An Inquiry-Based Project Added to Traditional Labs: Hands-On Fish Awareness Research in Freshwater Systems Conducted by First-Year Biology Students

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Abstract
This project involves students in an inquiry-based project added to the introductory biology laboratory course for majors in fall 2019. Research has shown that student engagement in authentic research has significant positive impacts on development of science literacy and reasoning skills. The authentic research conducted by students was the first attempt at quantifying self-awareness in North American freshwater fishes. Self-awareness in fish has garnered attention due to media coverage of recent peer-reviewed research indicating some fish are self-aware. Connections with media coverage and fish self-awareness were used to invoke student interest and provide relevance to the study. Students observed fishes from streams in the Great Plains and collected fish from local streams and rivers. They acclimated the fish in a holding tank before placing them in isolated microcosms for study. The students generated research questions, designed experiments, collected and analyzed data, and wrote a final manuscript that was submitted as a publication as part of this curriculum. This project could be incorporated at the high school or university level, for biology major or non-major courses.

Learning Goals
Students will:
◊ interpret the meaning of self-awareness.
◊ appreciate and learn field collection techniques.
◊ explore how species interact with their habitat.

Learning Objectives
Students will be able to:
◊ Weeks 1–3: Introduction to Fish Awareness
  » define self-awareness generally, and consider self-awareness in fish and how that may be observed.
  » formulate a hypothesis as to whether they expect fish to be self-aware.
  » discuss their definitions of awareness in fish with peers using terms learned in peer-reviewed articles.
◊ Week 4: Creating a Study
  » organize collection techniques used for fish sampling.
  » analyze peer-reviewed literature in order to construct a sampling protocol.
  » discuss and critique literature to discover what is relevant to their study.
◊ Weeks 5–11: Data Collection
  » format a timeline for their research project.
  » implement sampling techniques in the field.
  » use scientific equipment such as seines.
  » observe fish behavior both in person and using video capture software.
  » organize data.


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INTRODUCTION

Research experiences have long been used as a means of engaging students with scientific practices. While the benefits associated with research experiences are considerable (1–3), the reach associated with these opportunities has been narrow as the majority of research experiences fall under the category of mentored research between one student and one faculty member (1, 4, 5). One way to provide these invaluable research opportunities to a greater number of students is by implementing inquiry-based projects that can be added directly into an introductory biology lab. It is well established that hands-on, active learning benefits students, particularly women and other historically marginalized groups (6–8). Further, inquiry-based projects that have been successfully incorporated into a classroom show significant benefits to students and faculty (9). Finally, and in the opinions of the authors, inquiry-based learning activities, like the one delineated herein, are just more fun—for students and for teachers. Additionally, while ‘fish’ the organism is clearly in the realm of biology/ecology, fish (and fishing) are well positioned to facilitate cross-curricula exploration—from evolution to anthropology, economics, physics, or social science.

Getting undergraduate biology students excited about science and able to conduct rigorous and quality scientific research on their own are difficult goals that most academic institutions strive to meet (e.g., 10). Typically, in any course where students conduct research, there are challenges for undergraduates to design their own research projects or transfer their math class skills to biology class due to lack of experience practicing skill transference. The fear of failure and/or of the unknown is a difficult gap for students to cross, and educators have been striving to find new ways to create independent, thoughtful scientists. The purpose of this project was to bring an exciting and authentic cutting-edge ecology-based research project into the undergraduate biology classroom, allowing biology students to actively engage in the process of discovery (see NARST's description of Science Process Skills). After guiding information had been given, students created a testable hypothesis and designed an experiment. The project culminated with students collecting and analyzing data, reading and summarizing peer-reviewed literature, and finally editing their scientific paper which would be submitted for publication. The authors wish to make clear that this lesson plan is designed to be adaptive, and there are ways that a teacher could implement the concepts of this activity with little to no monetary cost to the teacher.

Learning Objectives

Students will be able to:

- Week 12: Understanding and Analyzing Data
  - determine a proper statistical analysis for their data.
  - implement their statistical approach by analyzing their collected data.
- Week 14: Concluding the Research
  - generate contextual questions regarding their manuscript.
  - critique various parts of a prepared manuscript draft.
  - communicate their findings in writing.

Intended Audience

This project was implemented in an introductory undergraduate biology laboratory. It is assumed students have little biology knowledge and no field/experimental design experience. The participating students were all majoring in a science field. We designed this curriculum for biology educators as an example of how to implement project methodology and provide unique and broadly relevant ecological research experiences in their classrooms. The intended students are introductory students who may or may not have a strong biology content knowledge base. While the authors conducted this lesson with introductory students at the university level, the lesson is also appropriate for upper-division high school students. Significant laboratory space may be required to set up several 5 to 10-gallon aquariums that will house individual fish (see Supporting File S5), but observations of fishes can be done remotely (e.g., Monterey Bay Aquarium’s live cameras) or a collaboration between the students and a local pet store that sells fish may be established. If fish are collected from streams or lakes, aquatic sampling equipment such as seines or buckets may be necessary. Potential student audience should be a class size of about 20 which allows for all students to actively engage in project creation, sampling, and final writeup.

Demographics

Emporia State University (ESU) is a master's-granting institution in rural central Kansas with approximately 3,500 undergraduate students and a total enrollment of approximately 5,700 students. In our implementation, 18 students in one introductory biology laboratory class engaged in the project. Of these 18 students, 30% identified as males and 70% identified as females. For ethnicity, students who identified as White comprised 68%, two or more ethnicities 16%, Hispanic 9%, Black and/or African American 4%, and Asian 3%. Freshmen accounted for 49% of the sample population, sophomores 45%, and juniors 6%. There were 11 different majors represented, with the three most common being Nursing and Pre-professional (55%), Biology (15%), and Athletic Training (8%). Other majors included Art, Business Administration, Chemistry, Communication, Health and Human Performance, Undecided, Political Science, and Psychology (combined enrollment = 22%).

Required Learning Time

Classes met once a week on Thursday for 170 minutes. The project requires a significant (20–50%) portion of class time during the first and final weeks of the 15-week semester. Each class period begins with a specific laboratory topic (like
a traditional lab), then students work on their inquiry-based projects. Once the students design their project sampling protocol (Week 4), the time required drops significantly. Responsibilities for the instructor turn toward maintaining the aquatic habitats (about 5 minutes each day). Students’ observations take 15 minutes, and they perform these observations at least 4 times throughout the semester.

**Prerequisite Student Knowledge**

This lesson is intended for students as their first introduction to authentic scientific research. Therefore, neither knowledge on the background of fish awareness, sampling techniques, nor scientific writing and/or literacy was assumed or expected.

**Prerequisite Teacher Knowledge**

Instructors are recommended to have experience with inquiry-based learning techniques prior to incorporating this lesson into their classroom. Instructors should feel comfortable taking students to an aquatic environment as a field trip experience. Finally, teachers must be comfortable with basic statistical analyses, scientific writing, experimental design, and spontaneous problem solving, which ranges from letting students into the laboratory outside of designated class time to basic aquarium maintenance. Knowing which communities and species of fish may be collected is likewise beneficial. An instructor who can use a dichotomous key prior to the experiment will help to facilitate the fish identification process. Maintaining the aquariums will vary based on the complexity of the specific design outlined by the students. Depending on the nature of the study, certain permits may be required. Studies that involve unobtrusive observation of animals in their natural habitats do not require additional permits. Studies that have a potential to cause harm or materially alter the behavior of the animals require Institutional Animal Care and Use Committee (IACUC) oversight. To use fish in a study similar to the one described herein, if the teacher has a fishing license and follows their state regulations, and the experiment is only observational, additional IACUC oversight should not be necessary.

**SCIENTIFIC TEACHING THEMES**

**Inquiry-Based Learning**

We describe four scientific practices below (A–D) that complement inquiry-based learning activities. Inquiry-based projects involve students in five types of activities: use of scientific practices (A–D), discovery (A–C), relevant or important work (D), collaboration (B–D), and iteration (A, B, D) (11). Scientific practices that students were involved in included: (A) Observational techniques, where students were asked to monitor fish behavior and record their findings. (B) Sample collection, which included students wading through local rivers, bringing the fish back to their tanks, and observing and quantifying fish behavior. (C) Data analysis, which included statistical analysis of their results. (D) Manuscript preparation, including peer-reviewed article searches, journal specific formatting, and editing a scientific paper. Active learning took place through other activities as well, such as peer-led discussions. These discussions stemmed from investigating peer-reviewed articles introduced by the instructor or found by students. Students took what could be used from peer-reviewed articles’ methodologies and began to apply these ideas to their experimental design. Through reviewing primary literature, students were able to see that there had been no previous published research on Kansas fish species’ self-awareness. This led to them filling that gap in the literature by designing an experiment to test their original hypotheses utilizing our Fish Awareness Behavior Project (FAB PROJECT). Inquiry-based learning projects provide relevant data which may provide answers to previously unanswered questions. These data are different than the experiments performed in a traditional laboratory, where the experiments have a static solution. Collaboration among students, instructors, and other pertinent faculty and staff is essential for this design to be effective. For example, in order to construct their observation schedule, students are engaged with maintaining contact with the department head in order to enter the building after hours. This type of collaboration encourages students to communicate with professionals as well as foster time-management skills.

**Assessment**

Learning will be measured using:

**Informal Assessment (See Supporting File S1)**

Students lead discussions to actively answer research questions. Students individually find, critique, critically analyze, and report their findings from peer-reviewed articles. Students create a testable hypothesis.

**Formative Assessment (See Supporting File S2)**

Students formulate and implement a research protocol that they create. Students conduct fieldwork, record observations, and report their data to the class. Students engage in collection techniques. Data analyses such as chi-square and t tests are introduced to students through in-class activities. For example, their initial introduction to t tests is a traditional-style lab exercise using the height as a variable.

**Summative Assessment (See Supporting File S3)**

Students produce a manuscript unique to their research question. In producing a manuscript for publication, students are challenged to meet journal expectations, including: (i) Determining the appropriate journal for submission. (ii) Meeting the specific design and format requirements requested by the specific journal. (iii) Listing, labeling, and formatting citations in the requested style. (iv) Editing their manuscript according to reviewer suggestions. If rejection occurs, adjustments are made, and the paper is resubmitted, which allows for iteration.

**Student Self-Evaluation**

Students will reflect on their learning by being tasked to properly implement prior learned sampling techniques while collecting data. In addition, being able to distinguish between peer-reviewed and non-peer-reviewed articles is a way student reflection was shown. Finally, by the end of the manuscript edits, the students have a physical piece of work that encompasses their entire semester of research.

**Inclusive Teaching**

There is a paucity of diversity in many professional STEM jobs, and the argument has been made this lack of diversity
is due, at least in part, to lack of opportunities for minoritized students majoring in Science, Technology, Engineering, and Math (STEM) fields (12). Offering inquiry-based projects in introductory courses sets the tone early in one’s STEM career that inclusivity matters, and all students enrolled in these introductory courses will be given research opportunities. Value is expressed for each individual student as a unique member of the research team. First, an inquiry-based project can be designed so that each participating student in the laboratory immediately becomes involved in impactful research. Involvement of every student signifies that an equal opportunity environment is created and encouraged. Offering the opportunity to perform observations after hours and on the weekends grants the student responsibility and ownership of the project. Observations are taken in the lab/classroom space, thus if the student can get to class, they can collect data. Even so, video recording software may be implemented to monitor fish behavior, which allows students who are unable to be present in person to record their observations and evaluate the recordings at a time that meets the students’ needs. Beyond being inclusive to every student, including observations from each student also produces the largest possible sample size, leading to greater power in the study’s findings. Additionally, emphasis is put on the responsibility that comes with being a part of a research team. Students are free to choose the research trajectory, granting true project ownership by allowing the students to own their research avenue. Furthermore, creating their own research plans, observational techniques, timeline, plus participating in peer collaboration, students may engage with the nature of science more strongly and having a greater sense of emotional ownership over their work can experience a greater sense of project enjoyment. It is important to understand that the data produced by the students are the only data that is going to be obtained. Teamwork in this project is necessary, and every member of the team counts.

LESSON PLAN

Weeks 1, 2 and 3: Introducing the Topic of Fish Awareness

Learning Objectives

Using an informal assessment, students will begin thinking about awareness, listing anything that they have previously heard. Students, through discussion, will pose any questions they may have and create their own definition of awareness, and specifically how that might pertain to fish. In the third week, the class has a short discussion about the topic of fish awareness with students encouraged to ask questions to the group as a whole as well as the student sitting directly next to them (termed their “shoulder partner”). There are 2–4 students per table. The discussion continues with probing questions from the instructor, such as: “Can you describe the term awareness?”; “Are fish able to be self-aware?”, and “Why is this knowledge relevant?” Students then, with their table partners (all students at a table), come up with possible answers for these questions to present to the class. Following the discussion, students are given 10 minutes to make hypotheses with their shoulder partner or small group about whether they expect self-aware fish to occur in Kansas freshwater.

Time

The Week 1 and 2 discussions took approximately 30 minutes of class time each. The entire activity during Week 3 took 60 minutes of class time.

Week 4: Creating the Study

Learning Objectives

Applying what was learned in Weeks 1–3, students will begin evaluating collection technique options, which will be used to create an appropriate methodology for collection of specimens and their data. By the end of class, students will construct a sampling protocol.

Activity

Peer-reviewed literature is to be used to guide the students to create a sampling protocol. Project design aspects are first discussed in class, where the instructor poses a series of questions followed by discussion. Questions include items like: “What kind of environment will we need to collect from?” or “Do you think that certain species of fish will have a higher likelihood of presenting traits that show self-awareness?” or “What types of variables might be quantifiable and observable in fish that show self-aware behavior?” After discussing these questions, a basic sampling protocol is written on the board using words and ideas generated by the discussion (see Supporting File S6). This protocol is what each student uses when observing the fish and collecting their data.

Time

Discussion and protocol creation last approximately 45 minutes.

Weeks 5–11: Practicing Collection Methods and Collecting Data

Learning Objectives

Students will be able to format a timeline for their research and implement sampling techniques by conducting fieldwork based on the sampling protocol they created.

Activity

Students design the study timeline by signing up for an observation time of their choosing. All observations must be complete prior to data analysis (Week 12). Students use scientific equipment such as seines (a seine is a specific type of fish net) to collect samples from streams. Cameras were set up by the instructor and also used to observe fish behavior, but this is optional, and all recordings can be shared on Canvas. During class time, all students and the instructor went to the
aquariums that were ready and they did a practice observation with guidance from the instructor. They then compared answers, discussed consistency, and addressed questions or confusion.

The instructor scheduled a time to collect fish and students volunteered to help. Our institution is within walking distance of several bodies of water, thus ‘field trip’ may be too strong a term, as no formal bus or other transportation was required.

**Equipment Needed From the Instructor**

- Aquariums (5–10 gallons) and associated filters, bubblers, decorations, fish food, mirrors, timers, seine, bucket, small hand nets, and visible implant elastomer tags (also not necessary if you do not have multiple fish per tank; or there are cheaper options available). Video recording equipment was provided by the university.

**Time**

Outside of class, it took roughly 8 hours by the instructor to construct the aquarium design. Construction includes cleaning all tanks, filling them with water (and waiting for chlorine to evaporate), inserting aerators and placing thermometers, and adding river rocks as substrate.

**Equipment Students Need to Have Themselves**

- Notebook, pencil.

**Time**

Outside of lab hours, volunteer students, with the instructor, capture fish from streams and bring them back to the microcosm fish tanks. Students observe fish during lab in-person or by using video recording cameras and observing from home. Observations totaled four intervals of five minutes each over a period of 14 days, making a total of 20 minutes of class time for each individual student.

**Week 8: Peer-Reviewed Literature**

**Learning Objectives**

- Students during Week 8 will be able to search for and summarize peer-reviewed articles. Students will demonstrate their knowledge by submitting an example to the instructor.

**Activity**

- A librarian at the institution introduces students to Google Scholar and the university library’s website, which has database searches (e.g., JSTOR, Web of Science). This allows them to collaborate with the librarian and dive specifically into peer-reviewed literature. It is not necessary to invite a librarian as a guest speaker, but we invited our librarian to encourage students to meet professionals. Then, a discussion of what “peer-reviewed” means starts with their table groups. We then join as a class to generate a definition. Students are asked to use the knowledge they learn in class discussions about peer-review plus the knowledge of their study design and data they collect to find an appropriate peer-reviewed article related to their research topic (see Supporting File S4 for details). Each student must find a unique article and provide a summary of the article’s content. The instructor uses these review summaries to begin building the manuscript. To do this, the instructor reads and grades all written summaries submitted by students for each peer-reviewed paper. The instructor uses the work provided by the students to begin shaping a scientific paper. Since each summary includes the citation for the paper, the Literature Cited section is easily built. Students have already designed the methods (Week 4), and the results are done together at a later time point (Week 12), leaving the introduction to be completed at this time. Writing the discussion of the article is done throughout the research. This initial draft should have all the parts and be generally readable, but the instructor should not be overly concerned with altering student writing and correcting grammar—this is what the students will work on as the final step (Week 14).

**Week 12: Understanding and Analyzing Data**

**Learning Objectives**

- Students will, by the end of Week 12, conduct a statistical analysis in class with instructor guidance.

**Activity**

- Students use chi-square and t test analyses in the traditional laboratory exercises co-occurring with their FAB project (for lesson examples, see 15). Students implement their knowledge to determine if a t test or chi-square is applicable and then analyze their own fish awareness data.

**Time**

- Organizing the data and running a t test by hand takes 60 minutes. If students have not had prior experience with a t test, the time to conduct one in class with the students will likely double. The sophisticated analyses for the published manuscript produced for this specific project were completed by the instructor in one day (approximately 2 hours); however, this step may not be necessary depending on the nature of the data.

**Week 14: Concluding the Research**

**Learning Objectives**

- Students, after their investigation has concluded, submit a reviewed and edited scientific manuscript.

**Activity**

- The students review the draft manuscript prepared by the instructor, using the summaries of peer-reviewed literature and the in-class data analysis and results. A hard copy of the paper prepared by the instructor is given to every student in Week 14. Using this draft of a manuscript, students are required to correct mistakes (spelling and grammar), highlight areas they found confusing, write questions in the margins, and make general comments throughout the paper. Each student makes these edits and comments individually. Students will turn these corrected documents in to the instructor. The instructor then addresses the edits and comments of each student on one final document, either accepting or rejecting suggestions. Once the final manuscript is complete, a fresh version that has incorporated the changes is given back to the students. Doing this as the final step allows students to see their own work presented in manuscript format. After the course concludes, students who wish to continue to be co-authors provide their
contact information, as the peer-review process can take a year or more.

**Time**
Addressing all student edits and comments takes 1–2 hours over 1–2 workdays. The instructor should have 1–2 weeks to complete this task. Outside of lab hours, volunteer students helped the instructor remove the fish from the microcosms and return them back to the same stream they were captured from. Once the fish were back in their native stream, the microcosms were drained and washed during lab hours to make ready for another research study. In our case, returning the fish to their native stream took 1 hour and draining and washing the microcosms took 2 hours.

**TEACHING DISCUSSION**

**Lesson Effectiveness (Learning Objectives)**
We compared students’ knowledge gains between this FAB PROJECT laboratory and two other traditional laboratories using two assessments. To quantify students’ enjoyment and attitude toward science, we utilized the Persistence In The Sciences (PITS; see 16 for PITS assessment) survey. In addition, we quantified content-knowledge, literacy, and performance skills using the Test of Scientific Literacy Skills (TOSLS; see 17 for TOSLS assessment). When questioned if the students had successfully met the learning objectives listed at the top of this article, we can look toward the final transcript that was written by the student researchers for guidance (15). Over the 14-weeks of this lab, the students achieved each learning objective through active learning. Creating a hypothesis, designing a research plan, implementing this plan, and producing a transcript are just a few of these learning objectives that were met. Learning objectives also included successfully engaging students in discussion, peer-reviewed article critique, and scientific writing. By observing the class interactions, we confirm that the topic provided stimulating discussions led by students’ interests. Peer-reviewed article critiques that were submitted by students were appropriate to the topic of awareness. These articles are essential resources needed to write the manuscript. As such, most of the writing and editing is done by students.

**Lesson Effectiveness (Knowledge)**
TOSLS assessments were given both prior to completion and after completion of the research project. Pre- to post-semester implementations of TOSLS did not show a change in knowledge, either positive or negative, between students engaged in the inquiry-based learning project and the students who were not. Our results suggest students learn equally from traditional and inquiry-based methods (18). Students had equal gains in their content knowledge, but the FAB PROJECT students were found to enjoy science significantly more when involved in the discovery techniques offered in the FAB PROJECT (18). Moving forward, future research possibilities might include a longitudinal study to examine affective factors rather than cognitive factors.

**Student Reactions (Emotion/ Identity)**
Comparing mid- to end-semester PITS surveys, evidence shows that students’ enjoyment of research is increased in FAB PROJECT courses (see 16 for entirety of PITS survey). In addition, students respond that their contribution to the scientific community is greater and their research relevance to the scientific community is also greater (18). Creating authentic research produces long-lasting impacts on students’ emotions toward the sciences (18–21). Our FAB PROJECT students responded that they were more confident in their ability to identify themselves as scientists, as opposed to non-inquiry-based students who did not model this confidence. Students in the FAB PROJECT described that they felt like the research project taught them about how real scientists conduct research. Our data reinforce other discoveries (4, 20, 21) that illustrate with inquiry-based learning students become more comfortable with involving themselves in the community of science. A continuing research avenue instigated by the positive reactions from the FAB PROJECT, focuses on investigating how involvement in inquiry-based projects influences student retention and interest in STEM fields.

**Possible Improvements/ Extensions**
Depending on the methodology an instructor uses to implement this design, the instructor may need to allow students to be in the laboratory after hours or on weekends. If after-hours work is required, students may need their own transportation to and from the laboratory. This could cause accessibility issues. Furthermore, after-hours work requires considerable confidence in these students to properly take observations independently. Video recording software may be implemented to monitor fish behavior, which allows for students who are unable to be present in person to record their observations. Combating issues of accessibility and including each student’s observations means the largest possible sample size is produced, leading to a more robust study, and triangulation of data. Summaries (Week 8) could be submitted with no instructor review or prior feedback. Our students were given the option to email their paper selection to the instructor who gave general constructive comments and students could revise before the final submission. Nearly every student took advantage of this option, but it does increase instructor workload. Statistical analysis (Week 12) can be adjusted to be more or less complex, depending on what statistical background students have. Students could simply make graphs by hand or with computer software. If students are more advanced, they could conduct these analyses as homework with a written assignment provided by the instructor.

A possible method to allow for implementation of the project more quickly would be to have the instructor design and construct the aquaria that they anticipate will be used prior to the semester starting (see Supporting File S5 for details). This would mean filling aquaria with water and cycling the water through for a week or two in order to ensure that the design is sound and will not leak in the future. However, this pre-initiation of the study may reduce sense of ownership by the students. In addition, to relieve some of the first week’s load, aquarium habitat pieces such as rocks and sediment could be collected from the surrounding environment, sanitized, and placed in the tanks prior to the start of the semester. Finally, performing a brief observational freshwater stream survey of the local environment prior to the semester will enable the instructor to be confident in where to send students for fish collection.

**Course Design**
To follow the semester timeline more rigorously, weekly activities may be scaffolded so that students perform relevant
lab exercises before transferring these techniques to their own research project. This modification would mean purposefully implementing the traditional laboratory techniques around the FAB PROJECT timeline.

Conclusion

The FAB PROJECT is a unique way to implement research in a classroom. Inquiry-based learning can offer emotionally impactful and memorable semester-long research to a wide variety of students. By including entire classes in research, students who would not otherwise have been involved in research are given the opportunity to participate. Likewise, when a student is engaged in research, they express feelings of being a true scientist, which has been shown to correlate with positive attitudes toward research, retention in STEM fields, and the ability to withstand obstacles. Here, we present the FAB PROJECT designed so that a secondary or higher education instructor can have the FAB PROJECT implemented in their biology classroom, and possibly benefit their students in these positive ways.

SUPPORTING MATERIALS

- S1. Fish Awareness – Informal Assessment
- S2. Fish Awareness – Formative Assessment
- S3. Fish Awareness – Summative Assessment
- S4. Fish Awareness – Written Summary Rubric
- S5. Fish Awareness – Aquarium Design
- S6. Fish Awareness – Protocol and Data Sheet

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<tr>
<th>Week(s) and Description</th>
<th>Project-Specific Tasks</th>
<th>Assessment Method</th>
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<tr>
<td>1, 2, and 3: Introduce topic</td>
<td>Week 1: Students will be assigned to read the same layman-friendly article (about aquatic fishes and awareness). Students will have read the article by the third week of class. Students, through discussion, will pose any questions they may have and create their own definition of awareness, and specifically how that might pertain to fish. After this assignment is introduced, an informal discussion is prompted by asking students if they have heard about fish awareness.</td>
<td>Informal: Discussion about awareness using prompt words written on the board. Formal: Students will form questions about awareness, ultimately leading to their research question.</td>
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<td>Define if fish can be self-aware, and define what is awareness in fish. Formulate a hypothesis as to whether they expect fish to be self-aware. Discuss their definitions of awareness in fish with peers using terms learned in peer-reviewed articles.</td>
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<tr>
<td>4: Creating the study Organize collection techniques used for fish sampling. Construct a sampling protocol.</td>
<td>Students will organize their sampling protocol to be used throughout experiment. To do this, students will be posed a series of questions followed by discussion. Questions include items like, “What kind of environment will we need to collect from?” This will lead students to think about different variables in their environment. A basic sampling protocol will be written on the board using the words and ideas generated throughout the discussion.</td>
<td>Informal: Reflect on peer-reviewed literature. Formal: Sampling protocol creation.</td>
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<tr>
<td>5–11: Data collection Format a timeline for their research project. Implement sampling techniques in the field. Use scientific equipment such as seines. Observe fish behavior both in person and using video capture software.</td>
<td>Student will format a project timeline and implement sampling techniques from the protocol they created in Week 4. Students will sign up for sampling times with all the observations being completed prior to Week 12. Students will employ sampling techniques using equipment such as seines to collect the fish from streams, multiple microcosm fish tanks to keep the fish in for observations, and cameras to capture the fish movement while no in-person observation can take place. Outside of lab hours, volunteer students, with the instructor, capture fish from streams and bring them back to the microcosm fish tanks. Students observed fish outside of lab both in-person and using cameras. No class time was taken.</td>
<td>Informal: Conduct field work and observations following the observation sign-up sheet.</td>
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<td>8: Peer-reviewed literature Invite librarian to classroom to give an overview of the resources available for students. Engage in collaboration in order to critique peer-reviewed articles.</td>
<td>Students are to be shown various databases of peer-reviewed literature to use for resources. A librarian may be invited to class to give a demonstration on how to use school related databases. Students will discuss what makes a peer-reviewed article. Topics might include the organization of scientific articles, the vocabulary employed, and the recognition of journals as reliable or not. Students will then find their own peer-reviewed articles they will later be compiled by the professor to write the rough draft of the manuscript. The presentation from the librarian should last 20 minutes. Discussion about peer-review lead by the instructor takes approximately 20 minutes.</td>
<td>Informal: Discussion over what is a peer-reviewed article. Formal: Find peer-reviewed articles relating to their project</td>
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Table 1. FAB PROJECT: Fish Awareness Timeline. The basic timeline of events with brief descriptions of activities and estimated class time dedicated to the research.
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<td>12: Data analysis</td>
<td>Students are introduced to both the chi-square and ( t ) test. Using the data collected, students will then organize their data. Data will then be presented to the instructor to complete any remaining data analyses. Organizing the data and running a ( t ) test by hand takes 60 minutes. If students have not had prior experience with a ( t ) test, the time to conduct one in class with the students will likely double.</td>
<td>Formal: Preform statistical analysis</td>
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<tr>
<td>14: Research conclusion</td>
<td>Students will create draft manuscript while the instructor takes charge of edits. A hard copy of the edited rough-draft manuscript is then presented to the students, and the students are asked to make further revisions as they see necessary.</td>
<td>Formal: Draft, edit, and publish manuscript</td>
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An Inquiry-Based Project Added to Traditional Labs: Hands-On Fish Awareness Research in Freshwater Systems Conducted by First-Year Biology Students

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