The Science Teachers Bulletin

Volume 75, Number 2
Spring 2012

PROMOTING EXCELLENCE IN SCIENCE EDUCATION

SCIENCE TEACHERS ASSOCIATION OF NEW YORK STATE, INC. 1896

STANYS EXECUTIVE BOARD
2011-2012

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The Science Teachers Bulletin

Volume 75, Number 2

SPRING 2012

Official Publication of the

Science Teachers Association of New York State, Inc.

PO Box 2121

Liverpool, NY 13089

(516) 783-5432

www.stanys.org

A State Chapter of the National Science Teachers Association and a member of the New York State Council of Education Associations.

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The Science Teachers Bulletin

Published twice a year (Fall and Spring)

Guidelines for submission of manuscripts are found on the last page.

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Don't Forget to submit **YOUR** article for the next issue of

The Science Teachers Bulletin

Deadline for the Fall issue is JULY 15, 2012

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Action Research for Earth Science:
Making Astronomy Real for Inner City Students

Tiffany May
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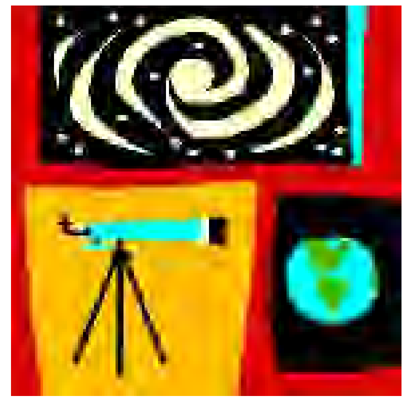


Ia. THEMATIC CONCERN

My action research centered about the issue of inner city students' inability to connect with the astronomy unit in Earth Science. By connect, I mean the ability to visually grasp astronomy and relate it to their daily lives, as a clear night sky full of stars does not exist from the glare of New York City's bright lights. Few of my students have ever seen a sky full of stars, let alone a real shooting star. Thus, a disjoint separates them from experiencing astronomy in their own lives to create prior knowledge, making it harder to fully grasp the essential understandings of the unit.

Ib. NEW YORK STATE PERFORMANCE INDICATORS

1.1 Explain complex phenomena, such as tides, variations in day length, solar insulation, apparent motion of the planets, and annual traverse of the constellations.
1.2 Describe current theories about the origin of the universe and solar system.

II. DATA COLLECTION

A Pre and Post test were given to collect data on measuring the key understandings of the unit. Students were also asked to write a reflective piece about how viewing the daily satellite images helped them to better understand the astronomy unit.

III. THE PLAN

My plan involved making astronomy more accessible to students by using visual satellite images during every lesson. These images were taken from various NASA sources, including many from the Hubble Space Telescope. Thus the students could really see what objects in space look like, creating a more concrete idea of what they were learning about. Many of these images were used during note taking PowerPoint sessions to link the concept to the image. I included videos which simulated Astronomical events such as "Cosmic Collisions" from the American Museum of Natural History, while using Brain Pop to clearly explain phenomena through visual animations.

IV. EXAMPLE ACTIVITY

During this one-period, 45- minute lesson, I introduced star classification based on temperature, luminosity, color and age. This lesson also covered the life span of a star with its beginnings in the ignition of nuclear fusion, while learning to read the HR Star Classification diagram from page 15 of the Earth Science Reference Tables.

As part of the Do Now, I asked students to brainstorm what makes a star shine, evoking their prior knowledge and misconceptions. I then played the Brain Pop segment "The Life Cycle of Stars." This assisted in correcting any misconceptions brought up in the Do Now, while answering the Do Now question itself. As students listened to the information, they completed a fill in the blank sheet of questions answered in the Brain Pop. After this, a brief PowerPoint was shown which explained the information in more depth along with revealing star and constellation satellite imagery. During this presentation, students filled out a note sheet to organize the concepts. Students were then taught to read the HR Diagram of Star Classification from the Earth Science Reference Tables, and given various questions related to the chart to complete on their own in working groups. After a given amount of time, the toughest questions were reviewed to check for understanding. To summarize the lesson, students were shown three different images of stars taken from the Hubble Space Telescope, and asked to match the image with its classification: Main Sequence, Red Giant, and White Dwarfs. The success rate on this last activity was extremely high.

V. DATA COLLECTION

A Pre-test of astronomy questions was given to all of the students (120 with variations due to attendance) prior to beginning the unit. This test consisted of twenty multiple-choice questions taken from the Earth Science Regents. The performance on this test measured in the lower range. The highest score out of all of the classes was recorded at 60%, while the lowest came in at 5%. The median of scores centered on 25%. The largest percentage of students scored between 20-30%.

After the unit was taught, a Post Test of 30 astronomy Regents questions was administered. I used twenty of the same questions from the Pre-test, and added ten more that covered similar concepts. On the Post Test, the highest score hit 90%, while the lowest score was 13.3%. The median rose to 56.7%. The largest percentage of students scored between 50-60%.

I then used item analysis to compare the percent correct and incorrect on the given questions. I focused on the questions that had the largest jump in percent correct from the Pre to Post Test. In the Pre-test, 52.8% of the students answered incorrectly about how the sun releases energy through nuclear fusion. On the Post Test, the percent incorrect dropped to 17.6%. Hence there was an improvement from 47.2% correct on the Pre-test to 87.4% correct on the Post Test.

Other areas of progress occurred on the Regents questions dealing with moon phases. On the Pre-test, only 23.6% of students answered correctly, while on the Post Test 61.8% answered correctly.

In viewing the Item Analysis and test results on the whole, a definite jump in the percentage of correct answers took place from the Pre to the Post Test.

VI. STUDENT FEEDBACK

As one last assessment of my action research, I wanted to hear from the students directly in writing if and how seeing these images helped them better understand the astronomy unit. Below I have included quotes from the student's reflections. Each quote remains anonymous to protect the privacy of the student. In my research, I believe these reflections solidified the success of making astronomy more real for these students.

"Seeing real images gives me a better understanding of the universe. They allow me to see how things really are. I never knew that the moon and the sun actually looked like that."

"Seeing real satellite images of space helped me to better understand astronomy because I'm a visual learner. It helps me to see how it looks...helps me to create a mental picture."

"It helped me to better understand because I'm sort of a visual learner. Seeing things and learning them at the same time is a really big help so that when you see questions about it on a test, you can visualize it."

"Seeing real satellite images of space has helped me understand more about our solar system in space. By seeing certain images of space and many planets helps me see what they look like. Also it helps me study information about the planets and learn new information about them. By seeing real images of the moon helps me figure out what phase it is in. It gives me a better understanding about astronomy when I see what it looks like."

"Seeing satellite images have helped me better understand astronomy because I get to really see how the solar system really looks. Also I get to see how the moon's surface can be seen. I didn't know how an eclipse really looked until I saw the satellite images. I never looked up in the sky to see the moon change."

"I like to see how things work and to have proof. Basically seeing pictures of planets and stars and everything in space helps me understand how they work. I find it interesting to see how things progress which makes me understand astronomy more. Once I see pictures of something the understanding comes easier because I can see what the teacher is talking about."

"Real satellite images help me understand this unit way better. I got to see what was really up there. I learned and saw how the stars and moon actually look. I would like to go to space and take satellite pictures of my own."

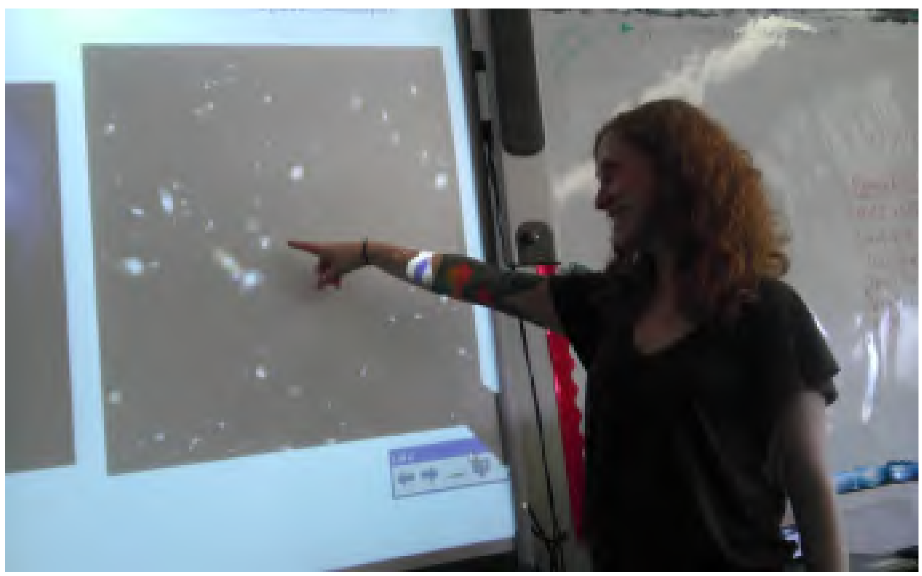
"Seeing real satellite images of space has helped me understand astronomy better because I can now determine which moon phase is which. I am able to tell red giants from main sequence stars. I can also tell the new moon from the full moon. I am able to determine elliptical and flat. I can find the eccentricity and I can now determine waxing and waning."

"Seeing images made it easier to connect to the galaxies and the universe."

" ...I can understand better when Ms. May showed me pictures about space. It also made me know what she talked about and maybe if she didn't show pictures I couldn't understand what she said because I don't speak English. I like when she shows the pictures, it helps a lot more than you think."

"Seeing real images helped me understand astronomy better because it showed me real images in space and how Earth and the moon really worked and what goes on in space, and being able to see an image helped me get a clear understanding of astronomy."

VII: CONCLUSION



Utilizing satellite imagery and visual animations greatly increased the level of understanding in astronomy for my students at the Cobble Hill High School of American Studies. The Pre-test proved that the students came in with very little prior knowledge, while the Post Test demonstrated definite growth in astronomical comprehension. While our class test scores and Regents passing rates are an issue at my school, I did observe a numerical jump in the percentage of answers correct between the two assessments.

Ultimately, the words expressed by the students on how the images helped them to connect to the concepts proved that using visual tools in teaching astronomy are a successful strategy for inner city schools. Satellite images from the Hubble Space Telescope made them see outside of their own planet to the vast universe that exists, even the images of the Sun's scorching surface (that to them could not be real). Listening to their comparisons of what the images looked like to them (The Hubble Deep Field image resembled a smattering of Fruity Pebbles) assisted in constructing the information and making it more real for them. For me it was exciting to watch their faces light up when seeing images like our Milky Way Galaxy, realizing that's where we are and it is REAL. The smallness of our planet in comparison to the Universe opened their minds to marvel at the vastness of space and our rare existence within it. These realizations and responses to the images made this unit more exciting, personal, and successful.

Tiffany May *has been teaching Earth Science for three years at the Cobble Hill High School of American Studies in Brooklyn, NY She received her Masters in Earth Science education from CUNY Hunter College. Currently she is participating in the Columbia University Summer Research Program for Science Teachers, working in the AGES lab at the Lamont-Doherty Earth Observatory for two consecutive summers. This specific action research was inspired by the 'Earth Science in Space Has No Boundaries' summer professional development program at the Rensselaer Polytechnic Institute. Tiffany can be reached at* tmay@schools.nyc.gov.

Using Astrobiology to Support Instruction in Earth Science

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AND
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Introduction

One of the most exciting possibilities for humankind is that life exists beyond our own planet. The inclusion of topics relating to the exploration of life on planets within and outside our solar system as part of classroom activities can increase students' interest in earth science concepts. The search for life beyond Earth can be used to provide a context for learning about terrestrial processes and, at the same time, instill a sense of awe in the students as a result of their exposure to the endless possibilities that lie within the universe. The level of student interest that this topic generates, provides an opportunity to engage students in class activities that help them understand stellar and planet-based processes that guide current research concerning the possibilities of the extraterrestrial. The *Astrobiology Teachers Academy*, is a group of NYS science teachers working cooperatively with a team of NASA scientist's operating out of the *New York Center for Astrobiology* (NYCA). This collaboration has been centered on the building and testing of learning modules directed toward using the search for life beyond the earth to encourage interest in the STEM disciplines and develop high level concepts and skills related to the NYS curriculum and NASA educational goals. The Academy holds an annual four day summer meeting at Rensselaer Polytechnic Institute. The scientists present an overview of their work and their latest findings, particularly in their specialty area of interest, the origins of life. The teachers then work with the scientists to develop learning modules that incorporate astrobiology into the existing curriculum using state and federal education standards and the NASA Astrobiology Roadmap as a guide. The goal of the academy is not to add additional content for the teacher to cover, but rather to use astrobiology as a means for capturing the attention of the students and increasing the students' level of interest in the existing syllabus. The learning modules identify goals for learning, align them with state and national standards, provide a guide to instruction, present techniques for assessing the learning goals and reports on student attainment over time. This article reports on research related to one of these learning modules in a New York State Regents Earth Science course.

This learning module was completed by Earth Science students in two separate classes at Maple Hill High School in Castleton, New York. Maple Hill High School is part of the Schodack Central School District which serves approximately 1,029 school children who reside in the 34-square-mile area which includes the town of Schodack and a small part of Stuyvesant. The students in these classes are grouped heterogeneously with twenty-five percent receiving some level of support services. The module was completed during October of the 2011 school year.

The Curriculum

Astrobiology is a multidisciplinary field dealing with the nature and existence of and search for extraterrestrial life (life beyond Earth). Astrobiology encompasses areas of biology, astronomy, and geology among others. The principal areas of astrobiology research include investigating the conditions under which life can arise, looking for habitable worlds, and searching for evidence of life.

The objective of this module was to connect astrobiology to the skills and concepts that are necessary for the students to be successful in earth science, while at the same time increasing the student's level of engagement. The concepts and skills that have been addressed by this module are included as part of the New York State Physical Setting commencement level standards, National Earth and Space Standard Science standards, and NASA's Astrobiology Roadmap.
The selected learning goals are as follows;

1. Students will be able to correctly plot a stars position on the H-R Diagram when given the stars absolute magnitude and spectral class. **(NYS Standard 1, National Earth and Space Standard Science Content D Standard)**

2. Students will be able to use the H-R Diagram to determine properties of a star including its temperature, luminosity and color. Describe current theories about the origin of the universe and solar system. **(NYS Standards 1 and 4, National Earth and Space Standard Science Content D Standard)**

3. Students will be able to identify which spectral classes of stars may have potentially habitable planets in orbit. **(NYS Standards 1 and 4, National Earth and Space Standard Science Content D Standard, NASA Astrobiology Roadmap Goal 1)**

4. Using the formula L (star)/L (sun) = r (star) ^{2}/r (sun) ^{2}students will be able to calculate the inner and outer boundary of the habitable zone around stars in each spectral class. **(NYS Standards 1,4, and 6 National Earth and Space Standard Science Content D Standard)**

5. Students will be able to construct a scaled drawing of the habitable zone around a star. **(NYS Standards 1,4, and 6 National Earth and Space Standard Science Content D Standard)**

6. Students will be able to identify the relationship between star temperature and color. . **(NYS Standards 1,4, and 6 National Earth and Space Standard Science Content D Standard)**

7. Students will be able to correctly use the astronomical unit. **NYS Standards 1,4, and 6 National Earth and Space Standard Science Content D Standard)**

8. Students will be able to demonstrate an understanding of the concept of tidal locking. **(NYS Standards 1,4, and 6 National Earth and Space Standard Science Content D Standard)**

Instructional methods

As scientists study the development of life on Earth, it has become clear that one of the most important features for life to develop and evolve is the availability of liquid water. The chemical properties of water make it an excellent solvent, and provide hydrogen and oxygen atoms, which have allowed biochemical processes to evolve and to be sustained throughout Earth's history. With this in mind, scientists have defined the Habitable Zone around a star as the region where liquid water may be present. Under the standard pressure of our atmosphere, water exists as a liquid between 273K and 373K. The Habitable Zone for our solar system has been estimated to be between 0.8 AU and 1.5 AU. There are many complex factors that may control whether or not a planet may be able to maintain liquid water on its surface. The structure and composition of the atmosphere, the size of the planet, tectonic forces acting on the planet, and the mineralogy of the rocks on its surface, are just a few of the planetary characteristics that influence the potential availability of liquid water. For this activity the students focused on just one of those factors, the luminosity of the star that a planet orbits. Students were given pre and post assessments relating to the material covered to help guide instruction and to measure the level of attainment achieved for each of the stated learning goals listed above.

Pre-Post Assessment Questions

1. An astronomical unit is best defined as
    a. The distance between the Earth and Mars
    b. The distance between the Earth and the edge of the solar system.
    c. The distance between the Earth and the Sun.
    d. The distance between the Earth and the center of the Galaxy

2. Spectral type O stars have which of the following characteristics?
    a. Low temperature and low luminosity
    b. High temperature and high luminosity
    c. Low temperature and high luminosity
    d. High temperature and low luminosity.

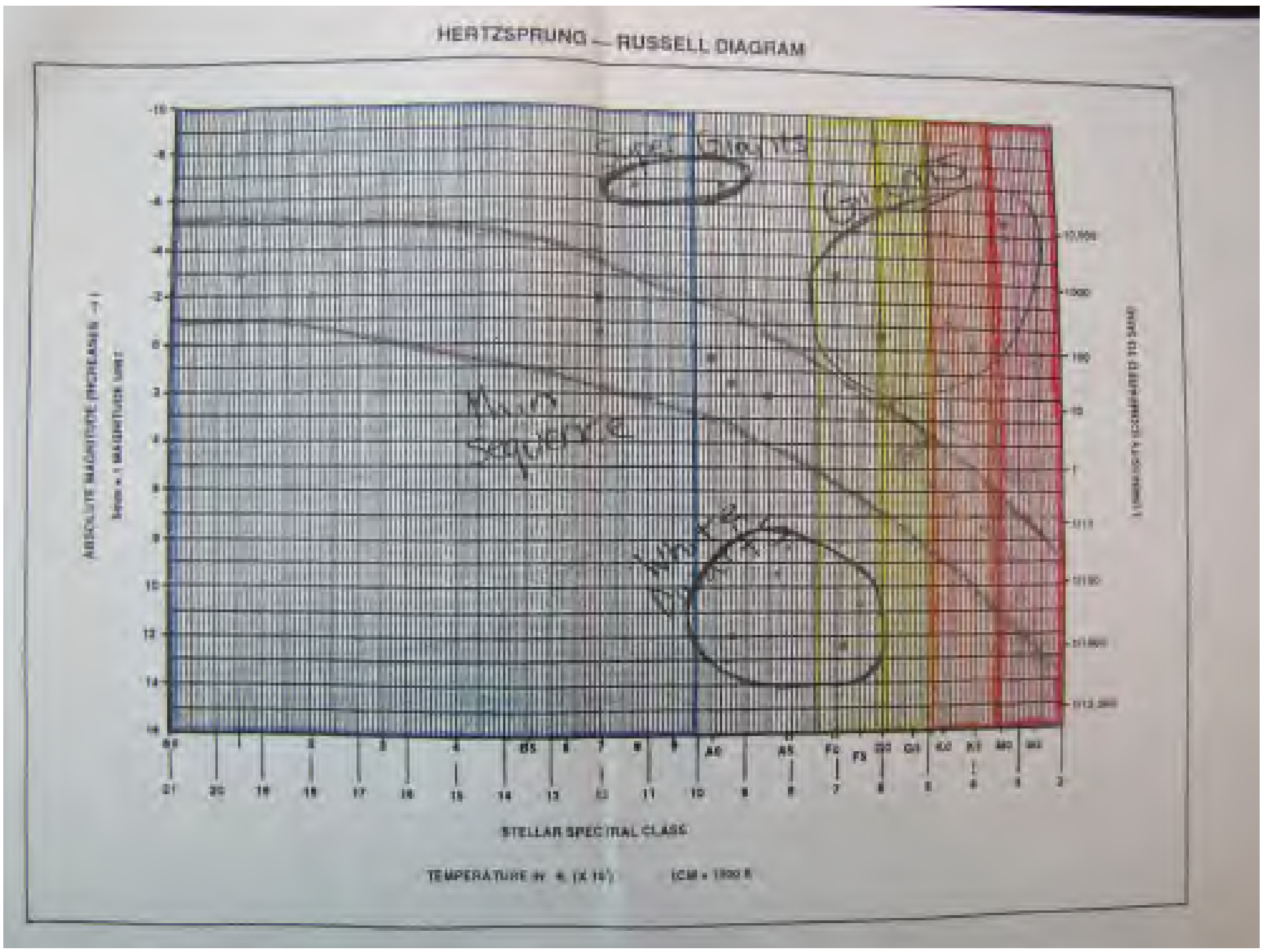
3. Which Spectral class of stars has the longest main sequence life span?
    a. B
    b. A
    c. F
    d. M

4. Which spectral class of stars would be good candidates to search for planets that could potentially sustain complex life?
    a. Spectral Class O
    b. Spectral Class B
    c. Spectral Class G
    d. Spectral Class M

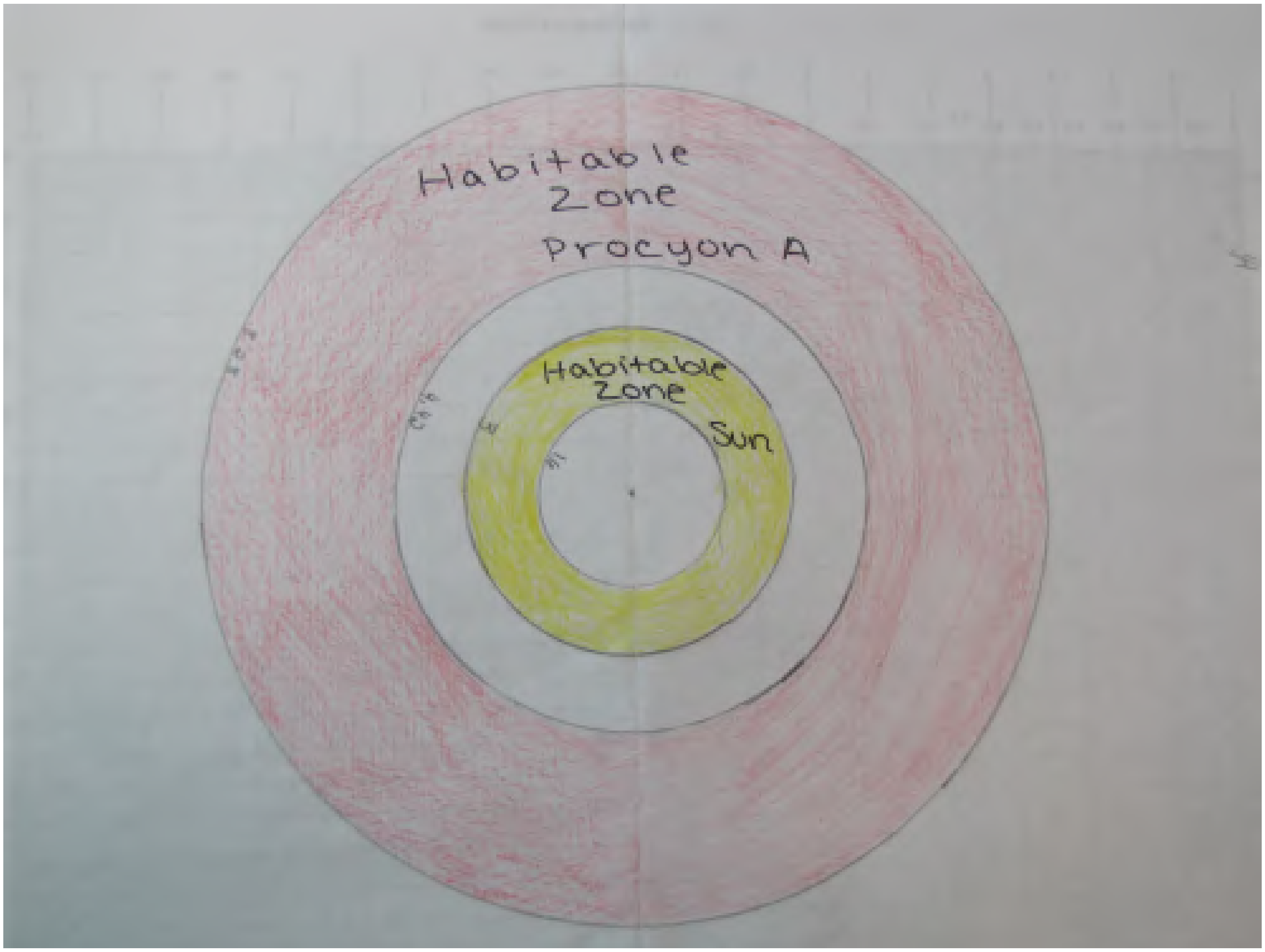
5. Where would the inner boundary of the Habitable Zone begin around a star with luminosity 3 times that of the Sun? Use the formula $L\ (star)/L\ (sun) = r\ (star)^2/r\ (sun)^2$ and set the inner boundary of Earth at 0.8 AU.

    a. 0.8 AU
    b. 1.0 AU
    c. 1.2 AU
    d. 1.4 AU

The bulk of the instruction was completed in a lecture/discussion format, culminating in the students performing the activity portion of the module. The activity is broken down into three sections. First students were given a Hertzsprung-Russell diagram (see below) and data sets for selected groups of stars. Using the star's spectral class and the absolute magnitude they plotted the stars position on the diagram. Next the students were introduced to the concept of the habitable zone. The students used the formula L (star)/L (sun) = r (star) ^{2}/r (sun) ^{2} to calculate the radius of the habitable zone around stars with different luminosities. They were also asked to construct a scaled diagram of the habitable zone using data from the Sun and Procyon A (see next page). This allowed the students to visualize the impact luminosity has on the width of the habitable zone and the distance of inner boundary from the star. Finally, using the information from the two previous activities, the students were asked to determine which spectral classes of stars would be good candidates for scientists to search for potentially habitable planets.



Star's plotted on the Hertzsprung-Russell diagram using spectral class and absolute magnitude.



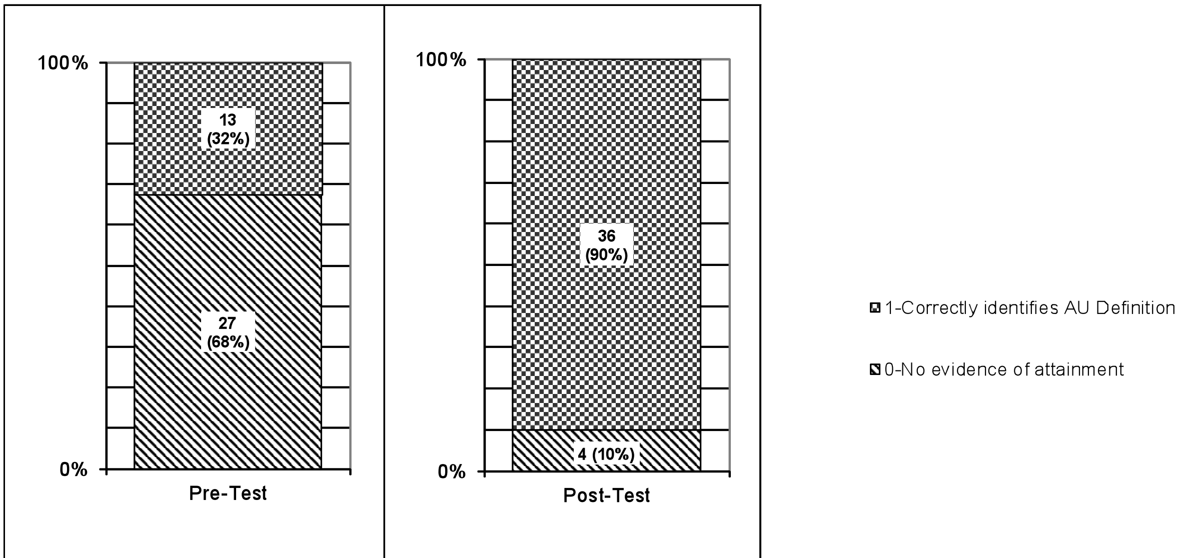
Scaled diagram of the habitable zone using data from the Sun and Procyon A.

Results

The results in Figures 1 through 3 represent the student responses for both the pre and post assessment for both classes. Figure 1 represents the student's pre-post responses to question 1 where students were asked to identify the correct definition of an Astronomical Unit. Figure 2 is the combined student response to questions 2, 3, and 4. Students were asked to identify characteristics associated with different spectral classes of stars. A student was given one point for each correct response for a maximum score of three. Figure 3 represents the students' pre-post responses to 5. The students were asked to correctly calculate the inner boundary of the Habitable Zone around a star using the luminosity and the formula given in the question.

Figure 1.

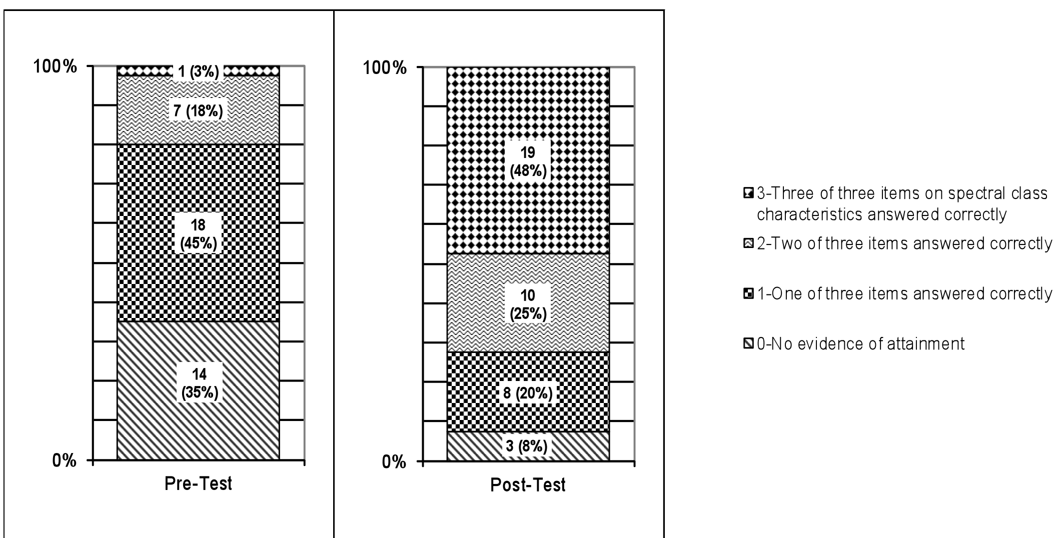
Combined
AU: Astronomical Unit



	Pre-Test	Post-Test
1	13 (32 %)	36 (90 %)
0	27 (68 %)	4 (10 %)
Total	40 (100 %)	40 (100 %)

Figure 2.

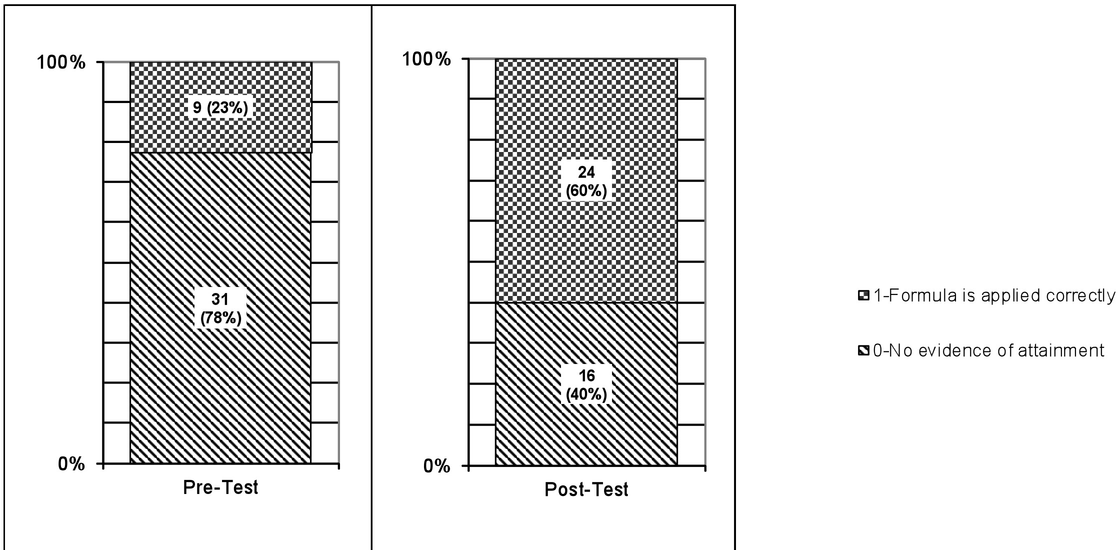
Combined
Spectral Class Characteristics



	Pre-Test	Post-Test
3	1 (3 %)	19 (48 %)
2	7 (18 %)	10 (25 %)
1	18 (45 %)	8 (20 %)
0	14 (35 %)	3 (8 %)
Total	40 (100 %)	40 (100 %)

Figure 3.

Combined
Luminosity Formula



	Pre-Test	Post-Test
1	9 (23 %)	24 (60 %)
0	31 (78 %)	16 (40 %)
Total	40 (100 %)	40 (100 %)

Discussion

Preliminary results indicate that the search for life beyond Earth can provide a context for students to gain a better understanding of stellar processes. The pre/post assessment data showed an increase in the number of students who could correctly define an Astronomical unit. Being able to use this unit will help them to describe the vast distances that exist between objects in our solar system. The students also demonstrated improvements in their ability to identify stellar characteristics associated with each spectral class. Responses to discussion questions included in the activity indicated the students were also able to competently apply their newly acquired knowledge to reasoning about the critical area of contemporary scientific investigation that concerns the search for potentially habitable planets. For example students learned that spectral class O stars are highly energetic, but they do not have a long main sequence life span. Students they were able to infer that even though there would be enough energy to potentially maintain liquid water at the proper distance on the planet's surface to support life, its main sequence life span would not be long enough for complex life forms to evolve on a planet in orbit around those stars. This demonstrates the students' ability to apply newly acquired knowledge to an alternative situation and arrive at a scientifically valid conclusion. Using the search for life beyond earth as a backdrop, the students were able to connect something that they can visualize, living things, to the abstract processes that govern stellar behavior.

Many concepts in science require the use of mathematics to be fully understood. Unfortunately students often freeze when they see what appears to be a complex formula without attempting to try and understand its meaning. The inclusion of the formula used to determine the inner and outer boundary of the habitable zone was an attempt to reduce the student's anxiety when faced with this issue. Pre-test results indicate that the students were unable use the equation correctly and many of the students did not even attempt the problem. The post-test results indicate significant improvement in their ability to correctly use the formula and may have helped them gain confidence in their mathematical skills. For students to pursue a career or advanced degree in a STEM related field they must be continually given the opportunity to see the application of mathematics in the field of science.

Since there is not a control group the increase in student understanding cannot be solely attributed to the integration of astrobiology into instruction. Other methods may have produced the same results. Integrating the search for life beyond earth into earth science instruction may also have had a positive impact on my students in another manner. The students were interested. The astronomy unit tends to be to one of the most difficult units for the students in earth science. The students find many of the concepts abstract and difficult to conceptualize and as a result, they do not show a great deal of interest in the material. Although it is difficult to quantify, this approach did increase the level of student engagement in the learning process. Class discussions were lively and there was higher than normal level of student participation. Students of all ability levels became involved in class discussions and it was quite evident that they were really thinking and were genuinely interested in the conversation. There were a wide variety of questions relating to the search for life on other planets as well as the long-term fate of life on our own planet. During these conversations there was a level of energy that is not normally present. The enthusiasm displayed by these students indicates that the integration of astrobiology into earth science instruction could increase student interest in other topics included in current the curriculum.

Leonard Bacon *has been teaching science at Maple Hill High School for the past 16 years. During that time he has taught Earth Science, Environmental Science, Biology, Advanced Biology, AP Environmental Science, Biotechnology, and Astrobiology. He has been a member of the New York State Astrobiology Teachers Academy since 2010 and is currently serving as a mentor teacher for that organization. He has been the recipient of a variety of grants including the Toyota Tapestry Grant for his project entitled "The Abiotic Influence on the Abundance and Distribution of Macroinvertebrates in an Abandoned Field and Mixed Hardwood Forest." He can be reached at:* LBacon@schodack.k12.ny.us

Paul Zachos (Ph. D.), Director, Association for the Cooperative Advancement of Science and Education – *Paul Zachos has worked in the field of education for over 35 years. This includes fourteen as an elementary, junior high, and high school teacher, and twelve as a researcher and planner for the New York State Education Department. As an independent researcher and educational product developer in the last nine years, he has provided services and courses to schools, school districts, professional organizations, and educators in the areas of assessment, evaluation, and the teaching of scientific research methods. His specialties and interests lie in developing scientific creativity and demonstrating alternatives to destructive testing practices. Since 1991 he has been the Director of ACASE (Association for the Cooperative Advancement of Science and Education). He holds an M.S.Ed. in Curriculum and Instruction and a Ph.D. in Educational Psychology and Statistics from the University at Albany. He can be reached at:* paz@acase.org

The 2012 Astrobiology Teachers Academy begins with a 4-day summer workshop at the Rensselaer Polytechnic Institute (RPI) in Troy, NY on Monday, July 9 - Thursday, July 12. (8:30 AM - 3:30 PM each day). Teachers will participate with a team of NASA-funded scientists, educational assessment professionals, and high school science teachers/mentors in this Summer Institute in Astrobiology. Participants will receive a $500 stipend and a certificate for 28 hours of Professional Development upon completion. Expenses for travel and accommodation will be reimbursed for those teachers who are accepted to the program and live beyond a 30-mile radius of RPI.

More information about the program and application forms are available at http://www.origins.rpi.edu. Applications for this summers institutes are due by Wednesday, June 20, 2012.

For questions, please contact Prof. Delano:
voice: 518-442- 5825
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Forensics Who Dunnit?
A Visual, Active Class Participation Simulation of Gel Electrophoresis

Patricia Nolan Bertino
Scotia, NY

Increase student interest, comprehension and retention of the process of Gel Electrophoresis through this simulation of how DNA evidence can be used to link a particular suspect to a crime scene or how DNA evidence can be used to exonerate a suspect. These visual and active participation demonstrations should be used *prior* to students performing a DNA gel electrophoresis "wet" lab. The demonstrations can be followed with students viewing simplified animations of gel electrophoresis such as those cited in the Visual Aids section of procedure step 19.

Objectives:

At the conclusion of these demonstrations, the student should be able to:

1. List sources of DNA used in gel electrophoresis
2. Describe the role of each of the following in gel electrophoresis:
    a. Centrifuge

b. Restriction Enzymes
c. Loading Dye
d. Gel
e. Buffer Solution
f. Electricity
g. Positive end of the DNA gel box
h. Power Source
i. DNA stain
j. Micropipettes
k. Staining Tray

3. Explain how DNA is:
   a. Obtained from different types of cells in the body
   b. Released from the cell and nuclear membranes
   c. Separated from the rest of the cell's contents

4. Describe how DNA is cut into restriction fragments using specific restriction enzymes.

5. Show how *different* enzymes would produce different restriction fragments from the same strand of DNA when using two different restriction enzymes.

6. Describe how DNA restriction fragments are loaded into the gel. Answers should include:

   a. Which end of the gel box is used to load the DNA, the positive or negative end?
   b. The role of the loading dye
   c. The role of the loading wells
   d. The role of micropipettes

7. Differentiate between the role of loading dye and DNA stain. *(Loading dye being more dense causes DNA restriction fragments to sink to the bottom of the well) (DNA Stain bonds to the restriction fragments of DNA making the bands visible on the gel)*

8. Summarize the steps of gel electrophoresis beginning with obtaining a sample of DNA through analyzing the gel after gel electrophoresis.

9. Analyze the following errors in gel electrophoresis and propose a solution to correct those errors:
   a. DNA bands are too close together on the gel.
   b. DNA bands are not visible on the gel.
   c. DNA appears as one thick band on the gel.

10. Explain the role of marker or standard DNA in gel electrophoresis. *(Standard or marker DNA are known lengths of DNA used to estimate the size of each DNA restriction fragment.)*

11. Given a photograph of a gel, analyze the gel and determine if a match exists or doesn't exist between a suspect's DNA and the evidence DNA.

Materials

String

Scissors

Masking Tape

4 manila folders (to be held by students representing marker DNA) labeled with:
- 5,000 base pairs
- 10,000 base pairs
- 15,000 base pairs
- 20,000 base pairs

4-16 students (it would be helpful to have 4 students of varying heights to represent 4 different sized DNA restriction fragments)

Gel Electrophoresis Equipment (or photos of gel electrophoresis equipment)
- Power Supply
- Gel Box
- Comb
- Agarose
- Staining tray

Procedure

Part 1 Background

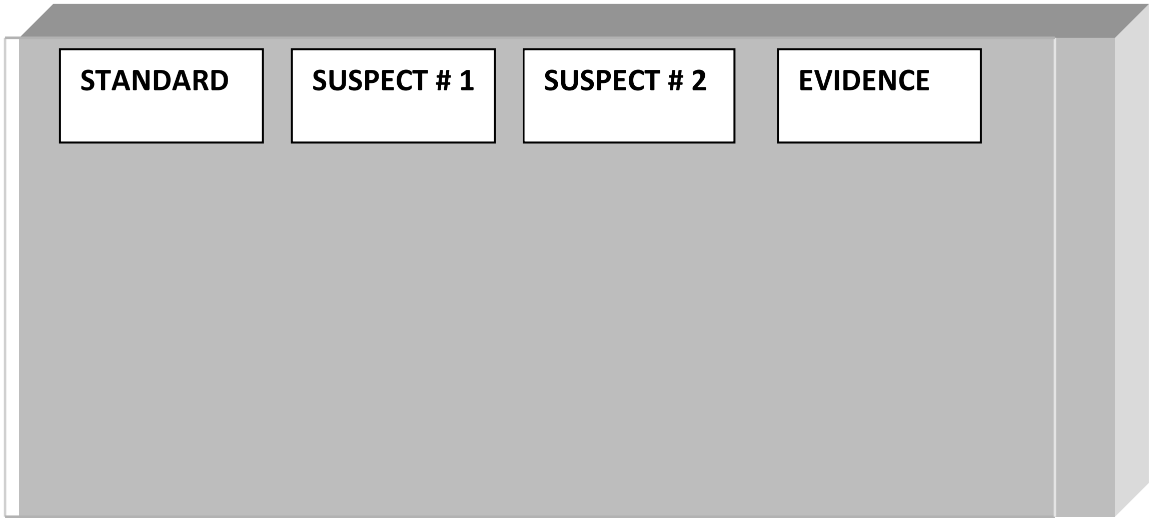
1. Show students the gel box, combs, gel, micropipettes, staining well, and power source so that they are familiar with the materials and apparatus used to separate DNA. (or show photos of the equipment)

2. Demonstrate how the agarose gel is heated and poured into the gel box containing ~~a~~ comb.

3. Remove a comb from a previously poured gel box so students can see the wells.

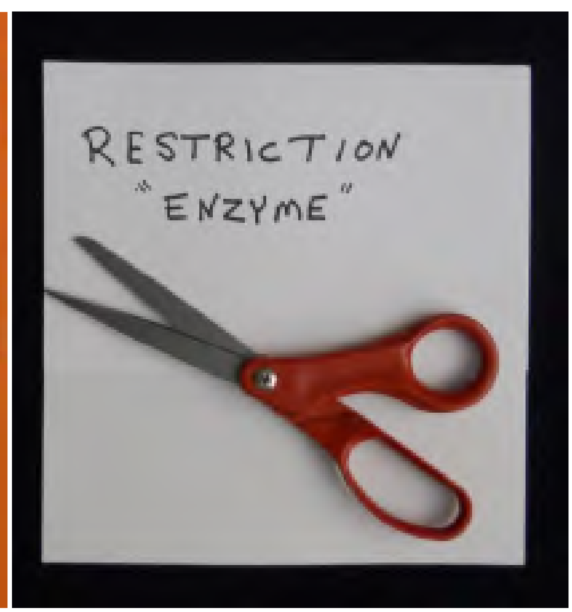
4. Describe a crime or a case study where DNA evidence left at the crime scene was used to help solve the crime. (Refer to the book entitled Picking Cotton cited in step 22 of Procedure)
   a. Indicate in this demonstration that there are two suspects whose DNA will be compared to the evidence DNA collected at the crime scene.

b. Draw on the board a sketch of a gel with four lanes. Label the first lane as the marker or standard DNA, Suspect #1 DNA, Suspect #2 DNA, Evidence DNA.



Part 2 DNA preparation

5. Using a ball of string and a scissors, describe the role of restriction enzymes which cut DNA at specific locations resulting in 4 different sized restriction fragments. Demonstrate how the scissors moves along the DNA (string) and makes cuts at specific locations (recognition sites) resulting in four DNA restriction fragments of varying lengths



6. Hold up for the students to view each of the four varying lengths of string that represent the four DNA restriction fragments.

Part 3 Student participation

7. Turn off/ dim lights to indicate that the power going to the gel box is off.

8. Select 4 students (try to find students ranging in height from tall to short)

9. Give each of the four students one of the 4 strings. Be sure to give the tallest student the longest strand of DNA and the shortest student the shortest piece of string.

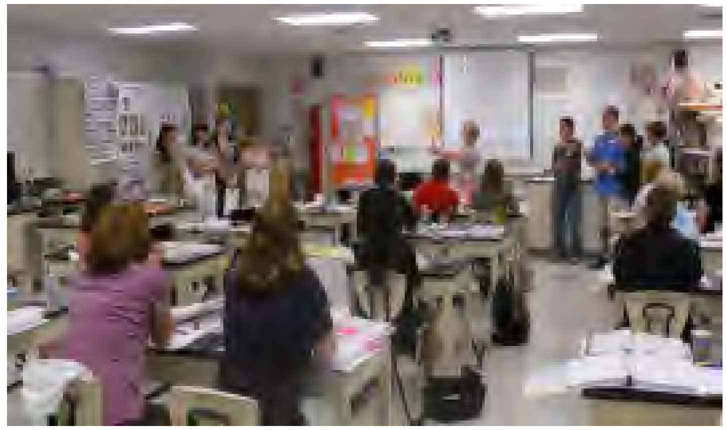
10. Explain that each of the four students represent the four different sized restriction fragments of DNA from Suspect #1.

11. Tell the four students representing the four DNA restriction fragments of Suspect # 1 that they (DNA fragments) are loaded into the well labeled Suspect #1. Use the aisle in between desks to represent a lane where DNA is loaded. Indicate to students that the area in front of that aisle represents the well). Remind the students that these fragments are loaded at the negative end of the gel box because DNA is negatively charged and will "run to red" (towards the positive end of the gel box) when the power is turned on.

12. Load the well

a. Ask the 4 students to bunch together at the beginning of an aisle.

b. Students should wiggle and bunch in a tight area representing the four DNA restriction fragments being pipetted into the well.



13. Questions:

a. Ask students what do you need to do to have the four DNA restriction fragments move through the gel?
   (Turn on the power box. You can simulate this by turning on the lights)

b. Ask students what was added to the DNA fragments to ensure that the DNA would not float away but would sink to the bottom of the well.
   (Loading Dye)

c. Ask students what will actually sort the restriction fragments?
   (Different sized pores within the gel help to sort the fragments by size)

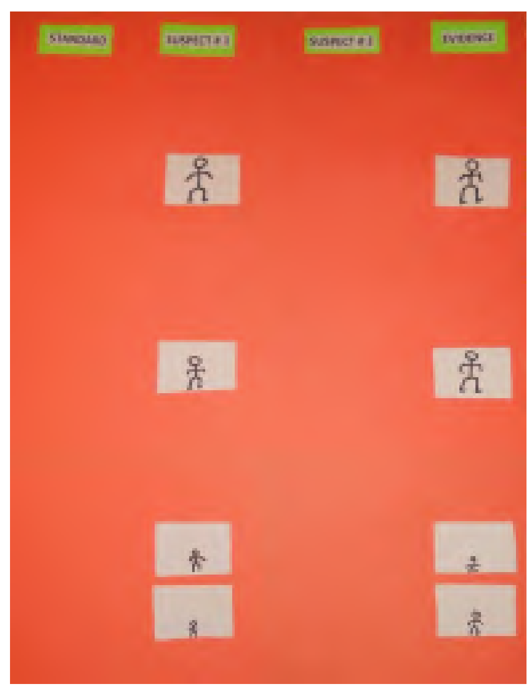
14. Movement of DNA Restriction Fragments

a. Ask the 4 students representing the restriction fragments from Suspect #1 to simulate moving through the gel.

b. Students should move with the shortest fragment moving further down the gel than the longer fragments.

c. The result will be that the four strands of DNA are sorted from shortest to longest.

15. Comparison with Evidence DNA



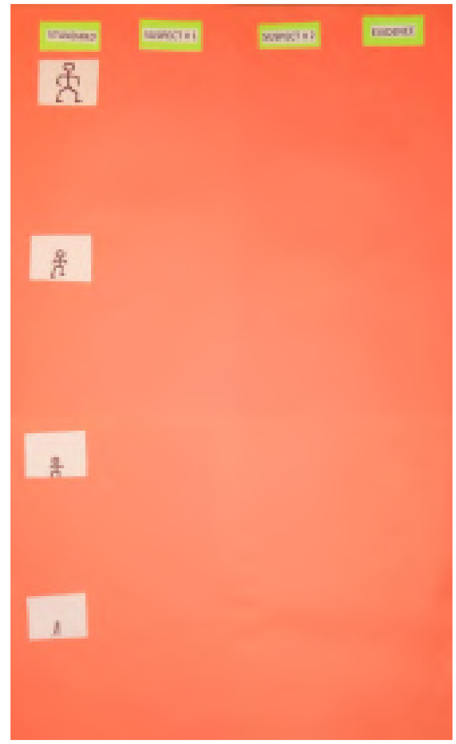
a. You could select four other students to represent the evidence DNA and have those students loaded into the well and sorted by the gel electrophoresis simulation.

b. Ask students representing the evidence DNA to line up showing a match with the suspect's DNA.

c. Ask students to rearrange showing that the evidence DNA did not match the suspect's DNA.

16. Role of Marker DNA or Standard DNA

a. Select four other students of varying heights.



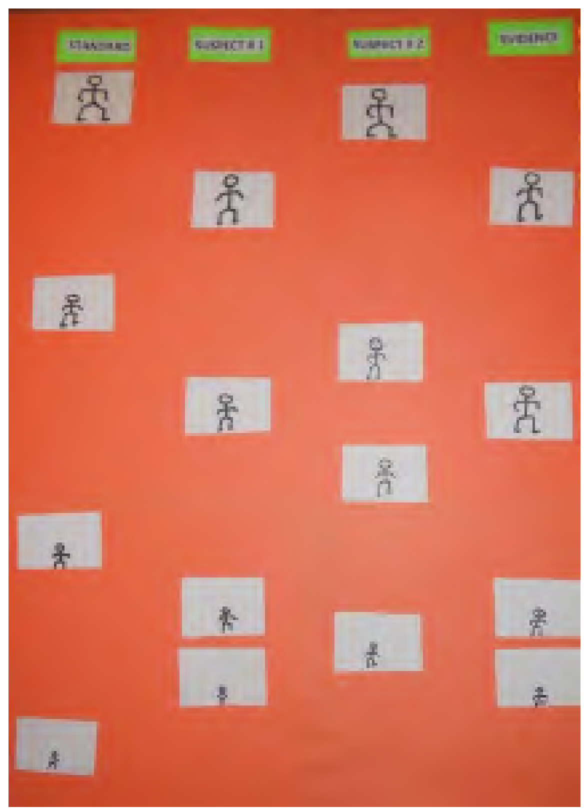
b. Give each of the four students one of the manila folders labeled with different number of base pairs (20,000; 15,000; 10,000; 5,000)

c. Ask the students to show how they would demonstrate how the marker DNA would be:
   i. Loaded into the well
   ii. Sorted by the gel based on size

d. Comparison of marker DNA (or Standard DNA) bands to other bands.
   Ask students to estimate the size of the bands found in the evidence DNA based upon the location of the evidence bands compared to the location of the marker or standard DNA bands

17. If time permits, repeat the process with four other students of varying heights to represent the DNA restriction fragments for Suspect # 2.

    The completed "gel" demonstration should be similar to the photo right.



18. <u>Role of DNA stain</u>
    a. After the students have been "sorted by size" on the gel, explain the role of DNA stain.
    b. Demonstrate how DNA staining and de-staining is done using a staining well, extra stain and water.
    c. Ask students to explain how to correct over-staining and under-staining of the gel so that bands are clearly visible.
       i. Over staining: needs to destain the gel longer
       ii. Under staining; need to stain the gel for a longer time

19. <u>Visual Aids</u>
    After students have seen these demonstrations, view the following websites:
    http://lpscience.fatcow.com/jwanamaker/animations.htm
    (created by J. R. Wannamaker)
    Select "Gel Electrophoresis"

http://learn.genetics.utah.edu/content/labs/gel/
Genetic Science Learning Center, University of Utah, "Virtual Lab Gel Electrophoresis"
http://learn.genetics.utah.edu/content/labs/gel/forensics/
Genetic Science Learning Center, University of Utah, "Can DNA Demand a Verdict?"

20. After the students have performed these visual class participation demonstrations and have viewed the different animations, they are ready to do the actual DNA gel electrophoresis "wet" lab.

21. **Alternative activity**: Instead of showing the students this activity, ask the students to devise their own visual demonstration that would simulate the process of gel electrophoresis.

22. **Extended Study:** Have students investigate how innocent persons have been released from long-term jail sentences after DNA evidence was used to show that they were wrongfully convicted.

References:

Innocence Project: http://www.innocenceproject.org/

Thompson-Cannino, Jennifer; Cotton, Ronald; Torneo, Erin: Picking Cotton, St. Martin's Griffin, NY, 2009

Patricia Nolan* Bertino** *taught biology and forensics at Scotia-Glenville High School for thirty-four years. She and her husband, Anthony (Bud) Bertino co-authored the high school forensic textbook* ***Forensic Science: Fundamentals and Investigations*. They currently are involved with teacher education by instructing and organizing The Bertino Summer Forensic Institute for Teachers. Both Patti and Bud are also frequent presenters at local, state and national conferences.*

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Note: Classroom photos: These are photographs of participants in our summer Bertino Forensics Summer Institute doing the DNA Simulation.

Connecting Adults with Nature

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For many years Natural Science educators have bemoaned the status of teaching their subject in schools and other forums, as well as the interest and knowledge that youngsters have in these natural sciences. In the recent STANYS Newsletter Special Edition our prior organization President iterated his concern on this subject linking it to the 'nature-deficit disorder', of Richard Louv, and our super-connected society, among other things. He referred, also, to the 'important role adults can have on correcting children's disconnect with the natural world.'

Unfortunately, adults don't know very much about the natural world either. In my small universe of New York City schoolteachers, paraprofessionals (teacher aides), and undergraduate non-science majors, knowledge of, and interest in, the natural world is minimal. I have presented scores of such educators and future educators with photostatic copies of common pressed and dried broadleaf trees (and the real specimens from which they came) and asked them to provide the common name. This has always been done under non-threatening circumstances (in college courses I explain that my quizzing them is for my own edification and not related to formal course assessment). Initially, few are able to identify even 'maple' or 'oak' when shown either the pressed, dried specimen or photostatic copy of our New York State tree, *Acer saccharum,* Sugar Maple, or the ubiquitous, *Quercus rubrum,* Northern Red Oak. This occurred, in the greenest of the five boroughs, the Bronx, with its 2700+ acre Pelham Bay Park, the 1100+ acre Van Cortlandt Park, the 250 acre New York Botanical Garden (free admission Wednesdays and Saturday mornings), and many more parks, parkways, and green open spaces. Furthermore, NYC Parks and the New York Restoration Project are currently in the middle of a major tree-planting initiative, (MillionTreesNYC), about which there has been considerable publicity. Since crime is way down; these green open spaces are quite safe for people to explore and enjoy. Pessimism among natural science educators should abound! But is there a ray of light somewhere?

In one of the first classes of a survey environmental science course I recently taught, I put the common names of 16 tree 'species' on the whiteboard. Under each, I also wrote the genus name plus spp. to indicate that there were really multiple species of maples, oaks, and most of the others. I used the full genus and species name for *Gleditsia triacanthos* (Honey Locust), *Liriodendron tulipifera* (Yellow Poplar), *Liquidambar styraciflua* (Sweetgum), and *Gingko biloba*

(Maidenhair Tree) because these were the only four selected without common generic variants in our area. I emphasized that all were extremely common as street trees, yard trees, and/or park trees throughout the Bronx. I started with the intention of using 10 'species', and then decided that I could not omit Dogwood (*Cornus* spp.), Cherry (*Prunus* spp.), and several others. I forced myself to stop at 16.

I started with the photostatic copies. I arranged the tree 'species' sheets in no particular order with regard to the names on the whiteboard. I showed the photostatic copy to the left, straight in front of me, then to the right for a total of about 15 seconds. I told the students to write one of the common names for each, selecting it from the whiteboard behind me. I repeated this 16 times. As we proceeded through the 16, I said that if they had already written a name but then they were more certain of their identification late in the exercise that they should write it again. Perhaps their first identification was wrong. I didn't want them failing to identify because they had selected a particular name earlier. Some students were amused by how little they knew; others were embarrassed. None resented being tested on something they had not been taught since I told them that the exercise was for me and would not influence their grade. One person got three right out of 16, three got two right out of 16, one got one right out of 16, and the rest (n=14) got none right. Nine were unable to identify either the maple leaf or the oak leaf. The average score for the class was 0.71, fewer than one correct out of 16. See Figure One (on page 25 and 26), the photostatic images reduced to 25% of their individual sheet sizes.

(Later, I regretted not having included *Robinia pseudoacacia* (Black Locust), *Ailanthus altissima* (Tree of Heaven), or any of the birches (*Betula* spp.). An important conceptual point, which I taught, was that the Maidenhair Tree – sometimes just called Gingko – though deciduous as were all the others, was not an Angiosperm 'hardwood'. Rather, it is a Gymnosperm – and in accordance with most taxonomic frameworks, belongs to its own class, order, family, and genus. Enough of the complications!)

Now I know quite well that leaf form is not the only way to identify trees and I explained this to my students. For example, it is difficult to distinguish Sugar Maple (*A. saccharum*) from Norway Maple (*A. platanoides*) without crushing a leaf and looking for milky sap in the Norway Maple. Moreover, there are the bark, the twigs, the buds (especially useful for winter identification work). There is the fine structure of flowers and the fruits they produce. Some 'maples' (e.g. *A. negundo* – boxelder), some 'oaks', (e.g. *Q. virginiana* - live oak), and others, do not have the exemplar leaf look. In this case one uses flowers and fruits to determine affinity. Also, hybridization – which creates intermediate forms in some genera - occurs frequently in the plant kingdom. These subtle botanical considerations go far beyond what I was looking for with my adult students and what might be done to improve the situation here.

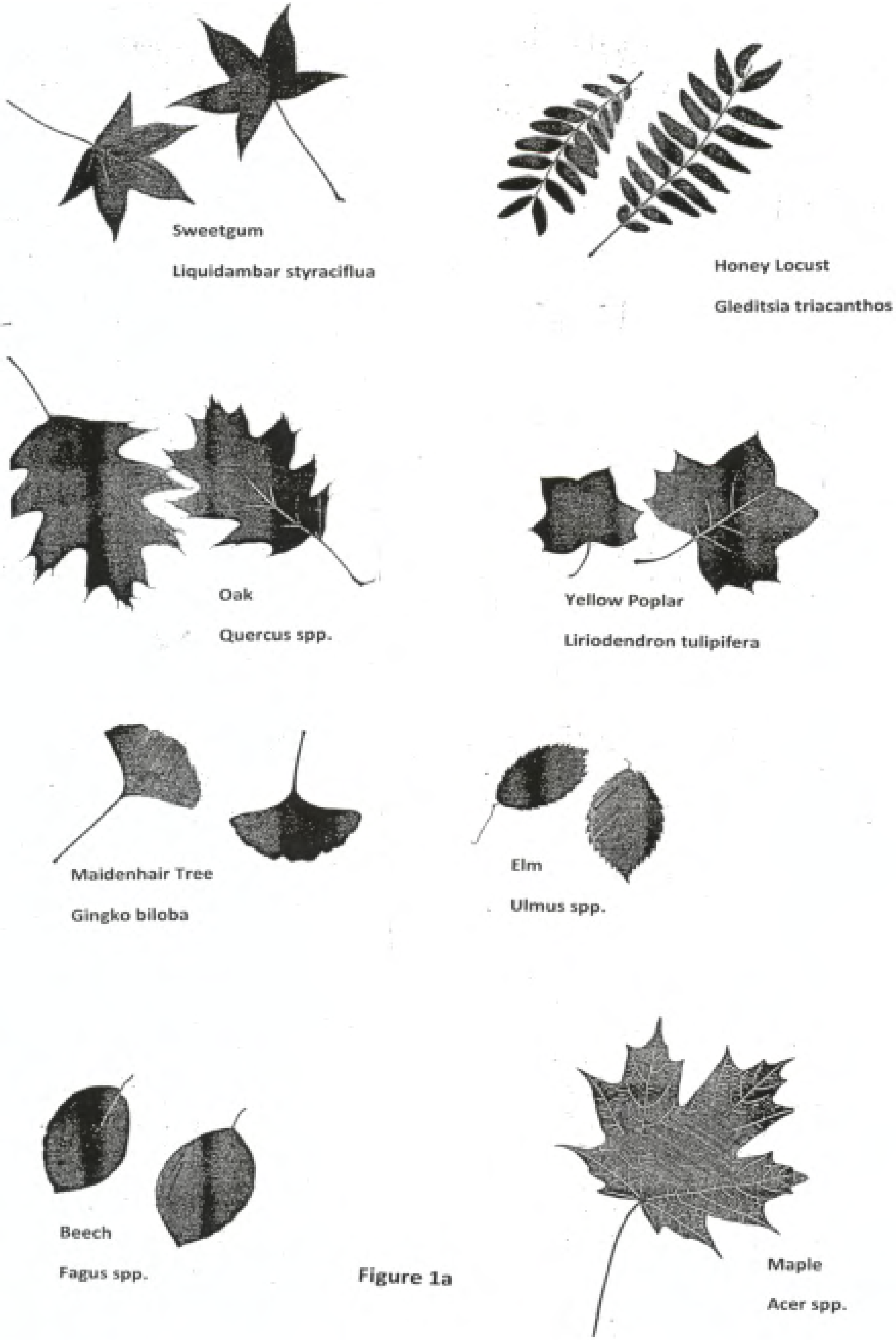
Sweetgum
Liquidambar styraciflua
Honey Locust
Gleditsia triacanthos
Oak
Quercus spp.
Yellow Poplar
Liriodendron tulipifera
Maidenhair Tree
Gingko biloba
Elm
Ulmus spp.
Beech
Fagus spp.
Maple
Acer spp.

Figure 1a

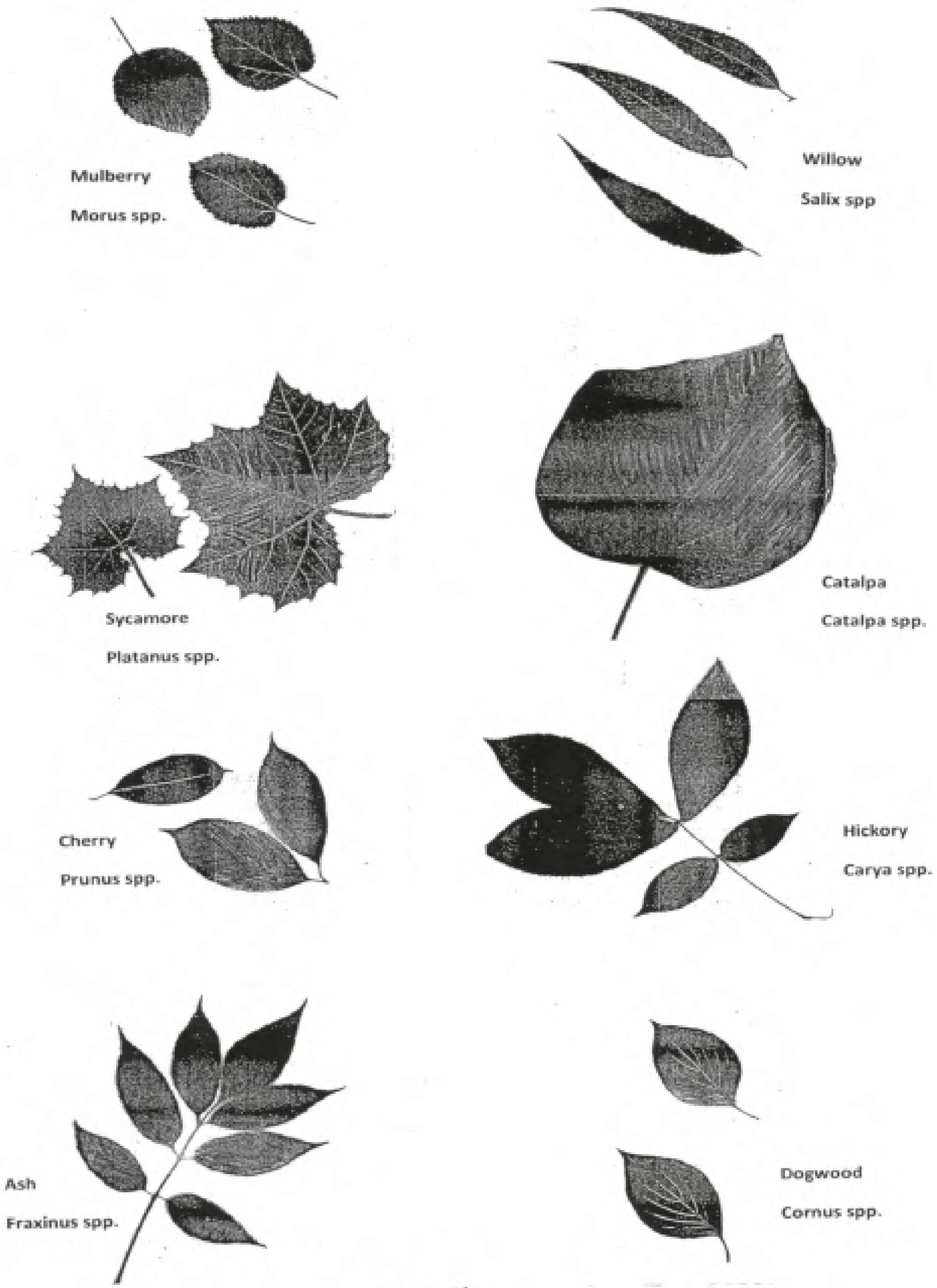
Mulberry
Morus spp.
Willow
Salix spp
Sycamore
Platanus spp.
Catalpa
Catalpa spp.
Cherry
Prunus spp.
Hickory
Carya spp.
Ash
Fraxinus spp.
Dogwood
Cornus spp.

Figure 1b

Now some of my students were born in the Caribbean; most were the children of people born in the Caribbean. While they may know the fruit of the mango (*Mangifera indica*), the papaya (*Carica papaya*), and the avocado (*Persea americana*), I'm fairly sure that nobody would have done better with the leaves of these trees either. It's just not priority to focus on the natural world around them. For example, they don't know (until I explain it to them) why the mud flats at the waters edge are covered by water twice a day and nothing but brown goo twice a day; they don't understand how I can predict the next full moon when they tell me the phase of the moon today. Some students don't even understand you could predict the time of sunrise on a particular day before the sun comes up! Therefore I suggest that 'nature deficit disorder' applies to large numbers of adults too. Some environmental scientists have suggested that this has a lot to do with the increasing urbanization and the consequent separation of people from the natural world. While there is plenty of open green space in the Bronx, if you're not compelled to focus on it, then it might just as well not be there. In addition the busy lives of so many of us today prevent a focus on anything besides making ends meet and raising our kids. Time to relax means watching TV, checking e-mails, and playing with smartphones, activities removed from the natural world.

Howard Gardner, the 'multiple intelligence' theorist, added a 'naturalist intelligence' to his original seven intelligences about 10 years ago. He proposed that there also exists a 'naturalist intelligence' which "enables human beings to recognize, categorize and draw upon certain features of the environment. It 'combines a description of the core ability with a characterization of the role that many cultures value' …" (Smith, 2002, 2008). As with Gardner's other intelligences, naturalist intelligence may be innate, and that, if neglected, it will decline. My dissertation advisor at Teachers College characterized an "environmental orientation dynamic" in individuals which disposes some to search for meaning and order in their surroundings. Presumably, if neglected, or disregarded, the desire for order wanes and acceptance of disorder increases (Anderson, 1976). These two elements of larger, more comprehensive theories mesh all too well with what the effects of urbanization and divorce from nature seem to be doing to busy adults and children. Mother Nature takes the back seat with blindfolds on.

Back to my environmental science classroom! During subsequent sessions, I grabbed a few moments almost every class and reviewed the tree 'species' with my students. Sometimes I used the photostatic copies. Sometimes I used the dried, pressed specimens. When the more complacent students saw how excited some of their classmates had become about proper identification of these 16, they didn't want to be left behind. They got into it. Nobody wanted to bomb the final quiz which I said was coming. Students started bringing in their own specimens of the 16. Students started bringing in other 'species' and asking for my help in their identification. Students started asking for my help as to where they might find a Gingko or Honey Locust tree. In the last class session I repeated the original quiz with, of course, a different order of common names on the whiteboard and a different order of visual presentation of the photostatic copies to the students, and I could not have been more pleased with the results. Five students got all 16 correct and the average score was 13.38 (n=13). So what does this tell us about adult urban students, initially ignorant of this basic aspect of the natural world? What does this tell us about their potential to have a positive impact on the children they teach now or will teach in the future?

For me, Schneider (1968) was the first to detail thoughts on the issue of urban dwellers and the natural sciences. He began his article with, "Our Nation and our State were once a wilderness. People were few in number. Streams were clear and the air was fresh." He continued, "Never before has the need for conservation action to improve, restore and protect the resources of the physical environment been so urgent. Never before has the need for a conservation conscious public been so necessary. *Especially critical is the need for effective conservation education in the* city." However, he seems to throw in the towel on adults, "For the most part, trying to teach conservation to adults has been a failure. Our hope – our destiny – lies in the hands and hearts of our youths, notably, our urban youths." He proceeds with a series of practical suggestions on how to teach conservation topics to urban youth. Tangentially interesting is how he touched – more than 40 years ago – on some of the very same themes that Richard Louv does today, "Vigorous adherence to adult-made time schedules is (also) unwise. As little as possible should be done to restrict unbridled enjoyment of the out of doors." In the same publication, but more recently, Eddy (2008) offered conservation tips on involving city kids in conservation projects (note how 'urban youths' became 'city kids' in just 40 years!). Both articles refer to a small cadre of knowledgeable adults who do the teaching. My feeling is that the cadre of knowledgeable adults can and should be enlarged.

My goal was modest and it was attained. If every science teacher K – 16 made it their business to include a few content skills related to their student's immediate environment (e.g. broadleaf trees in summer, conifers in winter, tidal cycles, moon phases, hours of sunlight, etc.) it would make a huge difference in the youngsters, teenagers, and the young adults who strive to improve their lot through education. Community colleges, four-year colleges, teacher professional development programs, and the like are where the adults are. They are reachable, and the more they are favorably impacted by relevant science content skills, the more they can pass these content skills on – to their colleagues, as well as the youngsters they teach both informally and formally.

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1. Anderson, O. R. (1976). The Experience of Science – A New Perspective for Laboratory Teaching. New York: Teachers College Press.
2. Eddy, Angie (October 2008). "Urban Growth: City Kids Discover Their Green Thumbs.", New York State Conservationist.
3. Gardner, Howard (1993). Frames of Mind. New York: Basic Books.
4. Louv, Richard (2005). Last Child in the Woods: Saving Our Children from Nature-Deficit Disorder. Chapel Hill: Algonquin Press.
5. Mitchell, Alan (2002). Trees of North America. San Diego: Thunder Bay Press.
6. Schneider, Gerald (August-September 1968). "Conservation Teaching in the City.", New York State Conservationist.
7. Smith, Mark K. (2002, 2008). 'Howard Gardner and multiple intelligences', the encyclopedia of informal education, http://www.infed.org/thinkers/gardner.htm.

Donald G. Fulton, *Ed. D. is a retired New York City School Supervisor and the retired Director of Children's Education at The New York Botanical Garden. He currently teaches biology and science education for Mercy College and Teachers College, Columbia University. His bachelor's degree was from the College of Environmental Science and Forestry. He holds the doctorate from Teachers College. He is a member of the Board of Directors of Westchester-Bronx STANYS. He can be reached at* dgf2006@columbia.edu or at dfulton@mercymavericks.edu.

A Hands-on Introduction to Displacement / Velocity Vectors and Frame of Reference Through the Use of an Inexpensive Toy

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Abstract: This paper presents a set of hands-on activities used by the author with 93 students as an introduction to vector terminology and those vector operations common in the New York State Regents Physics curriculum (NYSED, 2008) with a focus on displacement and velocity vectors. Through guided activity worksheets (Appendices A and B) and the use of inexpensive equipment, students were able to visualize the tip-to-tail method of vector addition, determine the horizontal and vertical components of vectors and observe the combination of two concurrent parallel or perpendicular vectors. Students observed the motion of a wind-up toy on a moving Cartesian grid within a static frame to establish the concept of frame of reference for relative motion. The terminology and level of difficulty were focused toward a high school Regents class.

Introduction:

Vectors are the natural language of mechanics. The activities presented in this document use a *Never Fall*™ wind-up toy to create a hands-on activity for introducing vectors to Regents Physics students with little to no prior exposure to vector quantities. The introduction of vector quantities and vector operations were limited to displacement and velocity scenarios. The skills introduced through these activities will subsequently apply to the topics of projectile motion, superposition of forces, momentum and force fields.

The two activities presented in this document, *Activity One: Ladybug Transit* (Appendix A) and *Activity Two: Ladybug on a Conveyor Belt* (Appendix B) were created by the author to serve as instructional tools that make vector characteristics both explicit and highly visual for learners. The activity expands a teacher directed demonstration by Mader and Winn (2008) into a student centered activity. Each activity was designed to be conducted in the space of a student desktop.

Vectors in the New York State Regents Physics Curriculum

The following chart (see Table 1) summarizes the portions of the *Standards of Mathematical Analysis and Scientific Inquiry* that relate to vectors in the *New York State Physics Core Curriculum.*

Table 1: Vector Skills From the NYS Physics Core Curriculum	
Standard 1: Mathematical analysis	
Key Idea 1: Abstraction and symbolic representation are used to communicate mathematically - use scaled diagrams to represent and manipulate vector quantities	
Standard 4: Scientific Inquiry	
Key Idea 5: Energy and matter interact through forces that result in changes in motion.	
5.1a	Measured quantities can be classified as either vector or scalar.
5.1b	A vector may be resolved into perpendicular components.
5.1c	The resultant of two or more vectors, acting at any angle, is determined by vector addition.

(NYSED, 2008) Full text available at http://www.p12.nysed.gov/ciai/mst/pub/phycoresci.pdf

In order for a student to transition from the basic level of functionality listed in Key Ideas 5.1a-c in Table 1, toward mastery of skills and concepts in the remainder of the curriculum, learners must be able to demonstrate the following skills and understandings:

- Define terms such as displacement, velocity, resultant, equilibrant and component.
- Establish the relationship between component vectors and the resultant vectors including the concept of additive inverse (Arons, 1997, p. 107).
- Define the meaning of a negative vectors in relation to the horizontal and vertical axes
- Understand that vector quantities are not fixed to a location (Brown, 1993).

Background:

The *Vector Knowledge Test* (Knight, 1995), administered to introductory college level physics courses comprised of primarily science majors, revealed that nearly half of the students who self-reported prior exposure to vectors from high school physics or math entered the class with no useful knowledge of basic vector skills. Based on interviews and activities, Aguirre (1998) concluded that students commonly held misconceptions regarding vectors include the following:

- Speed and displacement are independent of frame of reference.
- Vector components act sequentially rather than simultaneously.
- Time is different for the resultant path than for the components.
- Magnitude of component vectors change when two vectors interact.

Knight's (1995) recommendations from his analysis of the *Vector Knowledge Test* (Knight, 1995) suggested that vectors should be introduced over a course of several weeks, prior to introduction of projectiles or Newtonian mechanics. Subsequent investigations using diagnostic testing of introductory college students noted that students demonstrated some intuitive knowledge of vectors but lacked the ability to apply skills such as tip-to-tail and parallelogram methods of vector addition (Nguyen and Meltzer, 2003).

From a student's viewpoint, "adding velocity arrows appears very different from adding displacement arrows, and acceleration arrows are totally incomprehensible" (Arons, 1997, p. 107). In survey of introductory physics students, graduate students and physics TA's, Shaffer and McDermott (2005) found that the ability to correctly draw and label a vector was markedly greater for velocity related concepts than for acceleration concepts. As instructors transition from displacement vectors to force vectors, students are likely to become confused unless the nature of each of these quantities is discussed (Roche, 1997).

A number of activities are widely used to introduce vectors to students. Vector treasure hunts are a popular method. In this type of investigation students use a compass to create a treasure map using vectors (Windmark, 1998). The map is then passed to another group for them to follow. This method requires prior knowledge of tip-to-tail addition. A force table is a common introductory experience used to teach vectors, mechanical equilibrium and the vector triangle (Greensdale, 2002).

Required Student Prior Knowledge

These activities are intended to be sequenced within the curriculum just after the introduction of the terms: displacement, velocity, vector and scalar. Basic vector terminology, such as resultant, equilibrant, horizontal and vertical components should be introduced at the outset of the activity.

Within the physics curriculum, vector operations are taught using both the Cartesian coordinate system (x,y) for the horizontal and vertical components and the polar coordinate system (R, θ) for the resultant vectors (Hoffmann, 1975). The origin of the polar coordinate axis is aligned with the positive "x" plane of the Cartesian coordinate system. The "R" serves as a symbol for any vector quantity, but displacement and velocity are substituted by students as appropriate. Cartesian and polar coordinate systems are not terms familiar to students, nor are they used in the Regents Physics curriculum. Therefore, the terms used here for Cartesian coordinate system values will be "horizontal and vertical components" which refer in equations to R_x and R_y respectively. Values reported in the polar coordinate system will be referred to by magnitude (R) and direction (θ) given in standard position or reference angle form as appropriate. To successfully complete these activities, students must be able to translate between these coordinates systems by applying the following transformation equations:

$$R_x = R\cos\theta \qquad R_y = R\sin\theta \qquad \theta = \tan^{-1}(R_y/R_x) \qquad R^2 = R_x^2 + R_y^2$$

An understanding of methods used to express angles is required for reporting the direction of the resultants. Standard position refers to angles measured from the positive x-axis to the terminal side with respect to a 360 degree counterclockwise rotation (Ryan, 1993). For each angle of standard position students must be able to identify the reference angle and assign the appropriate quadrant. The reference angle is the acute angle formed by the terminal side of the given angle and the x-axis. For reference angles that do not fall in the first quadrant, students must be able to convert to standard position. Students must understand that the axes of the Cartesian coordinate system align with the quadrantal angles of 0^0, 90^0, 180^0, 270^0 and 360^0. For example, a polar coordinate vector of magnitude R at an angle of 180^0, would be written as $R_x = -R$, $R_y = 0$.

The table below lists the performance indicators for the NYS Regents math courses that cover content related to the required prior knowledge discussed here.

Table 2: *Integrated Algebra* (A.A.) and *Algebra 2 and Trigonometry* (A2.A) Performance Indicators	
A.A.42	Find the sine, cosine, and tangent ratios of an angle of a right triangle, given the lengths of the sides.
A.A.43	Determine the measure of an angle of a right triangle, given the length of any two sides of the triangle.
A.A.44	Find the measure of a side of a right triangle, given an acute angle and the length of another side.
A.A.45	Determine the measure of a third side of a right triangle using the Pythagorean theorem, given the lengths of any two sides.
A2.A.57	Sketch and use the reference angle for angles in standard position.

(NYSED, 2005) Full text available at http://www.p12.nysed.gov/ciai/mst/math/standards/core.html

Nearly all students enrolled in Regents Physics within our school have completed *Integrated Algebra*. Therefore, a basic understanding of trigonometric functions was assumed. Approximately eighty percent of my students are concurrently enrolled in *Algebra 2 and Trigonometry*. The remaining twenty percent of students are evenly split between *Geometry* and a higher level course. Given the composition of my classes it was necessary to provide students with some formal instruction on the transformation equations and standard position angles prior to these activities. The simulation, *Vector Addition,* available through PhET, was used to reinforce the connection between the two coordinate systems and allowed students to practice with the transformation equations (*http://phet.colorado.edu/en/simulation/vector-addition*).

Activities

Ninety-three students, enrolled in my three sections of 31 students each, completed both activities including worksheets. *Activity One* required roughly 80 minutes for introduction, student work and discussion. *Activity Two* required roughly 90 minutes for introduction, student activities and discussion. The completion of the follow-up questions required additional class time or were assigned as homework. Both of these activities took place within a science classroom setting as they require space and a flat desk or table.

Each activity utilized a guided worksheet but required active manipulation of materials. Students worked in small groups to problem solve throughout the guided activities. The guided format was necessary due to the fact that this was an initial introduction to vectors. Students would have experienced great difficulty creating the scenarios for themselves.

Equipment

Never Fall™ wind-up toys were used because they met the requirements of both activities. In *Activity One* it was necessary for the toy to pivot when it reached the edge of a surface. In *Activity Two*, the toy required a low center of gravity to prevent tipping when the surface Cartesian grid was moved and needed to maintain a constant velocity for approximately six seconds. These toys come in several varieties and ladybug themes were selected for this class to add some levity for the adolescent audience. I also purchased and experimented with the bulldozer variety but rejected these due to a lower speed. *Never Fall*™ toys are widely available online and in toy stores for a cost of approximately $3-4 each. It is advisable to purchase extra toys to allow for malfunctions or breakage. The *Never Fall*™ wind-up toy will hereafter be referred to as the “ladybug toy.”

The surface for both *Activity One* and *Activity Two* was a dry erase poster board with Cartesian grid lines. These are available at teacher supply stores. For *Activity One* the dry erase surface was attached to a piece of foam board with double-sided tape to provide an edge (see Figure 1a). For *Activity Two*, the movable surface should be 50-60 cm in length and a minimum of 25-35 cm in width and have a dry erase finish. The lines are helpful to verify straight motion of the ladybug toy. An additional large dry erase board, three-meter sticks and a stopwatch are also required (see Figure 1b). The cost of each lab set-up, consisting of dry erase poster board and toys came to approximately $10 (not including stop watches and meter sticks).

Figure 1a and 1b: Required equipment for activities.

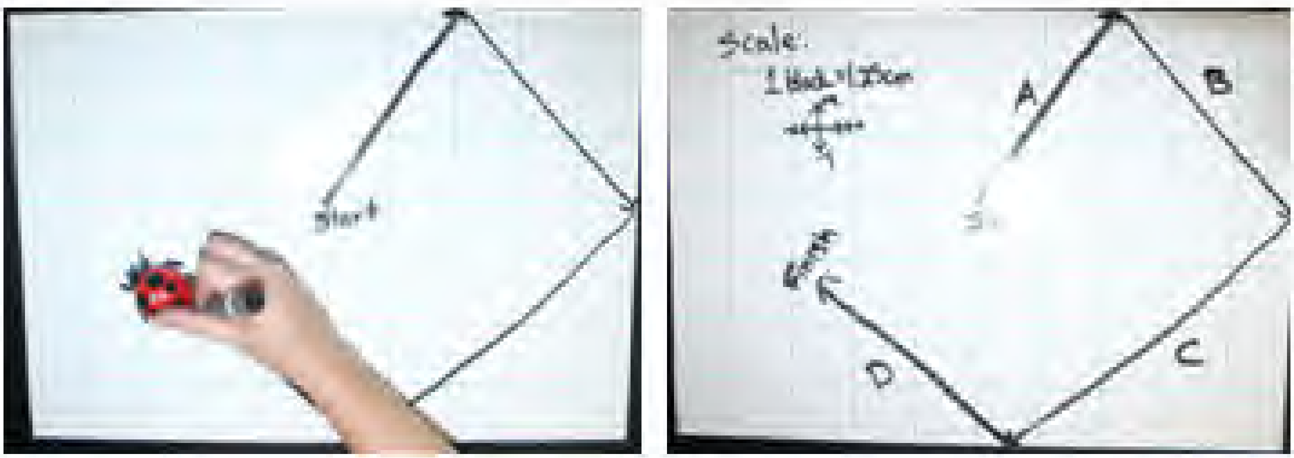
Activity One*: *Ladybug Transit

Overview:

Students traced the motion of the ladybug toy on a Cartesian grid and compared the path travelled with the horizontal and vertical components of the ladybug toy’s motion. For each displacement vector, students applied the transformation equations to determine the relationship between the components (R_x, R_y) and the resultant (R, θ). *Activity One: Student Worksheet* (Appendix A) provided questions and data tables to guide and organize student work.

Procedure and Instructional notes:

A fully wound ladybug toy was released from a point close to the center of the board and the motion was traced with a dry erase marker (see Figure 2a). Trials in which the ladybug toy traveled a path made up of at least three distinct vectors were considered successful. Each vector was labeled with an identifying letter. Students determined a measurement scale in centimeters for each block of the Cartesian grid and labeled the direction for the horizontal and vertical components accordingly (see Figure 2b).



Figures 2a and 2b: Sample student work, steps A-D.

The horizontal and vertical components of each vector were determined in block units (see Figure 3) and recorded in the data table (see Figure 4) using positive or negative signs to note the direction correlated with each axis. All displacements measurements were originally stated in block units since not all groups were utilizing surfaces with an identical scale. The scale was determined in centimeters and recorded by students.

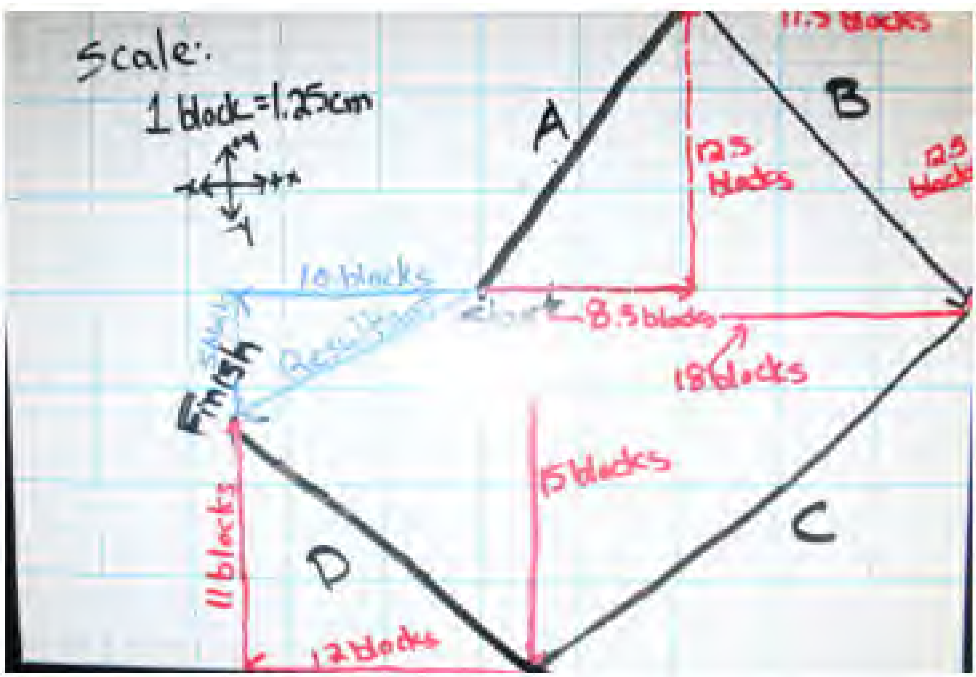


Figure 3: Sample of student work step E**.**

The total horizontal and total vertical displacements were found by adding each column. The resultant displacement was drawn as an arrow from the starting point to the end point. The horizontal and vertical components of the resultant vector were also found and compared with the results found by adding each column in the data table (see Figure 4).

Using this information, students determined the magnitude (R) and direction (θ) of each displacement vector. To determine the magnitude of each vector in block units the Pythagorean Theorem was used. The magnitude was then converted to centimeters. Reference angles were determined using the equation '$\theta = \tan^{-1} (R_y/R_x)$'. Students then found the angle in standard position based on the quadrant for the vector as determined by the horizontal and vertical components. The calculated magnitudes and angles were recorded in the data table to correspond with the displacement vectors traveled by the ladybug toy and the vector for the resultant displacement (see figure 4).

	Components		**Resultant**			
	Horizontal X (Block Units)	**Vertical Y** (Block units)	**Magnitude (block units)**	**Magnitude (centimeters)**	**Reference Angle**	**Angle (given Standard Position)**
A	8.5	12.5	15.1	18.9	55.8	55.8
B	11.5	-13.5	17.7	22.2	49.6	310.4
C	-18	-15	23.4	29.3	39.8	219.8
D	-12	11	16.3	20.3	42.5	137.5
∑	**-10**	**-5**	**11.2**	**14**	**26.5**	**206.5**

Figure 4: Sample data table.

Students were then asked to compare magnitude and direction values found in the data table with the original displacement vectors traced on the board (see Figure 3). Students were asked to look at each vector independently, compare with the data table and determine results were reasonable and realistic. Discrepancies were discussed amongst the group.

As a final phase of the activity, students investigated how changing the order of vectors would influence the magnitude and direction of the resultant. In order to achieve this, students wrote resultant (R, θ) for each vector travelled by the ladybug toy onto a separate index card. Each group shuffled the cards to produce a random order of vectors and then exchanged cards with another group. Students were then tasked to find the resultant displacement of the other group's ladybug toy using steps learned during the activity. Results were then compared between groups and discussed. Students concluded from this phase of the activity that the order in which you add vectors does not influence the magnitude or direction of the resultant.

Activity Two: Ladybug on a conveyor belt

Overview:

Students explored the simultaneous motion of a wind-up toy and the surface on which it moved. The movable surface served as the "conveyor belt" upon which the ladybug travelled. On a stationary surface, the velocity of the toy is found by dividing the displacement by the time interval. When the surface upon which the ladybug toy is in motion the, the resultant displacement and velocity of each component must be determined relative the static frame. The displacement of the ladybug toy was measured in relation to the moving surface and against a set of fixed meter sticks. The motion of the Cartesian grid was always measured against a fixed frame of reference consisting of a dry erase board with meter sticks attached to a large dry erase surface and below the movable surface.

Students were able to use both the moving surface and the fixed dry erase board to record starting and end points, sketch displacement vectors and to solve for values requested in the student worksheet. Students recorded data and findings in the appropriate data table on the student worksheet.

A third meter stick and protractor were used when necessary to measure the vertical axis or measure resultant displacements at an angle. The time frame for the displacement was measured using a hand held stopwatch.

Procedure and Instructional Notes:

After a brief introduction to the equipment, students set up materials and divided tasks as follows.

- One student was responsible for pulling the "conveyor belt" at constant speed.
- One student was responsible for timing the motion with a stopwatch.
- One student was responsible for winding the ladybug toy before each release, and stopping the ladybug toy at the conclusion of the scenario. This individual was responsible for clearly communicating start and stop to the other members of the group.
- One student used a dry erase marker to indicate changes in displacement. The start and end points for the following values needed to be determined: 1) the change in position of the Cartesian grid relative to the fixed frame 2) the change in position of the ladybug toy relative to the Cartesian grid and 3) the change in position of the ladybug toy relative to the fixed frame. This task was assigned to the student responsible for timing the motion when groups consisted of only 3 students.

Students practiced manipulating the equipment and coordinating roles before completing scenarios and recording data on the *Activity Two: Student Worksheet*. Groups also discussed and agreed upon a common set of procedures for releasing the ladybug toy, stopping the ladybug toy and measuring results. For example, a common point on the ladybug toy was used for measuring all displacement values. Students also agreed the ladybug toy would be fully wound prior to each scenario. Since students standing around the table had different viewpoints for observing motion, the groups each agreed to an orientation for horizontal and vertical axes. The Cartesian grid surface was able to move between the meter sticks on the horizontal to the right (+x) or to the left (-x). The ladybug toy was able toward the right (+x), left (-x), up (+y) and down (-y).

In the first stage of the activity students determined the average speed (or magnitude of the velocity) of the ladybug toy by averaging three trials. This was accomplished by allowing the toy to traverse the width of the stationary Cartesian grid and recording both displacement and time of motion (see Figures 5a and 5b, on following page).

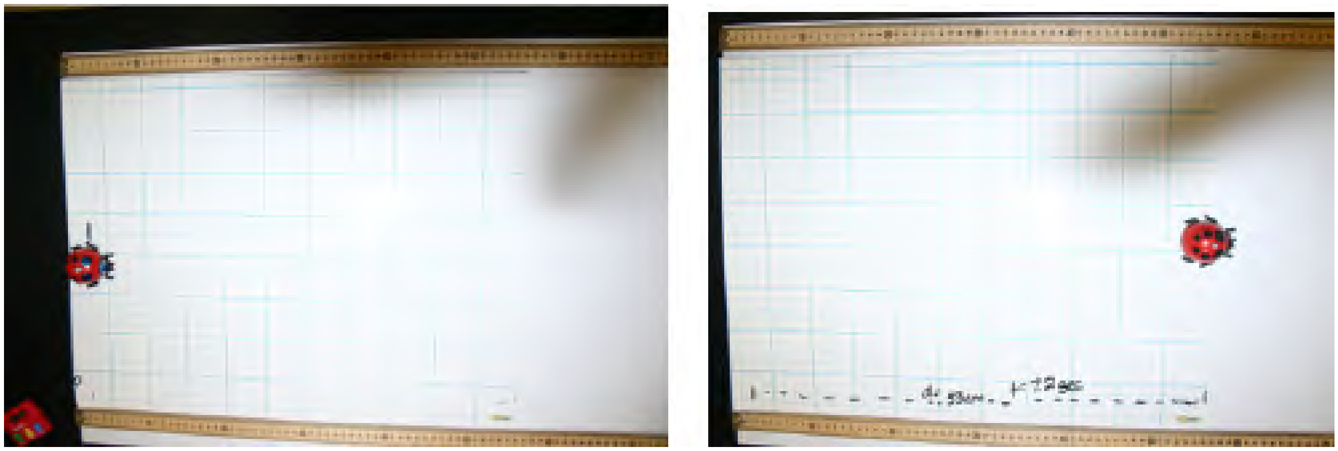


Figure 5a and 5b: Determining speed of toy (before and after).

Once an average speed was established, students proceeded through a range of scenarios involving concurrent motions of the toy and the Cartesian grid. Each scenario demonstrated how the resultant motion of the ladybug toy relative to the fixed frame reference is dependent on the direction and magnitude of the component velocities.

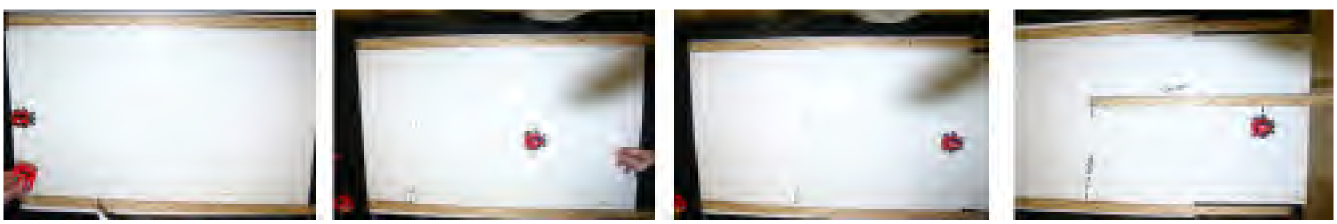


Figure 6a, 6b, 6c and 6d: Parallel velocities in the same direction (before, during, after).

Students compared the resultant displacements and velocities for parallel components moving in the same direction (see Figures 6a-d) with parallel components moving in opposite directions (see Figure 7a-b). When the velocities were oriented in the same direction the resulting displacement was large. When the velocities were oriented in opposite directions the resultant was small or zero.

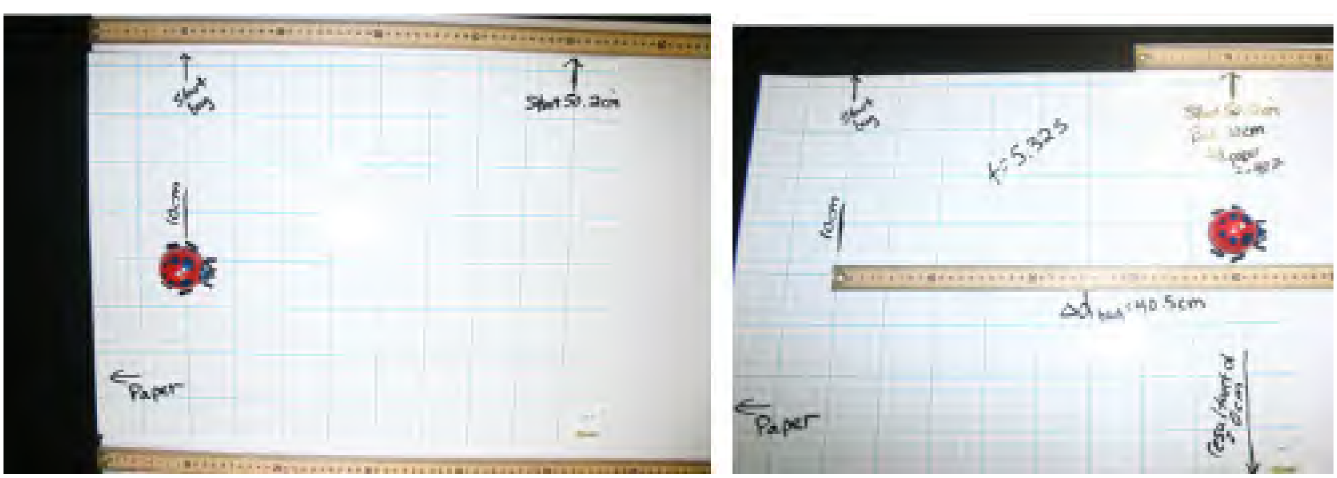


Figure 7a and 7b: Concurrent velocity in opposite directions, before and after.

For scenarios involving perpendicular components, students created a sketch of the path travelled as seen from a fixed frame of reference. The magnitude and direction for each combination of horizontal and vertical components were compared graphically (see Figure 8a-b).

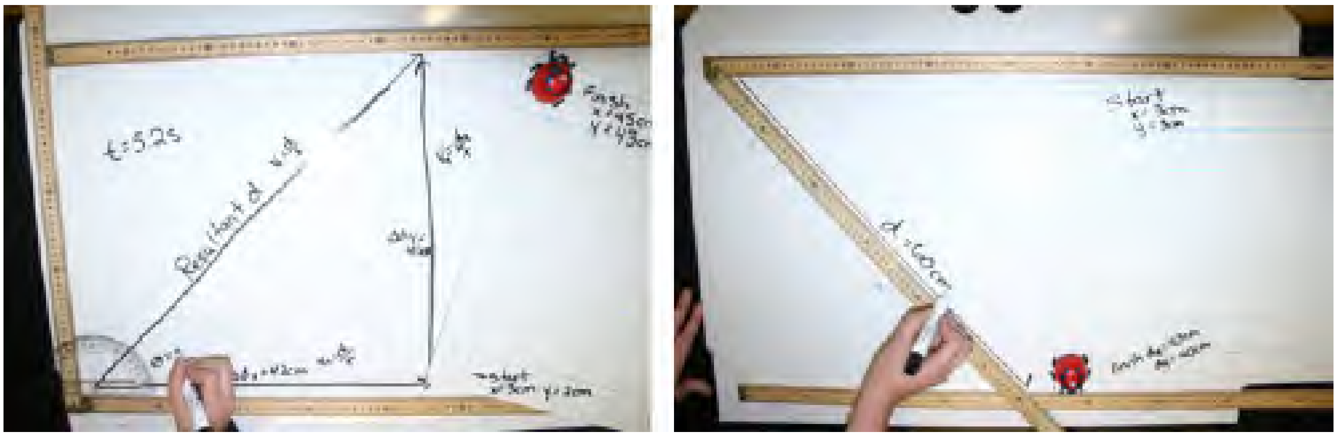


Figure 8a and 8b: Perpendicular motions of ladybug toy and Cartesian grid.

In each scenario, students were able to observe that a resultant displacement calculated by Pythagorean Theorem and a transformation equation were the same as the resultant as measured directly with a meter stick and protractor. By varying the speed at which the surface was pulled, students discovered how a change in the magnitude of the horizontal component influenced the magnitude and angle of the resultant displacement and velocity.

Reflections for *Activity One: Ladybug transit*

Students were able to easily break down the displacement vectors that served as the ladybug toy's path into horizontal and vertical components using the Cartesian grid system. Most students applied the positive and negative signs to the horizontal and vertical components on the appropriate axes with minimal difficulty with the presence of the Cartesian grid. The Cartesian grids helped address student confusion about the meaning of a negative R_x or R_y resulting from a transformation equation. Students were able to visualize tip-to-tail addition of vectors repeatedly throughout the activity. In subsequent class work, the majority of students were able to correctly draw a vector diagram showing perpendicular components and a resultant. Students were also able to use the transformation equations to find the magnitude and direction of the resultant given values for the components. The second phased of the lesson was successful in demonstrating to students that the order in which vectors are added does not change the magnitude or direction of the resultant.

Reflections for *Activity Two: Ladybug on a Conveyor Belt*

This activity introduced the idea of concurrent vectors but also further developed the concepts of displacement and velocity. As I walked around the room I heard many student conversations in which groups were actively working through the difference between the concepts of displacement and velocity. In several cases I needed to work with students on the difference between the two values. This was very insightful. The difference between how far an object travels and how fast an object travels seems implicit.

The activity provided a useful visual for students to establish a model for future discussions. In particular this activity emphasized the importance of the concept of frame of reference. The method I used to help students understand the idea of frame of reference was to query students as to what would be observed from various viewpoints. Examples of queries included: What would a ladybug toy moving parallel on the vertical path to the first ladybug observe? What would a ladybug moving only due to the horizontal motion of the paper observe? How are these motions different from a ladybug watching from a fixed position near the starting point? After adequate discussion students were able to explain the role of frame of reference in determining the magnitude and direction of the resultant.

The activity achieved the stated objectives. Students confronted each of the common misconceptions regarding vector quantities outlined by Aguirre (1998). The following table outlines the misconceptions and the strategy utilized within the activity to address the misconception.

Table 3: Vector Misconceptions (Aguirre, 1988) addressed in *Activity Two*: Ladybug on a Conveyor Belt	
MISCONCEPTION	**ACTIVITY CONNECTION**
Path is an intrinsic property of a moving body; that is, it is independent of any reference frame.	In each scenario, students measured the component displacements (d_x, d_y of the ladybug against the Cartesian grid, d_x of the surface against the fixed frame) and then determined the resultant displacement relative to the fixed frame.
The magnitude of the component velocities increases or decreases due to the interaction with the other component.	For every scenario students determined the displacement of the ladybug toy relative the Cartesian grid and the resultant displacement relative to the fixed frame. These values were then used to determine the ladybug toy's velocity and the resultant velocity. The ladybug toy's velocity on the conveyor was consistent throughout the lab and did not depend on the velocity of the surface against the frame of reference.
Speed is an intrinsic property of a moving body, and it is independent of any reference frame.	For each scenario students determined the component velocities and then determined the resultant velocity relative to the fixed frame.
The time required for a moving object to travel the resultant path is less than the amount of time required to travel the vertical or horizontal components.	Students only recorded a single time interval for each scenario that applied to all components of motion.

Feedback on Ladybug toy activities

These activities were used in whole or in part with 268 students enrolled in 9 sections of Regents Physics. My three course sections, totaling 93 students, completed the activities in their entirety as described here. Two colleagues taught the remaining six sections of physics students. These 175 students used the materials and worked through several of the scenarios. Students in these sections, however, were not asked to collect data or complete worksheet questions. For most of these groups the activity was presented after approximately one week of instruction focused on vectors.

The feedback from both colleagues about the manipulative portion of the lab was positive. Students expressed that the opportunity to complete a range of scenarios, with variations in the direction of the components, helped them understand the meaning of the arrows in vector diagrams of tip-to-tail addition. The teachers stated that students benefited from observing the concurrent perpendicular motions of the ladybug toy and the paper. In their view, this visual established a model for the concept of independent horizontal and vertical components in projectile motion.

Several weeks after the completion of these activities, the nine aforementioned sections of physics in our high school were administered the *Common Assessment of Motion* which consisted of twenty questions taken from recent Regent Physics Exams that related to kinematics. Eight of the twenty questions related to terminology or skills which were reinforced through the ladybug toy activities. Each teacher completed an analysis of student responses for each of the twenty questions and the percentages of incorrect student responses were compiled for all three teachers. The results were used as a basis for comparison and discussion of teaching practice for the topics covered on the assessment. For six of the eight items response rates were noticeably better for students who completed the entire activity. For the remainder of the assessment, scores were within two to five percent for all groups. Appendix C shows the eight vector related items on the test and the percentage of incorrect responses for each group described here.

Conclusions:

The background literature on how students learn vectors and student level of understanding conclude that instructors at the college and high school level do not realize how much difficulty students have with learning vectors (Shafer and McDermott, 2005; Knight, 1995; Nguyen and Meltzer, 2002; Arons, 1997).

In the past, I taught vectors as lead in to either projectile motion or superposition of forces and used the force table as a reinforcing activity. I have developed a new appreciation for the level of difficulty students must experienced with the traditional use of the force table as an introduction to vectors. Force tables do not encourage students to consider the frame of reference or develop an understanding of vector characteristics.

The activities described here developed a referential base of shared experience for the class, reinforced the vocabulary necessary for class discussion and allowed students to discover the essential characteristics of vector quantities. These activities required students to work through the vector operations necessary for subsequent learning in Regents Physics. By focusing attention on vector vocabulary and operations to a unit on non-accelerated motion, students were able to learn vectors in context without being overwhelmed by the difficulty of the underlying content. While students did ask pertinent questions about the concepts of displacement and velocity, they were able to understand these ideas with minimal help and devoted most of their learning to understanding vector skills. Vectors are essential for learning physics, the activities described here are a good investment of time for building a physics student's toolkit.

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Never Fall™ Wind-up toy pricing retrieved from http://www.officeplayground.com/Wind-Up-Toys-C35.aspx September 2011.

Acknowledgements: This paper is submitted in partial fulfillment of the requirements necessary for PHY690: Masters Project at SUNY – Buffalo State College under the guidance of Dr. Dan MacIsaac.

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Appendix A:
Activity One - Student Worksheet: Ladybug Transit

Procedure: Trace the path of the wind-up toy as it moves around the board.

A. Assign directions on the board representing the directions of +x, -x, +y and -y

B. Fully wind the ladybug toy and place at a location near the center of the dry erase Cartesian grid.

C. Trace the motion with a dry erase marker. Use an arrow to indicate the direction of the ladybug toy. Each line is a vector. [Optional: Copy the motion of the toy onto a piece of graph paper indicating the original scale centimeters (i.e., 1 block equals)]

D. A trial with a minimum of four vector arrows is considered a successful path. Each label should be labeled with a capital letter to match the data table below.

E. Determine the horizontal and vertical component of each vector by counting Cartesian grid blocks. Using a different color marker draw in horizontal and vertical vectors with appropriate arrows to indicate direction. Record the length of these vectors in the data table below. Note the sign of each motion according to Cartesian grid set-up in Step A.

	Components		Resultant displacement (d)			
	Horizontal X (d_x) (Block Units)	**Vertical Y (d_y)** (Block units)	**Magnitude (block units)**	**Magnitude (centimeters)**	**Reference Angle**	**Angle (given Standard Position)**
A						
B						
C						
D						
E						
R	∑	∑				

F. Determine the total horizontal and vertical components by finding the sum of each column.

G. Draw a line from the start point to the end point of the ladybug motion with an arrow pointing toward the end point. This line is called the **resultant**.

H. Determine the horizontal (d_x) and vertical (d_y) components of the resultant displacement by counting on the blocks. d_x = d_y =

I. Complete the data table by determining the magnitude and direction of each vector in the ladybug toy's path from the values of the horizontal and vertical components.

The magnitude reported in block units must be converted to centimeters. Reference angles (ie, 0-90 degrees) must be converted to standard position (0-360 degrees) based on horizontal components.

J. Write each of the vectors A-E onto individual index cards using the magnitude in centimeters and angle in standard position. Mix up order of the cards and exchange with another group. On a piece of graph paper, reproduce the path of the other team's ladybug toy and find the resultant displacement. (NOTE: You will need to determine a scale for the graph paper.) When done check your answer with the other team.

What does this tell you about the order of vectors when adding values?

Conclusion (Complete in the space below): Compare the distance of the path traveled by the ladybug toy to the displacement of the ladybug toy. Explain the difference in process for finding each value. In your comparison, explain the terms vector and scalar in terms of the concepts of distance and displacement.

Appendix B:
Activity Two - Student Worksheet: Ladybug on a conveyor belt

Purpose: To investigate and represent the motion of an object experiencing two simultaneous (concurrent) velocities. Vector addition and vector resolution will be used to analyze the motion of a wind-up ladybug toy.

Materials:

Wind-up ladybug toy
3 Meter sticks
Dry erase grid (Cartesian grid)
Large dry erase board
Stop watch

Procedure:

A. Motion of the toy is due to wind-up device. Before all experiments the toy must be fully wound.
B. The paper moves along the horizontal x axis by pulling it at roughly constant speed
C. The relative motion of the objects is found by moving both the paper and the toy between stationary meter sticks

Prior to data collection, students should practice coordinating materials and establish a realistic division of labor. See your instructor if you need assistance with this step

Data and Calculations

1. Determine the average speed of the ladybug as it moves toward the right across a stationary Cartesian grid. (Take the average of 3 trials).

Toy Data		
Distance (cm)	Time (s)	Speed (cm/s)
	AVERAGE	

2. Determine the resultant velocity of the toy and the paper if both have a rightward velocity. Attempt to move the paper at a speed similar to the toy. Fill in measurements on the table below

Time of Interval (s)	Displacement of paper relative to meter stick (cm)	Displacement of ladybug relative to the grid (cm)	Displacement of the ladybug relative to the meter sticks (resultant) (cm)	Velocity of the paper (cm/s)	Velocity of the ladybug on the paper (cm/s)	Resultant velocity of the ladybug (cm/s)

a) Show work used to determine the velocity values for the chart above

b) Construct a vector diagram that shows how the **displacement** of the ladybug toy and the displacement of the paper add to the resultant displacement of the ladybug toy. (Label each vector with a magnitude including units. Does not have to be drawn to scale but should show relative size.)

c) Construct a vector diagram that shows how the **velocity** of the ladybug toy and the velocity of the paper add to the resultant velocity of the toy when measured against the stationary dry erase board and meter sticks. (Label each vector with a magnitude including units. Does not have to be drawn to scale but should show relative size.)

d) Since the paper and the ladybug are both moving in the same direction, how would we define the angle between their motions?

3. Move the paper to the left at a similar constant speed to that of the rightward moving Ladybug for several seconds. As a group record the following. Note the direction of motion with a positive or negative sign.

Time of experiment (s)	Displacement of paper relative to meter stick (cm)	Displacement of ladybug relative to the grid (cm)	Displacement of the ladybug relative to the meter sticks (resultant) (cm)	Velocity of the paper (cm/s)	Velocity of the ladybug on the paper (cm/s)	Resultant velocity of the ladybug (cm/s)

a) Construct a labeled **displacement** diagram

b) Construct a labeled **velocity** diagram

c) What is the **difference** in direction (angle) between the papers velocity and the ladybugs velocity?

4. Vector Rule: The maximum resultant occurs when the vectors are arranged at an angle of ___________ or similar direction. The minimum resultant occurs when the vectors are arranged at an angle of _____________ or opposite direction. How could you get a different resultant without changing the magnitude (size) of the component velocities?

5. With the toy starting at the bottom left corner of the paper and pointed upward, pull the paper to the right at a pace close to that of the toy. Let it run until the toy reaches a point at the top. On the dry erase board, draw a line that connects the start and end point (ie, the resultant displacement) Fill in data on the chart below

Time of experiment (s)	Horizontal Displacement of paper relative to meter stick (cm)	Vertical Displacement of ladybug relative to the grid (cm)	Displacement of the ladybug relative to the meter sticks (resultant) (cm)	Velocity of the paper (cm/s)	Velocity of the ladybug on the paper (cm/s)	Resultant velocity of the ladybug (cm/s)
			Magnitude: Angle:			Magnitude: Angle:

Construct displacement and velocity vector diagrams showing components and resultants.

6. Predict what would happen to the angle of motion if you pull the paper at twice the speed to the right while the ladybug moves upward. Roughly draw the vectors (Hint: think of the paper as the x vector and the toy as the y vector)

7. Complete the scenario presented in the previous question. (ie Ladybug upward and paper 2X velocity right)

Time of experiment (s)	Horizontal Displacement of paper relative to meter stick (cm)	Vertical Displacement of ladybug relative to the grid (cm)	Displacement of the ladybug relative to the meter sticks (resultant) (cm)	Velocity of the paper (cm/s)	Velocity of the ladybug on the paper (cm/s)	Resultant velocity of the ladybug (cm/s)
			Magnitude: Angle:			Magnitude: Angle:

a. Draw a labeled vector diagram of the resultant displacement and horizontal and vertical components.
b. Determine the resultant velocity (magnitude and direction). Show work

8. Predict what would happen to the angle of motion if the velocity of the paper were moving to the right at a velocity about half that of the ladybug. Draw the predicted vector diagram. Complete this scenario with the materials. Does the actual motion match the prediction?

9. Draw the observed resultant path (and components) for the ladybug moving upward and the paper moving to the left (use similar speeds for both the paper and the ladybug). Label the components with the appropriate sign (+ or -).

10. Draw the observed resultant path (and components) for the ladybug starting from the top of the paper and moving downward while the paper is moving rightward. (use similar speeds for the paper and the ladybug)

11. Draw the observed resultant path (and components) for the ladybug starting from the top of the paper and moving downward while the paper is moving leftward at about twice the speed of the ladybug.

12. a) Determine the horizontal component of the motion of the paper if the ladybug travelled with a resultant speed of 14.2 cm/s and a vertical speed of 8 cm/s. Show your work including units.

Hint: V= V_x = V_y =

b) What was the angle of the resultant for the previous problem if the ladybug was moving upward and the paper was moving left? (show work with equation and substitution)

c) What will be the resultant displacement of the ladybug after 4 seconds? Show work (include magnitude and directions)

13. When an object is launched at an angle, the initial or start velocity can be broken down into two components, velocity directed horizontally and velocity directed vertically. What is the launch velocity of an object with a horizontal component of 40 m/s and a vertical component of 30 m/s?

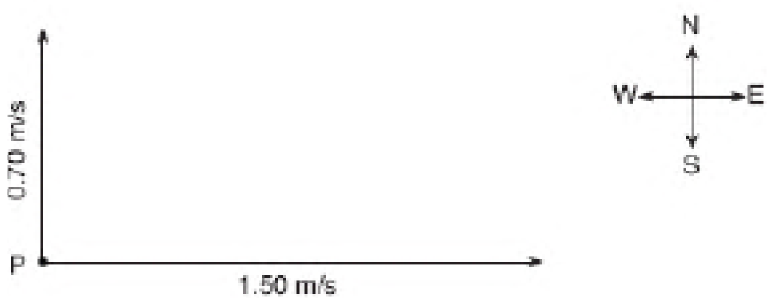
14. What are the initial horizontal and vertical components of an object's velocity if it is launched at 35 m/s at an angle of 60 degrees?

Conclusions: (to be completed on a separate paper and attached)

Explain how the addition of vector quantities is different from addition of scalar quantities. Differentiate between the terms speed and velocity. Explain why vectors are an important concept in motion and how they can be useful in other aspects of physics (Think about real life scenarios in which this applies). Summarize the methods of combining horizontal motion and vertical motion to determine a resultant and the methods for finding the horizontal and vertical components of a resultant vector. Explain how the angle between the vectors influences the magnitude of the resultant vector. Be sure to define terms used in your explanations.

APPENDIX C: Vector Problems that appeared on the *Common Assessment of Motion*

The following past Regents Physics Exam questions related to vectors appeared on an assessment given to 268 students enrolled in Regents Physics at our high school. They were part of a larger unit exam on motion. Each teacher administered the test and reported results of item analysis for the purpose of discussion within our Professional Learning Community.

	Students completin g entire activity	Students completing hands-on demo only
A model airplane heads due east at 1.50 meters per second, while the wind blows due north at 0.70 meter per second. The scaled diagram below represents these vector quantities.  		
June 2011, Item # 67 On the diagram *above*, use a protractor and a ruler to construct a vector to represent the resultant velocity of the airplane. Label the vector *R*. [1]	4%	13%
June 2011, Item #68 Determine the magnitude of the resultant velocity. [1]	0.8%	7 %
June 2011, Item #69 Determine the angle between north and the resultant velocity. [1]	8%	13%
June 2010, Item #2 A motorboat, which has a speed of 5.0 meters per second in still water, is headed east as it crosses a river flowing south at 3.3 meters per second. What is the magnitude of the boat's Resultant velocity with respect to the starting point? (1) 3.3 m/s (3) 6.0 m/s (2) 5.0 m/s (4) 8.3 m/s	6%	9%

June 2008, Item #1 The speedometer in a car does *not* measure the car's velocity because velocity is a (1) vector quantity and has a direction associated with it (2) vector quantity and does not have a direction associated with it (3) scalar quantity and has a direction associated with it (4) scalar quantity and does not have a direction associated with it	3%	5%
June 2008, Item #11 An airplane flies with a velocity of 750.kilometers per hour, 30.0° south of east. What is the magnitude of the eastward component of the plane's velocity? (1) 866 km/h (3) 433 km/h (2) 650. km/h (4) 375 km/h	4%	17%
June 2008, Item #62 A kicked soccer ball has an initial velocity of 25 meters per second at an angle of 40° above the horizontal, level ground. [Neglect friction.] Calculate the magnitude of the vertical component of the ball's initial velocity. [Show all work, including the equation and substitution with units. (Note: This question is analyzed only in terms of points lost due to incorrect application of vectors. Points lost due to missing equation or units were not included)	4%	15%
January 2008, Item #38 Two forces act concurrently on an object. Their resultant force has the largest magnitude when the angle between the forces is (1) 0° (3) 90° (2) 30° (4) 180°	7%	22%

Submission Guidelines

The Science Teachers Bulletin welcomes articles about science and science education. If you wish to submit an article for publication, please prepare the following:

1) Double-spaced manuscript (in Microsoft Word format) with figure, tables, photos or other images separated from the main body of the text. Permission for image/photo use may be required.

2) References (if used) at the end of the text using an appropriate reference format.

3) An autobiographical sketch including your background, email, telephone number and address.

For additional information or if you have any questions, please contact:

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The Science Teachers Bulletin is published twice a year (Fall and Spring). Submissions must be received no later than July 15 to be considered for the Fall issue and by January 15 for the Spring issue.

Submitted manuscripts should not have been previously published or under consideration for publication elsewhere.

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