# Connecting Newton's Laws of Motion and Electrochemistry to the Automobile Industry: Making Real-life Connections Through the Use of Instructional Technology in Secondary Physics and Chemistry Classrooms

***Michael Ivie[1], Richard Wear[2], Susan Beseler[3]***

**Abstract** – The National Science Foundation's Graduate Teaching Fellows in K-12 Education (GK-12) Program at the University of Alabama supports teaching fellowships for graduate students in the sciences, mathematics, engineering, and technology disciplines. An important task of each graduate fellow is the development of new learning modules for novice learners, created in the process of development and implementation of this program. Utilizing web-based animations, video clips, computer-based data collection devices and other technology forums, one such activity provides connections to promote and enhance conceptual and intuitive understanding of Newton's Second Law of Motion. In addition, another such design task module provides the opportunity for students to engage in hands-on building and exploration of battery design in electrochemistry while experiencing dynamic involvement in the learning process in a secondary chemistry classroom. In both learning modules, the active learning environment created by the design task format is conducive to a better understanding of the mathematically-based, procedural content necessary for scientific discourse and debate as it relates to the automobile industry.

*Keywords:* GK-12, physics, electrochemistry, Newton, battery

## INTRODUCTION

The National Science Foundation's Graduate Teaching Fellows in K-12 Education (GK-12) Program at the University of Alabama [1] supports teaching fellowships for graduate students in the sciences, mathematics, engineering, and technology (SMET) disciplines. The NSF graduate fellows participate in interdisciplinary teams to develop materials to be utilized in secondary science and mathematics classrooms. The project's goal is to enhance the educational practices in use by K-12 teachers and students with emphasis on materials that improve critical thinking skills, effectively reaching students in every grade, academic performance level, cultural background and learning style. An important task of each graduate fellow is the development of new learning modules for novice learners, created in the process of development and implementation of this program.

As outlined in the National Science Education Standards an increased emphasis on providing opportunities for scientific discussion and debate is promoted across school science arenas. The emphasis on selecting and adapting curricular activities to enhance student understanding is one of the hallmarks of an inquiry-based physics classroom.

[1] University of Alabama, Chemical Engineering, ivie002@bama.ua.edu

[2] University of Alabama, Mechanical Engineering, richard_wear@msn.com

[3] University of Alabama, Secondary CTL, besel001@bama.ua.edu

Utilizing web-based animations, video clips, computer-based data collection devices and other technology forums, one such activity provides connections to promote and enhance conceptual and intuitive understanding of Newton's Second Law of Motion. In addition, another such design task module provides the opportunity for students to engage in hands-on building and exploration while experiencing dynamic involvement in the learning process. In both learning modules, the active learning environment created by the design task format is conducive to a better understanding of the mathematically-based, procedural content necessary for scientific discourse and debate as it relates to the automobile industry.

## EXPLORING NEWTON'S SECOND LAW

Newton's second law states that force is equal to the time rate of change of momentum.

$$F = \frac{dP_{mom}}{dt} = \frac{d(m \cdot v)}{dt} \qquad (1)$$

If the mass is constant, it can be taken out of the differential and then force is equal to mass times the time rate of change of velocity.

$$F = m \cdot \frac{dv}{dt} \qquad (2)$$

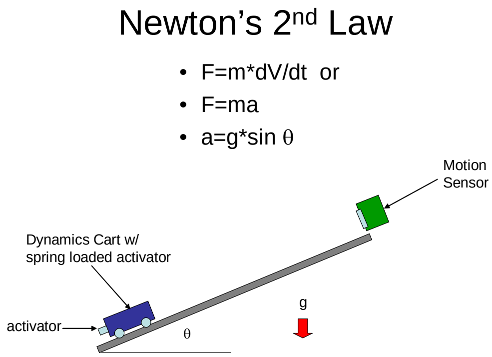
In the case of falling objects, the change in velocity is constant over time and is equal to the acceleration caused by gravity. This gives us the more common form of Newton's second law that states force is equal to mass times acceleration.

$$F = m \cdot a \qquad (3)$$

The mathematical content associated with this law in its primary form can be out of the scope of most high school science classes. It is important to use the form of the law that best suits the mathematical skills in which the students are most comfortable. An AP physics course could possibly utilize the form in equation 1, but average high school physics courses would be best suited to use a form of equation 2 or 3. Calculus can be eliminated from the equations by changing the derivatives to deltas and using appropriate language. For most high school level physics and physical science courses however, that last form of Newton's second law is most appropriate.

Newton's second law can easily be demonstrated using a number of different scenarios. The equipment used in this particular demonstration uses Pasco® dynamics carts and accessories. The schematic below shows the layout of a demonstration that can be used to illustrate Newton's second law. The necessary components in the demonstration are a dynamics cart with a spring loaded activator, a cart track, a motion sensor, and two test stands in which the track is mounted and adjusted. The dynamics cart can be fitted with different masses and the activator produces a constant and reliable force that pushes the cart up the track. The motion sensor can be mounted to the track and directly connects to a computer and can gather position, velocity, and acceleration data that can be displayed in graph form. Other connecting hardware has been omitted but should be used to connect and orient the track to the test stands and provide a barrier in which the activator pushes against.

The depth in which the variables of the demonstration are explored should also be chosen to fit the mathematics skills in which the students are comfortable. For example, a physical science class that has not had trigonometry, the angle of the track should not be considered, but the relation between that angle and the magnitude of the acceleration can be a point of consideration. It can be explained that the steeper the angle, the greater the acceleration.  A connection to student's own intuitive understanding can be bridged by referring to common activities such as riding a bicycle up a hill.  For a physics class that has trigonometry skills or calculus skills, further exploration can be completed.

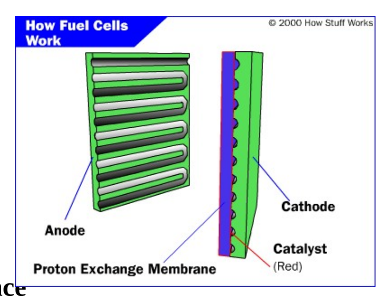



In a physical science class in which the students have algebra skills, changing velocity can be explored.  The motion sensor can measure the velocity over time and produce a graph that can be used to explain slope and how that relates to acceleration.  The mass of the cart can be modified and the angle of the track can be changed in order to show the relationship between those variables and force produced by the activator.  Another possible variation is to orient the track so that the cart is stopped by gravity and then travels the opposite direction.  This can lead into explanations of relative motion and vector notation.  The motion is relative to the motion sensor and the graph will show that motion in the opposite direction produces an opposite magnitude of velocity.  This demonstration can also be presented as an inquiry activity where the teacher asks the students to make conjectures as to results when certain variables are changed.  This demonstration is only limited by the teacher's vision in instructional design.

In a physics class in which the students have trigonometry skills, many more options are available for exploration that involves data collection and correlation.  In addition to all of the above variables and relationships, the angle in which the track is oriented can be measured and its relationship to the magnitude of acceleration and gravity can be presented.  The calculated acceleration will provide support for the associated measured acceleration.  The force of the activator can be calculated and free body diagrams can be explored.  This demonstration can be used a number of ways to help the students understand dynamics, data collection and correlations, units, and all of Newton's Laws.

This particular design task was piloted in a secondary physics classroom in a large suburban setting.  The overall success of the module was measured through a series of informal assessments.  During observations of the participants, it was noted that an enthusiastic reception of the demonstration fueled on-task behavior and increased motivation during the data collection, graph analysis and discussion portions of the lesson.  Informal interviews also provided the teacher with feedback regarding the success of the design task module.  The student participants all noted increased motivation when lessons incorporated visual representations of the physical phenomena that were being studied.  To "see" the data, namely graphical representations, in real-time as it corresponds to the relationships among the components was noted as the main advantage to these types of technological tools.  A majority of the students communicated a better understanding of the relationship between variables such as mass and angle to acceleration and were more successful communicating the meaning of the mathematical representations of the relationships.

## Battery Design Task




The battery design task is useful in a chemistry classroom in coordination with studying electrochemistry.[2] The battery design task has two main components.  As an introduction to this task, a PowerPoint presentation that described how a battery works and some new technology about the hydrogen fuel cell is used as a pre-cursor to the inquiry lesson. The presentation included an animated demo and some visual representations of hybrid fuel cell cars as a personal motivator and connector to the automobile industry. Following the anticipatory set component of the lesson, the students begin the active portion of their project. There are six stations for the students to complete including four different batteries, an internet station, and a new technology station. They work in groups (no more than 3 in a group) and are allowed to go to each station and put each battery together to get a hands-on experience of the outcomes. Following the battery assembly procedure, they record the voltage measured by each battery. The four types of batteries are a lemon battery, a concentration cell, a Daniell's cell, and a liquid (car) battery. [2] [3] [4]

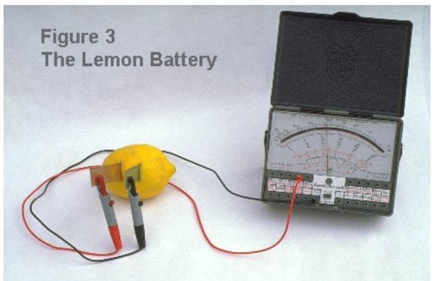


Figure 3
The Lemon Battery

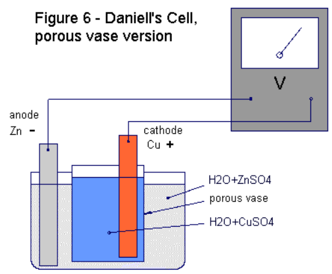


Figure 6 - Daniell's Cell, porous vase version

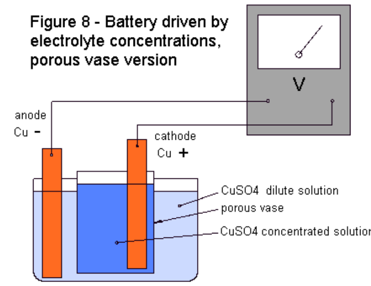


Figure 8 - Battery driven by electrolyte concentrations, porous vase version

[5]

The materials they need for each battery is provided and a set of instructions with a picture of how the battery is set up are also included. At the internet station the students must answer several questions related to batteries or electrochemistry. At the "new technology" workstation the students must read three recent articles on fuel cell technology and answer questions to synthesize the readings. [6] [7] [8] [9] The in-class demonstration, assembly and research portion of the lesson is designed to allow the students to learn the basic principles of how a battery operations.

Part two of the lesson is introduced at the completion of the in-class procedures and provides a competition forum for the participating groups. For the lesson, the teacher is the students' supervisor, and they work at a battery company. The company is competing for a contract with large automobile manufacturers to provide the batteries for their automobiles. After completing part one the students are considered experts on batteries. One type of battery is selected from part one so each group will get to modify the same type of battery. The battery used is the liquid (car) battery since it is similar to an authentic car battery. This battery produces about 1 volt of electricity and the students' goal is to improve the battery. They are encouraged to be as creative as possible and use any source they want for information concerning increasing the productivity of a battery. Two days later the groups must submit their ideas for modifications. The materials are collected and during the next class period the groups are allowed to make their improvements and complete a trial where the voltage is recorded.

This design task was also piloted in a secondary chemistry classroom in a mid-sized southern city. The overall success of the projects was overwhelming. When put to the challenge to be creative with their ideas of modifying the battery, they responded with some very unique, yet sound, ideas. Some of the ideas included: changing the electrode material, changing the electrolyte, increasing the strength of electrolyte, increasing the surface area of the electrodes, and put two batteries in series. Some of the groups used a combination of these ideas. One group actually recorded 4 volts, which is a tremendous improvement in the battery. The students level of excitement toward the inquiry process was witnessed during part two of the lab when they where competing against each other. The general response of the student's was very positive during all portions of the design task module.

## REFERENCES

[1] NSF Award DGE-0338312, National Science Foundation, 2004.

[2] Liem, Tik L., Liquid (car) battery, *Invitations to Science Inquiry, Second Edition*, Science Inquiry Enterprises, 1987, pg. 170.

[3] http://science.howstuffworks.com/fuel-cell2.htm

[4] http://www.fuelcelltoday.com/FuelCellToday/EducationCentre/EducationCentreExternal/EduCentreDisplay/

[5] Lemon battery, Daniell's cell, Concentration cell, www.funsci.com/fun3_en/electro/electro.htm.

[6] http://www.gm.com/company/gmability/adv_tech/400_fcv/index.html

[7] http://4hydrogen.com/

[8] http://www.fuelcelltoday.com/index/

[9] http://www.gm.com/company/gmability/adv_tech/400_fcv/index.html

**Michael Allen Ivie II**

B.S in chemistry from the University of Alabama, pursuing a M.S. in Chemical Engineering, Research area: Nanotechnology specifically making Iron Nitride particles for high density data on magnetic tape for information storage. Current position: GK-12 graduate fellow working with Hillcrest High School in Tuscaloosa County Schools.

**Richard Franklin Wear**

B.S. Mechanical Engineering: University of Alabama, Currently finishing masters in mechanical engineering/thermal fluids and starting Ph.D. on the same specialty at the University of Alabama. Research topic: Hydrogen Production Methods.Current position: NSF-GK-12 fellowship working with Hillcrest High School in Tuscaloosa County Schools.

**Susan Beseler**

Ph,D. candidate, Secondary Curriculum, Teaching and Learning/Secondary Mathematics Education, University of Alabama. Research interests: technology in mathematics, pedagogical content knowledge and teacher preparation programs in mathematics. Current assignment: University of Alabama, Graduate Research and Teaching Assistant; responsibilities include instructing the course "Technology for Mathematics Teacher," and supervising secondary mathematics practicum students in field-based experiences. Previous experience: Winona State University, Winona, Minnesota, Mathematics Instructor. Experience also includes secondary and middle school mathematics along with numerous conference presentations.