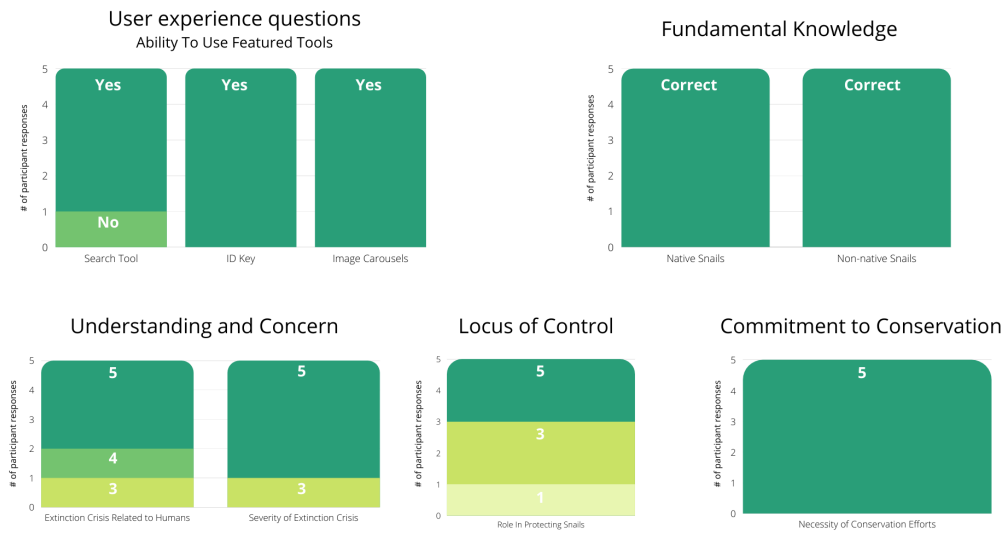
The survey found that my app is effective in teaching users about Hawaiian land snails and the necessity of conservation efforts toward them. Additionally, from the user experience questions, my app seemed useful in helping people identify and learn about non-native snails. Regarding the categories from Dimopoulos et al.'s study, I received positive results from the

fundamental knowledge and commitment to conservation categories. Participants answered my quiz questions 100% correctly and said they feel they understand the significance of native snail conservation efforts. However, my app had mixed responses in the understanding and control as well as the locus of control categories. This shows that my app needs more improvement in showing how people can personally get involved in helping snails, which will be incorporated with app updates in the future. From the open-ended questions, I received positive feedback supporting that users had increased their knowledge about snails in general as well as the state of land snails in Hawaii.

Conclusion:

This study has designed and coded a functional app about Hawaiian land snails that is available on the App Store. Featuring a slide-out sidebar menu, multiple image carousels, and an identification tool for non-native snails, this study has created an app for users to learn more about snails and why the native species need to be protected. Using information provided by Dr. Kenneth Hayes and Dr. Norine Yeung of the Bishop Museum, this study was able to organize the information into the Hawaiian Land Snails app. Additionally, the effectiveness of this app to teach people about Hawaiian land snails was tested for users via surveys, and results supported that users learned about Hawaiian land snails and why conservation efforts towards the native species are necessary. Some limitations of this study was the small survey participant size. For further research, I hope to add to my app when native snail information becomes available. Additionally, as mentioned in the results from my survey, my app has aspects that can be improved upon. I will continue to make improvements and updates. Finally, I could possibly use my app as the structure to create more nature conservation-related apps. In conclusion, with the Hawaiian Land Snails app, my goal of teaching conservation through this modern hand-held medium and potentially creating the structure for other conservation-related apps was met.

Figure 1: Results from my survey's user experience questions and four categories based on Dimopoulos et al.'s study. Darker green denotes more positive responses.



References

About iBird. (2018). Retrieved October 22, 2020, from <https://ibird.com/about/ios/about.html>

About iNaturalist. (2020). Retrieved October 22, 2020, from <https://www.inaturalist.org/pages/about>

Arts, K., van der Wal, R., & Adams, W. M. (2015). Digital technology and the conservation of nature. *Ambio*, 44(4), 661-673.

The authors of this article, Koen Arts, Rene van der Wal, and William M. Adams, published this article in 2015 with the intent of informing people about the effects that digital technology has had on nature conservation. The authors are credible because their paper was featured in *Ambio*, or *A Journal of Environment and Society*, which is a peer-reviewed scientific journal. The authors emphasize throughout their paper that digital technology in nature conservation should be seen as a force that will change the work of conservationists and may be effective under successful conditions. A question that arises concerns a problem that was proposed in the article that digital representations of the natural world may become a substitute for directly experienced nature. I question if this claim is applicable to all forms of digital technology, not only video games as mentioned in the article. However, I personally feel that this claim is not relevant to my Hawaiian Land Snails app because people can go outside in the natural world to search for snails to identify using my app. The authors' conclusion that nature conservation is a force that will transform the work of conservation efforts supports that my Hawaiian Land Snails app may have the power to effect conservation.

Keywords: technology, conservation, nature

Dimopoulos, D., Paraskevopoulos, S., & Pantis, J. D. (2008). The cognitive and attitudinal effects of a conservation educational module on elementary school students. *The Journal of Environmental Education*, 39(3), 47-61.

The authors of this article, Dimitrios Dimopoulos, Stefanos Parakevopoulos, and John D. Pantis, published this article in 2008 with the intent of informing the public about their study about using a conservation education module on elementary school students and seeing the cognitive and attitudinal effects it had. The authors are both credible, as they are experts in turtle conservation and ecology in Greece, and have had their article published in the *Journal of Environmental Education*. The authors emphasize throughout their paper that questionnaires are useful in

measuring knowledge, understanding, and thinking skills, hence their usage of questionnaires/surveys to study the conservation knowledge of elementary school students. They explain that in their sea turtle conservation study, they tested four different categories: fundamental knowledge, understanding and concern, locus of control, and verbal commitment to conservation. The authors' design of their sea turtle study gives this Hawaiian land snail app study ideas on how to survey app users.

Keywords: apps, conservation, testing, survey

Jepson, P., & Ladle, R. J. (2015). Nature apps: Waiting for the revolution. *Ambio*, 44(8), 827-832.

The authors of this article, Paul Jepson and Richard J. Ladle, published this article in 2015 with the intent of informing the public about the potential of nature apps. The authors are both credible in this field of conservation; Dr. Paul Jepson holds a PhD and studies conservation, innovation, and education, while Richard J. Ladle studies conservation and biogeography. The authors repeatedly emphasize throughout their paper that nature apps have potential to revolutionize nature conservation and environmental science, but this hasn't been completely acted upon. They explain that environmental science and conservationists need to engage with information engineers, software developers, and potential users for this revolution to happen. Additionally, this paper gives suggestions for how nature apps can be improved with sensors and data collection as well as interactive and recreational features. A question that arises concerns if this nature app revolution situation has evolved since 2015 when this paper was published. The authors' conclusion that there needs to be more nature conservation apps supports the necessity of a snail app.

Keywords: apps, conservation

Joppa, L. N. (2015). Technology for nature conservation: An industry perspective. *Ambio*, 44(4), 522-526.

The author of this article, Lucas N. Joppa, published this article in 2015 with the intent of informing people about the potential of Information Age technology to revolutionize conservation. The author is credible because he holds a PhD in Computational Ecology and Environmental Science and currently works at Microsoft as their first Chief Environmental Officer. Also, his paper was featured in *Ambio*, or *A Journal of Environment and Society*, which is a peer-reviewed scientific journal. Throughout this article, Joppa goes through the types of technology present in nature conservation and gives advice on how technology should be used to most beneficially impact conservation. Joppa says that the internet is becoming

a great space for addressing nature conservation problems. The author's conclusion that technology could revolutionize the practice of conservation if individuals work with a wide variety of partners supports my Hawaiian Land Snails app, which was created in collaboration with conservationists, computer scientists, and researchers.

Keywords: technology, Information Age, conservation

Kabassi, K., Botonis, A., & Karydis, C. (2018, July). Evaluating the Websites of the Museums' Conservation Labs: The Hidden Heroes. In *2018 9th International Conference on Information, Intelligence, Systems and Applications (IISA)* (pp. 1-4). IEEE.

Solem, A. (1990). How many Hawaiian land snail species are left? and what we can do for them. *Bishop Mus. Occas. Pap.*, 30, 27-40.

The author of this article, Dr. Alan Solem, published this article in 1990 with the intent of informing the public about native snails in Hawaii and the severity of the current native snail extinction issue. The author is credible in this field of snails, as he was one of the most renowned land snail experts of his time, earning a reputation for snails. The information from this article was featured in another paper by Yeung et al. that I also cited. Dr. Alan Solem states in his paper that the species diversity of Hawaiian land snails was extensive, and before the 1900s, the diversity of native Hawaiian land snails was the most extensive in the world. However, he emphasizes that is not the case because the land snail extinction crisis is quickly growing. He explains that a cause of land snail extinction is human interference through habitat alteration and destruction. A question that arises is if all of the information from this study is still supported over three decades later. The authors' conclusion that there needs to be more awareness regarding the current endangered state of native Hawaiian land snails supports the necessity of a snail app.

Keywords: snail, native snail, conservation

Soto-Martín, O., & Lodeiro-Santiago, M. (2015). Apps in the practice and teaching of conservation and restoration of cultural heritage. *Procedia Computer Science*, 75, 381-389.

The authors of this article, Ovidia Soto-Martín and Moisés Lodeiro-Santiago, published this article in 2015 with the intent of informing the public about the apps that teach about conservation. The authors are both credible as their paper was published in *Procedia Computer Science*. Soto-Martin is a pre-doctoral researcher at the University of La Laguna, and Lodeiro-Santiago is a computer engineering

graduate at the Advanced Technical School of Computer Engineering at University of La Laguna. The authors emphasize the innovative and technological learning approaches, ICT (Information and Communication Technologies) and LKT (Learning and Knowledge Technologies). They explain that students should be introduced to ICT and LKT, so they can be used to help inform students about conservation and restoration efforts. Additionally, this paper explains PBL, or problem-based learning strategies, which requires self-reflection from students to effectively learn from apps. The authors' conclusion that ICT, LKT, and PBL techniques are beneficial supports the my snail app and also gives this study ideas for how this app should be tested.

Keywords: apps, conservation, learning

Sturm, U., Gold, M., Luna, S., Schade, S., Ceccaroni, L., Kyba, C. C. M., ... & Piera, J. (2018). Defining principles for mobile apps and platforms development in citizen science. *Research Ideas and Outcomes 4: e23394*. <https://doi.org/10.3897/rio.4.e23394>
The authors of this article, Ulrike Sturm, Sven Schade, Luigi Ceccaroni, Margaret Gold, Christopher C. M. Kyba, Bernat Claramunt, Muki Haklay, Dick Kasperowski, Alexandra Albert, Jaume Piera, Jonathan Brier, Christopher Kullenberg, and Soledad Luna, published this article in 2018 with the intent of informing the public about defining principles for citizen science mobile apps. The authors are all credible as their paper was published with Research Ideas and Outcomes. The authors emphasize the importance of having a participant-centered approach to the design of apps. They explain that through co-creating and co-designing apps with the needs of participants, or users, in mind, better engagement and learning will be facilitated, as knowledge will be made increasingly accessible and inclusive. Additionally, this paper states that apps for mobile devices have been used more often in citizen science projects. The authors' conclusion that mobile applications can be beneficial for science with the right approach supports the Hawaiian land snail app.

Keywords: apps, citizen science, learning

Taufiq, M., Amalia, A. V., & Parmin, P. (2017). The Development Of Science Mobile Learning With Conservation Vision Based On Android App Inventor 2. *Unnes Science Education Journal*, 6(1).
The authors of this article, Muhamad Taufiq, Andin Vita Amalia, and Parmin, published this article in 2017 with the intent of informing the public about the apps that teach about conservation. The authors are both

credible as they are from the Department of Integrated Science and are part of the faculty of Mathematics and Natural Sciences at Universitas Negeri Semarang in Indonesia. Also, their paper was published in the Unnes Science Education Journal. The authors emphasize the rise of multimedia technology to help people learn and obtain information, especially about science. They explain the growth of e-learning, or mobile learning, which is a learning approach that allows people to access material anywhere and anytime. Additionally, this paper explains a research and development process called the “waterfall method,” which is a systematic approach used to make applications. The authors’ conclusion that e-learning is applicable in the field of science supports the creation of my snail app and information about the “waterfall method” gives this study ideas for how the methods section could be structured.

Keywords: app, learning, mobile learning

van der Wal, R., & Arts, K. (2015). Digital conservation: An introduction. *Ambio*, 44(4), 517-521.

Yeung, N. W., & Hayes, K. A. (2018). Biodiversity and Extinction of Hawaiian Land Snails: How Many Are Left Now and What Must We Do To Conserve Them-A Reply to. *Integrative and comparative biology*, 58(6), 1157–1169. <https://doi.org/10.1093/icb/icy043>

The authors of this article, Norine Yeung and Kenneth Hayes, recently published this article in 2018 with the intent of informing the public about the dire state of Hawaiian land snails that are becoming extinct. The authors are credible as they hold PhDs; Dr. Yeung is a malacologist, specialized in the systematics and conservation biology of Hawaiian native and invasive land snail fauna, and Dr. Hayes is an invertebrate biologist, specialized in evolution and conservation biology. The authors repeatedly emphasize that there needs to be more representation of invertebrates in conservation management and policies. Additionally, in their paper, the authors refer to a four-phase conservation plan by Dr. Alan Solem and suggest their own fifth phase of changing people’s perceptions and appreciation of invertebrate snails. A question that arises concerns non-native snail information, as the majority of the presented scientific information is about the ten families of native snails. The authors’ conclusion that there needs to be more snail representation and also a “fifth phase” to inform the public is important to my study because it supports the necessity of a snail app.

Keywords: snail, native snail, conservation

Yeung, N. W. (2019). Identity and distribution of invasive land snails infected with Rat Lungworm in Hawaii: Surveys, identification guides, and taxonomic workshops (FINAL REPORT). Retrieved March 02, 2021, from https://dlnr.hawaii.gov/hisc/files/2019/02/HISC_Yeung_HILS_RLW_survey_finalreport2019.pdf

The author of this article, Dr. Norine W. Yeung, recently published this report in 2019 with the intent of informing the public about non-indigenous land snails and explaining the project she conducted about identifying the species in Hawaii that may have Rat Lungworm. The author is credible as she holds a PhD and is a malacologist, specialized in the systematics and conservation biology of Hawaiian native and invasive land snail fauna. Dr. Norine W. Yeung emphasizes that non-native snails are dangerous creatures that pose threats to our natural ecosystems through competition, predation, and herbivory. Additionally, in her report, Dr. Yeung writes about Rat Lungworm, a disease-causing parasite that is found in many non-native snails. A question that arises concerns if there is something that people in the general public can do to help eradicate the non-native snails. The authors' conclusion that non-native snails are harmful because they may carry diseases is important to my study because it supports the necessity of a snail app to inform people about the dangers of non-native snails.

Keywords: snail, invasive snail, Rat Lungworm