Using Real-World Problems to Engage Physics Students and Teach Important Physics Concepts

William Hughes, Physics Education (7-12) with Alternative Certification, M.S.Ed.
Faculty Mentors: Professor Luanna Gomez, Physics and Professor Jill Singer, Earth Sciences and Science Education

Buffalo State
The State University of New York

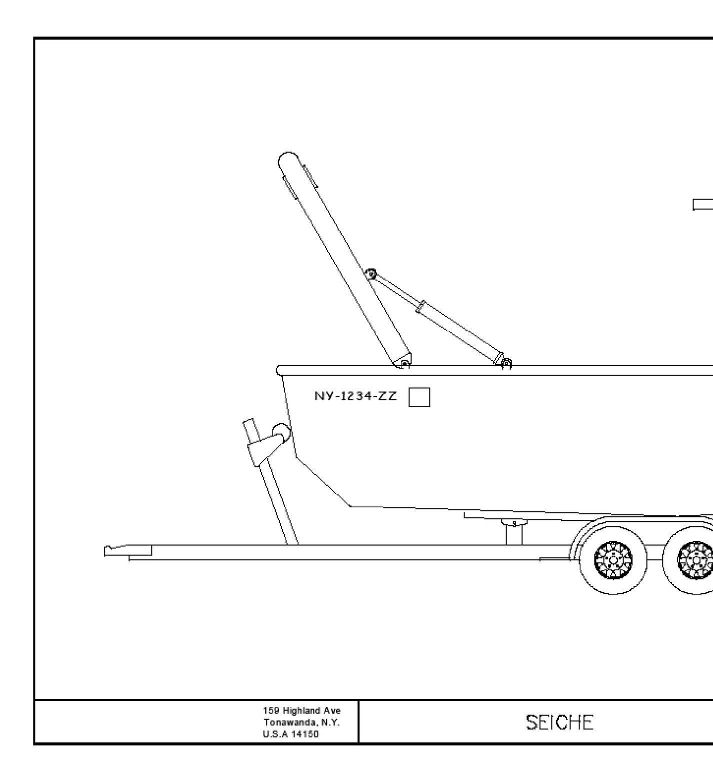
Student Research and Creativity Celebration

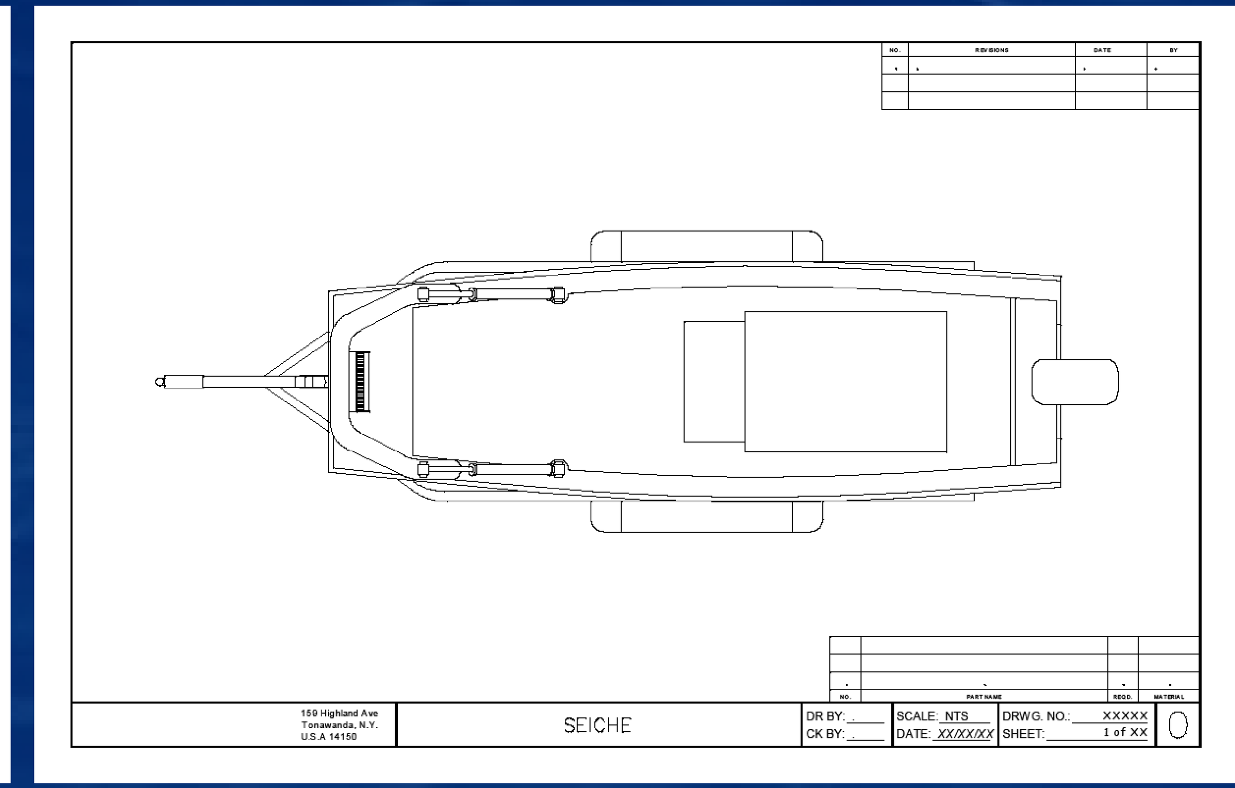
Abstract

My master's project in physics secondary education illustrates ways to help students connect real world problem solving to introduce and solidify introductory physics concepts. The 'problems' being solved reflect those that I have encountered over the past several years while conducting fieldwork on the Buffalo River. Much of this research has utilized a 24' workboat, the RV Seiche, named for the interesting phenomenon that occurs in the Buffalo River when Lake Erie seiche events reverse the flow direction in the Buffalo River. This work has involved the deployment and recovery of a variety of scientific instruments including temperature sensors, acoustic doppler current profilers (current meters), and water level gages. The operation of the vessel and the array of sensors translate into a suite of meaningful lessons for secondary physics students. Specifically, challenges encountered in river operations include transporting large and heavy equipment, raising and lowering (recovery and deployment) of sensors, and even the launching of the research vessel itself. For all these operations, I have relied on applying a range of physics concepts such as tension force, coefficient of friction, center of mass, impulse, and momentum to solve in the moment problems. To date I have developed six physics units that scaffold basic information into progressively more complex physics concepts and principles. The lessons are built around problems rather than presenting definitions and simplistic or artificial problems. This approach to teaching physics is informed by the literature that demonstrates that real learning occurs when students tackle problems and transfer knowledge. It is my desire to bring this type of instruction, supported by education reform, into the classroom, and inspire other educators to do the same. While I have used this approach in physics, it is not unique to physics and can be implemented in other subjects. My presentation will highlight the correlations among real-world experiences on the Buffalo River, the NYS curriculum standards, and physics education reform.

Technical Drawings

Physical measurements of the Seiche were taken to construct a 1/28 scale print generated from AutoCad software. The technical drawings of the Seiche were created to provide students with a visual aid in which to measure, create free body diagrams, and add notes to such as vocabulary or equations. This creates a platform for making real world predictions such as buoyancy, center of gravity, maximum load, A-frame capacity, and so on. The technical drawings can also be displayed on an overhead projector for illustrative or demonstrative purposes. Each time a new lesson regarding the Seiche is implemented a new copy of the technical drawings can be distributed for the students to notate. As a final note, the technical drawings will also expose the students to a more diverse vocabulary as nautical (bow, stern, port, starboard) and drafting (plan view, elevation view) terms can be introduced.





Locations on the Buffalo River where instrumentation is installed

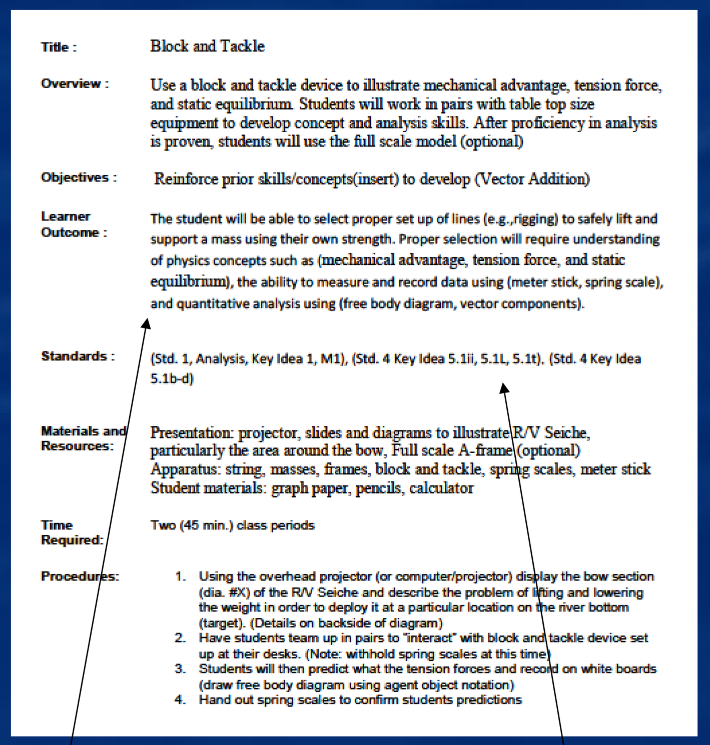
Deployment of a vertical acoustic doppler profiler

Discussion

The scope of my project is based mainly on mechanics to prove the premise of bringing life experience into the classroom has a positive affect on student learning. It is worth noting that using the Seiche as a reoccurring theme is not limited to mechanics but can be extended into electricity and magnetism as well. On board power supplies, navigation equipment, power winch, ignition system, and lighting can be applied to electricity and magnetism topics such as conductance, resistance, capacitance, magnetic field, electric field, and circuits. Ultimately it is the teacher's discretion as to what types of references are introduced in the classroom. I am not merely promoting colleagues to borrow from my experiences of working on the Seiche, but encouraging them to draw from their own as well. The project idea was born from my limited experience in the classroom (mainly student teaching). Pulling from my work on the Seiche seemed a logical way to enhance my comfort and confidence level during lesson and curriculum planning. Not only will I be more comfortable, but the students will have access to an interesting real world environmental science project as it pertains to their topic. Future work will involve more research into dealing with preconceptions and misconceptions, identifying areas of student difficulty, and better preparation for expected student response. Teaching is an ongoing learning experience.

Lesson: Block and Tackle

Students' prior understanding of force, free body diagram, vector and scalar quantities, and agent object notation is recommended before implementing this lesson. Emphasis is placed on learning vector addition using trigonometry functions to evaluate x and y vector components. The student will demonstrate their understanding of vector addition by sketching a free body diagram, and performing quantitative analysis to predict the tension force required to hold a given mass. Confirmation of their prediction is achieved from constructing a block and tackle setup and comparing the measured tension force to the predicted.



Title :	Block and Tackle
Overview :	Use a block and tackle device to illustrate mechanical advantage, tension force, and static equilibrium. Students will work in pairs with table top size equipment to develop concept and analysis skills. After proficiency in analysis is proven, students will use the full scale model (optional)
Objectives :	Reinforce prior skills/concepts(insert) to develop (Vector Addition)
Learner Outcome :	The student will be able to select proper set up of lines (e.g.,rigging) to safely lift and support a mass using their own strength. Proper selection will require understanding of physics concepts such as (mechanical advantage, tension force, and static equilibrium), the ability to measure and record data using (meter stick, spring scale), and quantitative analysis using (free body diagram, vector components).
Standards :	(Std. 1, Analysis, Key Idea 1, M1), (Std. 4 Key Idea 5.1ii, 5.1L, 5.1t). (Std. 4 Key Idea 5.1b-d)
Materials and Resources:	Presentation: projector, slides and diagrams to illustrate R/V Seiche, particularly the area around the bow, Full scale A-frame (optional) Apparatus: string, masses, frames, block and tackle, spring scales, meter stick Student materials: graph paper, pencils, calculator
Time Required:	Two (45 min.) class periods
Procedures:	1. Using the overhead projector (or computer/projector) display the bow section (dia. #X) of the R/V Seiche and describe the problem of lifting and lowering the weight in order to deploy it at a particular location on the river bottom (target). (Details on backside of diagram) 2. Have students team up in pairs to "interact" with block and tackle device set up at their desks. (Note: withhold spring scales at this time) 3. Students will then predict what the tension forces and record on white boards (draw free body diagram using agent object notation) 4. Hand out spring scales to confirm students predictions

Engage in critical thought and problem solving through hands on activity

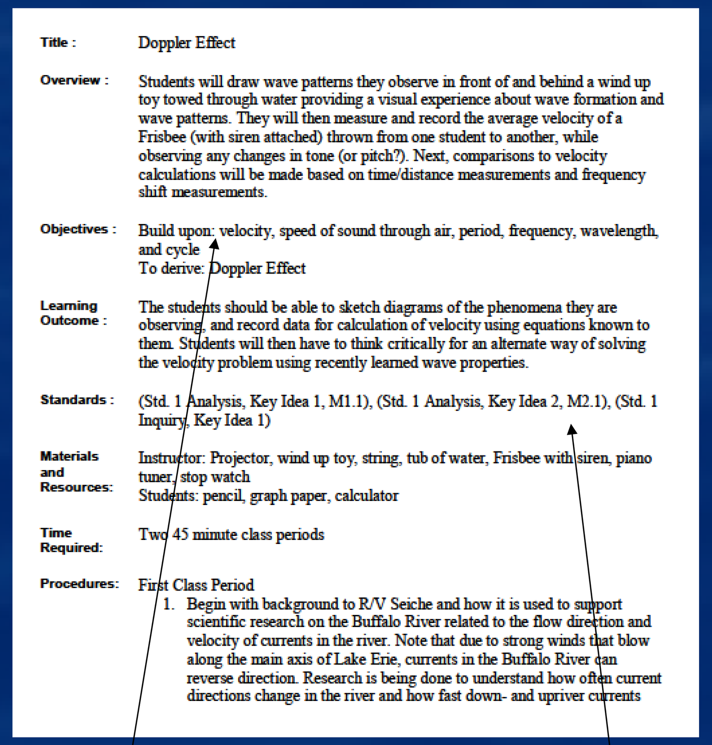
Applies to NYS Curriculum standards regarding (mechanical advantage, tension force, static equilibrium, free body diagram, and vector components)

Block and tackle style deployment of temperature sensor

Installation of a horizontal acoustic profiler

Lesson: Doppler Effect

Students' prior understanding of velocity, speed of sound in air, period, frequency, wavelength, and cycle are recommended before implementing this lesson. Emphasis is placed on understanding the Doppler Effect and why a shift in wavelength occurs due to the motion of an object. Students will engage in creative play using a tub of water and a siren Frisbee to reinforce their understanding of equations for wavelength, period, cycle, frequency, and amplitude. In small groups the students will demonstrate understanding of the Doppler Effect by deriving the equation necessary to predict the velocity of an object based on wave patterns.



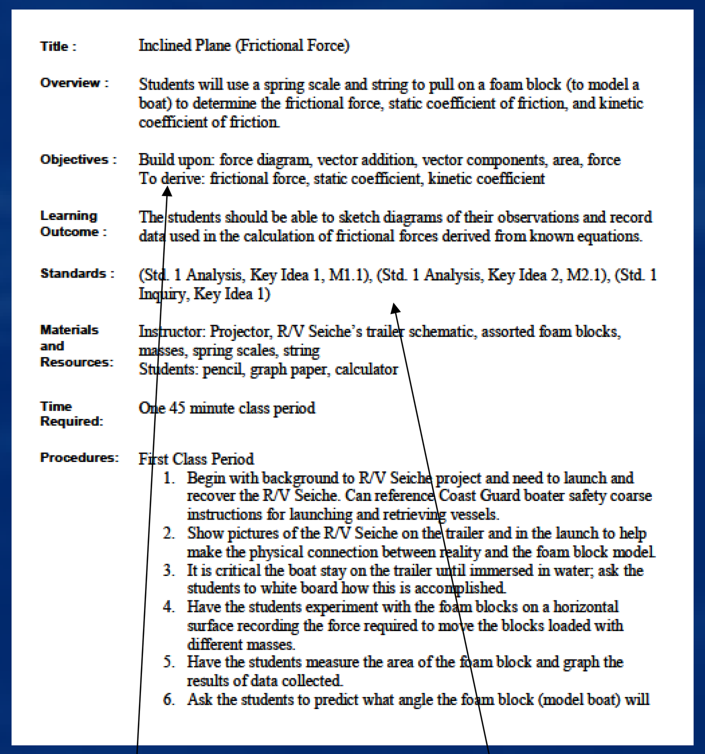
Title :	Doppler Effect
Overview :	Students will draw wave patterns they observe in front of and behind a wind up toy towed through water providing a visual experience about wave formation and wave patterns. They will then measure and record the average velocity of a Frisbee (with siren attached) thrown from one student to another, while observing any changes in tone (or pitch?). Next, comparisons to velocity calculations will be made based on time/distance measurements and frequency shift measurements.
Objectives :	Build upon: velocity, speed of sound through air, period, frequency, wavelength, and cycle To derive: Doppler Effect
Learning Outcome :	The students should be able to sketch diagrams of the phenomena they are observing, and record data for calculation of velocity using equations known to them. Students will then have to think critically for an alternate way of solving the velocity problem using recently learned wave properties.
Standards :	(Std. 1 Analysis, Key Idea 1, M1.1), (Std. 1 Analysis, Key Idea 2, M2.1), (Std. 1 Inquiry, Key Idea 1)
Materials and Resources:	Instructor: Projector, wind up toy, string, tub of water, Frisbee with siren, piano tuner, stop watch Students: pencil, graph paper, calculator
Time Required:	Two 45 minute class periods
Procedures:	First Class Period 1. Begin with background to R/V Seiche and how it is used to support scientific research on the Buffalo River related to the flow direction and velocity of currents in the river. Note that due to strong winds that blow along the main axis of Lake Erie, currents in the Buffalo River can reverse direction. Research is being done to understand how often current directions change in the river and how fast down- and upriver currents

Higher order problem involving conceptual understanding and mathematical evaluation

Applies to NYS Curriculum standards regarding (sound and waves, sketching diagrams, and deriving equations to solve problems)

Lesson: Inclined Plane

Students' prior knowledge of area, force, free body diagram, vector components, and vector addition is recommended before implementing this lesson. Emphasis is placed on the derivation of frictional coefficients both static and kinetic. The student will demonstrate their understanding of frictional coefficients through the activity of collecting data from scale models of the Seiche made from foam or wooden blocks. Then a prediction is calculated to determine the maximum angle the Seiche can be held on an incline before it begins to slide. Confirmation is provided by subjecting their model Seiche to an incline incrementally increased until motion is observed..



Title :	Inclined Plane (Frictional Force)
Overview :	Students will use a spring scale and string to pull on a foam block (to model a boat) to determine the frictional force, static coefficient of friction, and kinetic coefficient of friction.
Objectives :	Build upon: force diagram, vector addition, vector components, area, force To derive: frictional force, static coefficient, kinetic coefficient
Learning Outcome :	The students should be able to sketch diagrams of their observations and record data used in the calculation of frictional forces derived from known equations.
Standards :	(Std. 1 Analysis, Key Idea 1, M1.1), (Std. 1 Analysis, Key Idea 2, M2.1), (Std. 1 Inquiry, Key Idea 1)
Materials and Resources:	Instructor: Projector, R/V Seiche's trailer schematic, assorted foam blocks, masses, spring scales, string Students: pencil, graph paper, calculator
Time Required:	One 45 minute class period
Procedures:	First Class Period 1. Begin with background to R/V Seiche project and need to launch and recover the R/V Seiche. Can reference Coast Guard boater safety coarse instructions for launching and retrieving vessels. 2. Show pictures of the R/V Seiche on the trailer and in the launch to help make the physical connection between reality and the foam block model. 3. It is critical the boat stay on the trailer until immersed in water; ask the students to white board how this is accomplished. 4. Have the students experiment with the foam blocks on a horizontal surface recording the force required to move the blocks loaded with different masses. 5. Have the students measure the area of the foam block and graph the results of data collected. 6. Ask the students to predict what angle the foam block (model boat) will

A practical application for understanding the normal force and frictional force

Applies to NYS Curriculum standards regarding (diagram construction, and mathematical evaluation)