2006-1158: ESSENTIAL ELEMENT EXAMPLES OF ELEMENTARY ENGINEERING IN ELEMENTARY EDUCATION

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Essential Element Examples of Elementary Engineering in Elementary Education

Abstract

Developing an engineering curriculum at any level has similar requirements but different challenges. Douglas L. Jamerson, Jr. Elementary School in Pinellas County, Florida is a new school that has a Magnet Schools Assistance Program grant (MSAP) to design, create, and implement a curriculum that matches Jamerson's mission to be an engineering attractor school. For Jamerson, this attractor is not simply providing an overview of engineering or a quick trip through engineering careers and/or disciplines with occasional stops on the way to work on a project that have some element of engineering associated with it. For example, being a member of a team that can drop an egg the furthest distance without breaking the egg. Although these types of activities are valuable, they are not the essence of an engineering curriculum, nor are such activities necessary to have a good engineering curriculum.

This presentation highlights how Jamerson is integrating essential but elementary engineering and engineering science elements across its required State driven curriculum responsibilities. The energy concept and the corresponding conservation laws are presented with specific grade level examples to illustrate intra and inter grade level integration. The presentation will also illustrate how the science driven mandatory State testing on force and motion is used as scaffolding.

Upon first glance at this presentation, it might be tempting to conclude that there is very little content in the paper, primarily a flow of ideas about relating children's literature to engineering concepts and/or that the ideas presented are well-known. However, the challenge addressed is not how to teach state-of-the-art engineering to elementary school children. Nor is it to provided occasional or periodic instruction on engineering marvels and/or engineering career possibilities. Rather, the presentation outlines a method to integrate an entire public school state mandated elementary curriculum at all grade levels using engineering science principles and engineering design practices appropriate for each grade level and spirally connecting these principles and practices upward through all grade levels in the school.

Introduction

Douglas L. Jamerson, Jr. Elementary School opened two and a half years ago with a daunting challenge. Create a learning institution in a predominantly ethnically isolated inner city area that would naturally integrate the ethnicity of the student population within the school without the aid of a district assigned plan for student placement. To facilitate this challenge, the Pinellas School District provided three key resources. First, a brand new state of the art school complex was provided to create the school around a mathematics and engineering theme. Second, Jamerson was permitted to apply for and subsequently received a 1.5 million dollar Magnet School Assistance Program grant (MSAP). Third, Jamerson was given a wide range of latitude in hiring the staff as well as deviate from district hiring policies and conduct a national search for its teaching staff. One of the requirements of all teachers at Jamerson is that they attain the high standards encompassed in the National Board Certification process and attain this certification within determined period of time.

The combination of these three elements has resulted in a dynamic learning community. Students are mastering standards in all subject areas above their current grade and at the same time utilize engineering concepts and principles to foster their thinking and extend the application of key grade level science and mathematics concepts. Proactive partnerships with the University of South Florida's College of Engineering, IBM Corporation, and a local engineering consultant firm as well as a vibrant parent organization have rounded out our environment. An environment that is on the verge of transforming the way we think about student engagement, expectations for learning, and the currently debated achievement gap between groups of students.

Curriculum Challenge

The requirements for an engineering curriculum within an elementary school environment are not dictated by the engineering demands but by the public demands that the curriculum meet all the educational expectations and requirements of the school. The role of an elementary education is not to produce "miniature" engineers. The role of that education is to produce students that can read, write and do arithmetic at the highest possible skill levels. In addition, these students must begin to develop deductive and inductive reasoning skills. They must learn to analyze, synthesize and evaluate data. Students must also learn social interactions to ultimately prepare themselves to become productive citizens. The challenge for Jamerson's elementary engineering focused curriculum is to use engineering and engineering science elements to facilitate accomplishing the school's primary mission as structured by the benchmarks in Florida's Sunshine State Standards.

Using the Sunshine State Standards as a foundational platform, Jamerson is building an integrated curriculum using engineering as the primary tool to connect the different required subjects taught in every elementary school. Since all engineering is multidiscipline in nature, it provides a wonderful vehicle to integrated different subjects. Although Jamerson's engineering focused curriculum uses science, mathematics, economics, social science, history, language, and communication to get a project completed, it has an additional value to the school. Working within the engineering design process not only allows teachers to focus on the subject matter knowledge and skills but also on the development of a platform to foster the higher lever skills of synthesizing, analyzing, and comparing data.

In this regard, using an engineering platform challenges teachers to do what they do best. This includes developing meaningful lessons and activities that challenge the students to learn and understand the principles and concepts under study. The current climate in many K-12 school districts across the country finds teachers constrained by imposed pacing guides, driven by standardized tests, governed by a series of ongoing assessment/progress reporting requirements, and saddled with a variety of mandatory supplementary learning programs. This situation leaves teachers little time to focus on delivering enriching lessons and related innovating activities simply because there just is not enough time in a typical school day to do it all. An engineering platform permits subject integration which, in turn, frees up classroom time, provides meaningful context to the particular knowledge and skills being focused on, and sustains a very nurturing environment for developing higher level thinking skills.

One important bonus for the teacher in this environment is their own professional growth and development. Learning to think like an engineer thinks, questioning how, and, more importantly, why things are made the way they are, understanding that all science and technology is driven by a desire to meet human needs and desires, can expand their own understanding of and comfort with how the world "works". This deeper understanding of engineering as an integrating theme can provide a very enriching context for all classroom learning without the "hardcore" mathematics always associated with the foundation of all engineering.

Vertical Curriculum Integration with Engineering

At Douglas L. Jamerson, Jr. Elementary School, scaffolding for the engineering based vertically integrated curriculum is built with the school's science directives, i.e., following the State and District science topic requirements and Florida's Sunshine State Standards. Periodic Florida Department of Education screening and influence on various publisher submissions for adoption within Florida dictates the characteristics of the state mandated assessment tool. Periodic district wide science text adoptions from this list strongly influence local school presentation of those topics. Jamerson's buffer to these external pressures is to catalog its science curriculum within 4 overarching topic areas: the nature of science; physical science; earth sciences; and life sciences. These four areas are subdivided into to seven presentation units that facilitate the development and execution of the engineering themes. Gravitational force and the resultant motion represent one of the presentation units within the physical science topic area and it will be used as the example vertical integration and scaffolding element.

Vertical integration is fostered by using similar vocabulary introduced at an appropriate grade level and building. Because many engineering activities and design projects involve manipulation of energy and the conservation laws, these two concepts are introduced early and continually developed during the six years students are at Jamerson. Additionally, energy manipulation and the application of conservation laws provide vehicles to quantify the science taught in elementary school. Providing opportunities to measure and record data and results of activities then provides the raw materials to support meaningful higher level learning skills including analyzing, synthesizing and predicting as a culminating activity for the same lesson. It also provides the opening for discussions about how mankind has used the science topic to make our lives easier historically and in the present.

All lessons and activities at Jamerson are built around the design process of Plan, Design, Check, and Share. This process provides an integrating theme as well as providing a vehicle for developing good problem solving skills and high level thinking throughout the school day. Implementation of the Jamerson Design Process also builds with increasing grade level. All teachers are encouraged to use the process by setting learning activities in the context of at least one of these steps and explaining how the other steps follow or would be done. Thus, the Jamerson Design Process also provides a platform for introducing context to learning and the idea that learning is also an engineering activity.

The engineering themes associated with gravitational force that are developed at Jamerson are bounded by grade level skills and knowledge base. Since primary grade level students are just developing math skills including a sense of numbers, engineering activities have to be somewhat qualitative. However, this level of student can appreciate the concept of work and make displacement measurements generated by measured forces on known masses. Intermediate grade level students can expand those activities to include time measurements so that engineering design activities can use work and power as design criteria. Fifth grade students expand this manipulation of force field and force magnitudes to include vector calculations associated with their bridge project.

As suggested above, the business of elementary education is the development of student math and reading skills. The quantitative understanding of gravitational force and subsequent engineering activities addresses math expectations however, using the related engineering and engineering science in support of reading requirements at an appropriate grade level is also an important segment of Jamerson's engineering curriculum. Kindergarten students are introduced to gravitation force via nursery rhymes and folktales. For example, "Three Little Pigs" is a readaloud story that is not only a vehicle to develop language arts and math skills, but a way to have the kids think about and discuss the various structures and the properties of materials used to create them with respect to the force (push) they have to withstand. "Humpty Dumpty" is read to develop other language skills but is also used as a segway for engineering activities that introduce the word gravity as the force that impacted Humpty's life and also influences all living things. Force measurements are limited to "non-standard" units that can only develop weak, strong, and stronger characterizations of forces.

Reading activities are also used in first grade as a convenient way to make the force (push and pull) connection to work. Several books are used as dictated by grade level comprehension expectations. In addition to reading skills, the tall tale "John Henry" is used to develop student appreciation of health and diet requirements to develop strong bodies with energy (caloric) to do work that (in John Henry's case) exceeds the work done by a steam driven machine. Students also work with force magnitude (as measured in Newtons) and predict direction as a prelude to the introduction of vectors in later grades. Second grade marks the beginning of secured addition and some subtractions skills. This also triggers the addition of forces acting in the same direction and engineering design activities that use material costs as a design constraint.

Jamerson's third graders are ready to begin observing, measuring, recording real forces on objects and determining the work done in moving an object a given distance. Using the characteristics of simple machines, the third graders build this unit to culminate in the calculation of mechanical advantage of one machine (inclined planes) over another. They also use Legos in a design challenge to build a simple machine. The third grade stresses the use of Newtons as a unit of force and Newton-cm as a unit of energy. They introduce the term "load" for a force and introduce the vector as a mathematical tool that is used to help engineers and scientists work with forces in different directions.

The fourth and fifth grades at Jamerson really take off into unknown areas for elementary schools children. The fourth graders reinforce the same calculation of energy (work) that is facilitated in the third grade using an exploration of vehicles and what affects their movements. They introduce the concept of different kinds of loads. They learn about force diagrams and free body diagrams as tools to help visualize and quantify "forces" acting on a body. Equilibrium of forces is introduced as the "resting" position and that motion is the application of unequal forces. Rudiments of force isolation into vertical and horizontal components are also introduced. Students now do their own data organization, multiplication, graphing of data and results, and draw conclusions. A vehicle design challenge concludes the unit.

Bridges are the focus of the gravitational unit in the fifth grade at Jamerson. The quantified work and energy concepts introduced in earlier grades are reinforced with added depth and application. Vocabulary expands to include different types of load (live loads, dead loads) on structures, including several types of bridges. They also learn to characterize the forces as tension or compression in various structural members of bridges. These new terms are reinforced in force diagrams and free body diagrams of their bridges. Fifth graders culminate their gravitational unit with a design project in which they have to design, build, and test the most efficient and cost effective bridge to support a given load.

Results

Douglas L. Jamerson, Jr. Elementary School opened its doors as a fully operational elementary school with at least three classes at each grade level. As Jamerson entered its third year, it has begun to see data trends that are both positive and significant. The 2003-2004 baseline academic data placed Jamerson well below District and State averages in both reading and mathematics in all three tested grades. In addition, Jamerson failed to make Adequately Yearly Progress (AYP) under No Child Left Behind (NCLB) in all measured sub groups.

By contrast, 2004-2005 data with basically the same student population painted a different picture. During this second year, Jamerson students attained assessment scores in reading and mathematics above District and State averages and the school also attained AYP status in every category of NCLB. This dramatic transformation produced a cascade of positive reinforcing results. Student behavior data for the school has also mirrored the achievement data and has made Jamerson one of the safest schools in the District which, in turn, allows our children to be engaged in high quality learning activities to a higher degree than in most other elementary schools. The number of families that have selected Douglas L. Jamerson, Jr. Elementary School for their children's education has risen from practically zero on 2003 to a waiting list for incoming kindergartners this past fall.

Conclusions

This paper presented an overview of an integrated engineering curriculum for elementary school. The paper outlined one (Gravitational Force and Resultant Motion) of the seven presentation units within that curriculum. The general premise of the project outlined in this presentation is the belief that any elementary education curriculum can benefit from an engineering influence. The hypothesis of the project is that the integration of engineering science and engineering design within an entire elementary school curriculum can be done and will lead to dramatic measurable results. Douglas L. Jamerson, Jr. Elementary School student data at this point supports this hypothesis. However, the authors do realize that the data is only suggesting a trend that should be reinforced as the first generation of students (the first kindergarten class) continues through each grade level.

The question generated by this project relates to the project's impact on educators. The impact on the educators at Jamerson has been enormous. The project is producing an environment that is transforming the way these teachers think about student engagement, expectations for learning, and student performance. The instructional paradigm shift at Jamerson is shifting the standardized test score profile of the school, drawing positive public attention to the school's MSAP mission and generating additional school district interest and resources for support of K-12 engineering education.

The project's impact on the engineering educator remains to be seen. If the impression of one of the reviewers for this paper;

> "…, primarily a flow of ideas about relating children's literature to engineering concepts. In most cases, the ideas presented are trivial and well-known..."

is an indicator, then the project is of little value or interest to engineering educators looking at ways to expand the impact of engineering education in the K-12 environment. To be fair, this paper is admittedly short on extended detail but it does outline the progression of simple steps for an elementary curriculum to repeat ideas over and over again to achieve the desired results. One of those results is the ability of the fifth grade students at Jamerson to calculate appropriate scalars and vectors for use in their bridge "design, build, and test to failure" project. Although that accomplishment is not trivial and/or well known, it was only accomplished by integrating teaching components repeatedly into the entire curriculum that may be viewed by some engineering educators as being either or both.

Finally, the authors realize that with respect to education outreach, there are many levels of proactive interaction available to engineering educators. All of these options have a constructive influence on the students impacted. However, this project should present the possibility, if not a demonstration, that engineering can be completely immersed into an elementary school to facilitate the primary mission of an elementary education. It may also emphasize that a successful interaction with an elementary school can happen when you, the engineering educator, include an adjusted quantitative engineering message in their world. The reward of this approach is that the elementary school teachers will then eagerly want to work with you to adjust their "reading, writing, and arithmetic" message to your world.