When asked “What do you think of when someone mentions models?” the usual response involves model cars and airplanes or fashion models. I seldom find that responders recall the models used in classrooms from their days in school. But, students at La Marque Middle School have come to appreciate the construction and use of models in understanding the concepts and processes surrounding the motion of the earth and moon in their science classes.

As the SRT-STEM Center Co-Director for Education Outreach and Instruction at the University of Texas Medical Branch (UTMB), my role is to work with teachers and administrators in the implementation and integration of strategies for enabling student success in the areas of Science, Technology, Engineering and Mathematics (STEM). The Southeast Regional Texas STEM Center (SRT-STEM) is a program sponsored by the UTMB Office of Education Outreach under the auspices of Dr. Clifford W. Houston, Associate Vice President for Educational Outreach. The Office of Educational Outreach provides professional development activities for teachers and a series of interconnecting pipeline programs for students. These student programs provide a variety of hands-on and career exploration experiences that enhance science education and facilitate the development of a future Science, Technology, Engineering, and Math (STEM) career-related workforce.

Some of the strategies advocated by the SRT-STEM Center include Project-Based-Learning and the Engineering Design Process. By using these highly engaging strategies for classroom instruction, students more easily understand the processes and content of these fields. Students who show little interest in math, science, and engineering find that they are having fun learning complex concepts and are often able to better explain what they know when these STEM strategies are used. In a recent article in *The Science Teacher*, Daniel Meyer (Meyer, 2012) states that, “Simply asking students to create something, however, isn’t necessarily a meaningful design challenge. Rather, a meaningful inquiry experience is defined not just by the ultimate goal but also from the context that both constrains and drives solutions.” When students engage in the processes employed by career engineers, “they do so within a system of constraints, making their proposals nontrivial.” When student attempt to solve real world problems they become engaged and interested. They ask better questions. They want to know more – they want to learn. Students retain what they learn and score better on tests over the contents. Ultimately, they come to realize that careers in STEM fields are not out of their reach if they are persistent and continue to be interested in learning more.

I had the pleasure of working with the eighth grade students in Mrs. Melanie Burnett’s classes at La Marque Middle School using Project Based Learning and integrating the Engineering Design Process into their learning. Their current unit of study is in Earth Systems in which they explained the processes that cause the phases of the moon, the seasons of the Earth, as well as tides as required by the Texas Essential Knowledge and Skills (TEKS) for 8th grade Science. TEKS 8.3c requires student to use and describe the limitations of models and TEKS 8.7a states that students will investigate the cyclical movements of the Sun, Earth, and Moon. (Texas Education Code, 2009) Based on the findings of my
doctoral research into Inquiry Learning (Dickson-Talley, 2002) and the findings of the National Research Councils’ study published as *How Students Learn Science* (Donovan & Bransford, 2005), the use of models and the design process have been shown to be highly effective in students initially knowing how these systems work and in “dispelling misconceptions they may have about the Sun’s closer proximity to Earth in the summer than the winter” causing warmer temperatures in the summer in North America.” (Keeley, Eberle, & Dorsey, 2008).

Students began their study of rotation and revolution with the construction of spinning tops. The challenge was outlined in the PBL entry document. As described in the *Project Based Learning Handbook* (Markham, Larmer, & Ravitz, 2003) an entry document provides details, constraints, and the problem which students are being invited to solve. In this PBL, the entry document was in the form of a letter from a fictitious company called “Our Tops are Tops!” seeking a model of a top that could spin for 20 seconds and cost no more than $70 in materials. It needed to appeal to children between the ages of 10 and 14. In addition to the creation of a spinning top, the team also needed to plan a marketing campaign strategy designed in a manner as to gain a market share of toys for their age group. After dividing into design teams, and assigning roles, students began previewing the materials available and drawing two possible prototypes. After discussing the limitations and benefits of each for their model, they were given a budget and told they could “purchase” any item available from the supply store. Items such as pencils for spindles were $10 each and paper plates of many sizes and material were from $20 to $30 each. Additional materials such as pennies for weights, paper clips for stability, marking pens for designs, masking tape, and rubber bands provided options that could enhance the performance of their tops but also added to their bottom line.

Students worked in their design teams diligently for 30 minutes, Mrs. Burnett and I were available as consultants; never directly answering questions, but asking questions about their rationale for selection of materials as well as sharing the principles of momentum, inertia, center of gravity, balance and rotation as a way to move the student along in their understanding of how the spinning top works as a system and how to improve their models.

The following day, students gave oral presentations featuring their models and their marketing campaign, which included an explanation of why their top was able to sustain a spin as well as the benefits of the added modifications. The contract was awarded to multiple teams, in each period. Those who came in under budget, met the specifications of the Entry Document, and were able to clearly explain the processes of the system were provided actual tops and similar toys that used rotation or revolution for their movement. In each class, through the design experience, model building, and presentations, students demonstrated that they were able to express their understanding of rotation and revolution in a way that showed a depth of knowledge - not just the memorization of facts and definitions.

As part of the reflection about the Tops Design Experience, students completed two rubrics. One rubric was to evaluate the quality of their product and the other to self-evaluate their collaboration in their team effort. When asked for feedback about the activity, students shared the following comments: “This was fun.” “I can see how to improve our top by adding more pennies for momentum like their group did.” “I’ll bet ours would spin longer if we would have lowered the base for a lower center of gravity.” “Our top spun like the Earth on its axis.”
The follow-up lesson, for the remainder of the week, included a second Engineering Design Experience which began with an entry document from a Museum Concession/Gift Shop Manager. He was requesting prototypes for kits to be sold in their Museum Store that would be of interest to middle school age students for their upcoming Moon and Space Exploration Exhibit. They were given a budget, size constraints, as well as a description of the concepts they needed the models to demonstrate. Among the concepts were: moon phases, seasons of the year, tides, and day and night. The marketing campaign was required to not only have two prototypes, as well as a clear explanation of concept the model was depicting as well as an explanation of the Space System of which it was a component. The information would be included in the kit as well as shared during the marketing presentation. Students were provided a budget, a list of materials, as well as a time frame of two days to develop their model/kit and marketing campaign.

Using what they already knew about the Engineering Design Process, students eagerly began to check out the available materials, divide up team responsibilities and check other resources such as the Internet and their textbooks for information about the system they selected. Students relied on their knowledge of the concepts of rotation and revolution, balance and center of gravity, as well as what made a good marketing campaign in planning for their new task. Again Mrs. Burnett and I were available as consultants. We asked formative assessment questions to determine the depth of student knowledge about their concept and trying to uncover any preconceptions or misconceptions they may have had. We infused the appropriate level of vocabulary with each of our visits to the teams.

The materials available included balls of many sizes and materials such as whiffle balls, foam balls, golf balls, tennis balls, Ping-Pong balls and spindles such as: pencils, bamboo skewers and dowels. Other items such as: scissors, flash lights, modeling clay, markers, and rolls of masking tape were also available at a cost to their budgets. As teams were tackling design problems, they were able to return selected materials for some better suited to their prototype without taking away from their limited budgets. This gave students freedom to experiment with different materials to determine the best one for their concept design and budget.

As students were preparing for their presentations the next day, Mrs. Burnett and I asked student questions similar to those they would be asked by the Museum Contractor, such as budget expenditures, questions about their selected models, as well as how this related to their daily lives, and why would a middle school student want to purchase their kit. As students rehearsed their presentations, they became more confident in their knowledge and began to feel at ease about the next day’s task.

The presentations were attended by campus administration, guests from the UTMB program, as well as other teachers. Questions from the audience were answered with honesty and depth of understanding that showed conceptual learning on the part of the students. The product names and logos used were very creative and showed a sense of humor which delighted many of the guests.

As students were reflecting on their work of the past week i.e. the Tops Project and the Museum Project, they were asked again to complete the same two rubrics for the quality of their product and their collaboration in their group. Evaluation of the student rubrics reflected similar evaluations by Mrs. Burnett. She felt that it would not be a difficult task to be able to assign grades to the work completed for the week.
Although each group of student worked on their own space system model, through the design teams’ presentations and explanations of the models created, all students were equally knowledgeable and prepared for the content-based objective assessment, which will be given at the close of the Earth/Space System Unit. In this unit, both content and process were assessed and evaluated. As a bonus for Mrs. Burnett, high levels of student authentic engagement decreased the number of behavior redirections that were sometimes required for several of her students.

As evident from the descriptions above, Project Based Learning has many benefits which increase levels of student achievement. Hands-on learning, student directed inquiry and research, designing and building models for development of concepts, as well as student-generated scientific discourse are all strategies that lead to high levels of engagement. As highlighted in *Project-Based Learning* (Capraro & Slough, 2009), when actively engaged in PBL, "No matter whether schools have low achieving students or high achieving students, a high percentage of students find working with real-world projects to be exciting, engaging, fun, satisfying, and meaningful." When students are actively engaged in their learning and are asking questions about what they want to know – a rich learning environment is created.

When compared to this same unit taught in a traditional approach (a lecture enhanced with a PowerPoint presentation, a teacher demonstration using a model, students recording notes, the teacher asking comprehension questions, assigning vocabulary to be defined, student completion of an assignment – either a worksheet or questions and problems from the book, and finally taking a quiz or test over the material to show mastery), STEM-based instructional strategies may be a needed alternative. As many teachers are seeking increased student achievement, increased student motivation to learn, and decreased student apathy towards preparation for future careers in Science, Technology, Engineering, and Mathematics, the integration of these STEM strategies may make the difference. These differences ultimately may manifest themselves as: (1) significant changes in academic achievement that teachers are seeking and (2) in more students choosing a STEM career pathway that strengthens our future economy.

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**Works Cited**


