

SNAKESAVVY: UTILIZING VIRTUAL REALITY FOR EDUCATION ON SNAKE  
IDENTIFICATION IN NORTH CAROLINA

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## ABSTRACT

SnakeSavvy: Utilizing Virtual Reality for education on snake identification in North Carolina.

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The sight of snakes often triggers fear for many people, resulting in unnecessary killings of these important creatures that serve a vital role in our ecosystem. This study seeks to explore whether virtual reality (VR) can effectively educate people on how to identify five species of snake native to North Carolina. The application created in this study will combine immersive VR technology with educational content to create an interactive and engaging learning experience, which will be the first of its kind regarding snake identification. The qualitative and quantitative results of this study indicate that the utilization of VR technology to educate individuals on snake identification is possible. This shows the potential for knowledge sharing and positive perceptions of snakes that can be used to prevent future harm to them.



## CHAPTER 1: INTRODUCTION

### *1.1 “The Only Good Snake Is A Dead Snake”*

Most have heard of the old saying, “The only good snake is a dead snake,” but why is this a common way of thinking for snakes compared to other animals? An article posted by Cleveland Clinic revealed that people with ophidiophobia, an extremely overwhelming fear of snakes, develop the fear for varied reasons. Some people have genetic disorders, like anxiety, which could lead to the fear of snakes, while some may develop the fear from seeing how others react to them. Some people reported showing fear towards snakes due to cultural superstitions where snakes are often associated with lies, evil, temptation, and paganism; an example is Medusa from Greek mythology. Another reason people feared snakes was due to traumatic experiences where they were bitten or watched a scary movie involving a snake attack[1]. It’s apparent that this reaction stems from a lack of understanding and passed down misinformation about these creatures. This chapter of the research paper delves into the potential consequences of killing snakes, the essential roles they play in maintaining balance in the ecosystem, what you can do if you ever encounter a snake, what prevention methods you can take, and how VR can be used to deliver this information in an interactive way.

### *1.2 Avoiding Snake Bites*

It is imperative to recognize that killing snakes is not only ethically unjustifiable, but also counterproductive in mitigating potential risks. Despite what people may say, snakes do not attack humans unprovoked, and they do not chase you. Most snake bites occur when humans inadvertently enter their habitats or when humans attempt to kill them. North Carolina is home to 37 species of snakes. Of those 37, 6 are venomous and 31 are nonvenomous. 8 of those species, which include the Eastern Diamondback Rattlesnake, Eastern Coral Snake, Timber Rattlesnake,

Pygmy Rattlesnake, Southern Hognose Snake, Pine Snake, Carolina Water Snake, and Outer Banks Kingsnake, are protected under the state’s endangered wildlife law due to being classified as endangered or threatened.

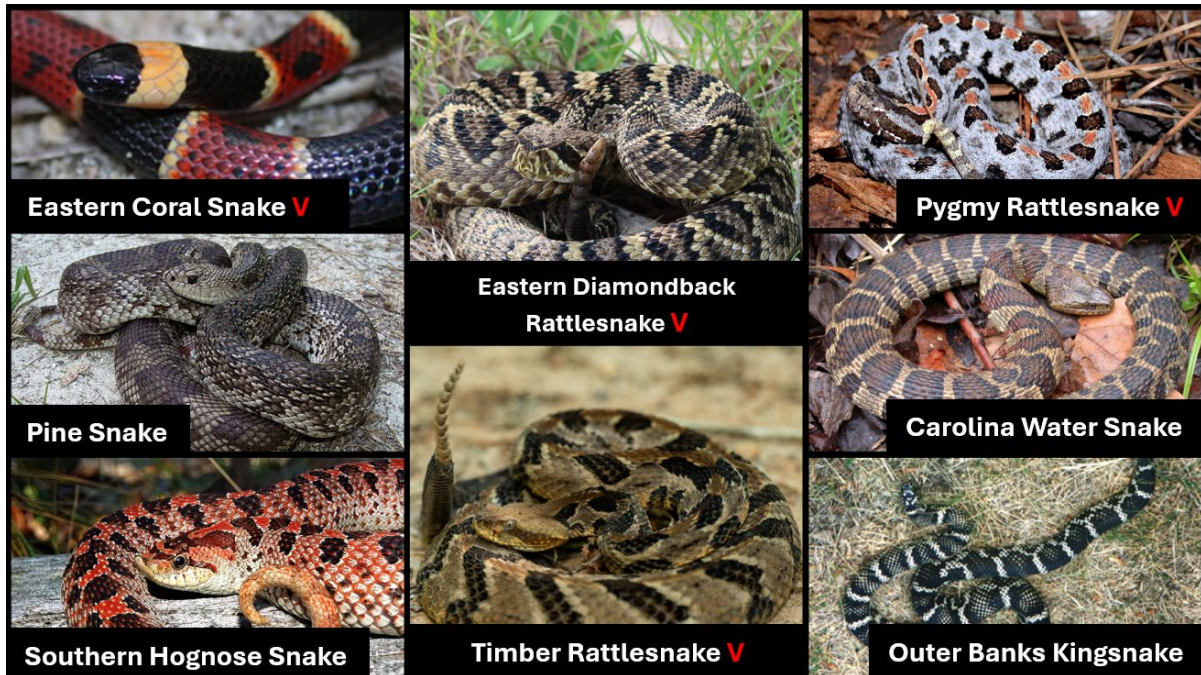


Figure 1: Protected Snakes of NC – A collage displaying the 8 protected snakes of North Carolina. A “V” next to the species’ name indicates the snake is venomous. Left hand side (from top to bottom): Eastern Coral Snake – venomous, Pine Snake, Southern Hognose Snake. Middle: Eastern Diamondback Rattlesnake – venomous, Timber Rattlesnake – venomous. Right hand side (from top to bottom): Pygmy Rattlesnake – venomous, Carolina Water Snake, Outer Banks Kingsnake.

Many people who kill snakes often identify them as being venomous, most commonly a copperhead or cottonmouth, and kill them because they fear someone or themselves being bitten. What makes matters worse is most of the time, their identification is wrong. While bites from a venomous snake can be medically significant and you should seek medical attention immediately, most non-venomous snake bites are not medically significant and can be cared for by cleaning the contact area with soap and water. It is not in your best interest to kill any snake,

much less a venomous one and the best course of action is to leave the snake alone. A study was done by the University of Florida that shows you are actually more likely to be bitten by a dog than a venomous snake[3]. It is also against the law to kill or purposely disturb any of the 8 protected snakes listed above which include 4 of the 6 venomous snakes in NC.

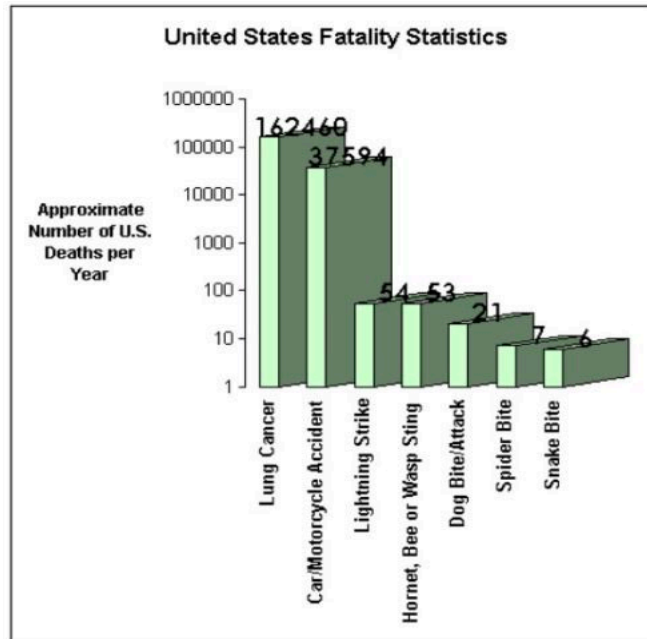


Figure 2: United States Fatality Statistics - A chart displaying the number of U.S. deaths per year by different events conducted in a study by the University of Florida.

### 1.3 Environmental Benefits

Snakes are an integral part of a healthy, thriving ecosystem. They play the role of nature’s free pest control and prey for other wildlife. Smaller snakes, like the deKay’s brown snake, or the venomous coral snake keep populations of earthworms, small lizards, and frogs in check. While larger climbing snakes, like rat snakes or the venomous eastern diamondback, tend to eat potentially disease-carrying rodents like mice, rats, and squirrels.

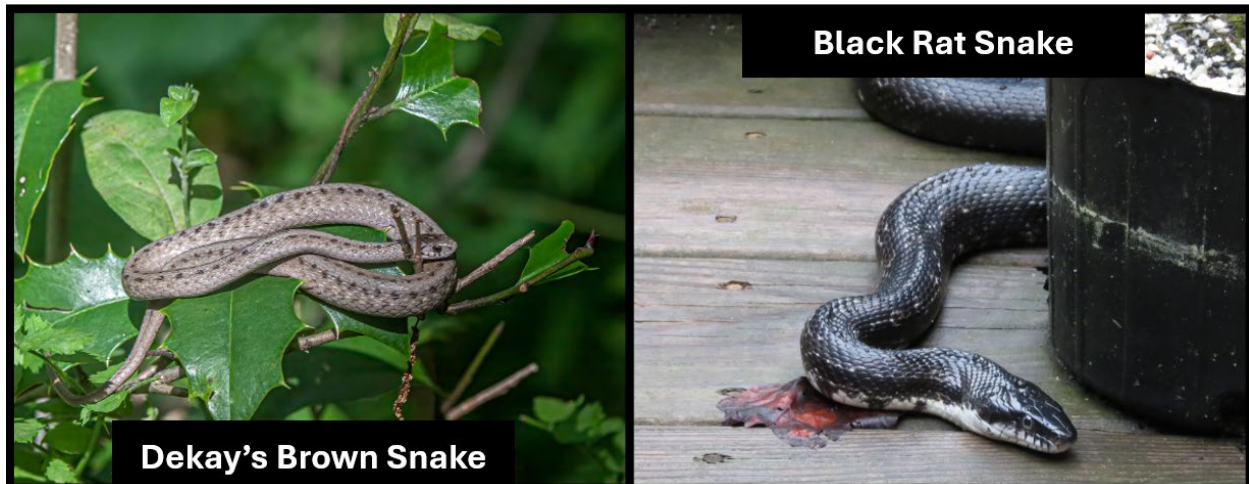


Figure 3: Dekay's vs Rat Snake Size Comparison – A side by side image of a Dekay's Brown Snake on a small branch of leaves(left) and a Black Rat Snake next to a planter(right).

The population numbers of those prey animals would soar without the help of snakes. Snakes are also a food source for agile predators like owls, hawks, eagles, herons, bobcats, foxes, and weasels. In addition to keeping ecosystems balanced and decreasing the spread of diseases, venomous snakes play an especially important part in the treatment of heart attack patients, folks with autoimmune diseases, diabetes, or victims of chronic pain. Some venoms are actually being studied to treat specific forms of cancer. In fact, it's likely the venom from a snake has created a treatment that has already saved the life of someone you know[3].

#### *1.4 Relocation and Prevention*

Some of you may be saying to yourself well, that's great and all, but I still don't like snakes. What can I do to get rid of them, or what should I do if I run into one? When encountering a snake, the first thing to remember is to remain calm and maintain a safe distance. If you don't mind the snake being there and assisting you with free rodent control, then simply walk away. If you would like the snake removed, you can contact trained professionals for safe relocation. Keep in mind, when snakes are relocated, they are usually only taken within a quarter or half

mile away from their original location. Snakes are vulnerable and often do not thrive if they are not around their familiar resources. It is impossible to prevent a snake from returning to your home, but to minimize the chances, you should keep your yard tidy and free from scrap wood, metal, and debris. In addition, if you own livestock animals, especially chickens, then ensure your shelter structures are tightly enclosed as heat, water, and animal products, like eggs, will also attract snakes. This advice goes for your home as well. While there are products out there that you can purchase, like snake repellents, there have been no scientific studies that prove the efficiency of these pesticides[3], and they can be toxic when ingested by children, pets, and other native wildlife. Keeping a clean and secure area will always be the best way to limit snake visits. It is also important to make sure dogs are taught snake avoidance and can obey leave it commands to avoid getting bitten or inflicting damage to the snake. Additionally, you should ensure children are also taught how to respect snakes' boundaries and are monitored closely around debris, shelters, and tall grass. Snake sighting with children can be a fun and an educational way to teach them about the importance of the role snakes play in our ecosystem. Fostering a mindset of coexistence is step one to breaking the fear of snakes and viewing them in a positive light.



Figure 4: Western Diamondback Rattlesnake Next to Snake Repellent - An image provided by Daniel Carrol at Rattlesnake Solutions of a Western Diamondback Rattlesnake lying next to a bag of Snake-A-Way snake repellent.

### *1.5 Utilizing VR*

In addition to educating people on the ecological importance of snakes and respecting their boundaries, the integration of Virtual Reality (VR) technology presents an innovative solution to diminishing snake fear and misinformation. By immersing users in a realistic simulation of a common habitat for snakes, VR offers a safe and engaging platform for experiential learning. Through interactive experiences, users can learn how to accurately identify different snake species based on their pattern, body shape, and location while also further understanding their ecological significance and practicing non-lethal methods of conflict resolution.

### *1.6 Potential Limitations and Solutions*

Naturally, there are going to be limitations to any application, especially one utilizing VR. With this application, the constraint of limited hardware accessibility, particularly VR headsets, poses a challenge in reaching a broad audience. Not everyone has access to a VR headset and funds may not be available for every user to purchase one. To mitigate this, offering alternative

versions of the game for non-VR platforms, such as a desktop application, ensures wider accessibility and inclusivity. Secondly, latency issues, which can disrupt user immersion by introducing lag. To counteract this, participants can utilize a wired connection to their computer for smooth gameplay if they have the minimum hardware requirements to run the application. Lastly, the limited selection of available snake models in Unreal Engine, pertaining to North Carolina, restricts future expansion of the game. To overcome this hurdle, efforts will be directed towards learning how to create additional snake models with the use of modeling applications like Blender or Maya. Collaboration with experts in herpetology will ensure accuracy in patterns and body shapes. By addressing these limitations, I can enhance the project's accessibility, performance, and potential for future development.

### *1.7 Goals*

My goal for this project is to develop an educational and immersive VR game that serves multiple purposes. The game will function as an educational tool, teaching users how to identify five snake species found in North Carolina: Eastern Diamondback Rattlesnake, Eastern Garter Snake, Scarlet Kingsnake, Eastern Rat Snake, and Eastern Coral Snake.

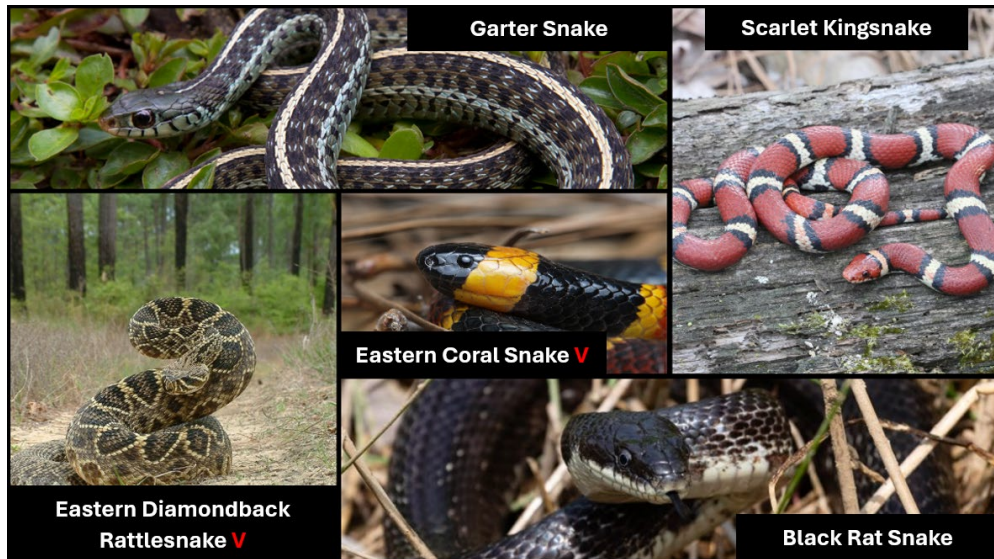


Figure 5: The 5 Snake Species – A collage displaying the 5 snake species that will be represented in the game as VR snake models. A “V” next to the species’ name indicates that the snake is venomous. Top left: Garter Snake, top right: Scarlet Kingsnake, Middle: Coral Snake – venomous, bottom left: Eastern Diamondback Rattlesnake - venomous, bottom right: Black Rat Snake.

Through gameplay, participants will learn to differentiate between these species and the ecological significance they play in their ecosystems. The game will also help participants confront their fears associated with snakes in a safe, virtual environment. People with a fear of snakes will have the opportunity to view them up close to learn how to identify them without the fear of getting bitten. This project will also serve as a platform for knowledge sharing, encouraging participants to educate others on what they’ve learned from playing the game to hopefully prevent future killings. The research questions to be explored and answered by this study are, “Is Virtual Reality an effective tool for teaching people how to identify 5 North Carolina snake species?”, and “Can Virtual Reality be used to help people form a positive perception of snakes?”.

The remainder of this paper will be organized as follows: Chapter 2 will include a literature review to examine the ability of VR to be used as an educational tool and it will also include related work on similar applications involving animals or snakes. Chapter 3 will include a methodology section that will first explain Unreal Engine, then the implementation and features of the game including the environments, models, blueprints and finally, review the testing procedure and tools used with it like the Empatica wrist sensor. Chapter 4 will report the results of the pre and post Google Forms survey questions and the Empatica wrist sensor readings. Chapter 5 provides a summary of the testing results, outlines all user feedback, and finishes off with any future work.

## CHAPTER 2: REVIEW OF LITERATURE REVIEW AND ANALYSIS

### *2.1 What is VR?*

Virtual Reality (VR) is an immersive technology that simulates realistic environments and experiences through the use of computer-generated imagery and sensory feedback. The concept of using virtual reality with a head mounted display (HMD) was invented in 1968 by Ivan Sutherland and his student Bob Sproull who created the Sword of Damocles which was a headset connected to a computer and not a camera. The large and scary looking device was too heavy for any user to comfortably wear and was suspended from the ceiling (hence its name)[4]. In today's age, we are now able to enjoy virtual reality with a lightweight and comfortable headset that can be worn without restraints. This allows users to focus on the application and freely enjoy what it has to offer. By wearing a VR headset, users are transported to virtual worlds where they can interact with objects and environments in a three-dimensional space. VR technology tracks users' movements and adjusts the virtual environments, accordingly, creating a sense of presence and immersion.

### *2.2 Studies Using VR For Education*

Virtual Reality (VR) has emerged as a transformative tool in education, offering many benefits that have changed traditional learning experiences. One significant advantage lies in VR's capacity to engage and motivate learners. VR captivates students with its immersive environments and interactive features, stimulating their interest and enthusiasm for the subject matter. Many researchers include measures of motivation and interest in their studies. Their findings consistently show that VR stimulates the interest and engagement of the participants[5]. VR has also been linked to a rise in student motivation by many researchers[7]. In a 2018 study,

conducted by Dr. Parong and Dr. Mayer, they compared giving a lesson via slideshow to a lesson using VR. The researchers found that students were “happier, more excited, and less bored” when taught using VR[7].

Another compelling advantage of VR in education is its ability to transport users to any environment. This enables educators to create virtual simulations of real or imagined locations, extending learning opportunities beyond traditional classroom settings, particularly in the realm of distance education. This provides students with learning experiences that would otherwise be unattainable. For instance, virtual field trips to historical sites like King Tut’s Tomb[12], remote ecosystems for exploring the world of the ocean[12], or cultural landmarks like at the top of Mt. Everest[12] would all be made possible with the help of VR. By leveraging VR's capability to replicate diverse environments, educators can enrich curriculum content and broaden students' perspectives, fostering a deeper understanding of complex concepts.

Additionally, VR serves as a powerful tool for exercising empathy. Through immersive experiences that allow users to embody the perspectives of others, VR promotes understanding, compassion, and social awareness[8]. Educators leverage VR to expose students to diverse perspectives and experiences and promote inclusive attitudes. VR simulations of real-world challenges, such as homelessness or racial discrimination, enable learners to empathize with other communities and gain insights into complex social issues[8].

VR offers a multitude of opportunities to modernize education, from enhancing student engagement and motivation to facilitating immersive learning experiences in inaccessible environments. Its capacity to promote empathy and collaboration makes VR a versatile tool for educators seeking to create dynamic, interactive learning environments.

### *2.3 Similar Applications*

Before deciding to create an educational VR snake identification game, I first entertained the idea of creating a mobile snake identification app that would use deep machine learning. After looking into this idea further, I decided a VR game would offer more engagement for the user and would provide multiple opportunities for education and exposure to snakes. These features are very important to me because I wanted the user to not only be able to learn about snakes and how they can identify different species on their own, but also, I wanted to reduce their fear of snakes as a whole so they could have an overall respect for them and hopefully educate others. When looking for VR snake applications that were used for identification or educational purposes, I unfortunately was not able to find any similar applications to the one I created. I was, however, able to find mobile and desktop snake applications that are similar, in ways, to my application. To start, there are a handful of simple snake quizzes offered by different universities and research societies like Stetson University with “The Florida Snake Quiz or Virginia Herpetological Society with “Snake Quiz #1” where the user is asked a question regarding snake identification or general facts and is provided a handful of photos/options to select from. The quizzes can be taken as many times as the user likes and provides a basic option for those interested in learning about snakes.

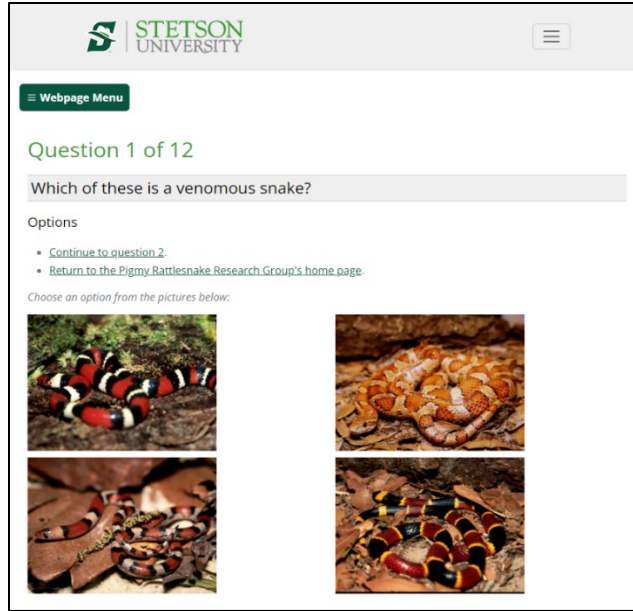


Figure 6: Stetson University Snake Quiz – A screenshot of the snake quiz Stetson University offers.

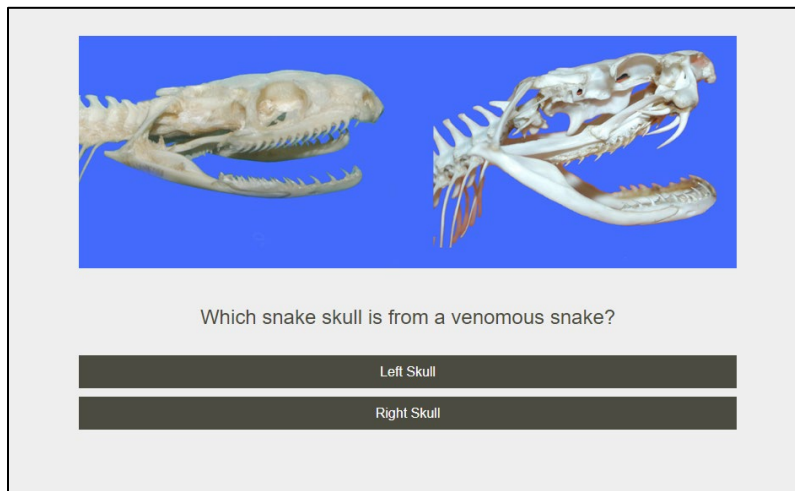


Figure 7: Virginia Herpetological Society Snake Quiz – A screenshot of the snake quiz Virginia Herpetological Society offers.

Next, is a VR snake game application called Snake Pass VR 360° which allows the users to slither around as a cartoon coral snake named Noodle and his sidekick hummingbird, Doodle, as they solve puzzles and traverse over different obstacles. The game is offered on different platforms including Nintendo Switch, PlayStation 4, Windows, Steam and Xbox One and was

created using Unreal Engine. The game is also suited for ages 8 years and older, making it a fun way for kids to experience VR and snakes in one game[11].



Figure 8: Snake Pass VR 360 – A screenshot of the VR game Snake Pass.

Another application similar to my project that you can find on the app or Play Store is Snake Snap, which is a mobile snake identification application that allows you to take a picture of a snake and get a quick identification back. This is done by using a combination of AI and manual assessment by an expert. The app also offers educational sections where you can learn more about the species; however, the snake identification feature does require a subscription (offered in 1 month, 3 months, or 1 year) which will run you at most \$10.00 for a full year of unlimited snake ID submissions[9].

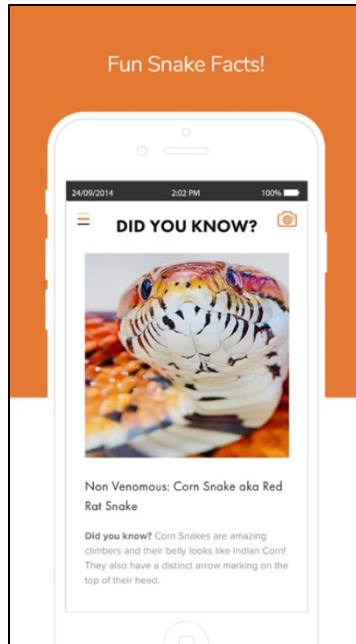


Figure 9: Snake Snap – A screenshot of the mobile app Snake Snap.

An application that is similar to Snake Snap is called Critterpedia. The app is currently undergoing testing, but from what the founders have posted, it is a mobile identification app for a wide variety of species, including snakes, spiders, and insects. This app focuses on quickly and accurately identifying species while also encouraging its users to get outside and engage with nature[10]. This is an Australian-based app, and on the website, it does mention switching to Australian dollars, so I am unsure if this app can identify any species within the U.S. or if there are required fees to use it.

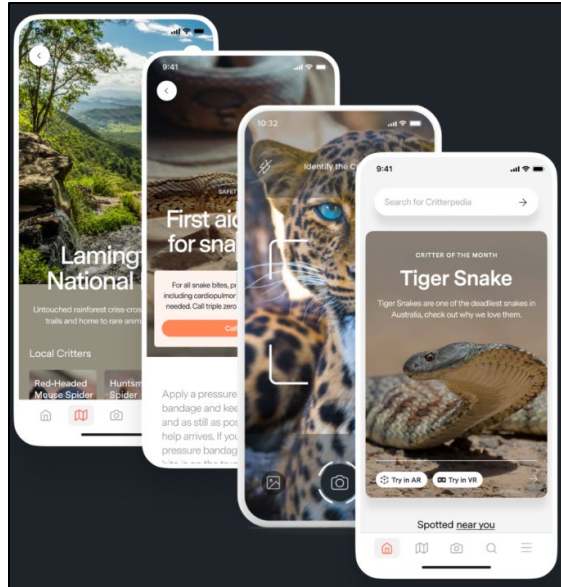


Figure 10: Critterpedia – A screenshot of the mobile app in development, Critterpedia.

I am inspired by several features from the existing snake identification and educational applications I've explored. It's evident that each offers commendable features aimed at facilitating learning and engagement. However, they each had their drawbacks and limitations that my application was able to improve upon. For instance, the snake quizzes are simple and easy to use; however, they don't offer much for learning how to identify the snakes other than seeing the same image repeatedly until you identify it correctly and there is little to no engagement required. Snake Pass VR 360 has more engagement as it allows you to play as a snake and is child-friendly, but it lacks in the educational department, and the coral snake character is not exactly accurate in terms of appearance. Snake Snap and Critterpedia are convenient, user-friendly, and educational applications, but they rely on systems that can make mistakes. While AI is often regarded as the future and offers advantages like the rapid generation of snake models, I believe it is not the safest approach for my application. AI-generated models carry the risk of inaccuracies, which could lead to dangerous misidentifications. For instance, someone might mistake a venomous snake for a harmless one due to subtle discrepancies in an

AI-generated model, potentially resulting in a life-threatening situation. In contrast, SnakeSavvy uses meticulously crafted, high-quality snake models that are carefully selected and will be developed in collaboration with snake experts in the future to ensure maximum accuracy. This empowers users to make independent identifications rather than relying on AI.

Through VR, SnakeSavvy immerses users in lifelike environments that teach users not only how to identify snakes, but also about their environment and how to get them relocated instead of resorting to killing them. By addressing fears and misconceptions, SnakeSavvy fosters a deeper respect for snakes and their role in the ecosystem, promoting wildlife conservation. While existing applications provide useful features, no application currently combines these elements with VR. SnakeSavvy bridges this gap, setting a new standard for interactive and educational experiences. In the next chapter, I will explore how Unreal Engine was used to bring this vision to life.

## CHAPTER 3: METHODOLOGY

As stated above, this study involved creating an educational VR snake identification game using Unreal Engine that is centered around identifying five native snake species of North Carolina (Eastern Diamondback Rattlesnake, Eastern Garter Snake, Scarlet Kingsnake, Eastern Rat Snake, Eastern Coral Snake). In addition to this, the application was used to educate participants on the ecological benefits they provide, debunk dated information, and reduce any fear to promote positive outlooks. The following sections will explain what Unreal Engine is and then go into greater detail regarding the components and tools Unreal Engine provides that were used to build the application for this research.

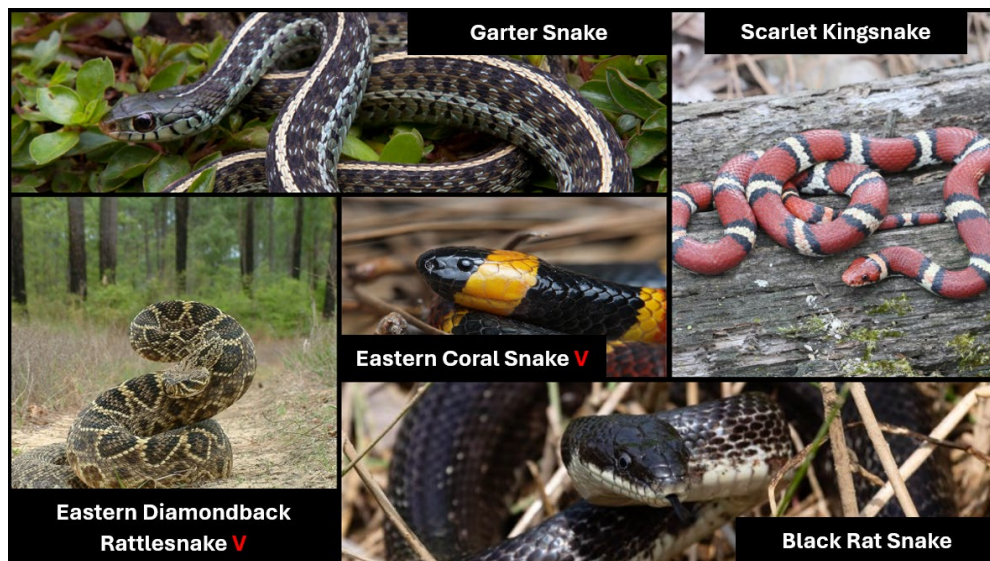


Figure 5: The 5 Snake Species – A collage displaying the 5 snake species that will be represented in the game as Unreal Engine snake models. A “V” next to the species’ name indicates that the snake is venomous. Top left: Garter Snake, top right: Scarlet Kingsnake, Middle: Coral Snake – venomous, bottom left: Eastern Diamondback Rattlesnake - venomous, bottom right: Black Rat Snake.

### *3.1 Unreal Engine*

Unreal Engine is a versatile game development platform created by Epic Games. It provides developers with a comprehensive suite of tools and resources for designing, building, and deploying high-quality interactive experiences across multiple platforms. Unreal Engine's interface and features make it an ideal choice for creating video games, virtual reality (VR) applications, augmented reality (AR) experiences, architectural visualizations, and simulations. Its advanced graphics rendering capabilities, along with its flexible scripting language, known as Blueprints, and extensive asset library, empower developers to bring their creative visions to life. Unreal Engine also features cross-platform compatibility which enables developers to reach a wide audience, from desktop and console gamers to mobile device users. The following sections will explain further what components of Unreal Engine I used for this application and how they came together to create SnakeSavvy.

### *3.2 Environment*

Environments are one of the primary features in Unreal Engine and they symbolize the virtual spaces or settings where the action of the game takes place. These environments can range from realistic landscapes to mythical worlds, all created within the engine's powerful editor. To create environments in Unreal Engine, developers can utilize a combination of pre-made assets, terrain sculpting tools, and various built-in features to craft immersive and visually stunning settings. For my application, I created a backyard environment that featured debris, tall grass, a shed, patio, pool, garage, and children's toys. The purpose of this environment was to replicate a common area where people encounter snakes and to enhance the player's immersion to make them feel as if they are in a real-life scenario. I duplicated this environment five times to create a

level for each snake model to be hidden. When the player starts the application, they are greeted by the SnakeSavvy main menu, and they can choose one of the five existing levels to play. Once a level is selected, they are dropped into the backyard environment where they are tasked with finding the hidden snake model and using the journal to make their identification.



Figure 11: UE Backyard Environment Part 1 – A screenshot of the backyard environment I created in Unreal Engine for this application.



Figure 12: UE Backyard Environment Part 2– A screenshot of the backyard environment I created in Unreal Engine for this application.



Figure 13: SnakeSavvy Main Menu – A screenshot of the main menu for the application SnakeSavvy I created in Unreal Engine.

### 3.3 Models

Models are another important feature in Unreal Engine. They are the digital representations of objects, characters, and other elements within a game or VR experience. These models can be created using external software such as Blender or Maya and then imported into Unreal Engine or developers can use Unreal Engine's built-in modeling tools to create or modify assets directly within the engine. Another great resource developers can use is Quixel Bridge which is a marketplace offered by Epic Games that is filled with over 14,000 megascans that are free to download and use in any Unreal Engine project. Megascans are photorealistic high-resolution scans of real-world objects and are a great option for developers who want to include realistic models in their project, but don't necessarily want to create them from scratch. For my application, I used high quality snake models that were created by Dibia Digital. I also used megascans of grass, trees, rocks, and flowers to add foliage to the backyard environments. The remaining assets used were found in Unreal Engine's store and were all free. This included the garage, shed, patio, pool, deck, and all other assets found within the environment. The snake models are an important aspect to the application because they display accurate body/head shapes, patterns and colors that are crucial to assisting in educating participants on identification.



Figure 14: Eastern Diamondback Rattlesnake and UE models – A collage displaying a venomous Eastern Diamondback Rattlesnake (middle) and 2 Unreal Engine replica models that will be used in the game (left and right side).



Figure 15: Eastern Rat Snake and UE models – A collage displaying a Black Eastern Rat Snake (middle) and 2 Unreal Engine replica models that will be used in the game (left and right side).



Figure 16: Eastern Garter Snake and UE models – A collage displaying an Eastern Garter Snake (middle) and 2 Unreal Engine replica models that will be used in the game (left and right side).



Figure 17: Eastern Coral Snake and UE models – A collage displaying an Eastern Coral Snake (middle) and 2 Unreal Engine replica models that will be used in the game (left and right side).



Figure 18: Scarlet Kingsnake and UE models – A collage displaying a Scarlet Kingsnake (middle) and 2 Unreal Engine replica models that will be used in the game (left and right side).

While each species of snake can differ from color and pattern, some even being completely absent of their pattern, these models are still an excellent resource to use for educating people on what the snakes typically look like and use it as a chance to explain why you should never use a single feature to identify a snake.

### *3.4 Blueprints*

Blueprints, or Blueprint Class, in Unreal Engine are visual scripting systems that allow developers to create gameplay mechanics, interactions, and logic without writing code. Alternatively, you could write code to create these interactions by using C++ for those who prefer to, but for this application I used Blueprints. Using a node-based interface allows developers to connect various pre-made nodes to define the behavior of objects, characters, and systems within the game. Blueprints are particularly beneficial for rapid prototyping and iteration, as they enable designers to quickly experiment with different ideas and iterate on gameplay mechanics. For SnakeSavvy, I used a combination of pre-made and custom-made blueprints. One of the most important blueprint classes used in this application was the VR Pawn that comes pre-made with the VR Template in Unreal Engine. The pawn is the equivalent to the playable character in the VR space. The VR Pawn blueprint class featured functionality for the

character's movement, camera location, and hand controls. I kept all hand functions the same and I modified camera location so that when a level was started It would ensure any widget blueprint would appear in front of the character regardless of where there were in the environment. All widget blueprints used in this application were custom-made and their functionality was also added to the VR Pawn blueprint class. The widget blueprints created for this application are the Journal and the Correct/Incorrect Identification screens. To display any widget blueprint in a VR environment, they must be placed on an actor, which is an interactable object in the form of a blueprint class.

### *3.5 Journal*

The first widget blueprint that was created was the Journal, which is an essential element of the application since it's the way the participant would read about the snake species and make their identification selection to proceed in the game. On the first page of the journal, users will find checkboxes for each snake species that can be found in the game, the Submit Identification button, and the Next button. The next series of pages will have detailed information and pictures for each snake. Information includes a description with the best way to identify them and information regarding their size, reproduction, habitat, and if they are a protected species. The last few pages include essential information regarding how to make an identification, deterrent and coexisting tips, relocation and bite guides, and environmental facts. Participants will use the journal to read about each snake and the additional information to make a correct identification on the snake species they have found in the level. Upon making an identification, participants will select the appropriate checkbox for the suspected species of snake they believe they have found, and then select the Submit Identification button to see if they were correct.



Figure 19: SnakeSavvy Journal – A screenshot of the first page of the journal widget blueprint used in the game.

### 3.6 Correct/Incorrect Identification Screens

After the Submit Identification button has been clicked, if the participant chose the correct snake checkbox, a widget blueprint will appear that shows the user they have made the correct identification. From here, the participant can select the Return to Main Menu button where they will be redirected to the SnakeSavvy menu and can then select another level to play.



Figure 20: SnakeSavvy Correct Identification Screen – A screenshot of the correct Identification screen widget blueprint used in the game.

In the case the user selected the wrong identification, a different widget blueprint will appear that shows the participant that they are incorrect. They then have the option to select the Return to Main Menu button or the Try Again button which will hide the incorrect identification screen widget blueprint, and they can make a different selection.

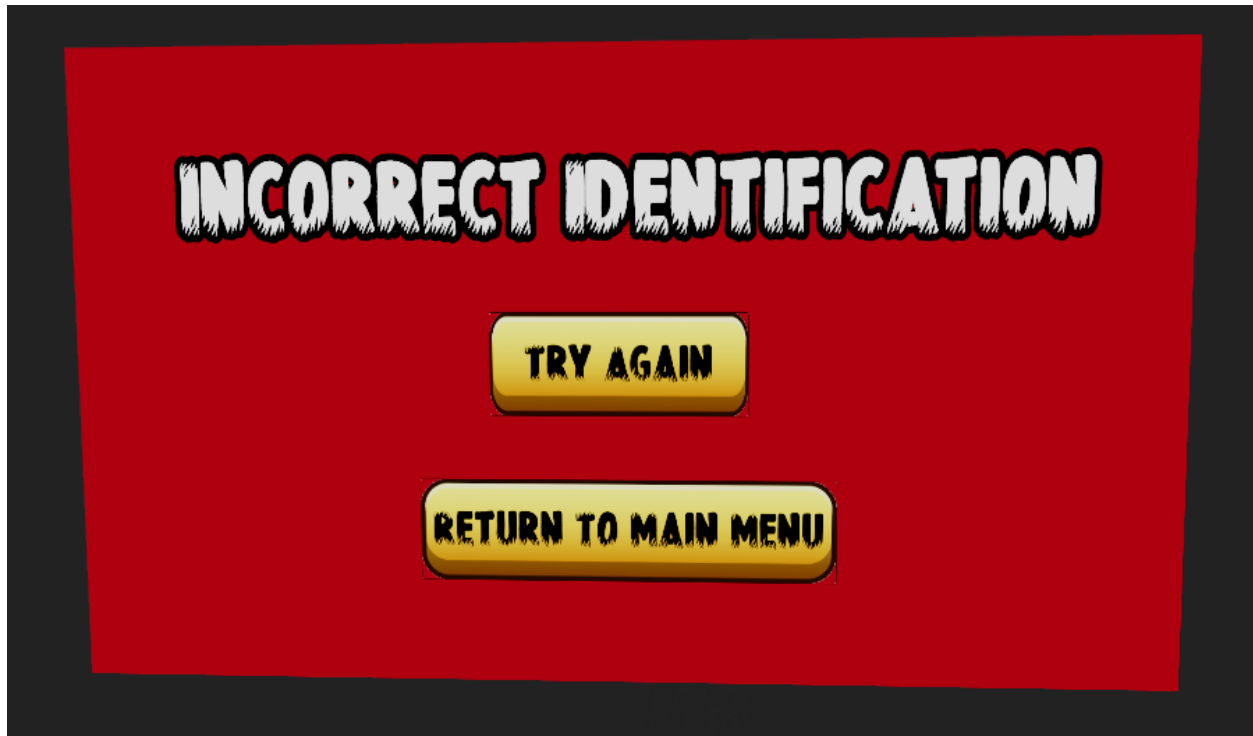


Figure 21: SnakeSavvy Incorrect Identification Screen – A screenshot of the incorrect identification screen widget blueprint used in the game.

### *3.7 Empatica Embrace Plus*

While the development of the application was the bulk of this study, the testing process is also important for determining if the application is effective. Part of my testing procedure will include using the Empatica Embrace Plus. The Embrace Plus is a wearable device designed to monitor and track physiological signals, particularly for individuals with epilepsy.



Figure 22: Empatica Embrace Plus – A screenshot of the Embrace Plus wrist sensor that will be used in the testing portion of my research project.

Equipped with advanced sensors, it captures biometric data such as heart rate, skin conductance, and motion patterns. These features enable its application in diverse research projects, including those focused on monitoring individuals' physiological responses during specific activities. For my testing procedure, I used the Empatica Embrace Plus to track the effects SnakeSavvy had on participants' heart rate. While wearing the device and engaging with the game, I was able to continuously monitor the participants' heart rate in real-time. This allowed me to collect and study the data of the physiological responses evoked by the VR experience. I was able to find differences in the results for people who are afraid of snakes when compared to those who were not. I was also able to see a decrease in elevated heart rates throughout the playthrough of the application.

## CHAPTER 4: RESULTS

### *4.1 Testing Procedure*

The testing procedure for this research project involved a study group of 14 participants that consisted of individuals both fearful and non-fearful of snakes. Participants were asked to read and sign a consent form (H25-0364) to show they were aware of the project's intent and potential risks while playing the game. Before starting the application, the participants were asked to wear the Empatica Embrace Plus wrist sensor and fill out a pre-survey (Appendix A). After completing the pre-survey, they were asked to put on the Meta Quest 2 headset and were handed the controllers. At this point, the application was started, and they were given a quick tutorial on how to use the controls. They were tasked with finding the hidden snake in each level and using the journal to learn more to make their identification. Following the completion of the application, the participants were instructed to complete a post-survey that contained most of the same questions from the pre-survey. After the completion of the post-survey, the participants were able to remove the Empatica Embrace wrist sensor and all data was collected and analyzed which will be explained in the following section. It is important to note that while a VR and Desktop version of the application was created, participants were only exposed to the VR version and all data below only reflects the results of the VR version.

### *4.2 Pre-Survey Analysis*

The pre-survey used in this study consisted of 32 questions and was created with Google Forms. Its purpose was to assess participants' general knowledge of snakes, their attitudes toward them, and their ability to identify the five snake species included in the application. The questions asked in the pre-survey are detailed in Appendix A.

Of the 32 questions, only 23 contributed to the overall score. On average, participants answered approximately 5 out of 23 questions correctly, indicating a limited baseline knowledge of the subject. Participants were instructed to select "I don't know" if unsure of an answer to ensure the scores reflected actual knowledge rather than guesses.

Among the 14 participants, 64% identified as beginners or no experience in using virtual reality (VR), and 93% rated their knowledge of North Carolina snake species as below average.

Additionally, 14% expressed a dislike or hatred of snakes, while only 7% reported enjoying seeing them in their environment.

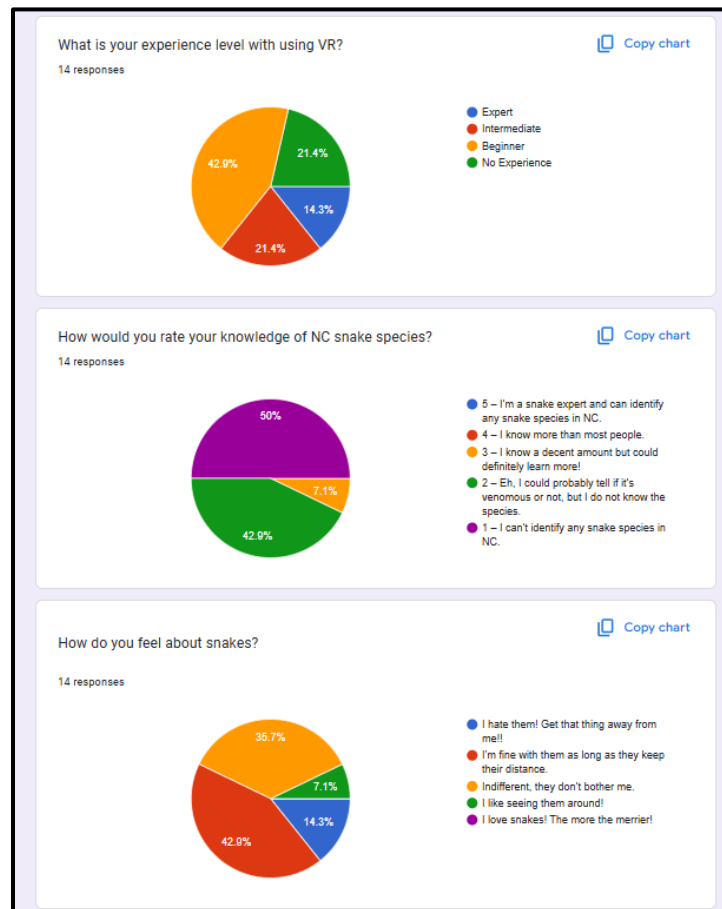


Figure 23: Pre-Survey Results - Screenshot for 3 of the questions asked during the pre-survey to gauge participants VR experience and their knowledge and opinion of snakes.

### *4.3 Post-Survey Analysis*

The post-survey in this study, like the pre-survey, consisted of 32 questions, with 23 counting toward the final score. Created using Google Forms, its primary purpose was to determine whether the 14 participants had gained knowledge during the application. Additionally, it allowed participants to reassess their attitudes toward snakes, with the hope that their perspectives had improved or remained positive. At the end of the survey, participants shared their honest feedback on the application's ease of use, effectiveness, favorite and least favorite aspects, and suggested improvements. The questions asked in the post-survey are detailed in Appendix B.

The results showed significant progress: the average number of correct answers increased from 5 in the pre-survey to 20 out of 23 in the post-survey. However, the most frequently missed questions involved identifying the key characteristics of the Eastern Garter Snake and Eastern Rat Snake, which were more challenging due to less emphasis in the learning materials.

Regarding the application's educational effectiveness on North Carolina snake species, 64% of participants rated it as "super effective," and 36% rated it as "mostly effective." When asked about its usability, 86% found it "most easy" or "very easy" to use, while 14% considered it somewhat difficult.

In terms of attitudes toward snakes after completing the application, 43% reported developing a newfound interest and respect for them, and only 7% expressed continued dislike—a notable improvement from the pre-survey. Finally, when asked to rate their knowledge of North Carolina snake species after using the application, 57% felt they had gained substantial knowledge, 36% believed they now knew more than most people, and 7% considered themselves snake experts.

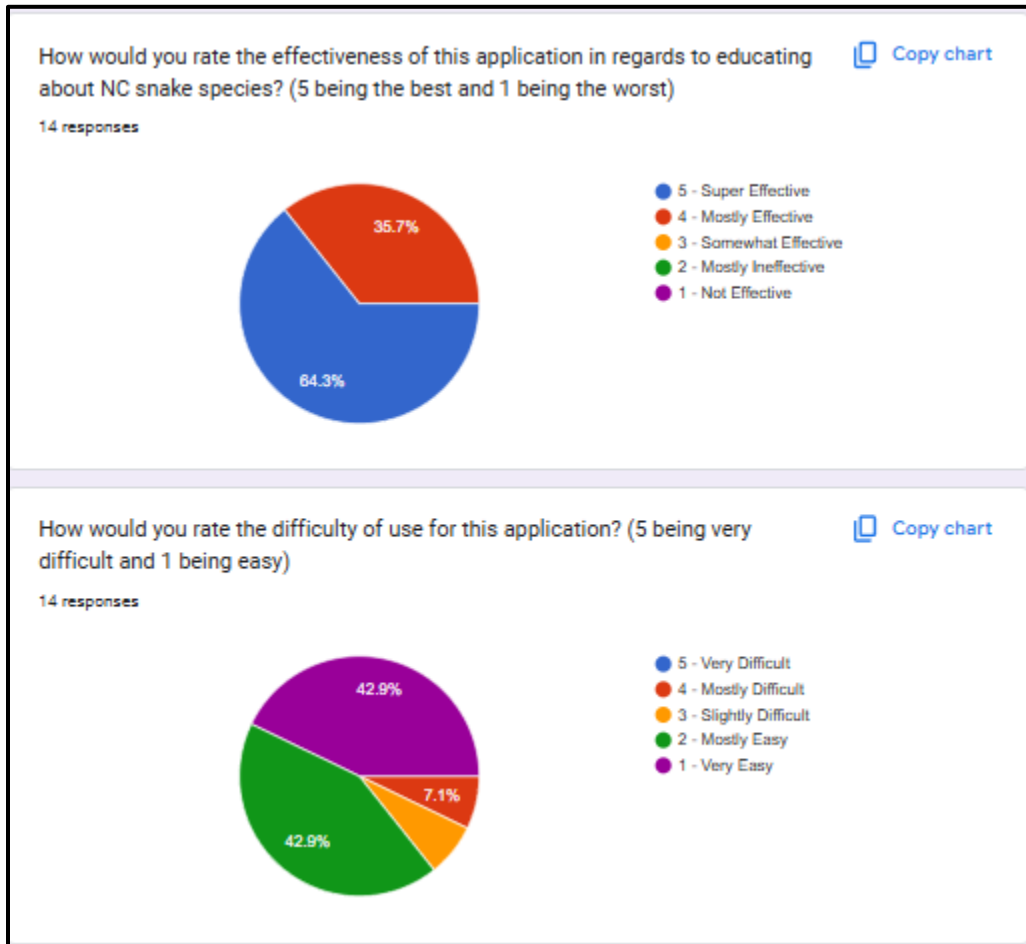


Figure 24: Post-Survey Results Part 1 - Screenshot of results for questions regarding the effectiveness and difficulty of the application.

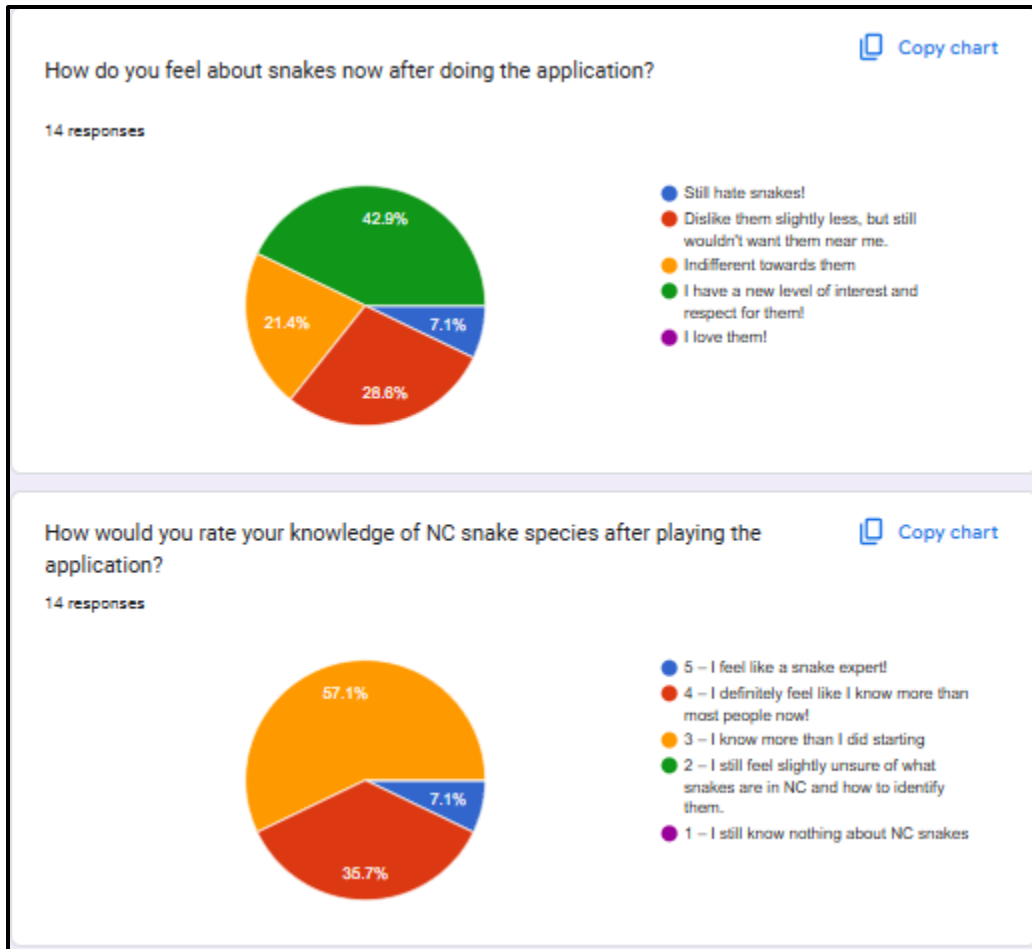


Figure 25: Post-Survey Results Part 2 - Screenshot of results for questions regarding the opinion and knowledge of snakes after playing the application.

#### 4.4 Empatica Embrace Plus Analysis

The Empatica Embrace Plus wrist sensor was used to monitor participants' heart rates throughout the study, beginning with the pre-survey and concluding at the end of the post-survey. Detailed results for each participant are provided in Table 1, labeled *Empatica Embrace Plus Heart Rate Results*.

On average, participants completed the study within 30 minutes to 1 hour. The pre and post surveys each took approximately 5 – 10 minutes to complete, while playing through all five

levels of the game required about 20 – 30 minutes. During the study, the Empatica Embrace Plus recorded participants' heart rates, and most did not experience significant spikes. Of the 14 participants, only 5 showed a heart rate increase of more than 20 BPM, which is considered a notable change for a resting heart rate.

Additionally, 12 of the 14 participants did not exhibit significant heart rate fluctuations by the end of the study, suggesting they felt comfortable viewing snake images and recalling what they had learned in the application to answer the post-survey questions. When these heart rate findings are compared to post-survey responses regarding participants' feelings toward snakes, it supports the conclusion that the application effectively helped participants manage their fear of snakes and positively influenced their perceptions of them.

Participant ID	Lowest Heart Rate (BPM)	Median Heart Rate (BPM)	Highest Heart Rate (BPM)	Difference in Heart Rate
1	57	76	93	36
2	66	81	100	34
3	76	88	105	29
4	71	78	85	14
5	64	67	73	9
6	76	82	89	17
7	72	75	81	9
8	69	74	81	12
9	81	84	90	9
10	60	73	90	30
11	61	67	77	16
12	68	72	76	8
13	75	82	86	11
14	61	75	86	24

Table 1: Empatica Embrace Plus Heart Rate Results - Table of low, median, high heart rates and the calculated difference (High HR - Low HR) for all 14 participants. Rows highlighted in purple indicate those who experienced a 20 BPM or greater difference in their heart rate.

## CHAPTER 5: CONCLUSIONS AND FUTURE WORK

### *5.1 Summary of Results*

This study aimed to answer two key questions: “Is Virtual Reality an effective tool for teaching people how to identify 5 North Carolina snake species?” and “Can Virtual Reality be used to help people form a positive perception of snakes?”. A literature review was conducted, examining mobile applications and quizzes focused on snake education as well as the use of VR for creating interactive games involving snakes. However, there remains limited research on using VR specifically to educate users on identifying different snake species.

The qualitative findings of the study revealed overwhelmingly positive attitudes toward the SnakeSavvy application. Quantitative results demonstrated that participants effectively learned to identify the five North Carolina snake species featured in the application and correctly answered questions about other important snake-related information on the post-survey.

The study’s findings highlight VR as an excellent tool for teaching snake identification and enhancing understanding and respect for snakes, regardless of a user’s prior knowledge. Furthermore, the results suggest that VR can help reduce fear and misconceptions about snakes, promoting knowledge-sharing and potentially decreasing unnecessary harm to these animals in the future.

### *5.2 Feedback*

The overall feedback for the SnakeSavvy application was positive, with most participants expressing interest and engagement while using it. Many found the application helpful and informative for learning about snakes and identifying them. A feature particularly appreciated

was the ability to pick up the snake models, which allowed participants to examine the snakes up close and in detail without the fear of being bitten.

However, participants noted some areas for improvement, including the lack of camera control, difficulty locating the snakes, and challenges with navigating the journal and the environment due to a lack of tutorials and ease of use buttons. During development, the pre-made rotate functionality for enhanced camera control was inadvertently broken. Unfortunately, I did not have time to debug and resolve this issue, but it is a priority if I continue developing the application.

Participants also provided valuable suggestions for improving the game, such as adding hissing sounds when approaching snakes, incorporating interactive elements like picking up other objects (like other VR games), refining camera controls and journal navigation for a more streamlined experience, and including additional snake species to enhance the application's educational scope. The responses to these questions in the post-survey are detailed in Appendix C.

### *5.3 Future Work*

The feedback from participants has been highly constructive, and I agree with the majority of their suggestions. Future improvements to the application will focus on several areas. First, I plan to fix the broken rotate functionality to enhance camera control. I will also work on reducing the resolution and rendering for environment assets, outside the snakes, to allow for a wireless and smooth gameplay experience on any VR headset. For the journal, I aim to add navigation buttons such as “Return to First Page” and tabs for easier access to specific species, eliminating the need to flip through pages sequentially.

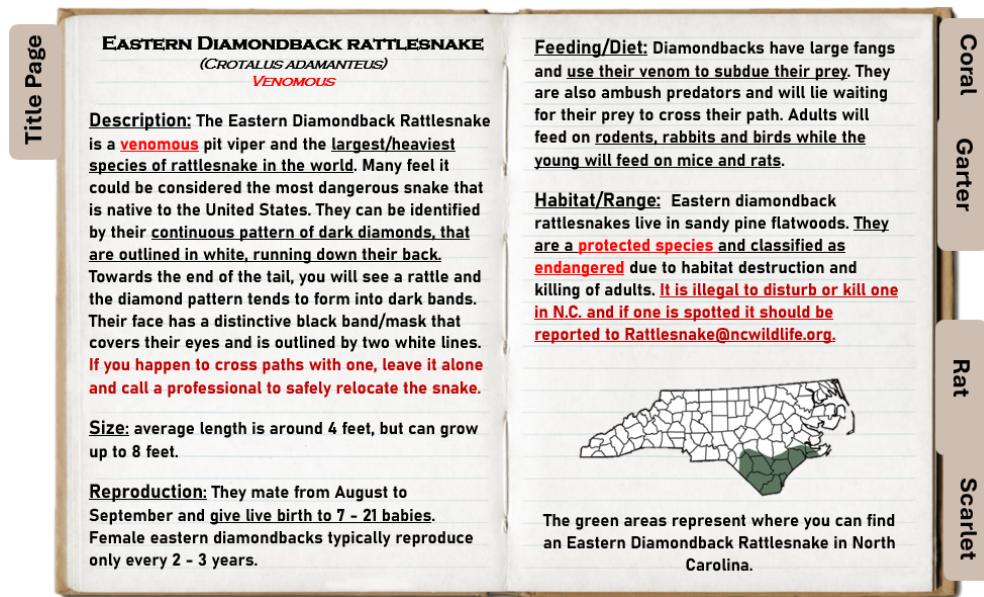


Figure 26: Journal With Tabs – Example image of a potential journal upgrade with tabs to quickly navigate to different pages for ease of use.

To improve user immersion, I will incorporate additional audio elements, such as ambient background noises like birds chirping or outdoor sounds, as well as snake-specific sounds like hissing or rattling. These auditory cues will not only enhance realism but also help users locate snakes and encourage caution around venomous species. Furthermore, I intend to add more snake animations, including natural movement patterns and defensive behaviors, to provide a realistic depiction of how snakes react when cornered or threatened. This will further educate users on snake behaviors and appropriate responses when encountering them.

Currently, the application includes only five snake species. I plan to expand this by learning how to create additional species using tools like Blender or Maya. I will collaborate with local snake experts, whom I've connected with through Facebook snake identification groups, to ensure each species is accurately represented. This expansion will also include variations in color, juvenile appearances, and pattern differences for certain species.

Another planned enhancement is the introduction of a tutorial that explains how to play the game. This tutorial will frame the user as part of a snake relocation team called to safely remove and relocate snakes from residential areas. This narrative will help refine the application into a more engaging game-like experience. Additionally, I will introduce a snake hook tool and bucket for handling venomous species and design new environments to reflect the typical habitats of each snake species in North Carolina. A disclaimer at the beginning of the application would also be a required addition to resolve any liability issues that could arise with user's attempting to handle venomous snakes on their own accord.

A few of my long-term goals are to expand the application beyond North Carolina to include snake species from across the United States and to recruit more participants to test the application. This would provide a broader educational opportunity for users to learn about snakes nationwide and see if the results in the initial study hold true for a larger study. Developing the application for a wider audience would be a significant achievement, as it has the potential to serve as an educational tool in museums, aquariums, schools, and other institutions. By fostering greater confidence, understanding, and respect for snakes, this application could help reduce misconceptions and promote coexistence with these important animals.

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## APPENDIX A

### Pre-Snake Savvy Quiz

**B** *I* U ↻ ✕

Form description

Participant ID \*

Short answer text

Select your gender

- Male
- Female
- Non-Binary
- Transgender

Select your race or ethnicity

- White
- Hispanic/Latino/Spanish
- Black/African American
- Asian/Asian Indian
- American Indian/Alaska Native
- Middle Eastern/Northern African
- Native Hawaiian/Pacific Islander
- Other

What is your age range? \*

- Under 18 years old
- 18 - 24 years old
- 25 - 34 years old
- 35 - 44 years old
- 45 - 54 years old
- 55 - 64 years old
- Above 64 years old

Have you ever experienced motion sickness, chronic nausea, migraines, balance issues, or any neurological disorders? \*

- Yes
- No

Do you have an extreme phobia of snakes?

Ex: Viewing an image of a snake causes you emotional distress?

**If you mark "Yes" please notify me and do not proceed to the next question.**

- Yes
- No

What is your experience level with using VR? \*

- Expert
- Intermediate
- Beginner
- No Experience

How would you rate your knowledge of NC snake species? \*

- 5 – I'm a snake expert and can identify any snake species in NC.
- 4 – I know more than most people.
- 3 – I know a decent amount but could definitely learn more!
- 2 – Eh, I could probably tell if it's venomous or not, but I do not know the species.
- 1 – I can't identify any snake species in NC.

How do you feel about snakes? \*

- I hate them! Get that thing away from me!!
- I'm fine with them as long as they keep their distance.
- Indifferent, they don't bother me.
- I like seeing them around!
- I love snakes! The more the merrier!

What is the name of this snake?



Multiple choice



- Swamp Snake ✕
- Rainbow Snake ✕
- Coral Snake ✓ ✕
- Glossy Crayfish Snake ✕
- I don't know ✕
- Add option or [add "Other"](#)

Answer key (1 point)



Required



What is the name of this snake? \*



- Mud snake
- Rat Snake
- Cottonmouth
- Brown Water Snake
- I don't know

What is the name of this snake? \*



- Scarlet Kingsnake
- Coral Snake
- Corn Snake
- Red Bellied Snake
- I don't know

What is the name of this snake? \*



- Garter Snake
- Pine Snake
- Ribbon Snake
- Pine Woods Snake
- I don't know

What is the name of this snake? \*



- Copperhead
- Timber Rattlesnake
- Diamondback Rattlesnake
- Cottonmouth
- I don't know

Out of these snakes, which one is venomous? \*

- Ring-Necked Snake
- Kingsnake
- Coral Snake
- Scarlet Snake
- I don't know

Do all snakes lay eggs? \*

- Yes
- No
- I don't know

Do all snakes in North Carolina lay eggs? \*

- Yes
- No
- I don't know

Can you use as little as 1 feature to identify a snake? Ex: Snake's pattern. \*

- Yes
- No
- I don't know

What is the largest species of rattlesnake in the world? \*

- Diamondback Rattlesnake
- Mojave Rattlesnake
- Cottonmouth
- Timber Rattlesnake
- I don't know

Which of these snakes is protected in North Carolina? \*

- Copperhead
- Queen Snake
- Coral Snake
- Coachwhip
- I don't know

By law, are you allowed to kill any/all venomous snake in North Carolina? \*

- Yes
- No
- I don't know

Do snakes play an important role in their ecosystem? \*

- Yes
- No
- I don't know

What should you do to humanely remove a venomous!!!! snake from your property? (Mark all that apply) \*

- Call animal control
- Contact a local snake expert
- Get your dog to attack it
- Call a pest control company
- Ask a friend or family member to help you remove it

What is the furthest distance you should relocate a snake? \*

- No more than half a mile
- At least 1 mile
- At least 5 miles
- At least 15 miles
- Over 20 miles
- I don't know

What is the most effective method for deterring snakes from your property? \*

- Moth balls
- "Snake Away" snake deterrent
- Teach your pets to chase them away
- Remove debris
- Install electric line around your fence
- All of the above
- None of the above

What is one key characteristic used to identify a scarlet kingsnake? \*

- Coffin shaped head with well defined irises.
- Body band pattern of red, yellow, black, yellow, red
- Body band pattern of red, black, yellow, black, red
- No pattern, solid deep crimson red in color.
- I don't know

What is one key characteristic used to identify an Eastern Diamondback rattlesnake? \*

- Continuous pattern of light diamonds outlined in black down their back
- Rattle at the end of the tail
- Continuous pattern of dark diamonds outlined in white down their back
- Vertical / slit shaped pupils
- I don't know

What is one key characteristic used to identify an Eastern Coral snake? \*

- Body band pattern of red, black, yellow, black, red
- Continuous pattern of light diamonds outlined in black down their back
- No pattern, round red head / snout
- Body band pattern of red, yellow, black, yellow, red
- I don't know

...

What is one key characteristic used to identify an Eastern Garter snake? \*

- Body band pattern of red, yellow, black, yellow, red
- Dark checkerboard pattern with stripes along the sides.
- Solid black with a white underbelly
- Green body with thin white and black stripes running along each side.
- I don't know

What is one key characteristic used to identify a rat snake? \*

- Dark checkerboard pattern with stripes along the sides.
- Coffin shaped head with well defined irises.
- Solid black with a white underbelly
- Body band pattern of red, yellow, black, yellow, red
- I don't know

Which of these is the most useful in assisting with identifying a snake? \*

- Location
- Size
- Color
- Eye / Pupil Shape
- Head Shape
- I don't know

If you see a triangular head and slit eyes on a snake can you assume you are looking at a venomous one? \*

- Yes
- No
- I don't know

## APPENDIX B

### Post-Snake Savvy Quiz

**B** *I* U  

Form description

Participant ID \*

Short answer text

What is the name of this snake? \*



- Swamp Snake
- Rainbow Snake
- Coral Snake
- Glossy Crayfish Snake
- I don't know

What is the name of this snake? \*



- Mud snake
- Rat Snake
- Cottonmouth
- Brown Water Snake
- I don't know

What is the name of this snake?



- Scarlet Kingsnake
- Coral Snake
- Corn Snake
- Red Bellied Snake
- I don't know

What is the name of this snake? \*



- Garter Snake
- Pine Snake
- Ribbon Snake
- Pine Woods Snake
- I don't know

What is the name of this snake? \*



- Copperhead
- Timber Rattlesnake
- Diamondback Rattlesnake
- Cottonmouth
- I don't know

Out of these snakes, which one is venomous? \*

- Ring-Necked Snake
- Kingsnake
- Coral Snake
- Scarlet Snake
- I don't know

Do all snakes lay eggs? \*

- Yes
- No
- I don't know

Do all snakes in North Carolina lay eggs? \*

- Yes
- No
- I don't know

Can you use as little as 1 feature to identify a snake? Ex: Snake's pattern. \*

- Yes
- No
- I don't know

What is the largest species of rattlesnake in the world? \*

- Diamondback Rattlesnake
- Mojave Rattlesnake
- Cottonmouth
- Timber Rattlesnake
- I don't know

Which of these snakes is protected in North Carolina? \*

- Copperhead
- Queen Snake
- Coral Snake
- Coachwhip
- I don't know

By law, are you allowed to kill any/all venomous snake in North Carolina? \*

- Yes
- No
- I don't know

Do snakes play an important role in their ecosystem? \*

- Yes
- No
- I don't know

What should you do to humanely remove a venomous!!!! snake from your property? \*

- Call animal control
- Contact a local snake expert
- Get your dog to attack it
- Call a pest control company
- Ask a friend or family member to help you remove it

What is the furthest distance you should relocate a snake? \*

- No more than half a mile
- At least 1 mile
- At least 5 miles
- At least 15 miles
- Over 20 miles
- I don't know

What is the most effective method for deterring snakes from your property? \*

- Moth balls
- "Snake Away" snake deterrent
- Teach your pets to chase them away
- Remove debris
- Install electric line around your fence
- All of the above
- None of the above

What is one key characteristic used to identify a scarlet kingsnake? \*

- Rattle at the end of the tail
- Body band pattern of red, yellow, black, yellow, red
- Body band pattern of red, black, yellow, black, red
- No pattern, solid deep crimson red in color.
- I don't know

What is one key characteristic used to identify an Eastern Diamondback rattlesnake? \*

- Continuous pattern of light diamonds outlined in black down their back
- Rattle at the end of the tail
- Continuous pattern of dark diamonds outlined in white down their back
- Vertical / slit shaped pupils
- I don't know

What is one key characteristic used to identify an Eastern Coral snake? \*

- Body band pattern of red, black, yellow, black, red
- Continuous pattern of light diamonds outlined in black down their back
- No pattern, round red head / snout
- Body band pattern of red, yellow, black, yellow, red
- I don't know

What is one key characteristic used to identify an Eastern Garter snake? \*

- Body band pattern of red, yellow, black, yellow, red
- Dark checkerboard pattern with stripes along the sides.
- Solid black with a white underbelly
- Green body with thin white and black stripes running along each side.
- I don't know

What is one key characteristic used to identify a rat snake?

- Dark checkerboard pattern with stripes along the sides.
- Coffin shaped head with well defined irises.
- Solid black with a white underbelly
- Body band pattern of red, yellow, black, yellow, red
- I don't know

Which of these is the most useful in assisting with identifying a snake? \*

- Location
- Size
- Color
- Eye / Pupil Shape
- Head Shape
- I don't know

If you see a triangular head and slit eyes on a snake can you assume you are looking at a venomous one? \*

- Yes
- No
- I don't know

How would you rate the effectiveness of this application in regards to educating about NC snake species? (5 being the best and 1 being the worst)

- 5 - Super Effective
- 4 - Mostly Effective
- 3 - Somewhat Effective
- 2 - Mostly Ineffective
- 1 - Not Effective

How would you rate the difficulty of use for this application? (5 being very difficult and 1 being easy)

- 5 - Very Difficult
- 4 - Mostly Difficult
- 3 - Slightly Difficult
- 2 - Mostly Easy
- 1 - Very Easy

How do you feel about snakes now after doing the application? \*

- Still hate snakes!
- Dislike them slightly less, but still wouldn't want them near me.
- Indifferent towards them
- I have a new level of interest and respect for them!
- I love them!

How would you rate your knowledge of NC snake species after playing the application? \*

- 5 - I feel like a snake expert!
- 4 - I definitely feel like I know more than most people now!
- 3 - I know more than I did starting
- 2 - I still feel slightly unsure of what snakes are in NC and how to identify them.
- 1 - I still know nothing about NC snakes

What are your general thoughts for this application? \*

Long answer text

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What did you like most about the application? \*

Long answer text

What did you like least about the application? \*

Long answer text

What would you change about this application? \*

Long answer text

## APPENDIX C

Participant ID	Response to question: "What are your general thoughts for this application?"
1	"Fun! I like snake going mlem."
2	"I thought this was a great experience. It was really cool that the snakes were so detailed and that you could hold them up and see their patterns. I loved the journal style and that it had a built in quiz so that you could guess what snake you just learned about."
3	"Provided a visual example of where one may run into certain snakes. The visual interactive aspect does more to teach someone about the snakes than just simply reading about them."
4	"excellent learning application."
5	"I found this to be very helpful and very easy to learn this way."
6	"This was a really fun way to learn about different snake species and the importance of using multiple characteristics to identify them. The addition of custom assets & increased interactivity would make this app viable for use in conservation centers (i.e. NC Aquariums)"
7	"Great Application!"
8	"Super cool to be able to look at one and look at references at the same time."
9	"The application is informative and interactive enough that it encouraged me to explore the appearance of the snakes and attempt to learn more about them. The locales where the snakes were found were not as intuitive as you'd think: for example, I expected to find snakes in the flower bed and in the pile of branches/leaves, but none were found in those locations. The information book/menu was easily accessible and navigable but lacked convenience such as a 'Back to Front Page' button or a side menu to click/jump to a particular section. The literature presented was enough to not bore you or keep you wanting more information."
10	"very cool way to see snakes without the fear of them, and educating on how to identify different kinds and where they would be."
11	"Love the use of VR to perform education."
12	"easy to navigate and images of snakes were good."
13	"It is neat and effective at showing snakes and where you might find them. The graphics were also pretty realistic."
14	"Very fun and educational!"

Responses to the question: "What are your general thoughts for this application?" from the post-survey for each participant.

Participant ID	Response to question: "What did you like most about the application?"
1	"The snake going mlem."
2	"I liked that you could pick the snake up and examine the snake up close!"
3	"The vr aspect."
4	"being able to hold the snakes close and look at them."
5	"I like the interactivity of the this."
6	"Getting to closely examine the snakes - their animations were a plus with the little tongue sticking out!"
7	"The models and the descriptions associated with them."
8	"Getting to look at all parts of the snake close up."
9	"The ability to hold and explore each snake."
10	"how interactive it was, how it showed example pictures and important information about each kind."
11	"Tying the process of learning new information into a gamified setting. Most people love games and this provides an easy way to disseminate information to those people."
12	"navigating the yard and finding snakes in hidden places."
13	"You can pick up and rotate the snake around to see how it looks from whatever angle. Moving around was easy."
14	"Learning more about the differences between 2 similar snakes (coral & kingsnake)"

Responses to the question: "What did you like most about the application?" from the post-survey for each participant.

Participant ID	Response to question: "What did you like least about the application?"
1	"Can't pick things up."
2	"I can't think of anything I really didn't like about the application. I thought that the concept of finding the snake was fun and it was nice that you could move around and bring the journal with you anywhere!"
3	"lack of camera control."
4	"cant move your position around with the left joystick."
5	"I didn't find anything bad about it."
6	"There were several controls I had to learn on the fly - an introductory period at the beginning of the app on how to move around would be helpful. If implemented, it should be skippable for experience VR users."
7	"I'm not great at finding things lol."
8	"Lots of places the snake could be hiding."
9	"Graphics were okay."
10	"i'm bad at finding the snakes (was still fun looking)"
11	"Character model did not rotate with the controller."
12	"no sound and no backward/side-to-side walking"
13	"Pressing buttons in the UI was difficult and I had trouble remembering the controls, but that last part may just be me."
14	"Not related to the application - i just get motion sick."

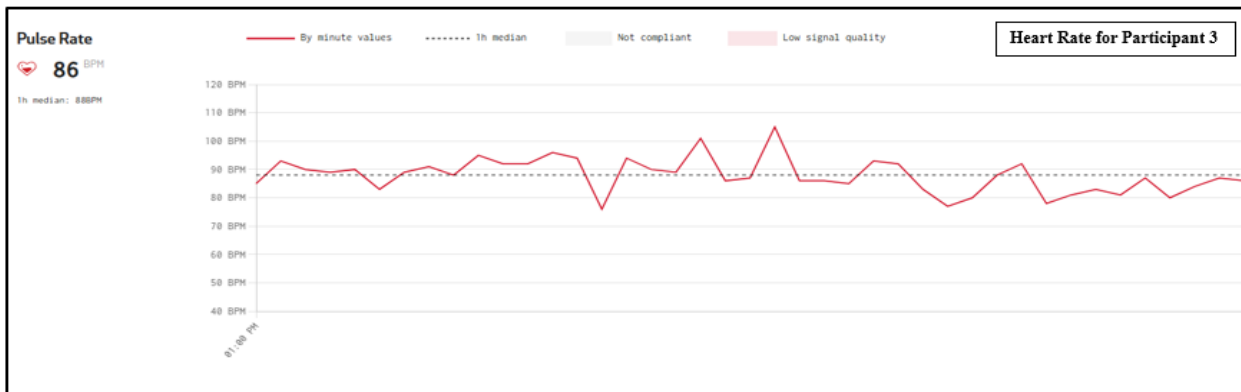
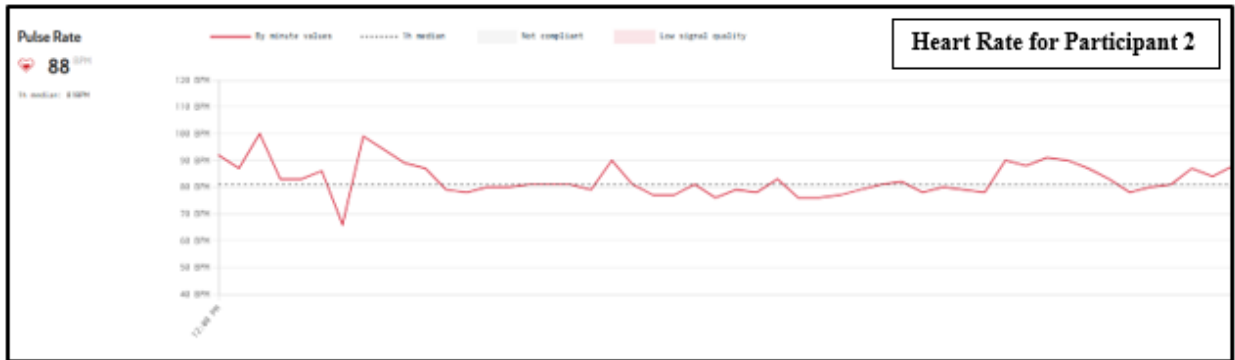
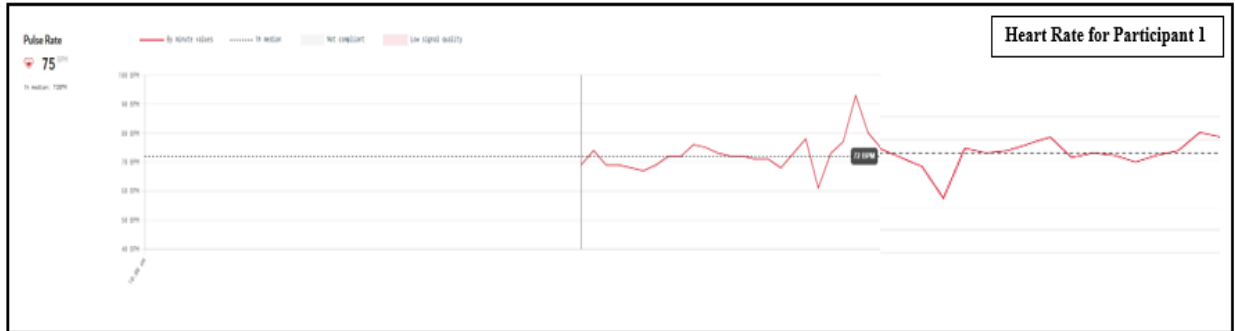
Responses to the question: "What did you like least about the application?" from the post-survey for each participant.

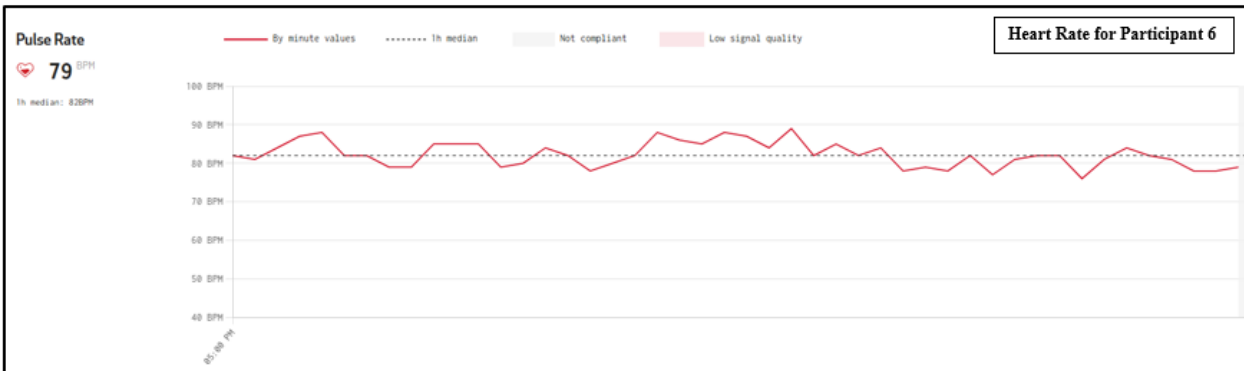
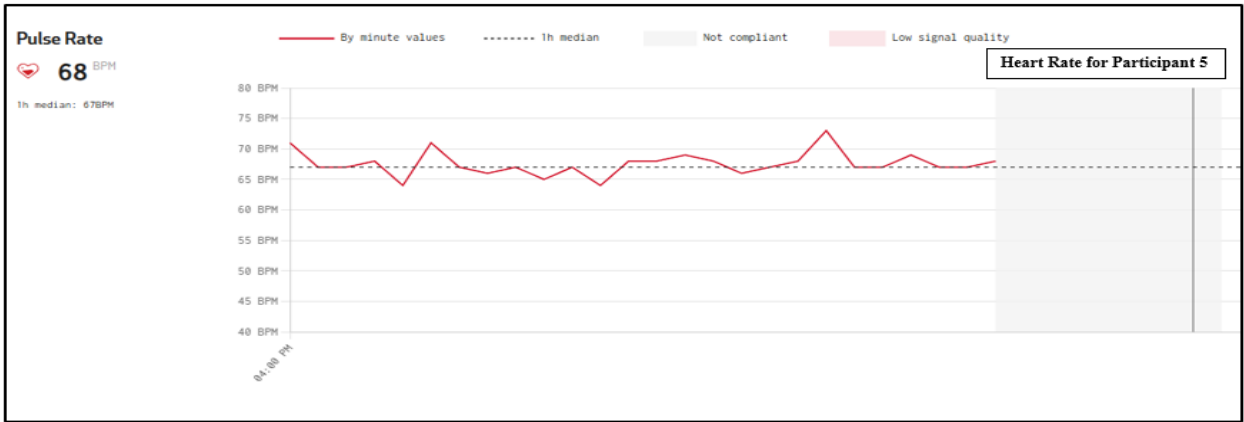
Participant ID	Response to question: "What would you change about this application?"
1	"Put general information at front, in instructions give general identification instructions to look for in each description of snake."
2	"There isn't something that I would necessarily change, but I would love to see more species to interact and learn about in the future."
3	"camera control and snake noises!"
4	"being able to turn with the left joystick so I don't have to rotate my body to go a different direction"
5	"Nothing really."
6	"The addition of hissing noises as you get closer would be cool!"
7	"Maybe a section with multiple snakes to have a closer up reference (coral and king next to each other), etc."
8	"Smaller backyard."
9	"A side menu for ease/faster browsing and more intuitive (easier to find snakes)."
10	"would be hard for older people/people not interested in VR, but that won't apply to people wanting to use it for knowledge purposes!"
11	"Perhaps when selecting each level you are told which type of snake you are trying to find. Since most people will know little to nothing about each species, presenting a picture may help show what you are seeking for."
12	"Some sound as you get closer to snake and being able to walk backwards or sideways"
13	"The layout of the popup guide was slightly annoying in having to hit forward/back to get to different species. I would maybe change how you interact with the guide to chose snakes and then more information about them. Also probably a separate section for the general information."
14	"add more snakes!"

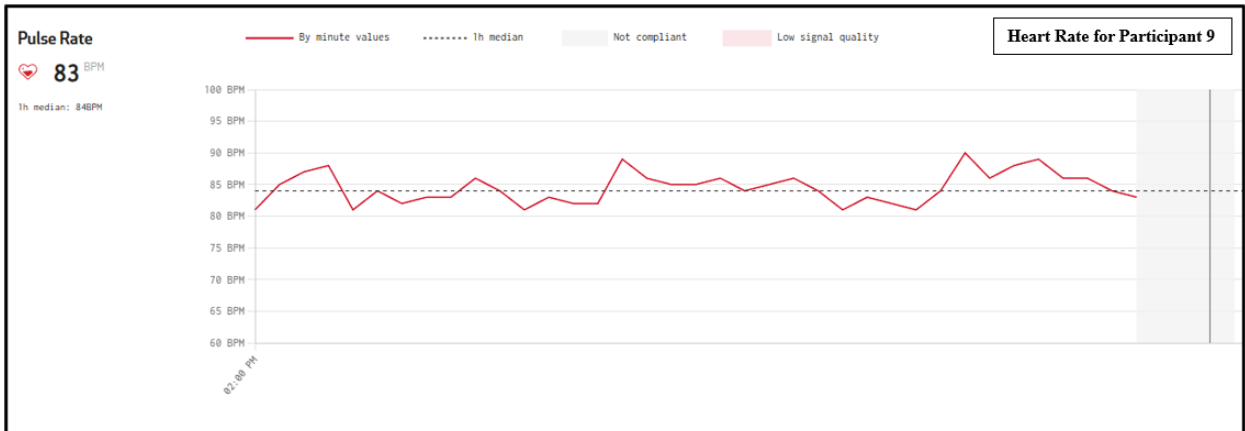
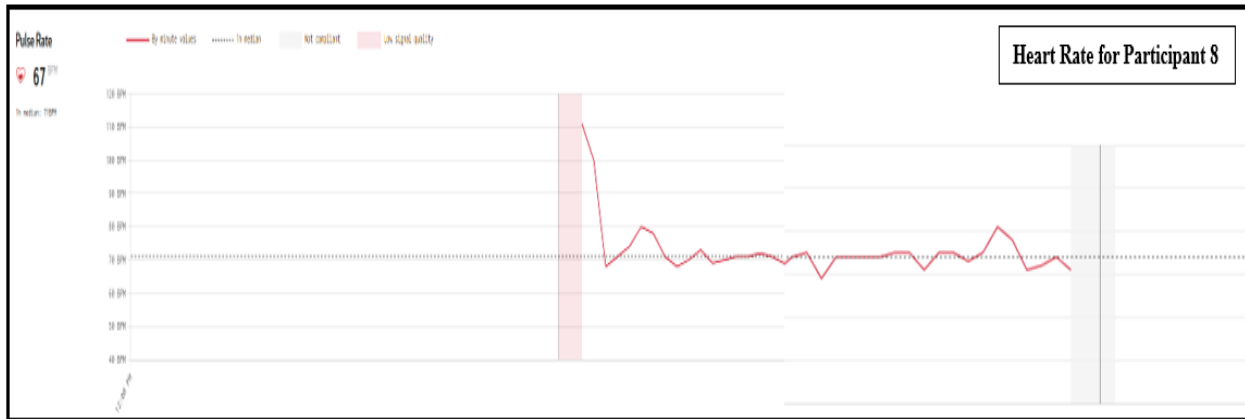
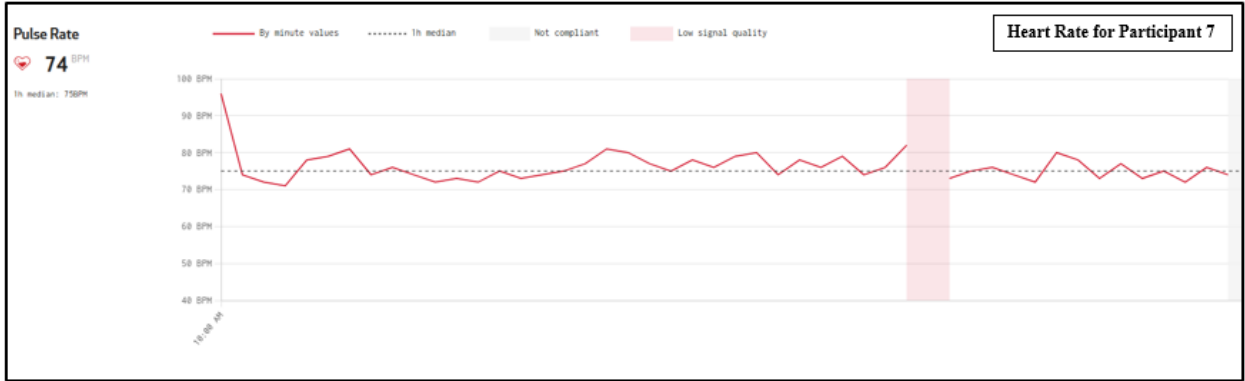
Responses to the question:" What would you change about this application?" from the post-survey for each participant.

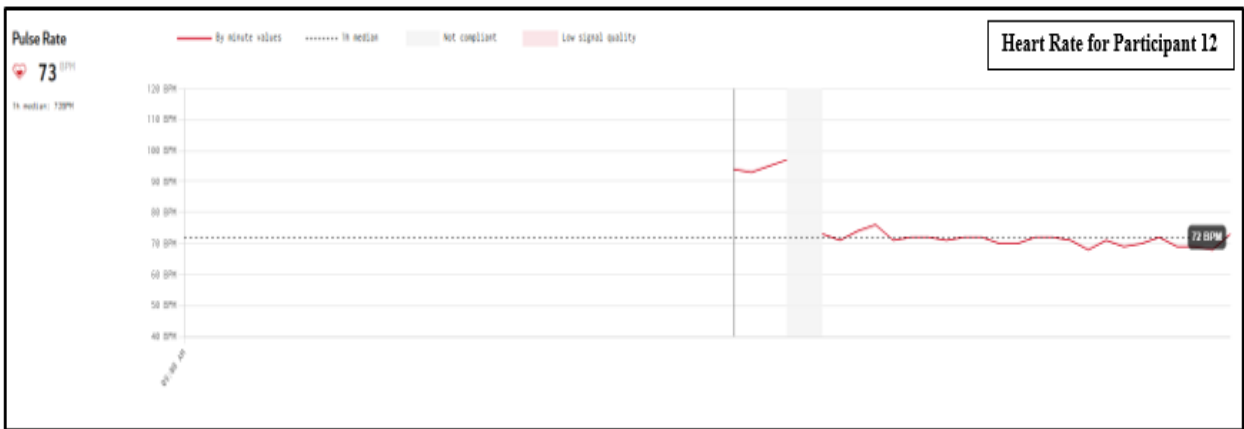
## APPENDIX D

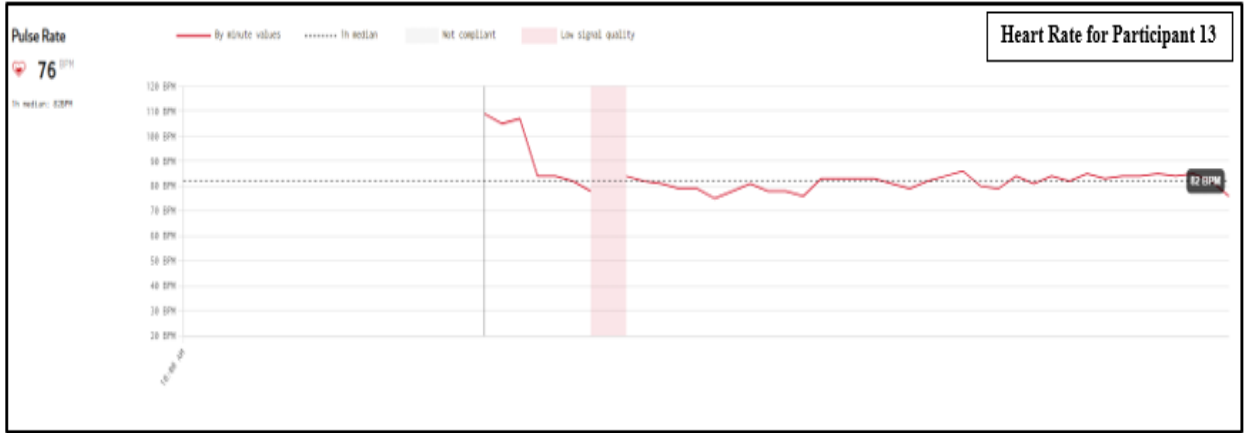
The Empatica Embrace sensor takes roughly 3-5 minutes to calibrate. To save time for testing, I calibrated the sensor on myself in between participants so it was ready when they arrived. Due to this, the data points at the beginning of some participant's charts contained my data. When analyzing each chart, if I noticed a beginning heart rate of over 100 that quickly dropped down over 20 BPM, I assumed those were my vitals and they were ignored when looking at the high, median, and low heart rates for each participant.











## TIMELINE

**April 2024:** I started the creation of the backyard environment in Unreal Engine. I treated it as a first-person game until I got a VR headset to test with. I used Quixel Bridge to locate free megascan assets of different foliage that I used to add grass to the level. I used the built-in landscaping tools to add some small hills and dips in the ground, so it had variation like normal backyards. I did some research on where I could find free assets to place in the level and found that Unreal Engine's store had multiple options to choose from. I created the main menu level for the game and a pause menu (decided not to use it later on). I put together a PowerPoint presentation that included chapters 1-3 of my paper. I proposed my project on April 25<sup>th</sup> at 2:30.

**May 2024:** I continued adding assets to the backyard environment. I looked at videos on how to create the journal widget. I gathered information and pictures about the snake species I would be using in my game, so I had them for the journal. I set up functionality for the main menu to enter a level when the start game button was pressed.

**June 2024:** I picked up the VR headset. I started creating the journal widget in Word and added text and pictures for each snake species. I found free button images to use for the next, previous and submit buttons. I set up functionality for opening and closing the journal in desktop mode.

**July 2024:** I worked on getting the journal widget to work in VR: opening/closing, next and previous button to turn the pages, checkboxes, and submit button. I set up the Empatica Embrace Plus and did some testing with it on myself to understand how the data gets logged into the Empatica Care website.

**August 2024:** I continued to work on getting the journal widget to work in VR. I updated all deprecated input actions to use the new Enhanced input actions that were created by Unreal Engine. I added more assets to the level to make it more realistic.

**September 2024:** I worked on adding functionality to pick up the snake models and keep them stationary in the air so they can be viewed while the journal was open. I duplicated the main level 5 times so I could create a level for each snake model to be hidden in. I continued researching how to get the journal widget to work in VR.

**October 2024:** I finished functionality for getting the journal widget to work in VR and be interactable. I added functionality to have the journal appear in front of the user regardless of where they were in the level. I updated the main menu to have a button to play each level instead of having it randomized and added functionality to the buttons, so they drop you in the correct level. I created the correct/incorrect identification screen widgets for the game and added functionality for them to appear in the level when the correct or incorrect checkbox on the journal was selected. I updated the journal widget to add more pages so less text was on each page and pictures of the snakes could be on their own page.

**November 2024:** I completed functionality for picking up snake models. I fixed bugs with the journal widget, main menu and correct/incorrect identification screens. I conducted testing for my application at nCino and processed all the data from the Empatica sensor and the surveys. I revised chapters 1-3 of my paper and added chapters 4 and 5, which included the outline of the completed project, my results, my conclusions, and future work I have planned for the project. I added photos of my pre and post survey to the paper and tables of the participants responses to the short answer questions at the end of my post-survey.

**December 2024:** I revised my final paper, added references and pictures of the Empatica Embrace Plus heart rate results. I updated my PowerPoint. I defended my capstone project on December 3<sup>rd</sup> at 11:00 am.