ENGINEERING AND TECHNOLOGY AS A NEXUS TO INTEGRATE STEM COMPONENTS

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Abstract- The purpose of this paper is to propose a pedagogical model where engineering provides the interconnection to integrate the other topics of science, technology, engineering, and mathematics. The author(s) will first present a brief discussion of cognitive theory and then derive an integrated pedagogy to use engineering and technology, such as drones, sensors, camera, iPhone, radio waves as the nexus to an integrated curriculum development for the other topics of STEM. Based on this pedagogy, one example developed by the author(s) called "Drones and Environmental Science," will be presented that uses a drone and related technology as an appropriate instructional delivery medium to apply Piaget's cognitive theory to create environments that promote the integration of different STEM subjects that relate to environmental science.

IndexTerms- Cognitive Theories, Drone, Environmental Science, Pedagogy.

I. INTRODUCTION

The Next Generation Science Standards (NGSS) strives for integration of sciences, engineering, mathematics, and technology (STEM). The purpose of this paper is to propose a model for engineering and technology as a nexus to integrate the other topics of STEM.

NGSS emphasizes that students should learn the ideas of science through actually doing science and calls for full integration of science practices with other subjects such as math and engineering. NGSS has three dimensions:

1) Disciplinary core ideas in science.
2) Crosscutting concepts provide students access to connection of knowledge.
3) Scientific and engineering practices thatfocus on practices used by scientists and engineers.

II. DISCIPLINARY SCIENCES AND THE SIGNIFICANCE OF EARTH AND SPACE SCIENCES

NGSS clearly emphasizes that there is an urgency to train and make younger generations aware about the catastrophic consequences of human interactions with the environment. To deal with these catastrophic consequences, NGSS recommends an integrated approach to teaching earth science with other disciplines of STEM.

III. CROSSCUTTING CONCEPTS

The idea of crosscutting conceptscan be defined as a set of general themes cutting across science disciplines. Crosscutting concepts provide the opportunity to bridge, as well as,form a deeper understanding among the disciplines of STEM. In our proposed model, we will implement the crosscutting concept of "Cause and Effect" to connect earth science with other topics of STEM such as engineering and environmental science.

IV. SCIENTIFIC INQUIRY-TRAINING MODEL

The third concept from NGSS is similar to the phases of instruction for the scientific inquiry-training model that has been derived from cognitive development theoriesthat attempt to explain cognitive activities that naturally occur and contribute to the learners' intellectual development. Piaget argued that children and adolescents must continually reconstruct their own knowledge through a process of active reflection upon objects and events until they eventually achieve an adult perspective.

Piaget's explanation of cognitive theory is similar to recent findings of human brain neuroplasticity. In order to understand brain plasticity, we should have a working knowledge of Piaget'sconcepts schema, assimilation, accommodation, and equilibrium.

Schemata are intellectual structures, in terms of "neuron assemblies", that organize perceived events and group them according to common patterns. In reality schemata are collections of synaptic connections. During cognitive development, because of brain plasticity, children's synaptic connections are constantly restructured as they encounter new patterns in their learning. The internal mental mechanism or processes that are responsible for the restructuring of schemata are called assimilation and accommodation.

During assimilation and accommodation one of two things can happen: The learner can create either new schemata or modify the existing schemata. In either case the structure of schemata is being physically changed, due to brain plasticity, so that it can accommodate new information.

Piaget posited four major stages of cognitive development.The Formal Operation development applies to students who are going through the adolescent period.Formal reasoning is characterized

by abstract thinking by adolescents who have become capable to make hypothesis,test hypotheses, and generalize results to future occurrences. As they generalize,brain plasticity occurs to represent new synaptic connectionsof the acquired knowledge.

Based on Piaget's theory, a pedagogical modelscientific inquiry-training has emerged in the US.Table 1 compares the phases of the scientific inquiry-training processto NGSSScientific and Engineering Practices.

Table 1

Scientific Inquiry Model	NGSS
Ask question or pose a problem	Asking questions (for science) and defining problems (for engineering)
Students make *hypothesis*	Developing and using models
Studentsreview or make models Students gather, explore, analyze, and interpret data, Using mathematics to explain their finding of data Provide answers to the problem	Planning and carrying out investigations Analyzing and interpreting data Using mathematics, computer technology, and computational thinking Constructing explanations (for science) and designing solutions (for engineering)
In depth discussion of their solution	Engaging in argument from evidence
Report findings	Obtaining, evaluating, and communicating information

V. DRONES AND ENVIRONMENTAL SCIENCE

The authors of this paper collaborated to design an integrated scientific inquiry-training model for Environmental Science. Two aspects of the project played significant roles. First, we chose "Cause and Effect" as the crosscutting concept to bond together the science of flight dynamics, the significance of drought and its effect on the environment, andto use mathematics to calculate the effect of conservation. Second, engineering and technology wouldprovide a nexus toengage students in STEM topics such as flight science, environmental science, and earth science.

As seen in Table 1, there is similarity between the scientific inquiry-training model and NGSS Scientific and Engineering Practices. In order to study the effect of drought on the environment and learn about environmental science, the authors along with the students decided to use a drone to take pictures and video tape of Lake Anderson.

Following the NGSS Scientific and Engineering Practices, we designed ascientific inquiry-training model in three phases.

- Preparation Day
- Drones in Practice
- Data Analyses and Final Report

A. Preparation Day

The class began by Miss Gillani asking "How can we study the effect of the drought on Anderson Lake?" Students made several suggestions such as walking around the lake to take photos. Miss Gillani suggested that walking around the lake does not give the total picture of the dire state from which the lake is suffering. She suggested a drone as a medium to take video and photos of the environment from above the lake. Miss Gillani further informed the students that in order to use a real drone students had to learn what causes it to fly. First students were asked (to hypothesize) what makes an airplane fly? The answer students most provided was that the engine makes an airplane fly. ThenMiss Gillani started the lesson by presenting the following explanations and activities:

B. How Do Drones Fly

1. The main goal of a wing is to create a force that is equal to the weight of the aircraft but pointing in the opposite direction, so the thrust/push of the wing can lift the aircraft's weight. The shape of a wing is called an airfoil.

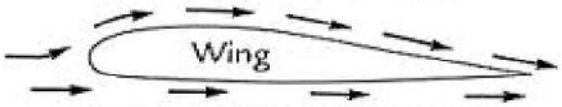


Figure 1

2. As a wing moves through air, the air is split and passes above and below the wing. The wing's upper surface is shaped so the air rushing over the top speeds up and stretches out. This decreasesthe air pressure above the wing. The air flowing below the wing moves in a straighter line, so its speed and air pressure remains the same. Since high air pressure always moves toward low air pressure, the air below the wing pushes upward toward the air above the wing. The wing is in the middle, and the whole wing is "lifted".The crosscutting concept of "Cause and Effect" is the hidden theme that will relate flying to the effect of drought.

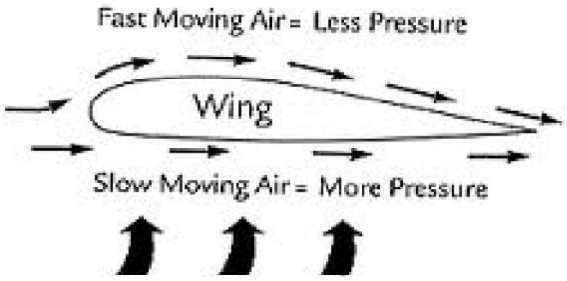


Figure 2

3. Pinwheels use the same principle as propellers. Students were given the opportunity to make their own pinwheel.



a) A propeller is a special kind of wing that spins. However, instead of pushing air behind a plane, the airfoil shaped blades pushes the flying object upward. All students were provided with several different kinds of propellers to make spin around as they blew on them.
b) Students were then given fly-wheel propellers to try. The enthusiasm in the class was lively, exciting when they saw fly-wheels fly.





The website“Brainpop” was used to furtherstudents’ understanding of the science of flying and to evaluate their understanding.
It was gratifying to see the enthusiasm and understanding the students had about the science of flying. Their answers to the questions on the testwere one-hundred percent correct.



4. Next the authors introduced the parts that make a drone.
5. The most exciting moment of the first session was when students were asked to make a model drone. The authors had purchased and had taken apart a toy drone. With the help of the authors, students put the toy drone together and took it outside to fly. The toy drone actually had a radio control that allowed it to fly. Here students learned about radio waves and how the radio control sends waves to control the toy drone. The Crosscutting Concept of “Cause and Effect” was the hidden theme to connect physics to the science of flying.



6. Next students were introduced to a real drone. Students followed the authors to the play-field in order tolearn how to fly a drone. First they watched the teacher fly the drone. Then, with the help from the authors, each student was asked to try to control the drone to travel up, down, right, and left.

C. Reflection

Back in the classroom,Miss Gillani explained how the first session will relate to the second sessionthat is about how engineering and the science of flying will be used to study the effect of drought on Anderson Lake by taking video and photos.

D. Drones in Practice

Lake Anderson has a capacity of 89,073 acre-feet of water. To gather and explore data on the effect of drought on Lake Anderson, the studentstook a field

trip to Lake Anderson to fly the drone above the lake. Students took turns to take pictures of the lake and the sedimentation of the lake level in different years.



Below is a sample of photos and video we took of Lake Anderson.



E. Reflection

Miss Gillani reviewed and explained the purpose of the field trip. She also added that the following week students will be comparing and contrasting photos and video of Lake Anderson between the data gathered on the field trip and photos of the lake in previous years.

F. Report Findings

Following the phases of instruction as seen in Table I, students compared and contrasted, and discussed their photos with the photos of the previous years. Students collaborated to answer the questions and solve the mathematical problems and made a poster from their discussion.

- Compare the photos from previous years to the photos we took at Lake Anderson and describe the differences.
- What is a drought?
- How has the drought affected Anderson Lake and its environment?
- Lake Anderson at its fullest capacity holds 89,073 acre-feet. Currently it holds only fifty percent of its full capacity. Calculate how many acre-feet Anderson Lake holds today.
- One acre-foot equals to 325,851 gallons. Can you calculate how many gallons of water are in Lake Anderson in the fall of 2014?
- Calculate how many more gallons Lake Anderson needs to be at its full capacity.
- Can you think of any tips you can give about how to conserve water?
- What do you think of the teaching method used for the “Drone Class”?
- Did you like the activities used for understanding the science of flying?
- Did you like the activities used for understanding Environmental Science? Why or why not.
- Did you like observing the drone fly over the lake? Why or why not.
- Did you like flying a drone to learn sciences? Why or why not.

Students created a poster that answered most of the questions. We also used Google forms to evaluate the outcome.
https://docs.google.com/a/csueastbay.edu/spreadsheets/d/1NGgcbNwR-PmBquNU758nsY92DcRRy_as3TjWtX2kegE/edit#gid=592247803

CONCLUSION

NGSS emphasizes crosscutting concepts, disciplinary core ideas, and scientific and engineering practices. To support adoption and implementation, states are now moving toward NGSS goals. The most difficult part of NGSS is appropriate implementation that includes all recommendations and sound pedagogy for an integrated STEM that actually works. The novelty of the implementation of NGSS in this paper is where engineering and technology is central to provide the interconnections to integrate other topics of STEM. This paper adopted and implemented what NGSS hopes curriculum developers will develop. The astonishing outcome of this project was students’ comments about pedagogy. All comments were similar to: “I believe that the teaching method for the "drone class" was really fun and exciting because I loved the learning part and hands-on methods of learning.”

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