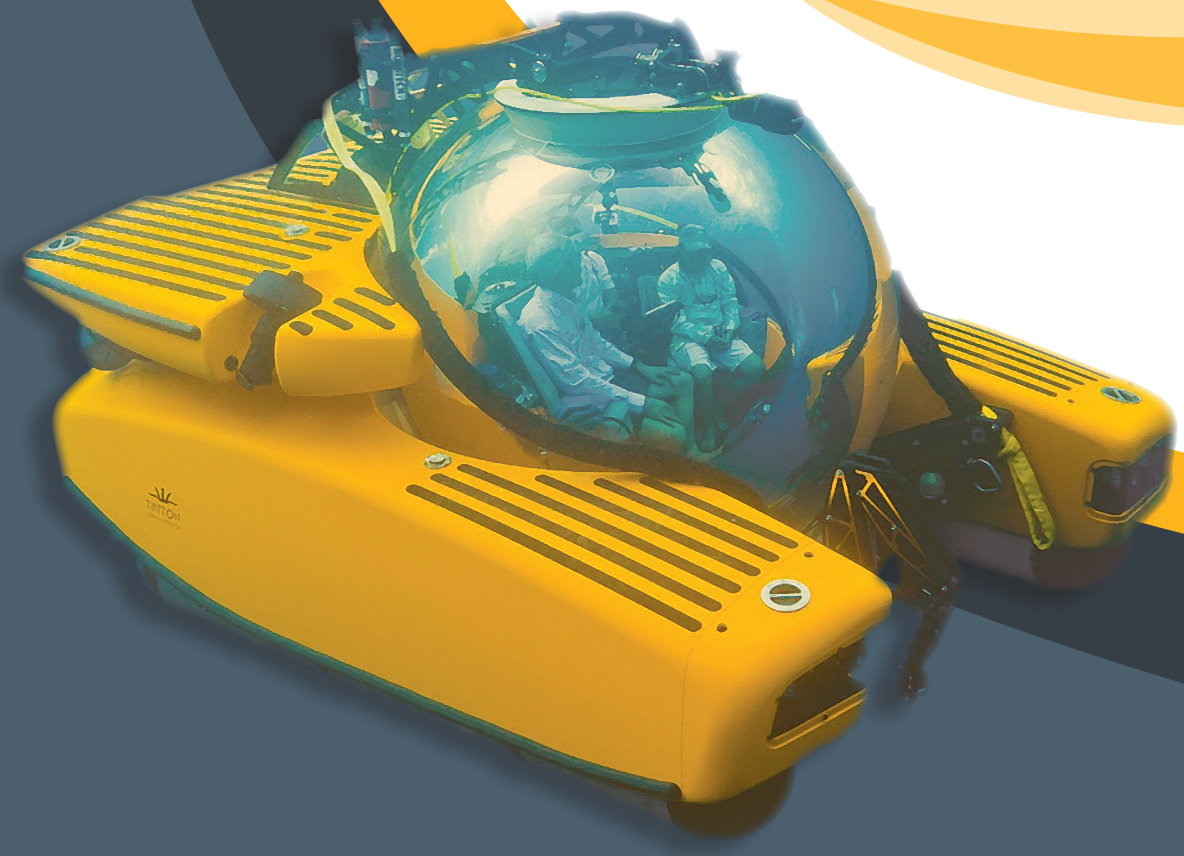
Bio-Prospector:

Ocean Expedition

Game Guide for Classroom Use



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T543 Final Project

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About Bio-Prospector

Age Group:
14-16

Subjects:
Science (Biology, Chemistry), Society

Duration of Lesson:
2 or 3 class sessions

Materials:

Lesson Standards:
- Ocean Literacy Principle #6

Bio-Prospector is a game for 14-16 year olds that induces users to engage in light science inquiry in order to discover new medicinal resources.

Narrative: The game is set hundreds of years in the future. Players learn that after not properly managing Earth's resources, the people of Earth have had to spread out across space into disparate colonies. Now one colony has decided to try and give life on Earth another chance. The colony faces many perils as it tries to not fall into the same traps from years ago. The colony must also make sense of this new environment, and reconstruct knowledge that was long lost. Part of this process involves rediscovering what resources humans can use to help society, while managing and taking care of these resources.

The player is introduced to one of these problems facing the new colony: a need for new sources of medicine. The player's individual goal is to collect 8 different samples from marine organisms that show pharmacological activity. In order to achieve this goal, the player must gather background information, interact with non-player characters, conduct a series of exploratory studies and collect qualitative data, and present these data, all while managing allocated funds. Through an engaging narrative with game mechanics intrinsically tied to learning goals, the game presents to users a more realistic conception of the scientific method, while providing a bit of content knowledge about ocean science.

The classroom version of this game is designed to frame this mission as a collective initiative. Each individual player will collect two samples. These samples will be added to a class-wide library, accessible and viewable by all players. The class goal will be to find 8 unique marine animals that produce compounds with anticancer, antiviral, antibacterial, and anti-inflammatory properties; two organisms for each category.

Learning Outcomes

Bio-Prospector *seeks to improve science inquiry skills and provide a small amount of* ***content knowledge*** *about* ***ocean resources and ecosystems****. The game addresses* ***procedural, structural and conceptual knowledge.***

Introducing Science Inquiry

Science in practice involves goal-oriented exploring, tinkering, failing, revising, and discovering (Gilbert, 2007). These are the basic tenants of the scientific process. Because these ideas are so critical to every field of science, it's important to begin cultivating inquiry skills in the science classroom (Citation). Developing science inquiry skills in students, however, is not a simple task. Students who have never been exposed to inquiry thinking can often become confused when allowed to engage in completely open-ended investigations (Honey & Hilton, 2011). Bio-prospector is designed to gently introduce science inquiry in a low-risk way, to invite student curiosity, and stimulate critical thinking skills.

Bio-Prospector: Steps in the Inquiry Process

Asking questions
Students will be presented with the problem of needing to find new sources of medicine. Through internal scaffolding of the game, and external scaffolding from the instructor (outlined in the Suggested Procedure section), students will begin to consider questions that will guide them in their investigation.

Making observations and taking notes
Students will save information gathered from research, along with transcripts from discussions with non-player characters in the game. They can also write down notes from their expedition or any other experiences. Students will be encouraged to actively reflect on these observations and notes.

Collecting and analyzing qualitative data
In the game, students are given a special device, called an Oshindex, which will act as an interactive qualitative data table. Every organism encountered will be saved in this device. If a student gathers a sample of this organism, this organism will be labeled accordingly. If the organism was sampled, and then later shown through a bioassay to show promise for drug development, it will also be given a unique identifier. All animals that have been sampled will have basic information about their taxonomy, ecology etc. saved in the Oshindex.

Each student or student pair's data from their Oshindexes will be added to a whole-class Oshindex viewable by all.

Interpreting patterns in the data and communicating these patterns
From the qualitative data table (aka Oshindex) viewable by all students, patterns should start to emerge. Students can select which organisms to compare across. For example, if students are comparing the taxonomy and ecology of organisms that were tested and shown to produce biologically active compounds, they would notice that these organisms tended to defend themselves by using chemicals, tended to be slow-moving animals, lived in diverse habitats, etc.

Learning Outcomes Cont'd

Suggesting hypotheses based on observations and data

Students could then make inferences about the typical characteristics of organisms that are most likely be the best candidates for producing useful compounds. For example, students could hypothesize that sessile animals are more likely than mobile animals to produce a diversity of useful chemical compounds, based on the patterns observed in their data.

Presenting findings and suggesting next research steps

Students will draw conclusions based on their observations and participate in a class discussion about what they discovered. The final report will require them to give suggestions for what types of organisms should be the focus of future sampling expeditions and to think about what the next steps in the drug discovery process will be. The report will be directed towards a senior scientist non-player character in the game.

The ultimate purpose of this game and associated activities

is to set students up for conceptualizing science in a more holistic manner as they progress through their science classes. Ideally, this program would be presented at the beginning of the school year to stimulate student curiosity and bring personal relevancy to the science classroom.

Throughout the rest of the school year, students should be stimulated to think about the broader implications of the current subject matter they are studying. Reinforcing a more flexible use of the scientific method should also be a reoccurring theme. Pre-defined laboratory experiments can be gently modified to encourage more open inquiry and exploration

By the end of this experience, students should be able to:

- **Understand the value of gathering background information for directing new scientific endeavors**
- **Understand that discovery is part of the scientific process**
- **Understand that scientific studies can last a very long time, and may require iteration**
- **Understand the importance of collecting and organizing data when conducting a scientific study**
- **Know that certain marine organisms produce compounds with a variety of properties that can be isolated and tested for pharmacological activity**
- **Understand the importance of oceanic research, why it matters to them and society, and why ocean ecosystems need to be protected**

Why a Game?

This section will include a justification for using simulations embedded within a game mechanic for teaching science.

-The highly visual nature of many science subjects; games can help illuminate complex scientific concepts

-The ability to simulate complex scientific proceses and relationships

-The ability to contextualize /situate an issue in an environment that would not be possible in the classroom

-Goal-oriented nature of games. Science seeks to answer questions; applied science seek to solve a problem, with a goal in mind (how can we generate new medicines?); games are essentially goal-oriented problem solving experiences, making them excellent conduits for simulating these big ideas in science. (Gee)

-Can foster all three types of knowledge (procedural, structural, conceptual) building within one experience

-Many of the above work together in tandem with the developmental and cognitive abilities and interests of the target age group

Game Context: Bio-prospecting & Marine Pharmacology

A brief introduction about the topic will go here, along with links to related resources.

This section will serve to prime instructors with the basic background needed to apply Bio-Prospector.

Links and references used:

Suggested Procedure

Before Using Bio-Prospector: Suggestions for Thinking and Discussion

Get students to start thinking about the idea of science and the scientific process.

Ask students to think about a problem they may have discovered in the past, and what steps they thought about to solve it.

o Students should start to think about the problem-solving process; what it means to discover a problem and think about how to solve it
o **Example:** The light goes out in a flashlight. What do you do? When solving a puzzle, how do you figure out where the pieces go?

It may be helpful to probe and see if students have experiences with games, whether these are board games, sports, short-duration cell-phone games or console games. Ask students what problems they encounter and what strategies they employ.

Ask students what they think it means to do science, and what they think the scientific method is.

o Students will likely have a rigid idea of what the scientific method is. Draw connections between the previous activity and this discussion.
o Show how flexible the scientific method really is. **Use tangible examples from history,** like Darwin's development of natural selection and Newton's theory about gravity. Show how these scientists discovered a problem, and went through a much messier version of the scientific process in order for their theories to emerge.

Show how everyday problem-solving that students themselves engage in is much like this version of the scientific method.

Get students to think about current investigations in science now (finding alternative fuels, discovering new planets, etc.)

o Encourage discussion among students regarding these topics. Perhaps a student mentions drug discovery (finding new cancer treatments).
o Use this discussion to segue into a discussion about what it means to discover new resources that can help advance fields such as medicine.

Suggested Procedure Cont'd

Using Bio-Prospector: Suggestioned Use

Prep students for gameplay: Inform students they will be playing the game Bio-Prospector: Ocean Expedition.

- Ask students what is means to prospect. **Think about prospecting for gold; could use this as an analogy** to prospecting for valuable chemical compounds, which is the essence of bio-prospecting.

- Pair students up and play the opening narrative of the game for all students to see at once. This can help draw students into the story and elevate motivation to engage with the game material (Barab, et al). Then have students begin gameplay

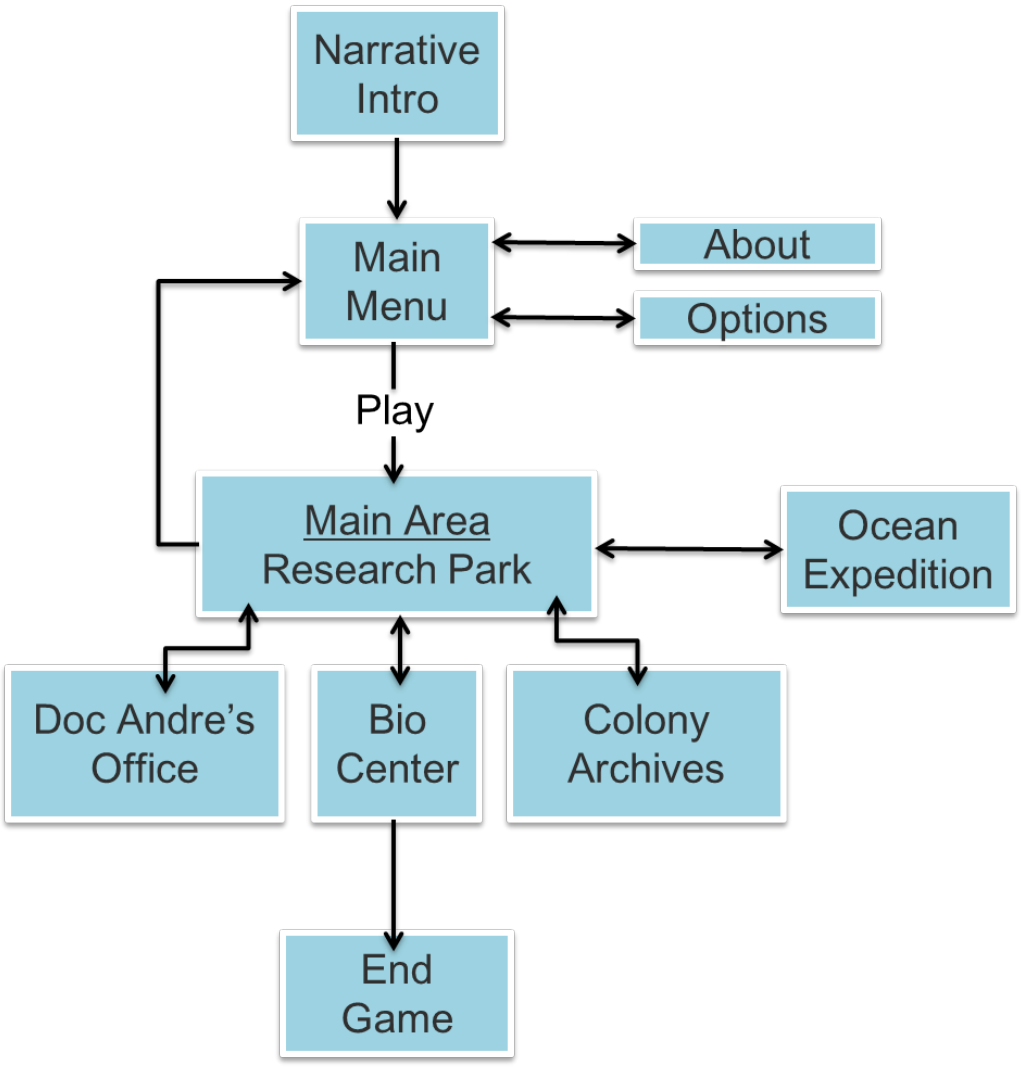
The following pages outline general suggestions for scaffolding through the Bio-Prospector gaming experience. On the left will be instructor scaffolding suggestions. On the right will be an outline of the game flow and likely student actions.

By no means is this a prescription for how the experience should occur. Use this as a guide to ensure students are getting the most out of the experience.

Suggested Procedure Cont'd

Game Flow: Quick Overview

It is strongly recommended to visit the detailed game flow experience in Appendix A



Suggested Procedure Cont'd

Instructor Scaffolding	Student Experience
• Encourage students to talk out loud with each other as they proceed through game play	**Game Flow:** **1. Meet Doc Andre** • Player learns about the dwindling medical supplies and the need to find new sources for biologically-active chemicals **Student Actions:** -Continue through game play
• Continue to encourage students to talk out loud with each other as they proceed through game play • Encourage students to note information they think will be helpful for solving the problem	**Game Flow:** **2. Meet Dr. Jillian, a biologist, at the Bio Center** • Player learns about sponge species case study • Dr. Jillian gives the player the "Oshindex:" • Game Goal Revealed: 8 samples needed for next stage of drug development funding. **Student Actions:** -Continue through game play
• If some students are having trouble, have other students who understand what they're doing help others • Encourage students to note information they think will be helpful for solving the problem • Freedom of choice and getting students to think about what sorts of information they should save is an important part of this experience. Try not to tell students exactly where and what information they should	**Game Flow:** **3. Exploring the rest of the Bio Center** • Player will meet other non-player characters that give the player clues and other useful items • Player meets a microbiologist. Pick-up: The player is given a magnifying attachment for their submersible **Student Actions:** -Continue through game play

Suggested Procedure Cont'd

Instructor Scaffolding	Student Experience
• For this research gathering, split the class into two: half the class will research the sponge case study, the other half will research general information about analogous terrestrial organisms • Encourage students to note information they think will be helpful for solving the problem • Have students pair up with another pair from the opposite group, forming groups of 4. Students should discuss and share what they've found	**Game Flow:** **4. Exploring the Archive Center** • The player can read about the sponge case study. • The player can choose to learn more about other known drugs and their precursors. **Student Actions:** -Student should be saving information from what they are reading/seeing -Students may be discussing thoughts and ideas with others -Students may be taking notes in their Oshindex log -Continue through game play
• Split the class into 3rds: with 1/3 of the pair groups for each of the 3 different ocean zones • Encourage students to remember what they've learned so far to help guide them in their sample collecting -What organismal traits are they looking for? What habitats? Etc.	**Game Flow:** **5. Player Begins Ocean Expedition** • Player can explore the ocean zone. • Player can collect samples • Once the player has collected the 2 samples they want, can return to the surface **Student Actions:** -Students should be using the background information they collected to guide their sample collection -Students can discuss with others -Continue through game play

Ask guiding questions throughout the experience to further scaffold student thought. The detailed game flow description in the appendix can help with the generation of these questions.

Suggested Procedure Cont'd

Instructor Scaffolding	Student Experience
• This might be a difficult part of the game conceptually. Enourage student pairs to talk through the testing process • After students test two samples and add any positive samples to the class-wide Oshindex library, have students pause for reflection	**Game Flow:** **6. Reentering the Bio Center** • Dr. Matt guides player in the sample testing process • Player will mark samples if shown to have pharmacological activity **Student Actions:** -Students will be comparing their bioassays to a reference chart for the 4 drug types. Looking for positive qualitative similarities -Duscussion with partners
• Encourage students to make inferences based on the data collected so far. Are there any particular types of organisms that seem to be producing more positive results? • Have students pair up with another pair of students from a different ocean zone. As a group, have students create a concept map of their processes and what they've discovered so far	**7. ++Pause++ Game** **Student Actions:** Looking for patterns so far: -Students accessing information in their Oshindexes -Students observing class-wide Oshindex -Students constructing concept maps, making connections, discussing
• If the class goal of 8 useful organisms for each target drug class in the Oshindex library has not been acheived yet, students can run through the experience again. • Get students to realize this happens all the time in science: new observations, revisiting data, confirming/disconfirming ideas, etc.	**Game Flow:** **8. Revisiting Dr. Jillian** • Winning criteria will be determined • If the player has not gathered the needed number of organisms, Jillian will tell the player they have enough grant money for one more trip • If goal is achieved, the player wins a large sum of grant money for the bio lab, and receives an honorary research award **Student Actions:** -Continue through game play

Suggested Procedure Cont'd

After Using Bio-Prospector: Suggestions for Post-experience Discussion

Closing discussion with reflection

Ask students how science can help us learn about our world

Example answers:

- Through asking questions about problems and unknowns and providing a rough map of how to investigate these problems and unknowns
- By providing us with an ever-growing body of knowledge that can be used to help direct these questions in the first place, and give us something to reference during an investigation

Ask students if they can think of other areas besides medicine where science improves our lives

Example answers:

- Computer technology (space exploration, nanotechnology, robotics, etc.)
- Using principles from physics to guide the construction of bridges, buildings etc.
- Developing new methods for cleaner energy and protecting the environment
- Giving us clean water and many aspects of food production

The winning criteria of Bio-Prospector is gathering enough biologically-active samples with diverse chemical properties in order to win a large grant reward to fund the next stage of drug research. But what does this mean?

Get students to think about what this means in terms of the scientific process.

It would be important to address that the game represents just one step in the drug discovery process. This should be done in order to develop an understanding for the often lengthy process of applied science, from research to discovery to clinical trials and human use. Because students are used to cookbook lab experiments that can be completed in one or maybe two lab periods, this contributes to an oversimplified understanding of the process of science (Honey &Hilton, 2011)

Start a discussion about how to create sustainable methods for extracting useful marine animal compunds

- Aquaculture
- Synthetic replication

Assessment

This section contains suggestions about how to assess student performance from the Bio-Prospector game.

After discussion and unpacking of student experiences from the game, each student pair should write a final report addressed to the non-player character, Dr. Jillian. The report should address:

- The generalities of what students observed during the ocean expedition(s).
- How students determined what samples to take
  - What did they discover during their background research?
  - Who did they talk to in the bio center? How did these discussions help frame their thinking?
  - What students should have been able to determine from the background information gathering:

    1. Students will know that cancer, inflammation, and chronic diseases could be treated with drugs derived from natural sources, if only these natural sources could be found…

    2. These natural derivatives come from living things, most likely from animals with similar properties to the sponge they researched (sessile or with limited mobility, chemical defenses, etc...), and perhaps from microorganisms, as mentioned by the technician in the bio lab, and analogous to the fungi that led to penicillin development.

    3. They should think about the diversity of the environments they explore on the expedition…the more animal and plant life diversity, the more likely these animals in these habitats will have a number of unique chemical defenses…

  - What was revealed during the testing of their samples? What activity (if any) did their samples show against which targets (antiviral, antibacterial, anticancer and/or anti-inflammatory)?
  - Did they have to go back and do another expedition trip?

This report should suggest plans for future research initiaves:

- What would the students recommend to future explorers like themselves in terms of what organisms to focus sampling efforts on?
- Give suggestions for sustainable methods of producing more of the compounds produced by these organisms

Since each student pair is likely to have undergone a slightly different process and collected different organisms, students could present thier reports to the rest of the class

- The student audience should note what aspects of the presenter pair's process are different and/or the same as their own.
- The student audienece should note the different organisms that were discovered, sampled and tested.
  - What were the properties of these organsims? How are these organisms similar and different?

Supportive Activities

Research has shown that students need to be exposed to a science concept in 4 to 6 different contexts before making clear sense of what they are learning (Koba).

As mentioned in the beginning of this guide, the Bio-Prospector experience is meant to serve as a foundational hook: harnessing students' innate curiorsity about their world while showing them the relevancy of the scientifc process. The ultimate goal of the Bio-Prospector experience is to establish overarching scientific principles that will permeate into science lessons throughout the school year.

The following two examples review related activities on the same general topic of ocean science and testing for biologically active compunds. These examples serve to reinforce the learning goals.

Reveal the authenticity in what students experienced in Bio-Prospector

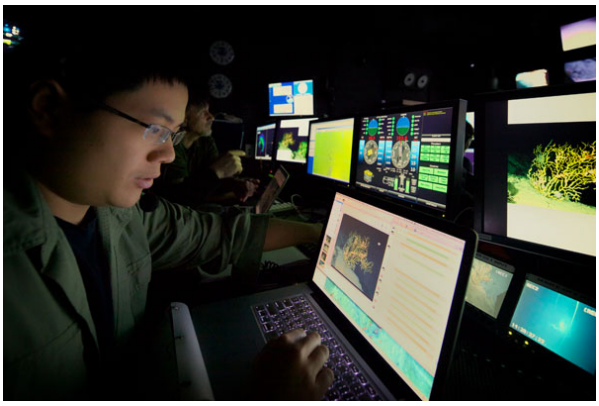
Okeanos Explorer
The 2014 Gulf of Mexico Expedition

This exploratory expedition is the most recent mission out of the National Oceanic and Atmospheric Administration (NOAA). Scientists on this mission are engaging in the same basic practices that students experienced in Bio-Prospector. In addition to other research initiatives, the team plans to explore deep coral reefs, shipwrecks, and more.

The NOAA website hosts a live feed of the expedition, showing scientists in real time as they explore the Gulf of Mexico.

The concreteness of this experience, showing real scientists collecting and using real data, will help to solidify content and processes explored in Bio-Prospector.

View the live feed here:
http://oceanexplorer.noaa.gov/okeanos/explorations/ex1402/background/intro/welcome.html



Technician working in ROV control room for an exploratory dive http://oceanexplorer.noaa.gov/okeanos/explorations/ex1202/logs/apr5/media/apr5-4.html

Hands-on lab: testing for antibiotic activity

The NOAA website provides a number of lesson plan resources, including hands-on actvities. In the "Watch the Screen!" activity, students have the opportunity to screen natural products for biological activity. This hands-on lab can reinforce concepts explored in the bioassay testing phase from Bio-Prospector.

It is recommended that this lab be gently modified to allow for more open inquiry:

http://oceanexplorer.noaa.gov/okeanos/edu/collection/media/wdwe_watchscreen.pdf

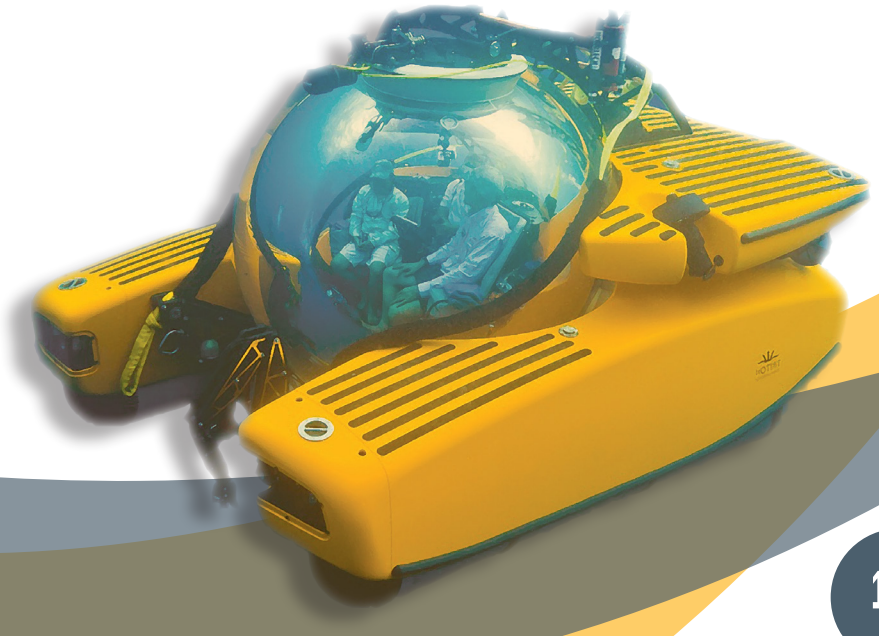
Summary

References

Gilbert, J. K. (2007). Visualization in Science Education . Dordrecht: Springer

Koba, S., & Tweed, A. (2009). Hard-to-Teach Biology Concepts: A Framework to Deepen Student Understanding. Arlington: The National Science Teachers Association

Submersible image retrieved from: **http://www.showmanagement.com/fort-lauderdale-international-boat-show-2012/event/product_listing/5656**



Appendix A: Detailed Game Experience

1. Meet Doc Andre

- Player is prompted to visit Doc Andre's office to learn about a pressing issue facing the colony
- Player learns about the dwindling medical supplies and the need to find new sources for biologically-active chemicals (*"We need to find compounds to help inhibit cancer, chronic diseases and inflammation…"*)
- Player is told to visit Dr. Jillian for further direction

2. Meet Dr. Jillian, a biologist, at the Bio Center

- Player is told that most new drugs come from studying plants and animals.
- Player learns of a case study of a sponge species that showed promise for cancer treatment, but all the samples have been destroyed
- Dr. Jillian encourages the player to learn more about this case study at the Colony Archives, and to research other pertinent information for the player's ocean expedition
    - i. Jillian also encourages the user to walk around the rest of the Bio Center and interact with other scientist characters
- Dr. Jillian gives the player the "Oshindex:"
    - i. A storage device that will document all marine life encounters. It will document every creature seen on the expedition. It has the ability to analyze the animals' habitat and general ecology, but it can't analyze its chemical properties (the player must do this after taking a sample back at the Bio Center). The player must actually take back a sample to the bio center for analysis, before the chemical properties will show up.
    - ii. It will also record every conversation with a known scientist and save this as a transcript.
- She also gives the player enough grant money for two ocean trips.
- Jillian informs the player that they need to find at least 8 samples that show promise, so that the next stage of drug development can be funded. If the player succeeds in gathering 8 samples that show promise for medicinal use, the player will win a large grant reward for the Bio Center to help fund the next stage of drug discovery and be given an honor (aka win the game).
- Jillian informs the player that she will be able to see information in the Oshindex and read output from the player's submersible. With this access, she will be able to help guide the player (internal game scaffolding)

Appendix A: Detailed Game Experience

3. Exploring the rest of the Bio Center

• Player will meet other characters that give the player clues and other useful items. Example information:

i. Tech1: *We think that the more different types of habitats that exist in an area, the higher the diversity of marine life there will be.*

ii. Microbiologist: *There are more microorganisms in the ocean than all other animals combined. Due to their diversity, we think there's a high probability these microorganisms may prove useful, but we aren't sure.* ***Here take this: it's a special microscope attachment*** *you can use to see bacteria and other unicellular life.*

iii. Another microbiologist: *We love microbes, and we hope you find some out there:* **here's a water sampling attachment** *to help you sample any microbes you see. Sometimes microbes show up where you may not expect them; some live symbiotically with other organisms.*

iv. Tech2: *I've been studying the biology of cancer. It seems like we would need a compound that would inhibit rapid cell division…I wonder if there's an animal that would have a reason to produce such a compound….*

v. Tech3: *I study the biology of inflammation. Prolonged inflammation can be pretty harsh on the body, if only humans could produce their own anti-inflammatories…*

vi. Tech4: *We need to find a way to prevent viruses like HIV from infecting their host's cells.* ***Here, take this: it's a special target that you can use to test your samples on****, they don't have this stored in the biochemistry labs yet; hang onto it, you'll need it for testing your samples for effects against HIV.*

vii. In biochem lab: meet Matt: *Hey, nice to meet you-- come back here when you have some samples, you'll test them here!*

viii. Tech5: *Welcome to the sustainability lab. Man I hope you find some useful critters out there. But we have to think of ways to sustainably derive their potentially useful compounds.* **Here, take this: this attachment will help you take more precise samples***, allowing you to take only what you need for testing*.

Appendix A: Detailed Game Experience

4. Exploring the Archive Center

- The player can spend as much time here as they want
- The player can read about the sponge case study.
  - i. The sponge case study: **The Orange Wall Sponge**, Porifera phylum, a sponge, strictly marine, is a sedentary filter feeder, has a porous body with holes and channels that allow water flow throughout, depends on water flow through its body to obtain food and remove waste. **To defend themselves, they produce chemicals that prevent bacteria and other rapidly dividing cellular animals** from growing on them. It showed anticancer properties by causing cell death in Leukemia tumor cells. General: http://www.carsten-thoms.net/sponges/ecology/1_frames.html
  - ii. Students can look at photos and video of this sponge, and a 3D model.
- Researching General Information
  - i. Researching about penicillin. Produced when growth of the fungus is inhibited by stress. Perhaps there are some other microorganisms competing with the fungus for food—the **fungus would need to produce antibiotics to fight these bacteria**. Review the serendipitous discovery of penicillin. Note that the scientist stumbled upon this discovery. Then, other scientists built upon this work to make the medicine that we now know as penicillin.
  - ii. Researching other known drugs: aspirin,
- The player can learn about the other few known marine animals that the colony has been able to document
- **Pick-Ups:** The player can determine which information they would like to save to their Expedition Log for later reference. This log will always be available for them (this simulates a basic literature review)

Appendix A: Detailed Game Experience

5. Player begins Ocean Expedition

- There will be 3 different ocean zones accessible for the expedition
- The player chooses a zone; submersible is dropped into the water.
    - i. Giving students choice: will they chose the cheaper glider, but with poorer abilities, or a more expensive submersible? Can't observe in situ with ROV's; many scientists refuse to accept remote observation
    - ii. There will be a time limit related to the power of their submersible
    - iii. The sub takes 2 hours to dive and 2 hours to surface, so leaves 2 hours to exploration.
    - iv. Modeled off of the Alvin submersible
    - v. Can collect sediment cores, water samples, and there are sensors to detect chemical environmental conditions
    - vi. Costs 30k each day to operate http://oceanexplorer.noaa.gov/technology/subs/alvin/alvin.html
- The player will see a diversity of marine life; right away they will see the sponge species from the case study
- **Pick-ups:** Player can take a sample of this sponge species. The player can collect up to 6 different samples at a time (two different samples in classroom version).
    - i. The player must use what they've learned from research to infer which marine animals are most likely to show promise for drug development (should they take back a small shark species or a sample from a tunicate?)
    - ii. If this pattern is unclear at first, it should become apparent to the players as they gather more species. The Oshindex will store an image for each species encountered. If the species has had its sample analyzed, basic taxonomy information will be added, and a star will be added next to the organism's picture if it showed pharmacological promise. In this way, the Oshindex acts as an interactive qualitative data table, whereby the user will be able to glance at and begin to see patterns as they gather more data.
- If the player discovered the biotech room at the Bio Center, the player can choose to use the magnifying attachment they were given and collect microorganism samples
- There will be areas within each zone that are fairly void of life. There will be some red herring animals here, such as a species of sponge that doesn't produce any useful chemicals, because it doesn't have to (because of no predators, plenty of space, etc.).
- Jillian can prompt user to find a more populated area.
- Other things to explore: Have a rich diversity of animals to look at and learn about. Have some animals respond to the submersible in amusing, but naturalistic ways ("fun" factor)
- Once the user has collected 8 (or 2 for classroom version) samples, they will return to the surface

Appendix A: Detailed Game Experience

6. Reentering the Bio Center

- Dr. Matt greets the player, and explains the basic process for testing the samples: mashing the samples into slurries, and then performing bioassays to test the slurries for pharmacological activity.
- Each bioassay would have a distinct pattern to indicate whether it was effective or not. Students would reference a chart that had typical patterns for each, then would label the sample in their Oshindex if it showed medicinal promise.
- Have the students test the sample against all 4 targets. They will get a result for each of the 4 tests. They will have to compare, qualitatively, to a chart that shows what a positive test would look like. Then, open their Oshindexes, find the organism they sampled, and input whether it showed medicinal promise and of what type.
    - Anticancer
    - Antimicrobial
    - Antiviral
    - Anti-inflammatory
- The player will receive a report for each tested organism
- ****This process is complicated. Would have to consult with a subject matter expert in order to determine the best way to represent this process in the game****

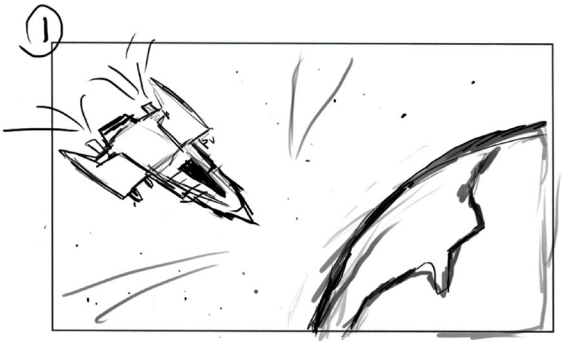
7. Revisiting Dr. Jillian

- Dr. Jillian will review the reports. Possible outcomes:
    i. **The player found no organisms with medicinal utility**. In this case, Jillian will tell the user they have grant money for one more trip. The user can endeavor on a second ocean expedition, perhaps double checking the archives to make sure they've done enough research.
    ii. **The player found some organisms with medicinal utility**. Jillian will give the user more grant money for further ocean exploration. If the player found at least 3 useful organisms, the player will have enough grant money to use a ROV to get into tighter spaces around the ocean floor
    iii. **The player finds 8 or more organisms, at least 2 for each taregt category, with medicinal utility**. Jillian informs the player that the player has provided enough samples and evidence to earn a huge grant award, allowing the Bio Center to take the samples to the next stage of drug development. User also recieve an honorary research award.

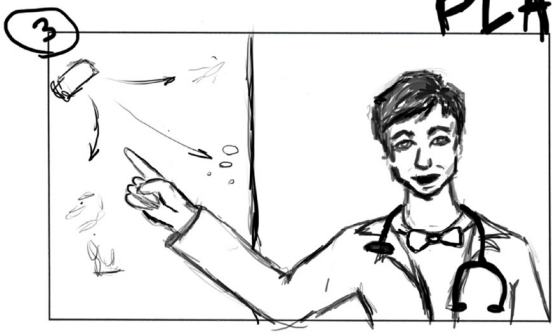
Possible future extensions:

- The player partcipates in the next stage of drug development
- The player must start an aquaculture project

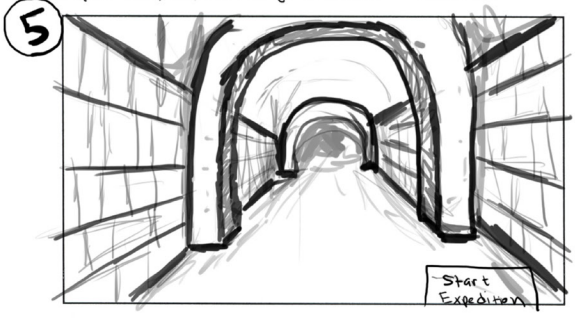
Appendix B: Game Concept Sketches

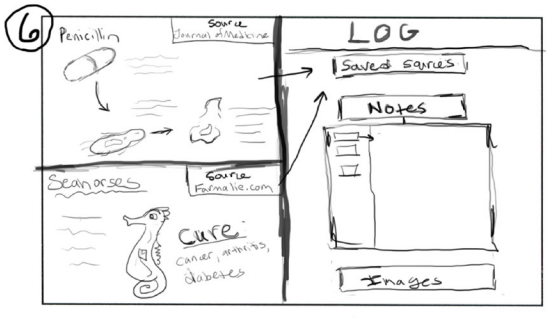


PLAY SELECTION



*User can choose to go to ocean or archives





Appendix B: Game Concept Sketches