AC 2008-179: DEVELOPMENT OF A MATH INFUSION MODEL FOR MIDDLE SCHOOL ENGINEERING/TECHNOLOGY EDUCATION

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Development of a Math Infusion Model for Middle School Engineering/Technology Education

Abstract

Engineering design projects can provide a rich opportunity to enhance middle school student knowledge in core disciplinary subject areas, such as mathematics and science and forms an important aspect of the NSF supported Mathematics, Science, Technology Education Partnership (MSTP) project. A key goal of the project has been to develop a model for infusing mathematics into science and technology at the middle school level. The informed design process was created as part of a NSF materials development program and formed the engineering design framework for this study. Structured mathematics activities (knowledge and skill builders - KSBs) were developed that linked to the design challenge. As a result of these hands-on activities, students apply the mathematical reasoning developed in order to solve an engineering problem; the design of a bedroom. A unique professional development model was created to facilitate cross-disciplinary support and communication during the development and piloting of math infused technology and science lesson plans. A pilot research study, involved implementation of a math infused bedroom design lesson. A paired t-test indicated the difference was statistically significant $t(128) = 2.828$, $p<.005$, providing evidence that students were showing gains on their math content knowledge.

Introduction

In recent years, there has been a growing recognition of the educational value of design activities in which students create external artifacts that they share and discuss with others[1,2,3]. A synthesis of the literature reveals that pedagogically solid design projects involve authentic, hands-on tasks; use familiar and easy-to-work materials; possess clearly defined outcomes that allow for multiple solutions; promote student-centered, collaborative work and higher order thinking; allow for multiple design iterations to improve the product; and have clear links to a limited number of science and engineering concepts[4]. The design process begins with broad ideas and concepts and continues in the direction of ever-increasing detail, resulting in an acceptable solution[5]. Research shows that hands-on activities supported by meaningful discussion and theory building helps students construct meaning.[6] When children are encouraged to create artifacts, such as in design[7], they reflect and student understanding is enhanced.

Studies of the use of design-based activities in mathematics have shown that students who are not high achievers in traditional mathematics, were very successful when using design[8]. However, in middle school mathematics classroom settings, the types of problems presented often do not require the type of open-ended exploration for solutions.

Although challenging for students and teachers, introduction of design into mathematics would provide teachers with less defined problems that require more student exploration. As Jacobs argues, “No matter what the content, we can design active linkages between fields of knowledge. An interdisciplinary approach to learning may be seen as a curriculum approach that consciously applies methodology and language for more than one discipline to examine a central theme, problem or experience"[9]. While many educators discuss the integration of subjects across disciplines, the standards based movement forces teachers to remain more discipline focused.

Yet, we believe that technology education in particular should connect to core math and science learning objectives. The complexity of the topics that are addressed by technology education indicate that students need to understand and apply math and science concepts. This may require a higher level of understanding than is provided in the mathematics and/or science instruction, which is often done in a procedural manner. Bloom's taxonomy[10] indicates that traditional instruction often focuses on the knowledge level, this is consistent with Wiggins and McTigue's[11] search for enduring understandings, which underpins this work which focuses on ability at the application/analysis level, hence the challenge for instruction and professional development.

The design strategy used in this study was to infuse mathematics into engineering technology education based on the informed design cycle[12]. This design process is congruent with Wiggins and McTigue's Understanding by Design[13]. Informed design is an iterative process that allows, even encourages, users to revisit earlier assumptions and findings as they proceed. A critical element of the informed process occurs during the differentiating the Research and Investigation phase. The use of Knowledge and Skill Builders (KSBs) provides students with opportunities to engage in structured research and practice related to key ideas that underpin the design solution. The KSBs are short, focused activities designed to help students identify the variables that affect the performance of the design. In a pilot study by Akins and Burghardt[14] using informed design found significant improvement was found in students' mathematical competencies for the mathematics topics that were linked to the design challenge. In their study, the mathematics related to area, perimeter, percentage and linear and non-linear functions.

Developing the Mathematics Infusion Model

The Math Science Technology Education Partnership[15] (MSTP) is a five-year, $12M NSF Mathematics and Science Partnership project (MSP) that is targeted to improve mathematics instruction and student learning in middle school mathematics, science, and technology education classes. The thesis of the project is simple: with more instructional time devoted to mathematics, and with mathematics taught with current pedagogical practice, student learning should improve. As part of the MSTP project, we researched student performance data and found that percent, measurement, area, and perimeter were concepts students did not demonstrate understanding of on standardized examinations. In part the difficulty arose from instruction frequently occurring at too low a level. For instance, in asking math teachers how they taught percents, most gave formulaic answers that failed to teach depth of understanding. When discussing area, the approach was the memorization of an equation with a mnemonic. It became clear that students needed more opportunities to experience, apply and work with mathematics in different settings. Infusing mathematics into science and technology would provide more time on task, but in order to assure students would have exposure to more than formulaic mathematics, professional development would be essential.

The Project's mathematics infusion model is designed to increase the amount of time students spend on mathematics in science and engineering technology education (ETE) classes.

Supporting the model is a unique professional development approach that provides for peer collaboration of science, technology, engineering and mathematics (STEM) teachers, with a particularly strong focus on math infusion into science and technology. There are three essential elements of the STEM professional development: (1), guided lesson plan design, implementation, feedback and revision; (2), academic year implementation; (3), peer review and learning communities. Teachers examine their own practice, participate in professional development related to mathematics content and pedagogical enhancements, and then engage in development or math infused curriculum. These lessons are then used in their classrooms and later revised. The innovative "A/B" mathematics infusion workshop model, as it has been called, provides science and technology teachers with an opportunity to work with the mathematics teachers and university faculty in a structured way, as they design, implement, review and revise math infused science and technology lessons. Teachers meet twice (A workshop and B workshop) and between the workshops they implement a math infused lesson.

During the A workshop, teachers used a curriculum template to guide development of math infused lessons. They were encouraged to building upon existing lessons, thereby "infusing" math and enhancing the "inquiry based pedagogy." Feedback and assistance was provided by other middle school science, math, and technology teachers from their district as well as a university faculty member of the team. The lessons that were written during the A workshops were typically designed to last between 2 and 3 days. The lessons template helped to guide teachers to build more explicit and inquiry-based mathematics into the existing technology and science curriculum In addition to writing lessons, teachers developed pre and post student assessments during the A workshop, along with a scoring rubric to assess student learning of lesson objectives. During the next two weeks, teachers implemented the lessons with at least one of their classes during the regular school day. After teaching the lessons, teachers reconvened for the B workshop, during which time the collaborative learning group of teachers examined samples of student work, discussed pedagogical issues, and revised their lessons based on their own experiences and input from their colleagues.

Guided lesson plan design

The Appendix shows a model lesson plan template for development of math infused science or engineering/technology lessons. The focus of the lesson plan is on the teaching process. Preceding the teaching process is a checklist of assessment methods that will be used. However, the use is not gratuitous, and must be indicated. The primary focus of the lesson plan is on embedded assessment of student learning in science and technology education and mathematics. The lesson plan format also invites handouts, questions and rubrics to be used for assessment.

Development of the template included expert reviews of the format, field testing, revision, and re-testing. There are several features to the template that are worth noting. Asking teachers to reflect upon the background knowledge required to complete the lessons and the overall complexity of the lesson content was included to help direct teachers to consider what additional support activities were needed. By having teachers articulate what concepts are difficult for students to grasp, they were better prepared to develop extension tasks to reinforce these concepts. Teachers were also asked to focus on one or two major math and science content topics, along with the related process and performance standards. This was intended to help teachers focus on important topics. Because the MSTP project focuses on mathematics, the template was designed to help teachers explicitly find math related work that would enhance the lesson, not just be a mathematical add-on without a direct connection to the content of the science or technology. An important consideration in the design of the lesson plan was that science and technology teachers would be responsible for teaching (or reinforcing) mathematics concepts. This was not a non-trivial consideration and one that required support of the math teachers in terms of math content and pedagogy. Even when the template was used, the lessons that were developed were often very broad without sufficient depth and focus, reinforcing the reason for learning community support in lesson plan development.

Academic Year Implementation

The second element of STEM professional development is to have academic year implementation. This occurred during the A and B workshops. The math infusion "AB" workshop model was designed to gives teachers greater investment in what they plan and how they instruct, since the instruction occurs the next day or the next week, rather than months in the future. The lessons focus on a unit that can be implemented in a short period of time, not a long comprehensive unit. By clearly identifying specific learning objectives and assessments, teachers learn to look for detail and to engage in on-going reflection. As this talent becomes more engrained, teachers are able to provide the same level of attention to a sequence of lessons (a unit). However, attention to detail is important; as with an artist, each brush stroke must have a purpose.

Peer Review and Learning Communities

The final element of the program is to use peer review and learning communities. The MSTP project held a two-day training workshop for its leadership team conducted by Dr. Giselle Martin-Kneip, a nationally recognized assessment expert. The focus was on peer review and professional learning communities. While teachers often found it very difficult (as colleagues) to support and critique one another in a professional manner; this process was found to be essential for the development of exemplary lesson plans. Teachers gradually developed a level of detail in their lessons that was sufficient clear to allow for review by their peers and that was pedagogically optimal. Similarly, through this collaborative process, teachers learned to effectively present and review student work, using information gleaned through embedded assessment as formative feedback and to gain insights into what students do or do not understand. Based on peer feedback and analysis of student work, the lesson plans are revised , providing teachers with additional opportunities to reflect upon their lessons.

We worked with over 300 middle school teachers from 10 low performing districts and 20 Higher education faculty. For six months during 2006-2007 STEM teachers met for a total of six A/B workshop sessions. Survey data were collected from teachers and Higher Education faculty before and after each set of A/B workshops. Their lessons were examined before and after revision.

Teacher Perceptions about the AB workshops

When teachers were asked what they liked and disliked about the A/B workshop process, the majority stated they enjoyed and benefited from the collaboration with other teachers. Common responses mentioned the unique opportunities that the workshops provided for teachers to discuss lesson development with peers, as well as facilitate lesson development, implementation and revision. Teachers appeared to appreciate and value the opportunity for collaboration and review. Some quotes about different workshops include:

> "The A workshop was very informative. The B workshop was helpful regarding the development of my lesson and possible pre-post revisions."

> "It was very helpful to discuss and plan a lesson with colleagues; and I believe the result was successful"

> "I like the ideas I received from my colleagues about my lesson. I feel my students are benefiting from incorporating math in all subject areas."

Although the majority of teachers' comments were positive, a few had negative responses about the workshops. These teachers indicated that the A/B process was rushed, they desired additional opportunities to work with teachers from other disciplines, and they disliked the paperwork involved.

Across all months and districts, the preponderance of participants, over 95% of all teachers found the workshop to be very useful or useful and only 1.3% of teachers (for a total of 5 teachers, each from different districts) stated the workshops were not at all useful. These are highly impressive response rates, considering the number of teachers involved in the project over time (over 150) and the amount of engagement and work required from teachers who participated in the A/B professional development model.

What is equally impressive, as Table 1 indicates, is that teachers were generally satisfied in the lesson development process of the A/B workshops. Over 82% of teachers indicated they were successful, or very successful in writing lessons that helped students develop a deeper understanding of the content. With over 93% noting that they were successful or very successful in collaborating with teachers in order to write lessons during the workshop. Teachers also strongly supported writing lessons based on the work during the A/B workshops, indicating the workshops were an important facilitator of the lesson writing process.

Table 1. Teacher ratings of lesson plan development based on last B survey results.

	Not at all Successful (1)	(2)	Moderately Successful (3)	(4)	Very Successful (5)
Writing lessons based upon work at A/B workshops? (n=106)		1.9% (2)	18.9% (20)	49.1% (52)	30.2% (32)
Collaborating with teachers in order to write lessons? (n=105)	1% (1)	1% (1)	4.8% (5)	31.4% (33)	61.9% (65)
Writing lessons that help students develop a deeper understanding of math? (n=106)			17.9% (19)	50% (53)	32.1% (34)

To add to this, teachers felt that the template was an integral part of the math infusion process. Across all workshops, 92.5% teachers stated 'yes', they were able to use the MSTP lesson template to create a successful lesson that included enhanced math and/or that infused math into science or technology. One teacher explained, "The form [template] allowed for the thought process in how to infuse the math concepts into science and technology." Another teacher noted, "Yes, explaining the steps we took to create the lesson helped us to break down the topics and see connections in science and math."

Peer Collaboration and Review

Teachers were asked to indicate if collaboration helped in lesson topic choice and in planning appropriate pedagogy. Most teachers noted that they enjoyed the feedback they received, not only from teachers in their own disciplines, but from teachers in other disciplines as well. One teacher responded "The collaboration gave more insight into ideas for lesson and constructive criticism for review to create better lessons".

Teachers were also asked if they spent enough time working with teachers from their discipline, as well as teachers from other disciplines. Approximately 85% of teachers believed they spent enough time working with teachers from their own discipline and 65% of teachers believed they spent enough time working with teachers from other disciplines. Most noted that collaboration with other disciplines was positive. One teacher noted that, "Time was spent with teachers from other disciplines and grade levels during general discussions. This was helpful to identify similar challenges and concerns with implementation and approaches". The majority of comments were similar, indicating that collaboration with colleagues from within their own and other disciplines was quite beneficial in identifying similar challenges, implementation approaches, content concerns and pedagogical aspects.

Enhanced Math and Math Infusion into Lessons

About 80-90% of teachers in most districts stated that they were able to use the MSTP lesson template to create a successful lesson that infused math into Science/Technology. One teacher explained, "The form [template] stimulated thought processes in how to infuse the math concepts into science and technology." Teachers were more able to enhance or infuse math into lessons as workshops progressed throughout the year. This indicated that teachers were more capable of creating math-enhanced or math-infused lessons as participation in the A/B cycle progressed. Typical comments from technology teachers were:

> "The template was very helpful in streamlining my technology lesson. The template got me to look not only on the technology standards, but also the math and science standards."

> "Yes, explaining the steps we took to create the lesson helped us to break down the topics and see connections in science and math."

Student Understanding

Teachers reported that over 90% of students developed a deeper understanding of the topics covered in the lessons. Several teachers based their responses upon students improved performance on the post test for the taught unit. One teacher noted that, "Through my post test observations, I was able to immediately see student understanding and how their understanding grew from before to after the lesson." Other teachers explained that students developed deeper understanding from making real life connections or applications that were included in their lesson.

Lesson Revision

Teachers were allotted time during each B workshop to revise their lesson based upon student work, their own reflections, and the comments they received from their peers. About 84% of teachers indicated that they used the assessment data that they collected to revise their lesson, student activities, and/or assessment tools. One teacher explained, "Results of student work drove my decision to rewrite pre/post assessments and lab packets." Another teacher elaborated on the idea and noted, "Revisions were made based on student work, self evaluation of lesson procedures and time." The majority of teachers explained that looking at student work was helpful in deciphering what the students did not understand, and on which areas they needed to spend additional instructional time. Those that did not report that they used student work to make revisions typically indicated that they used other methods to do so. A teacher noted that, "I revised my lesson based on insights from the other teachers and on my own reflections".

Usefulness of Lesson and Workshops.

Overall, the preponderance of participants (approximately 90%) indicated that they would use the lessons they created during the A/B workshops in their classrooms again. Additionally, the leadership team members conducting the workshop were asked to indicate if teachers had "bought in" to the A/B process and the MSTP project. Across all districts, responses consistently indicated that teachers were enthusiastic about MSTP and engaged in the A/B workshop process.

Furthermore, leadership teams explained that teachers had enjoyed their participation in the process, and the benefits were seen in their lessons and during the school day. For example, one district's members noted "Yes, we have full participation. Teachers are working together in a collegial way to design math infused lessons". Another district's members indicated, "Yes, again it is evident in the conversations the teachers have throughout the school day regarding pedagogy, content, lessons and assessment. Collegial sharing is common place at the middle school among STEM teachers. This is directly related to the A/B workshops". Through these responses, it is evident that teachers had not only enjoyed the A/B process, but also felt as if they benefited from the workshops as well.

Based on teacher perceptions of improved student mathematical understanding and prior research supporting this approach, the project decided to lengthen the extent of math infusion over a longer time period to four continuous weeks. This required that there be training and lesson plan development during the summer prior to the 2007-08 academic year. Based on the quality and interest of science and math teachers during the A/B workshops, six science teachers and three technology education teachers were recruited to participate in the program.

Summer 2007

Three technology teachers worked for one week in July 2007 with engineering and mathematics specialists to refine a five-week design challenge called *Bedroom Design*. In this challenge students need to design a scale model of a bedroom with a budget of $15,000. There are specifications and constraints—the window area must be at least 20% of the floor area, the minimum room size is 120 square feet, the minimum closet size is 8 square feet and the minimum height of all walls is 8 feet. The room must have two outside and two inside walls and the basic cost of construction is estimated at $75 per square foot of floor area.

The KSBs related to mathematics had been developed by the authors to reflect NCTM pedagogical guidelines with consultation from mathematics consultants. In addition, the teachers decided to use Google Sketch-Up so students could first create a virtual design, as well as a traditional 3-dimensional scale version. Students also created scaled versions of the furniture and furnishings in the bedroom.

The mathematics in this unit related to ratio and proportion, percent, area and perimeter. A consultant was hired with expertise in middle school STEM to develop the pre/post mathematics assessment using questions from the New York State mathematics assessments. These included multiple choice and extended response questions, consistent with the state's assessment practice. The assessment was developed after the summer workshop so the consultant could align the questions with the lesson plans.

Fall 2007

In the early fall of the 2007, the technology teachers met with project staff and went over the pre/post assessment questions to gather teacher input before the assessment was finalized. There were several other assessment tools the project used: weekly teacher reflections while the unit was being instructed; student work; and at the end, student reflections along with the post assessment. A comparison teacher also gathered pre/post assessment data regarding student performance.

The technology teachers identified 12 math questions that had originally appeared on prior state eighth grade math and grade tests which they believed were "relevant" given the content of their math infused lessons. These 12 items included seven multiple choice questions (scored as correct or incorrect) and five long answer questions that were scored using a four point rubric (scored from 0, no knowledge of the concept to 3 full knowledge of the concept). The assessment was administered before and after students participated in the math infused technology lesson. Although the same questions were asked during both administrations, the order of the items was randomly changed. Two doctoral students scored of the open-ended questions. The assessments were completed by 144 students

An alpha reliability coefficient was calculated as a general indicator of the degree to which students consistently responded to the questions. The .692 alpha reliability coefficient provided some confidence that the test items were measuring the same constructs. (This coefficient was calculated based on the post-scores, assuming the knowledge is most consistent after students have received the training.)

A summed score was then created by adding student responses to each of the 12 questions. Theoretically, responses could range from 0 (all items were incorrect or received the lowest rating on the rubric) to 22 (a correct or "1" to the seven multiple choice questions and "3" to the five long answer questions.) However, examination of the data showed that scores on both the pre and post administrations ranged two to 17, in part because students rarely scored a three on any open ended question. Additionally, an item analysis of the multiple choice questions showed that the questions were generally easy for students both before and after participation in the lessons.

A paired t-test was performed to determine if students demonstrated greater mastery of the material following the math infused lessons. Pre-post data were available for 129 of the 144 students. (Several students did not complete both the pre and post assessment and therefore their data could not be included in the statistical analyses.) The summed mean test score on the pre-test was 9.108 (standard deviation of 3.30) and on the post-test 9.652 (standard deviation of 3.14). Although these means are very similar, a paired t-test indicated the difference was statistically significant $t(128) = 2.828$, $p<.005$, providing evidence that students were showing gains on their math content knowledge.

Despite the small mean differences, the results were encouraging for several reasons. Based on teacher feedback and examination of the data, it appears that the assessment items were not optimal. Many students found the multiple choice items, even on the pre-assessment, were easy to answer correctly. This suggests the math content may not have been challenging enough to truly test the model, because there was limited room to indicate growth. The open ended questions were clearly more difficult for all students (few students ever scored a "3.") However based on feedback from teachers and scorers of the assessments there may be a need for more refined categories which could differentiate between smaller incremental learning. Furthermore, the length of the intervention, that is the number of days devoted to math, were at most 20 days, and, in reality most likely fewer.

In debriefing with the teachers following the implementation, they reported the experience was very valuable. They would definitely implement the unit again, in part because they were so well prepared. The students could implement the informed design process; the teachers were comfortable with the process and had been using it earlier in their classes. The students did complain initially about the amount of mathematics they had to use because this was not supposed to be a math class. The teachers reported the students were able to use Sketch-Up with very little difficulty, it took about two class periods for instruction and then they could create rooms, furniture and furnishings using the software.

They also reported their belief that new teachers to the process would greatly benefit from the AB professional development model. The experience of developing standards based instruction, particularly examining the mathematics standards was very important. Similarly, the opportunity to work with math teachers in the collegial learning groups of the AB workshop was important to learning effective mathematics pedagogy. All three of the technology teachers had been educated as engineers, so they had a strong math content background, but their math pedagogical background was not strong, hence the workshops and the summer experience provided value for them when developing the lesson plans.

All reported that infusing mathematics is time consuming; the unit took several days longer than anticipated. The reason for this was that students did not remember the mathematics, so the teachers had to expand on the KSBs and provide additional instruction and guidance. The teachers reported that they sought out assistance from math teacher colleagues in this regard.

Conclusions

The results of the various assessments are being further analyzed and the results will be disseminated. To date, all qualitative and quantitative measures indicate that math infusion in technology education classes is effective and students gain an improved mathematics understanding. Teacher professional development in support of the mathematics infusion is important and developing professional relationships with mathematics teacher colleagues is similarly important.

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Teacher(s):			Date:
Subject: Science/Technology	**Grade(s):**	**Time to complete (in periods):**	
Unit:	**Lesson Topic/Title:**		
Student population: ☐ Special Education ☐ LEP ☐ LD ☐ G&T ☐ Academically Average ☐ Low achieving			

OBJECTIVES of the lesson:
[State the SPECIFIC goals of this lesson. What will students know or be able to do by the completion of the lesson? Start each statement with "Students will understand…" or "Students will be able to…".]

BACKGROUND KNOWLEDGE necessary for students before engaging in this lesson:

PRECONCEPTIONS that may need to be addressed:

List 1 or 2 of the overarching NEW YORK STATE SCIENCE/TECHNOLOGY STANDARDS to be addressed in this lesson:	Write out CODES and PERFORMANCE INDICATORS of RELATED SCIENCE/TECHNOLOGY PROCESSES addressed in this lesson:

List 1 or 2 of the overarching NEW YORK STATE MATHEMATICS STANDARDS to be addressed in this lesson:	Write out CODES and PERFORMANCE INDICATORS of RELATED MATHEMATICAL PROCESSES addressed in this lesson:

How do the Mathematical understandings listed above INFORM Science/Technology knowledge?

ASSESSMENT Methodologies [Embedded and Summative] planned to demonstrate the degree to which students have mastered the NYS Processes and Performance Indicators indicated above. *Attach COMPLETE EXAMPLES of all methods checked below*
☐ Classroom observation ☐ Whole class discussion (*indicate guiding questions and sample student responses*) ☐ Small group discussions (*indicate guiding questions and sample student responses*) ☐ Individual student interviews (*indicate interview questions and student responses*) ☐ Performance assessments (*indicate type and scoring method; explain development and use of rubrics*) ☐ Journals/Portfolios (*indicate scoring method; explain development and use of rubrics; provide an example of a finished journal or portfolio*) ☐ Homework Assignment (*explain assignment and scoring method*) ☐ In-class worksheet/written assignment (*explain assignment and/or provide example of student w*ork) ☐ Individual or group presentations (*indicate criteria required; describe student presentations*) ☐ Quiz/Test/Exam (*indicate scoring method; provide an example*) ☐ Others (*describe*)

How does this lesson represent BEST PEDAGOGICAL PRACTICE? (Please check 2-3 best practices that you will focus on while teaching this lesson.)	
□ Focuses on important (standards-based) ideas & skills and promotes conceptual understanding □ Includes key questions to elicit responses that reflect understanding of important content □ Promotes procedural fluency □ Addresses naïve conceptions □ Builds on prior student knowledge □ Aligns curriculum, instruction, and assessment □ Prompts discourse among students and with teacher □ Encourages guided discovery, inquiry, and design □ Promotes group work and team work	□ Establishes cross-disciplinary connections □ Establishes real-world connections for students so that they generalize lesson concepts to MST applications □ Prompts higher order thinking (students analyze, compare and contrast, classify…) □ Prompts students to generate alternative ideas and strategies □ Adjusts instructional methods according to student population and understanding □ Procedure includes summary that focuses on key ideas □ Motivates learning during and beyond the lesson

MATERIALS Needed:

INSTRUCTIONAL PLANNING: PROVIDE A <u>COMPLETE SEQUENCE</u> OF ALL TEACHING PROCESSESS AND STUDENT ACTIVITIES FOR IMPLEMENTING THE LESSON. **This should include ALL teacher explanations, examples, questions, and student activities associated with the delivery of the lesson. Nothing should be left to the imagination. *Other teachers should be able to reproduce this exact lesson using this lesson plan.* Indicate (with an asterisk) where embedded assessments will occur during the implementation of the lesson. Indicate instructional alternatives that may be employed for differentiating instruction for students with special needs.** ****BE SPECIFIC ABOUT HOW MATHEMATICAL CONCEPTS ARE INFUSED INTO THIS SCIENCE/TECHNOLOGY LESSON****

AFTER LESSON IMPLEMENTATION **-**

REFLECTIONS: Tell the story of what happened in the classroom. Indicate what worked, what you would change for the next implementation, and students' reactions to the lesson.

*** Attach to this lesson template: any and all WORKSHEETS and HANDOUTS, examples of ALL indicated ASSESSMENTS, and SAMPLE STUDENT WORK.***