GOOSE CAM: The Development of a Practical Underwater Exploration Platform

William R. Miller[1*], Colleen Mitchell[2], and Jeffrey D. Miller[3]

1Department of Biology, Baker University, Baldwin City, KS 66066; 2 Center for Canopy Ecology, TREE Foundation, PO Box 48839, Sarasota, FL 34230-5839; 3 Department of Biology, University of Central Arkansas, Conway, AR 72035

Email: William.Miller@BakerU.edu

*Corresponding Author

Abstract: We challenged an Aquatic Biology class to find a way to access, observe, and record aquatic habitats and organisms without causing disruption. Using off the shelf components the class was guided in the design and assembly of a remote controlled, video broadcasting, data collecting, floating vehicle based on a molded goose decoy. GOOSE-CAM or Guided Object Observatory for Scientific Experiments-Camera Afloat Module is now used to observe, count, and record aquatic invertebrates, fish, and plants. Recent additions have expanded GOOSE-CAM to record temperature, light (turbidity), and depth. The project fulfilled the dual educational goals of (1) integrating student biological knowledge with engineering, physics, and chemistry and (2) providing a context in which students develop problem-solving skills. The project required active participation, research, teamwork, and application learning in a realistic context to be able to support the collection of ecological data. With a bit of imagination, the concept could be adapted to other courses and environments.

Keywords: Remote Sensing, Underwater Video, Environmental Measurement, Undergraduate Research.

Introduction

Nature television and the World Wide Web provide a glimpse into worlds that most people seldom see. Today audiences watch remote vehicles explore the Titanic or the surface of Mars and with a few mouse clicks students in China can observe osprey chicks being fed in Florida. However, as interesting and engaging as these experiences are, they are essentially vicarious as there is an obvious gap between seeing and doing science.

Yet, inquiry is the basis of scientific research whether or not it is shown on TV. Inquiry is "a multifaceted activity that involves making observations; posing questions; ... planning investigations; … using tools to gather, analyze, and interpret data …" (NSES, 2004). Science education should involve inquiry (Windschit and Buttemer, 2000) while stimulating critical thinking and decision making skills in the context of scientific principles (BSCS, 2004). "The intention is to improve the quality of student learning by enabling them to acquire the abilities of inquiry, develop knowledge of scientific ideas and understand the work of scientists" (NSES, 2004). The process of thoughtful inquiry "encourage students to view science as an ongoing, relevant process of learning, as well as a body of knowledge" (BSCS, 2004). In short, students become engaged in science by doing science.

Today, much of the practice of scientific inquiry is closely linked to technology. The development of machinery, instruments, and methods necessary to answer scientific questions is an integral part of scientific investigation. Woods Hole built ALVIN to investigate the deep ocean and found the Titanic. NASA built the rovers to explore Mars and found evidence of water. Bringing scientific technology and investigation into the classroom is challenging; to do so we must add a mixture of structured inquiry and cooperative learning to our more traditional techniques to encourage and guide students to ask questions, evaluate information, and make decisions.

Goals

The learning objectives of our Aquatic Biology course were to introduce students to the biology of stream and lake organisms and to the methods used to study their ecology. To the basic course we added two additional educational goals: to integrate knowledge from related disciplines (e.g. engineering, physics, and chemistry), and to provide a context in which students develop problem-solving skills. The first two goals were addressed with lectures, laboratory exercises, and field trips. The new goals were addressed with a semester long laboratory project that required active participation, teamwork, and research to design and build a vehicle to collect ecological data. The project was presented to the class in the form of a challenge.

The Challenge

The Aquatic Biology class at Chestnut Hill College was challenged to discover and document the diversity of fish species living in the Wissahickon Creek, which runs through their suburban Philadelphia campus, without disrupting the population(s) or the habitat. In order to address the challenge students had to think both creatively and scientifically about the problems of assessing the stream ecosystem. They had to work as a team to develop an analysis strategy, assess methods that did not disturb the stream ecosystem, and develop a workable solution.

Process

After being presented with the problem, general criteria, and limitations the students developed a four step process in a brain storming session. First, they would identify and evaluate options for solving the problem. Second, they would design, construct and test equipment. Third, they would use the equipment to address the challenge. Fourth, they would review, evaluate, and enhance the solution to the problem. Each step was allotted a three hour lab period spaced through the semester. The eight students independently researched questions, assembled equipment, conducted experiments, and solved problems as a study group. The resulting GOOSE-CAM was used not only to identify fish but it became a tool to collect data on other laboratory field trips. The instructor served as mentor and consultant during the process.

Step 1: Identify and Evaluate Options

Initially students thought they could use the internet to answer the challenge but the information they found was too general to produce a list of species that actually lived in the Wissahickon Creek just a few yards from our class room. For example, they found a list of fish of eastern Pennsylvania from the Pennsylvania Fish and Boat Commission (PAFGC, 2005); however, there was no information about smaller drainages. They followed other links to university courses; again, although useful, these did not provide direct answers. Some websites were informative on aquatic sampling methods and guided students back to published references (books and articles).

During this step, students read and evaluated material of varying quality from a variety of sources ranging from superficial websites through scientific papers. They evaluated the material both for the application to the project and the biological, practical, and ethical ramifications. They discovered that many of the options would necessitate obtaining permits from one or more regulatory agencies. Students prepared synoptic reports of several options and we discussed the merits of the methods during laboratory class.

Option one was to stretch a net across the stream, poison the water, and collect all the dead fish for identification in the laboratory. This option was rejected for biological, safety and criteria reasons: because it required a permit for the poison, killed the fish, and caused changes in the structure and composition of the aquatic community down stream. The second option was to electroshock the fish; this option was rejected because we did not have the permits, equipment, or appropriate training to ensure safety during field work. The students also voiced the same conservation concerns of killing so many fish and other organisms for a small learning reward. We discussed the appropriate use of these research tools and decided they were outside the design intent of the challenge. The third option was to conduct a survey of fishermen to determine what they were catching; this was rejected because of the built in bias in sampling. A creel count would be limited by the number of fishermen and the few larger species they seek. Our fourth idea was to SCUBA dive to examine the aquatic community; this was rejected for three reasons. First, no one had the training and certification for diving; second, bias would result from the presence of a diver in water only 3-6 feet deep; and third, in the spring semester (January-May) the water temperature is quite cold and uncomfortable.

Finally, the class felt the method that caused the least disturbance and had the greatest possibility of success in identifying the actual diversity of fish was to put a camera into the stream and take pictures of the inhabitants. However, this option posed its own challenges. A camera had to be (1) water proof, (2) small enough not to be disruptive to the fish, and (3) the image had to be of a quality sufficient to facilitate identification. Further, the unit had to be (1) portable, (2) maneuverable, and (3) affordable.

Our discussion considered building a Remote Submergible Vehicle (RSV) similar to the one used to find the Titanic but it was quickly realized that this was beyond our resources. Our discussion settled on the idea of suspending a waterproof video camera under a model boat, that we could motor around and observe the aquatic wildlife. The class also felt that if a Canada goose hunter's decoy was chosen for our boat, it might have less impact on the behavior of the aquatic fauna. We developed a design concept (Fig. 1A) and named the idea GOOSE-CAM for Guided Object Observatory for Scientific Experiments, Camera Afloat Module.

Figure 1. A. Original design and concept drawing; B. GOOSE-CAM on the Wissahickon Creek; C. Building GOOSE-CAM; D. Internal compartment showing wooden platform supporting the motor, batteries, and radio controls; E. Rudder / propeller mechanism on transom; F. Underwater camera on keel; G. GOOSE-CAM in aquarium for first water tests; H. GOOSE-CAM in pool during maneuvering tests; I. Model radio-controller used to guide GOOSE-CAM; J. Video receiver & camcorder recording system.

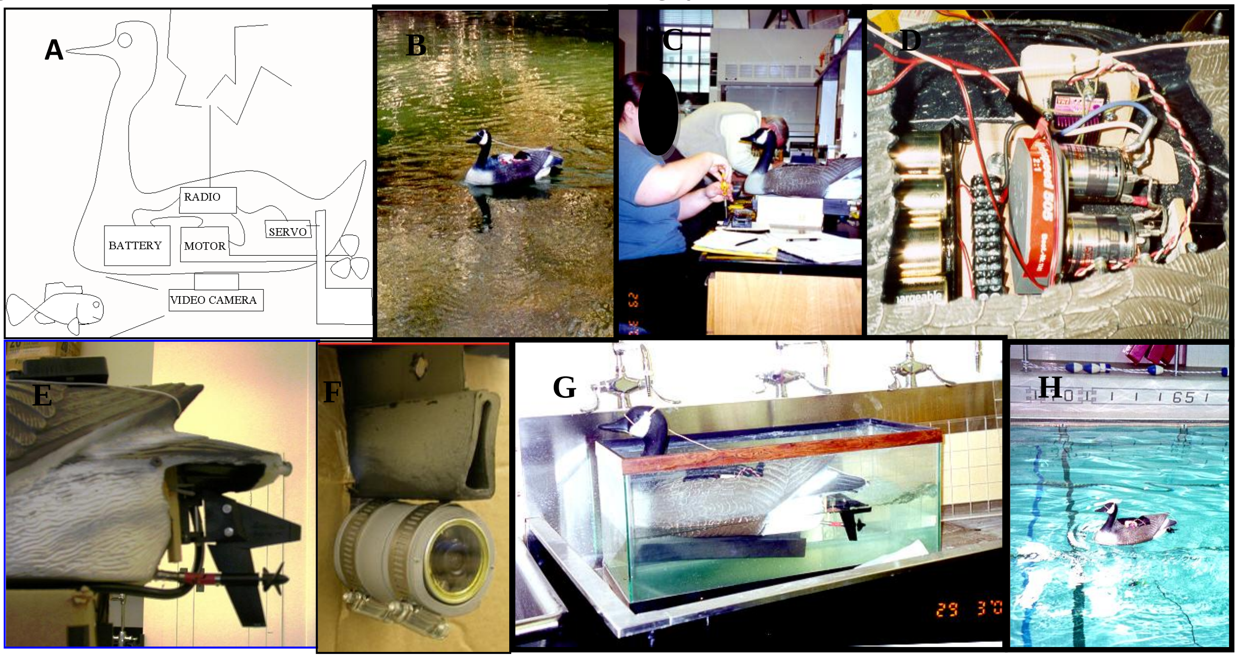
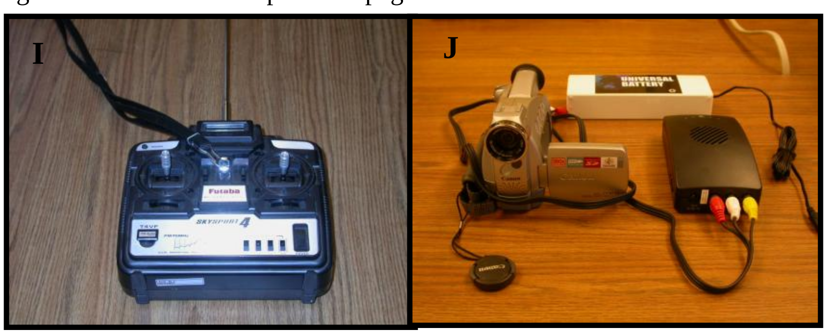


Figure 1. continued from previous page.



Step 2: Design, Construct and Test Equipment

The selection of components was restricted by the availability, the cost, the weight and the time allotted within the class to complete the project. We have listed the parts, descriptions, where we found them, and approximate prices in Table 1, brand names have been omitted because several different companies make similar items; a search of the internet will display alternatives. Minor components such as screws, bolts, scrap wood etc are lumped together.

The use of off-the-shelf components kept the focus on the goals of the project. Each component was selected for its contribution to the total; however, the assembly presented unique problems in getting the different parts to work together inside the goose decoy. This served as an allegory for the cooperative learning situation imposed on the students. Each student contributed their own unique skills and knowledge to the team effort. Some knew about sealants, adhesives, and fasteners. Others calculated buoyancy, matched voltage, and wired circuitry. One student had flown model airplanes and another was into video editing. Some searched the internet for components while some sought out experts (fathers, teachers, and friends) to answer questions. As individual components were acquired they were bench tested and pre-assembled for fit and function. Faced with practical problems of designing, constructing and testing GOOSE-CAM, students developed problem solving skills, improved communications, and learned from each other.

Assembly. A 4x5 inch opening was cut in the top (dorsal) surface of the goose decoy with a jig saw (Fig. 1D). The hatch piece was hinged back to the body with hook and loop material and could be sealed with duct tape when in the water. Two 3/8 inch bolts were inserted into body cavity through holes drilled in the bottom of the decoy and sealed in place with silicone bath tub caulk. The bolts served as positioning guides for the wooden platform to which the motor, batteries, and radio control modules had been attached with small wood screws (Fig. 1D). A second opening was cut in the posterior (caudal) end of the goose under the tail. This hole was fitted with a wooden plug, attached with screws through the sides of the decoy and the seams sealed with silicone to make a transom. The plug was waterproofed with urethane finish, a hole was drilled through which the propeller shaft extended, and the rudder assembly attached (Fig. 1E). The waterproof video camera was mounted on the keel of the decoy with wood screws and band clamps (Fig. 1F). Note: for safety reasons the cutting and drilling was preformed by the instructor at home.

Testing. The assembled system was first tested in a large fish tank (Fig. 1G) and then in a swimming pool (Fig. 1H). These steps provided project milestones, ensured the assembled unit would function, and allowed the adjustment of the position of the batteries to avoid capsizing. The pool test gave us training and practice in the operation of GOOSE-CAM.

The GOOSE-CAM was maneuvered with a radio control (R/C) model controller (Fig. 1I) but was tethered to the shore by the cable between the video camera and its TV monitor and battery. The cable was buoyed with small fishing floats, but the drag hindered GOOSE-CAMs movement and it became entangled in floating debris and vegetation during field trials.

We found a wireless video transmitter designed for a home security system that did not require a license (Fig. 1J). It gave a line-of-site video signal up to 700 feet even though GOOSE-CAM has seldom been deployed more than 150 feet from the operators. Video observation became portable and recordable by replacing the TV monitor with a camcorder, borrowed from our Audio-Visual department (Fig. 1J). But putting the video transmitter onboard GOOSE-CAM presented new challenges because the camera system, motor, and radio controls each required different voltages.

Field trials of GOOSE-CAM demonstrated that the motor was sufficient to propel the decoy against the mild current and that it could be maneuvered easily with the R/C controller. Fish could be seen clearly on the side screen of the camcorder when the turbidity was low. We quickly learned that vertical visibility translated into horizontal fish visibility.

Step 3: Using the Equipment

GOOSE-CAM allowed us to observe fish with little disturbance. Bigger fish did not mind the moving decoy but smaller fish only came around while it was still. Students checked GOOSE-CAM out of the lab on non class days to explore different habitats in the stream and recorded and identified 12 species of fish and five different aquatic plants. Our applications expanded beyond viewing the fish in the Wissahickon as GOOSE-CAM quickly became part of our field trip equipment. We it to a lake in a state park and were able to watch the fish under docks and we followed a big bass as it swam between lily pads in a marsh. The transmitted video improved our understanding of three dimensional spaces even in shallow water. The observation of invertebrates was more difficult because of distance, magnification, and lighting limitations but we did observe a few crayfish and one large dragonfly larva. Once, we tried to get close to a beaver but it swam too fast. Another time, a large male Canada goose landed next to GOOSE-CAM and followed it around the stream honking loudly; eventually, he lost interest and left.

Step 4: Enhancing the Unit

Having demonstrated that GOOSE-CAM actually provided a window under the water, it allowed us to answer the challenge of identifying what fish lived in our stream. As a tool, GOOSE-CAM introduced the class to questions of double counting, estimating populations, and spatial and temporal differences.

As we started to discuss other applications, the class decided that by adding instruments to GOOSE-CAM, we could take measurements in places we could not reach. We decided to measure location, water depth, turbidity, and air and water temperature. The students selected instruments based on function, size, weight, and cost (Table 1). A small data logger was suspended in a clear plastic case from the keel behind the camera, this recorded water temperature and light (turbidity). A similar unit on the back of the decoy recorded air temperature, light and relative humidity. A fisherman's depth gage was found that could be towed behind the decoy.

But data is meaningless unless it can be spatially oriented, thus location on the water was determined to be a critical element. A small, light weight (6 oz) GPS unit capable of recording waypoints was found and with one of the free channels on the R/C controller we were able to construct a simple lever to activate the waypoint button. We later downloaded the data from the data loggers and the GPS into a spreadsheet and matched the times at a specific waypoint. Thus GOOSE-CAM was enhanced to a remote sensing instrument in space and time.

Table 1. Components used in GOOSE-CAM.

ITEM	Description	Approximate Cost (2004)
Goose Decoy Fig. 1B	A plastic, Canada goose decoy was hollow and water tight. It had a flat bottom with a small keel. Sporting Goods Store.	$20
Radio Control Fig. 1D, 1I	A four channel radio control (R/C) system of the type used in models. One channel to control forward, reverse and speed of the propeller; second channel to control the rudder for steerage; the third & fourth channels were free. One was later used to mark location (waypoints) on the GPS. Hobby shop.	$150
Propulsion Fig. 1D, 1E	A model boat electric motor with propeller, shaft, and rudder mechanism. Hobby shop.	$80
Video Camera Fig. 1F	An off-the-shelf underwater video camera designed for exploring sewer pipes, it had a built-in LED illuminator and included a 7" TV monitor for viewing. Internet / mail order	B/W $150 or Color $350
Video Transmitter / Receiver Fig. 1J	2.4 GHZ technology which requires no license to operate allowed line-of-sight video transmission up to 700 feet. Included transmitter and receiver. Internet / mail order	$100
Supplies	Miscellaneous hardware, batteries, wires, connectors, tape, Velcro, screws, bolts, sealant, etc.	$50
Total	Basic GOOSE-CAM w/o instruments or camcorder	B/W $550 or Color $750
	Options: Instruments	
Location	Small, light weight (6 oz) GPS capable of recording waypoints when activated by R/C controller. Included unit, cables & software. Down loadable to a computer spread sheet. Sports Retail Store.	$100
Depth	A small digital depth sounder and wristwatch receiver. Sports Retail Store.	$85
Environmental Sensors	Temperature and light (turbidity) data loggers. Internet / mail order or Science Catalogues.	$100 ea
Totals	Basic GOOSE-CAM with instruments, w/o camcorder	$835 - $1135
	Options: Recording	
Images Fig. 1J	A camcorder that accepts external analog A/V input can capture images for later use. Digital recording allows image analysis and editing. Borrowed from AV Dept.	$300 - $1,000

Discussion

The making of GOOSE-CAM was not an end in-itself. The goal was to engage students in a project that would further their knowledge of biology and improve their problem-solving skills. Throughout the GOOSE-CAM project students were encouraged to think critically, incorporate their existing knowledge, test ideas, interact to find solutions, and to achieve the goal: to access, observe, and record aquatic organisms and habitats without causing disruption.

Based on our experience, we agree with Lord (2001) that the application of cooperative learning in the teaching of biology encourages critical thinking and improves students' practical problem-solving skills. We chose the GOOSE-CAM class project as a structured, inquiry-based learning project (Windschit and Buttemer, 2000) because of the availability of laboratory time. This approach proved useful because our class size was small (8 students) and because we emphasized student learning with a mixture of inquiry and classical classroom experience. Based on our students' active participation, we believe we achieved the goals of integrating biological and related knowledge while developing problem solving skills.

Because we can not afford to build a new GOOSE-CAM every year, the challenge for the next Aquatic Biology class will be to develop quantitative and qualitative applications for GOOSE-CAM. Students will be challenged to design experiments that will provide data of our stream and lake communities as an undergraduate research tool. Our class has envisioned mapping the depths and developing thermal profiles of small ponds. They suggested deploying dissolved oxygen and pH meters on GOOSE-CAM to record the diurnal chemical cycles. They also want to document fish behavior relative to structures (tree stumps, rocks, and docks).

Since this project was conducted, several students have continued to experiment with variations of the technology. One student mounted the underwater camera system on the bottom of a pole and used it for reef walking on the Great Barrier Reef. She observed and recorded shrimp, feather worms, an octopus and a small shark. When we took a class to the Amazon we used the camera to observe piranha feeding in a black water lagoon. Another student mounted a wireless camera on an R/C toy truck and monitored the behavior of geese on our soccer field. Still another student carried the video camera aloft with a helium balloon for a low level aerial measurement of invasive plants encroaching into a wetland. For now GOOSE-CAM motors through the shallows and broadcasts images of the animals and vegetation that are in front of it.

Acknowledgements

We wish to thank the students in the Chestnut Hill College Aquatic Biology classes who participated in the development of GOOSE-CAM. This project was presented to a standing room only audience at the Pennsylvania Academy of Science meeting in 2004.

References

BSCS (Biological Sciences Curriculum Study). 2004. Web Pages: Why we are different; Frequently Asked Questions. Accessed from http://www.bscs.org on 25 May, 2005.

LORD, T.R. 2001. 101 reasons for using cooperative learning in biology teaching. *The American Biology Teacher* 63(1): 30-38.

NSES (National Science Education Standards). 2004. Inquiry and the *National Science Education Standards*. Accessed from http://www.nap.edu/readingroom/books/nses on 9 May, 2007.

PAFGC (Pennsylvania Fish and Game Commission). 2005. Fishes. Accessed from http:/www.fish.state.pa.us/fishes.htm on 21 February, 2005.

WINDSCHIT, M. AND BUTTEMER, H. 2000. What should the inquiry experience be for the learner? *The American Biology Teacher* 62(5): 346-350.