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The Nano-Adventures of Gold and Silver: an iOS Game

Elizabeth Pruett

Director of Thesis: Dr. Jose Vidal
Second Reader: Dr. Jamie Lead

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THESIS PROJECT SUMMARY

The *Nano-Adventures of Gold and Silver* is an iOS game intended for young students to learn about nanoscience and the benefits and harms of various nanoparticles in the environment, originally created by the Center for Environmental Nanoscience and Risk. This project exists as the first iteration of a game about two superheroes, Nano-Gold and Nano-Silver, who invite players along as they use their powers to deal with different scenarios. Over the course of a year, the game was designed, developed, and tested; the resulting application includes user authentication capabilities, an origin story detailing the Nano-Girls narrative, and a complete level, including a lesson, tutorial, mini-game, and quiz.

INTRODUCTION

Nanoscience deals with particles and materials on a scale smaller than what is visible to the naked eye, specifically 1-100 nanometers [1]. At the University of South Carolina, researchers with the Center for Environmental Nanoscience and Risk (CENR) work to study how nanoparticles, both manufactured and naturally occurring, interact with the environment and affect human health. In addition, the CENR explores how nanoparticles can be specifically developed for use in medicine, pollution cleanup, and more.

Despite the breadth of applications for nanoscience, the field itself is relatively new. As part of an outreach effort to educate more people on nanoscience and encourage youth to become involved, the CENR partnered with the EdVenture Children's Museum [2]. Two doctoral students, Shelby Butz and Samantha McNeal, created the *Nano-Girl* superheroes: two scientists who have the ability to shrink to the size of nanoparticles. Butz and McNeal traveled to EdVenture dressed as these characters to teach children about nanoscience and measure students' learning on the subject. While this program was quite successful, it required participants to travel to Columbia and attend the museum sessions. Part of outreach involves bringing learning to classrooms, and the

CENR wants to ensure that the Nano-Girls' adventures are accessible to even more people. Thus, the idea for the Nano-Girls mobile application was born.

As opposed to live interactive sessions which require scheduling and traveling, mobile games are portable, and available at any time of day. They are also incredibly popular. Approximately 64% of American adults, and 85% of young adults own a smart phone [3]. More and more classrooms are receiving funding to purchase iPads for student and teacher use. Studies have shown that, when used properly, tablets are a dynamic tool that can keep students engaged and entertained at their own individual paces [4].

In person, gathering information about the students' experiences, enthusiasm, and retention is time-consuming. The use of a mobile application will allow the CENR to further monitor student learning; through built-in quizzes and mini-game scores, a mobile application can send user gameplay data back to the teachers and CENR. Students can provide feedback without ever leaving the game. By extending the Nano-Girls narrative to mobile devices, the CENR can expand their outreach efforts for little to no cost.

The CENR reached out to the College of Computing and Engineering to recruit senior students to work on the Nano-Girls application and create an initial prototype.

ORIGINAL DESIGN

To begin design of the application, the CENR had several basic requirements. The application needed to: follow the narrative of superheroes Nano-Gold and Nano-Silver; be separated into different levels with scenarios involving nanoparticles (oil spills, algae, etc.); include mini-games with each level; and track players' learning and retention through each level. Additionally, due to the superhero nature of the characters, the game needed a comic-like aesthetic.

The original designs, explained in detail below, were created with an application mock-up software called Justinmind.

Color Scheme

To reflect the design of the main characters, the color scheme of the game needed to include gold and silver. However, most video games for children include bright, bold colors; comic books, too, often utilize strong contrasting color schemes. The team chose to use five main colors: the three primary colors (red, yellow, and blue), as well as purple and green for contrast (Figure 1). The colors gold and silver would be used specifically for the characters, to emphasize the different molecular symbols for Gold (Au) and Silver (Ag). The basic background of each page of the game would gradient from blue to purple, against which speech bubbles, characters, and buttons would appear bright in comparison.

Figure 1: Original game color scheme

User Authentication

The Nano-Girls application is primarily intended for use in classrooms, on school-owned iPads. Due to this fact, it was important to design an application that would verify the player's identity (to make sure students could not play for other students), and also keep student information private. By password-protecting the game, student information could be separated and protected, and teachers could control how the game is used in their classrooms. Additionally, having user information stored on the internet, rather than locally on a device, would allow players to store their gameplay information across devices (for example, if one wished to play the game at home on a parent's device, all of the previous gameplay scores would be available).

Following basic game design protocol, the application opens to a Home Page (Figure 2), which includes the game logo, a "login" button for logging in with existing account information, and an "about" button to help the user with navigation, how-to-play instructions, and information about the game creators. Several of the colors from the initial color scheme were used. The original game logo mock-up, shown at the top of the *Home* page, was intended to resemble action bubbles from classic comic book art (Figure 2).


Figure 2: Home Page mock-up

The two fonts used, *Adventure Hollow* (game logo) and *CrimeFighter BB* (buttons, text throughout game) were also chosen to resemble a comic book.

Upon clicking the login button, a page would appear where the player could enter a username and password (Figure 3). Because the Nano-Girls game is aimed primarily at younger students, the buttons needed to be larger and easy to click. The same font was chosen for consistency throughout the game.

Character Narrative

As previously mentioned, the Nano-Girls were already established characters played by Shelby Butz and Samantha McNeal, so the game characters Nano-Gold and Nano-Silver were modeled after the two graduate students. Their features, personalities, and general storyline already existed; however, these needed to be incorporated into the game in a way that would introduce a new audience, unfamiliar with the CENR, to the story. Thus, we created the idea of an "origin story," which would appear whenever someone started a new game. To match the established aesthetic, the original design presented the Nano-Girls' origin story as a page in a comic book (Figure 3).
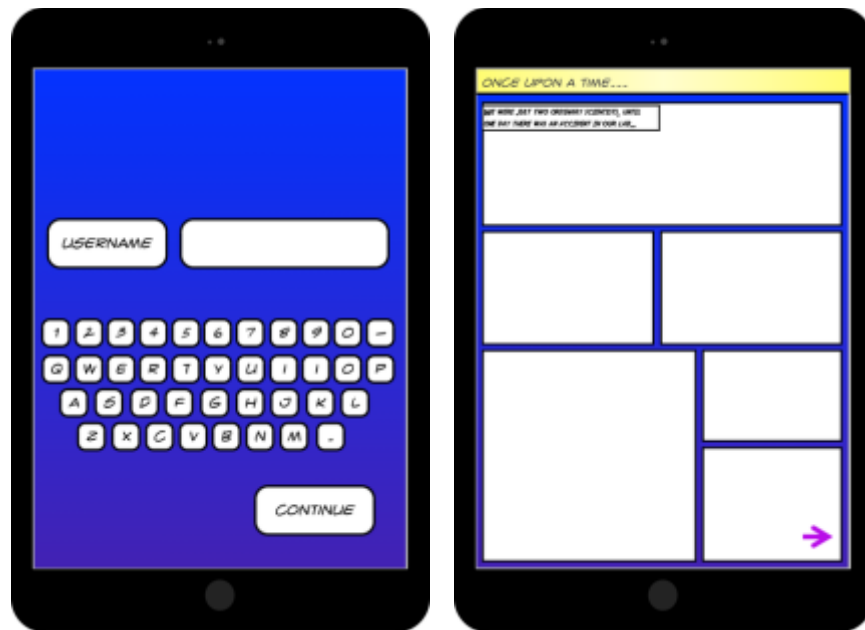
Figure 3: Login Page and Origin Story Page

Each panel of the origin story page would be clickable, so that players could enlarge the image and zoom in on the art. Players would have the option to view the entire comic page at once, or flip through each panel one at a time. The narration of how the two characters became

superheroes would appear in boxes above the art. An arrow, present at the lower right-hand corner of the screen, would allow players to navigate to the next page.

So as not to force players to read the same content repeatedly, the origin story page would no longer appear once it was read through. However, a button directing players back to the story would appear on the *Home* page if they ever wished to reread it.

Game Levels and Nanoscience Scenarios

The game was split into multiple levels, each consisting of a scenario involving nanoscience, a dilemma that needed to be solved (essentially, a task for the player to complete), a mini-game, and a small quiz that would test the player's retention of the facts presented in that level. Having a set layout for each level like this would allow for reusability within the code, where the same pages could be used for different levels simply by replacing the text and images. Additionally, each level would become progressively more difficult, and would require knowledge from previous levels.

At the beginning of each level, one of the Nano-Girl characters would appear on the screen with a speech bubble conveying her dialogue. She would greet the player, and then explain the level's scenario. For example, in Figure 4, the character would explain that she and her friends were on a hiking trip, but the drinking water was contaminated with bacteria. She then explains the level's key fact: Silver nanoparticles can be used to fight bacteria in drinking water. The player must complete a mini-game in which they use this knowledge to help clean the drinking water, by quickly "popping" bacteria as it appears on the screen.

The CENR clients stressed that the game mechanics should mimic real-life scenarios as much as possible. For example, in a game with free-moving a organism that can consume harmful

or beneficial nutrients, coming into contact with the harmful nanoparticles should cause the organism to slow down, and touching the beneficial nutrients should cause it to speed back up. In the game shown in Figure 4, the user would choose which nanoparticle to drop onto the bacteria in order to clean the water. For each mini-game, the player would need to accumulate a certain number of points in order to move on past the game; otherwise, the game would restart, allowing the player to try again.

Figure 4: Mock-up of first level (lesson, game, quiz)

After completing a level, a small *Quiz* page would appear on the screen. Usually a one- or two-question quiz, the material would relate to what the player was taught during that level. To keep the game somewhat interactive, one of the Nano-Girls would ask the question, and the player could select one of the answers. If incorrect, the player would be able to try again. Whether a player got the question correct or not on the first try would be logged within their account, so that the CENR and teachers could monitor student retention.

TECHNOLOGY

Although a mobile game for multiple operating systems would reach the largest audience, the CENR decided to begin with a game for iOS, specifically for iPads. iOS is the operating system for all Apple devices, and Apple provides a free software called Xcode on which developers can create their own applications. Xcode has two main methods to build an application: via a "Storyboard," which includes drag-and-drop functionality so that users can view and edit all of the pages and layout of their application, and via the code itself, so that users can write the application programmatically. Combining the Storyboard and code best fit the needs of this project, as this method allowed for general setup of the layout and then specific programming for functions like user authentication and individual game elements.

Another benefit of using Xcode was its simulator capabilities. Instead of requiring a physical device on which to test the application, Xcode provides a built-in simulator for testing one application on multiple devices (nine different iPhones, and five different iPads). This is especially important when making sure an application fits onto different screen sizes.

iOS applications are almost always either written in Objective-C or Swift. While Objective-C is an older programming language and thus has more published resources, Swift is Apple's newer programming language. The team decided to use Swift for the purposes of this project because Apple seems to be moving in the direction of Swift (and thus, for undergraduates, it is a more desirable skill to have moving into the workforce) and because it is specifically designed for simplicity and ease of writing. A piece of code that might require ten lines of Objective-C can achieve the same goal in only a few lines when written in Swift.

In order for everyone on the team to work on the same code simultaneously, a code repository was created on Github, an online code repository. This repository allowed each team member to have a "branch" of the code, where one could make individual changes, and then push

their changes to a default branch that would serve as the full version of the code. Github automatically checks for conflicts when merging different sections of code, so as to avoid causing errors creating by overwriting. The Wiki feature on Github also allowed team members to post weekly logs and store meeting notes, and the Issues feature allowed those testing the application to indicate bugs or other suggestions for the game to their teammates.

For user authentication, particularly regarding students, it was important to choose a platform that was reliable and secure. Thus, Firebase, a mobile and web application platform acquired by Google, was chosen to store user data and sync that data across multiple devices.

PROCESS

The process of creating the Nano-Girls application began in September of 2016, when the initial team came together. Over the course of two semesters, the team learned the basics of creating iOS applications, designed the initial game, met with clients from the CENR, and worked to produce the first prototype. Throughout the year, milestones were used to mark important deadlines.

Research

Due to the team's unfamiliarity with iOS programming, the project began with research into the basic tools and terminology involved. Everyone installed Xcode onto their respective devices, and began following tutorials for creating very simple iOS applications. Practicing these skills beforehand prepared the team to create a more complex application.

Descriptions and Rough Design

At the first meeting with the clients at the CENR, the team discussed the basic goals for the application. In general, the game was intended to be a fun way to teach students about

nanoscience, and get them interested in the field, while allowing the CENR to monitor their progress. The next week, the team met to sketch out a rough design for the game on paper. The sketch included the basic home page, introductory narrative, levels, and mini-games. This sketch would later become the initial design mock-up discussed above; said designs were finalized in December of 2016.

Requirements Document

In addition to designing the aesthetics of the game, the team needed to produce a document specifying exactly which features the software would implement; this document would outline the specific goals for the rest of the year. Within this list, certain features were designated as requirements for the first prototype to be completed in December. These technical requirements were as follows (prototype requirements indicated with a (P)):

1. Display loading screen (P)
2. Display help screen (P)
3. Display home page (P)
4. Teacher can log-in (P)
5. Teacher can add students to their class list (P)
6. Student can log-in (P)
7. Display origin story comic (P)
8. Origin story displays only once for each new game (P)
9. Display level 1 narration (P)
10. Run tutorial mini-game (P)
11. Run complete mini-game with sound
12. Keep track of players' running score
13. Display review question with multiple choice options
14. Everyone in team can run the app locally and complete level 1
15. Send students to next level if they answer quiz correctly

16. Display level 2 storyline

17. Display mini-game for level 2

18. Display review question for level 2

Release Candidate 1 and Testing

The Release Candidate 1 (RC1), completed in early April, was the first semi-official release of the application. The RC1 acted as the draft version of what would become the finalized project. This version of the application implemented the majority of the features that would be included in the final project. The senior project advisor and members from another team tested the application and submitted issues on the team's Github.

Once the application was tested by others, the Nano-Girls team needed to review the issues and fix the existing bugs. After all of the errors and other comments were resolved, the application was ready for official release.

Overall Process

Throughout both semesters, team members worked individually and together to complete the application. Following a divide-and-conquer strategy, each teammate assigned themselves different tasks – for example, one person worked on user authentication and login, while another worked on art, and another worked on game mechanics – and then contributed their portion of the code to the overall project. Each person had a branch on the Github repository, where they would store their personal code; when ready to add the code to the overall project, one person would submit a pull request, and another team member would look it over, check for conflicts, and approve or deny the request.

Every two weeks, the team met with the Capstone project advisor to review progress and discuss requirements for upcoming milestones. One team member would download the existing

application onto a device and demonstrate it for the advisor. Additionally, semi-regular meetings with the clients at the CENR allowed everyone to discuss new ideas and ensure the game was heading in the desired direction.

To debug code or resolve issues, the team held Google Hangout calls. With multiple people contributing code to a single repository, errors inevitably arose; if one person was unable to resolve the issue, another team member worked to debug the program. Each person kept a copy of the most recently working application on their local device, in case code on the Github repository needed to be reverted to an earlier version; this ensured that no work was ever lost.

RESULTS

Over the course of the year, the aesthetic design of the application changed greatly, but the overall flow of the game remained the same. By the end of the project, the team successfully created a *Home Page* with login and account creation capabilities, an *About* page describing *Nano-Adventures* and how to play it, an *Origin Story* page introducing the background of the Nano-Girls, and a first level, complete with a nanoparticle scenario, game tutorials, a complete mini-game, and a review quiz.

The *Home* page (Figure 5) includes the new logo for the game, keeping the two fonts from the original design. While the initial idea was to have the logo resemble classic comic-book art, the team decided to go with something more unique that incorporated the main characters' color scheme.

Players are able to create a new account by providing their email addresses and passwords. They receive an email requesting that they verify their account before they are able to log into the game. With Firebase, all user login information, as well as level completion information, is stored online, so that players can log into any device and pick up where they left off.

The *About* page contains information about the purpose of the game and why it was designed, the overall goal of the game and how to play, as well as instructions on how to create a new account. The font on this page is in a plain style to set it apart from the rest of the application and show that this is more of an "official" page, rather than part of the game. This text, unlike other sections of text in the game, is selectable, in case someone using the application wished to copy/save certain parts.
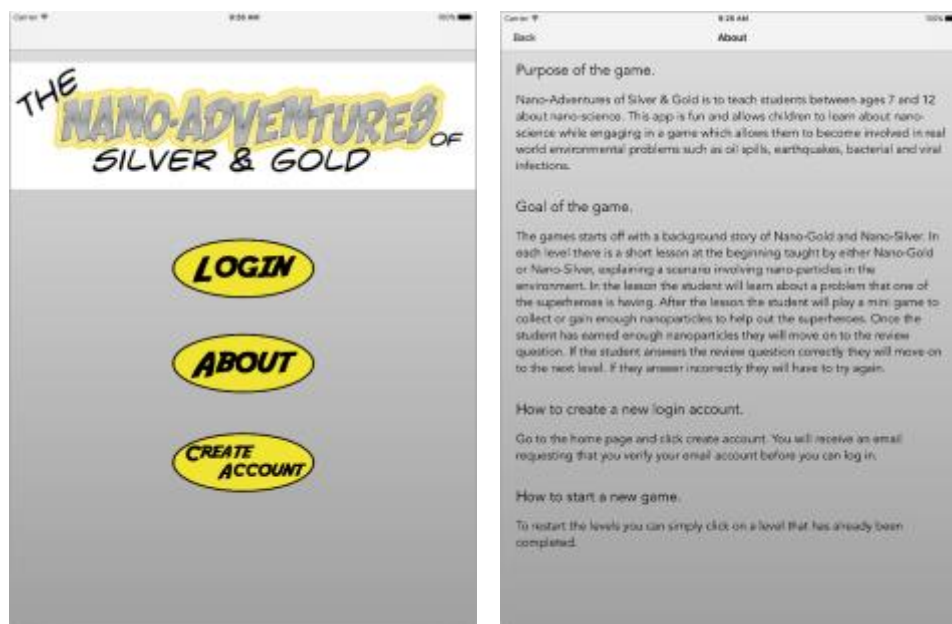

Figure 5: Finalized Home Page and About Page

As shown in Figure 6, the *Login* page remains approximately the same, with the exception that the final page uses the build in text-entry method for iOS, rather than a custom keyboard. Using built-in functionality was more efficient for the programmers, and more secure. It also helps the application be more consistent with most other apps one will find on a device.

One new feature incorporated into the game was the *Levels* page. On this page, users can view all of the available levels. When a new account is created, only the first button, "Origin Story"

is highlighted and clickable. As the user progresses through the game, buttons become clickable after every completed level. This ensures that the game is played in order, and allows teachers to monitor student progression. Players can also revisit older levels if they wish to replay a certain part, or re-read the characters' origin story.
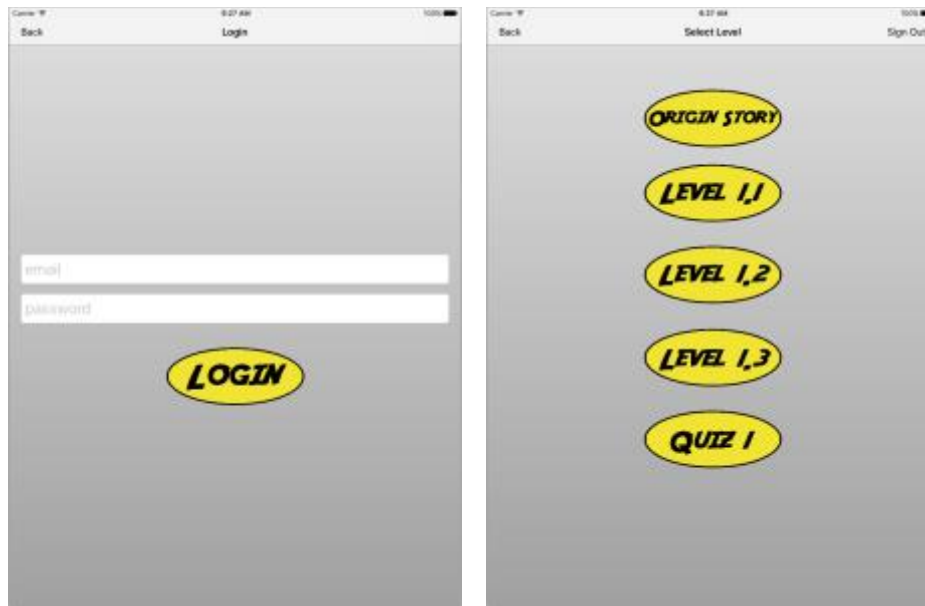

Figure 6: Finalized Login Page and Levels Page

The *Lesson* pages, where one of the Nano-Girls introduces a scenario and explains how the game will work, remained fairly close to the design. One of the Nano-Girls appears in the lower left-hand corner, with a speech bubble conveying her dialogue. The player navigates with an arrow button located in the lower right-hand portion of the screen (Figure 7).

In the first level, the player has to help a dinoflagellate move around in the ocean and consume nutrients. Nano-Silver explains that when hand soaps and lotions run off into the ocean, they deposit Silver nanoparticles into the water, which are harmful to dinoflagellates. The level consists of two simple tutorial-like games, so that the player can adjust to the task and learn the

difference between nutrients and silver nanoparticles, as well as a full-on mini-game. In the full game, the player has to collect at least 10 points (gained when the dinoflagellate comes in contact with a nutrient) before the timer runs out. Coming into contact with Silver nanoparticles causes the dinoflagellate to move more slowly, and removes points. If the player fails to accumulate at least 10 points before time runs out, they must retry the game.

Figure 7: Finalized first level (lesson, game, quiz)

Finally, the *Quiz* page asks the user which nanoparticle was harmful to dinoflagellates. Because this game is intended for young students, the question is very simple, and is only meant to test basic retention. Once the player answers the question correctly, the first level is complete.

The overall color scheme for the game changed fairly drastically from the initial design. After input from the project advisor and clients, it was decided that the original color scheme was too bright and busy, and it was more appropriate for the game to reflect the color scheme of the main characters. Changing these colors allowed for a more cohesive design across all pages.

Because the background for each page is a silver gradient, the buttons are gold. All dialogue text is in the font *CrimeFighter BB*, while all button text is in *Adventure*. The navigation buttons

and gameplay arrows were drawn to match the cartoon-like style of the Nano-Girl art. All text and buttons are quite large so that they are easy to read and press for young players.

DISCUSSION

Due to the fact that the team needed to learn the basics of iOS development before completing the game, it was difficult to know at the outset how long it would take to complete each component of the application, or how much could be feasibly accomplished within two semesters. As outlined in the Requirements Document, the team originally intended to complete at least two levels within the game. However, after the size of the team was reduced, and certain features of the game took longer than expected to implement, it became more realistic to focus on only one level for the year. This would allow the team to fully implement one level, complete with a tutorial, rather than have multiple underdeveloped levels in the game.

The team quickly learned that due to the complexity of Xcode projects, merging code into Github is a delicate and somewhat unpredictable process. If two people moved the position of the same page even slightly within the Storyboard and tried to push their changes to the default branch, a merge conflict would arise. Eventually, the team learned to push all changes one at a time, and make sure every member had pulled the latest version of the default branch before adding new code. Occasionally, when code was merged with the default branch that caused the application to crash, the team had to "erase" the latest changes and revert to an earlier version of the default branch. While this is not typically recommended for software projects, due to time constraints, this was the best option for keeping the project moving forward.

One of the overarching lessons learned in completing this project was to always look to existing pieces of software as a model for new programs, rather than try to create an application from scratch. *Nano-Adventures* was created like many iOS applications, with pages dictated by

basic View Controllers embedded in Navigation Controllers. All code was developed using Xcode's Storyboard feature and through various Swift files. However, in retrospect, the team learned that Xcode has a separate development option specifically for creating games, with many built-in features such as game sprites and user interactions. Using this development option would have quickened the programming process by allowing the team to implement pre-existing features, rather than code everything from the bottom up. Additionally, this would have avoided many of the bugs the team encountered while working on this project.

Despite the complications that arose during the year, the team used its previous software engineering knowledge to keep the project on track and handle difficulties. By aiding one another and staying in frequent communication both with each other and with the CENR, the team members made consistent progress over the year. The final Nano-Girls application represents a successful completion of the original goals, and more importantly, a valuable learning experience.

FUTURE WORK

This version of *Nano-Adventures* is the first iteration of a much larger project for the CENR. It will serve as a sort of proof-of-concept, displaying the general layout for a much larger game. Keeping this in mind, the team designed the application so that much of the code could be reused. For example, for every level, the structure of the game will be generally the same (lesson, tutorial, game, quiz). Pages like the Lesson page and Quiz page can easily be reused for every level, simply by replacing the dialogue and questions.

In the future, several changes are planned for *Nano-Adventures*. First, the CENR wishes to add more characters, so that players can choose which character they want to play as. To appeal to a larger audience, they plan to include male Nano-Heroes in addition to the Nano-Girls. They also

hope to adapt the game to suit older students, by making the lessons more challenging and the quizzes more complex.

Finally, the game will expand as more and more levels are added. Level One discusses how pollution can affect organisms in the ocean; the CENR has plans to include levels about algae, oil spills, medical uses for nanoparticles, and more. However, regardless of what changes are ahead for *Nano-Adventures,* the purpose will remain the same as that of this version: to entertain and education young students about the world of nanoscience.

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