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Drafting a Blueprint for Educating Tomorrow's Engineers Today

Beth McGinnis-Cavanaugh
Springfield Technical Community College

Glenn Ellis
Smith College, gellis@smith.edu

Diana Fiumefreddo
Smith College

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AC 2010-1579: DRAFTING A BLUEPRINT FOR EDUCATING TOMORROW'S ENGINEERS TODAY

Beth McGinnis-Cavanaugh, Springfield Technical Community College

Glenn Ellis, Smith College

Diana Fiumefreddo, Smith College

Drafting a Blueprint for Educating Tomorrow's Engineers Today

Introduction

With the establishment of a STEM middle school and other initiatives, the Springfield, Massachusetts Public School System (SPS) has made a commitment to excellence in Technology/Engineering instruction for all of its 5700 students. To support this commitment, a partnership between the Springfield Middle Schools, Springfield Technical Community College (STCC), and Smith College has been funded through an NSF MSP-Start Partnership Grant. "Drafting a Blueprint for Teaching Tomorrow's Engineers Today" is a partnership program designed to foster deep and meaningful learning of engineering concepts among SPS Middle School Technology and Engineering teachers, as well as collaboratively enhance active learning that is designed to support deep learning and improved student success.

"Tomorrow's Engineers" has three ultimate goals:

- To increase awareness about engineering in approximately 5700 middle school (grades 6-8) students in the Springfield Public Schools,
- To improve the knowledge base of about 240 future and in-service middle school science teachers so that they will have the skills, materials, and enthusiasm to excite their students about engineering, and
- To create a fluid and dynamic engineering education pipeline where each level informs the preceding level about the skill base needed to ensure success

The overall objective of the grant is to enable teachers to reach and inspire students typically outside of the engineering "pipeline". Fundamental to the project is supporting teacher professional development that is based upon research from the learning sciences. In particular, the research shows that effective instruction requires teachers to have both a deep understanding of the subject area and an understanding of how students develop their understanding.[1] Recognizing the need for a sustained and multi-faceted commitment, our approach to teacher education includes professional development workshops, a meaningful and useful online learning community, and a variety of strategies for directly supporting teachers in the classroom. This paper focuses on our first teacher workshop.

Needs Assessment and Workshop Planning

In late 2008/early 2009, discussions between PIs Beth McGinnis-Cavanaugh (STCC) and Glenn Ellis, Ph.D. (Smith College), the SPS Science Education Officer and Instructional Resource Teachers in Technology and Engineering regarding improved middle school student performance in STEM indicated the need for professional development and collaborative support for teachers in required technology/engineering strands set forth in the Massachusetts Science and Technology/Engineering Curriculum Framework (MA Framework)[2]. The results of a formal needs assessment administered to SPS Middle School Technology/Engineering teachers in early 2009 also indicated the teachers' need and desire for such professional development. The needs assessment was administered to twenty-eight SPS Technology/Engineering teachers in early

2009 (see Appendix A). Each of the seven Technology/Engineering strands was addressed separately.

Nineteen teachers responded. Findings indicated that the teachers did not believe they had very strong content knowledge in the Technology/Engineering strands in general and would find professional development in any of the seven curriculum strands to be very beneficial. Of particular interest was the Construction Technologies strand (Fig. 3). SPS stated in preliminary meetings that this strand was typically emphasized on the Massachusetts Comprehensive Assessment System (MCAS). With respect to this strand, almost 37% of responding teachers strongly agreed that they had strong content knowledge in this area – by far the strongest strand in that regard – yet 0% felt that their students had sufficient knowledge in this area upon completion of middle school. Only 21% felt comfortable teaching this topic and approximately 58% felt that professional development is this area was worthwhile.

The levels of content knowledge and confidence varied greatly among the seven curriculum strands, but almost all were typically lower than those for Construction Technologies. One indicator, however, was virtually constant across the board: the students' level of knowledge upon completion of middle school fared poorly in all strands. Based on these results, McGinnis-Cavanaugh and Ellis were concerned that, while teachers indicated greater confidence in their level of knowledge in Construction Technologies as opposed to other strands, this strength stemmed from their familiarity with "kit" type projects, such as popsicle or toothpick bridges, activities designed to neither foster deep learning of fundamental engineering concepts nor to engage all students. Therefore, one goal of the workshop was to learn the teacher's true level of knowledge in this strand. In other words, it became necessary to learn what teacher confidence in a subject area or strand really meant.

The inaugural professional development workshop was designed as an eight-day, forty-hour program at Smith College in Northampton, MA and took place on July 13-16 and July 20-23, 2009. Sixteen teachers enrolled in the course; this number exceeded the target of fifteen participants, and was 57% of the possible twenty-eight teachers eligible. Teachers received a stipend of $1000 for their full participation, which included a December 2009 follow-up session as well as their participation in evaluation and data collection activities and potential follow-up classroom visits and interviews.

To allow time for in-depth learning, it was agreed that the workshop focus would be narrow in terms of content. Well-suited to the civil engineering background of PIs McGinnis-Cavanaugh and Ellis and in response to SPS' concern about the importance of this content in terms of testing, the workshop focused on the Construction Technologies strand (Fig. 3). In addition, content in highly compatible strands 1 and 2 of the MA Framework was also included – Materials, Tools, and Machines (Fig. 1) and Engineering Design (Fig. 2) – and easily integrated.

1. Materials, Tools, and Machines *Central Concept*: Appropriate materials, tools, and machines enable us to solve problems, invent, and construct.	
1.1 Given a design task, identify appropriate materials (e.g., wood, paper, plastic, aggregates, ceramics, metals, solvents, adhesives) based on specific properties and characteristics (e.g., strength, hardness, and flexibility). **1.2 Identify and explain appropriate measuring tools, hand tools, and power tools used to hold, lift, carry, fasten, and separate, and explain their safe and proper use.** **1.3 Identify and explain the safe and proper use of measuring tools, hand tools, and machines (e.g., band saw, drill press, sander, hammer, screwdriver, pliers, tape measure, screws, nails, and other mechanical fasteners) needed to construct a prototype of an engineering design.**	• Conduct tests for strength, hardness, and flexibility of various materials (e.g., wood, paper, plastic, ceramics, metals). (1.1) • Design and build a catapult that will toss a marshmallow. (1.1, 1.2, 1.3) • Use a variety of hand tools and machines to change materials into new forms through the external processes of forming, separating, and combining, and through processes that cause internal change(s) to occur. (1.2)

Figure 1. Learning Standard #1, MA Framework.[2]

2. Engineering Design *Central Concept*: Engineering design is an iterative process that involves modeling and optimizing to develop technological solutions to problems within given constraints.	
2.1 Identify and explain the steps of the engineering design process, i.e., identify the need or problem, research the problem, develop possible solutions, select the best possible solution(s), construct a prototype, test and evaluate, communicate the solution(s), and redesign. **2.2 Demonstrate methods of representing solutions to a design problem, e.g., sketches, orthographic projections, multiview drawings.** **2.3 Describe and explain the purpose of a given prototype.** **2.4 Identify appropriate materials, tools, and machines needed to construct a prototype of a given engineering design.** **2.5 Explain how such design features as size, shape, weight, function, and cost limitations would affect the construction of a given prototype.** **2.6 Identify the five elements of a universal systems model: goal, inputs, processes, outputs, and feedback.**	• Given a prototype, design a test to evaluate whether it meets the design specifications. (2.1) • Using test results, modify the prototype to optimize the solution (i.e., bring the design closer to meeting the design constraints). (2.1) • Communicate the results of an engineering design through a coherent written, oral, or visual presentation. (2.1) • Develop plans, including drawings with measurements and details of construction, and construct a model of the solution to a problem, exhibiting a degree of craftsmanship. (2.2)

Figure 2. Learning Standard #2, MA Framework.[2]

5. Construction Technologies *Central Concept*: Construction technology involves building structures in order to contain, shelter, manufacture, transport, communicate, and provide recreation.	
5.1 Describe and explain parts of a structure, e.g., foundation, flooring, decking, wall, roofing systems. **5.2 Identify and describe three major types of bridges (e.g., arch, beam, and suspension) and their appropriate uses (e.g., site, span, resources, and load).** **5.3 Explain how the forces of tension, compression, torsion, bending, and shear affect the performance of bridges.** **5.4 Describe and explain the effects of loads and structural shapes on bridges.**	Design and construct a bridge following specified design criteria (e.g., size, materials used). Test the design for durability and structural stability. (5.3)

Figure 3. Learning Standard #5, MA Framework.[2]

The Workshop

The workshop began with an "appreciative inquiry" to identify the essence of teachers' strengths and needs as well as to nurture a community of learners. Recognizing the importance of context in both effective engineering and in the learning process, teachers learned about the fundamentals of engineering mechanics through hands-on activities that they could use in their own classrooms and within a variety of contexts that included the design process, an ethics case study, and the history and aesthetics of bridge design. Fundamental principles from the learning sciences and the research on educating under-represented minorities were also discussed and modeled throughout the workshop. Examples include the use of conceptual frameworks and narratives for making engineering concepts relevant to grade 6-8 students in an urban, diverse, and challenged community. Teachers applied what they learned during the workshop by developing and sharing curricula for their own classrooms.

The workshop was designed as a learner-centered program to promote deep and meaningful learning within the chosen Technology/Engineering curriculum strands with the following significant core beliefs as a foundation:

- SPS teachers are experts in their classrooms
- The experiences and challenges of SPS teachers are valuable and important and must be validated and appreciated
- Workshop instructors have expertise in the subject matter, but do not have knowledge of the challenges of an SPS middle school classroom
- The workshop was a collaboration, not a top-down teaching experience
- Learning how teachers learn and teach is a critical step in understanding the teaching of the Technology/Engineering content in the classroom

- The establishment of a useful learning community is critical to the success of any ongoing effort in this project, and that learning community must be "born" at the workshop
- Educational theory on how to promote deep and meaningful learning—such as the use of narrative to engage the imagination or concept maps to help students frame their learning—were as important to the success of the workshop and the overall objectives of the program as the engineering content

To support the goals of the workshop, the following learning objectives for the workshop were developed:

- Achievement of a deeper understanding of the mechanics of how the forces of loads, tension, compression, torsion, bending, and shear affect the performance of different structural shapes
  - Specifically, sections 5.3 and 5.4 of the MA Framework and the application of sections 5.1 and 5.2 (refer to Fig. 3)[2]
- Ability to apply the deeper understanding of mechanics to describe and explain parts of a structure
- Integration of educational theory with student engagement and deeper understanding using tools such as concept maps and narrative
- Discussion and analysis of gender issues in engineering
- Unification of the community of educators in a useful network of sharing and support
- Development of the connection between engineering and the Liberal Arts

In addition to content dealing with fundamental mechanics concepts, the workshop explored topics such as innovation in engineering design, educational theory for deep and meaningful learning in STEM, and sustainability. A variety of topics and situations were introduced to bring issues in engineering ethics and engineering in the liberal arts to the forefront and to provide feedback in terms of current beliefs and opinions of teachers. Issues involving gender and race and their role in student engagement were also a focus.

The sixteen teacher cohort met for five hours per day, four days per week. All teachers attended all days except for two absences for prior personal commitments. Each day began promptly at 8:00 AM and the teachers were engaged until 1:00 PM, even through a "working" lunch. PIs McGinnis-Cavanaugh and Ellis were the lead instructors and shared duties accordingly. A Smith engineering student, Diana Fiumefreddo, provided clerical and at-large services as needed, and was present throughout, even leading a lab exercise during one activity. Active learning centered upon group hands-on activities and was accompanied by lectures and multimedia presentations.

Day 1 – Appreciative Inquiry and Concept Mapping

The learning outcomes for Day 1 consisted of an appreciative inquiry and consideration of the structural and material properties of a plank bridge, including a group analysis of how factors such as loading, material, and geometry fit together.

Activities:

- The workshop began with an appreciative inquiry (AI). AI can be described as a search "from a strengths perspective for latent, untapped capacity to pursue shared images of a preferred future". Thus, it "discovers, builds, and expands capacity to cooperate".[4] For the workshop, AI was used as a method of identifying positive and important themes in transformative learning for teachers. This exercise was used to kick off the workshop for several reasons. First, the exercise was positive, energetic, and synergistic, and set the desired tone for the workshop. Second, the exercise identified ways or experiences in which the teachers themselves have experienced transformative learning. Identification of the situations in which the teachers learn most effectively potentially assisted the Partnership in (1) tailoring the workshop to enhance the learning experience, (2) planning future workshops, (3) identifying ways in which learning is effective, (4) establishing a community of learners at the outset of the workshop, and (5) gleaning insight into the teaching methods of the teachers in their own classrooms. Dr. Linda Meccouri, STCC Professor of Informational Technology, facilitated the process.
- Pre-assessment containing open-ended essay questions were administered.
- Teachers discussed a styrofoam plank "bridge" to determine the structural and material properties that affected its safety. Free responses were categorized and the cohort was asked to determine if and how the categories were related. This activity demonstrated for the students that they possessed considerable knowledge of the mechanical behavior of materials, while also showing that they needed to learn more about how to quantify the effects of each variable and how the many variables they listed were related to each other. After completing this exercise, the class was introduced to a mechanics of materials concept map[3] that included many of the variables that they listed.

Figure 4. Dr. Glenn Ellis of Smith College leads a discussion about the structural strength and stability of a beam bridge. A lesson in concept mapping followed.

Day 2 – Basic Engineering Concepts

The learning outcomes for Day 2 were the introduction of the engineering concepts of load, stress, and strain, as well as a presentation and discussion of the future of engineering and the engagement of all learners in STEM.

Activities:

- An interactive lecture on the concepts of load, stress and strain was conducted
- The future of engineering was discussed using a National Academy of Engineering presentation as a reference. An example of the creative engineering design process was presented using an IDEO video.
- The lunch discussion centered upon key concepts for engaging all learners.

Day 3 – Tension and Compression Testing

The learning objectives for Day 3 included the introduction of an ASCE "Designing and Building a File Folder Bridge"[5] project learning exercise and a discussion regarding engineering failure and ethics.

Activities:

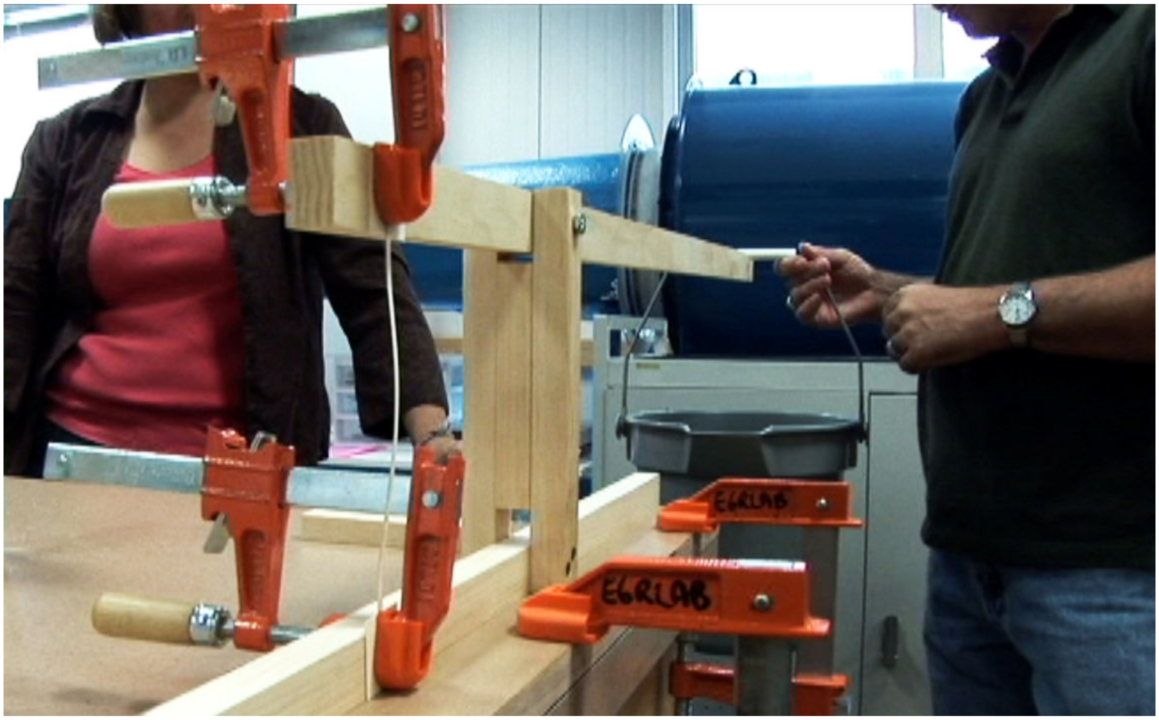
- This exercise involved the tension and compression testing of tensile coupons and columns made by the teachers out of file folders. The tests were conducted using a testing machine constructed for and in accordance with the activity instructions. This activity was selected for contribution to deep learning of basic mechanics concepts, its suitability for classroom use, especially in terms of overall cost and use and availability of resources.
- Students played the role of investigators and jurors in a case study of the 1981 Hyatt Regency walkway collapse. Students considered both mechanics concepts and engineering professional ethics as they investigated the causes of the failure and discussed the roles and responsibilities of various principals in the failure.

Day 4 – Stress and Strain, Bridges as Art

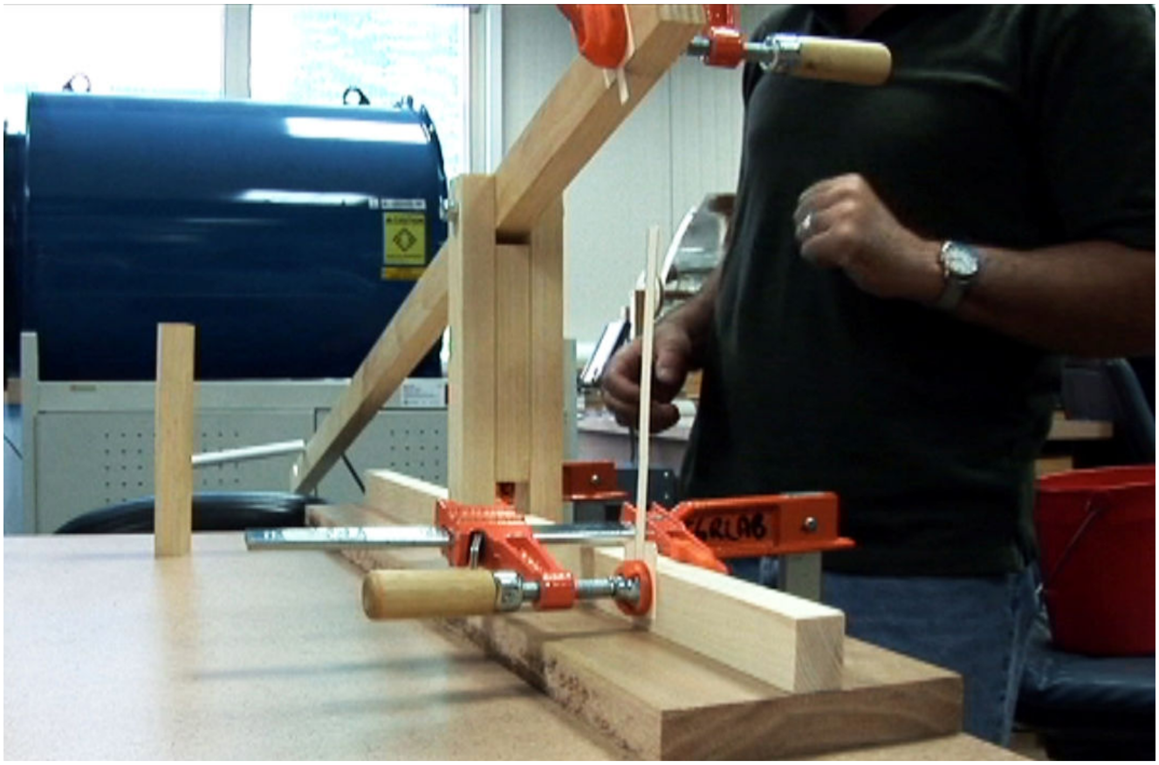
The learning outcomes for Day 4 included the study of stress and strain and a presentation of structures as art.

Activities:

- Students worked in small groups to test various materials on an Instron load frame. Stress-strain curves were generated and analyzed.
- The testing of file folder tensile coupons and columns continued, with students generating spreadsheets comparing failure loads to the geometry of the specimens.
- A presentation by Dr. Andrew Guswa, Smith College, entitled "Robert Maillart and the Inescapable Art of Bridges" was offered as a history of bridge engineering and the aesthetics of bridge design. The lecture emphasized the relationship between engineering and the liberal arts.



Figures 5 and 6. Teachers use testing machines to deeply explore concepts such as tension, compression, ductility, and brittleness as well as the relationship between load, geometry, and materials.



Day 5 – Concept Maps and Narrative, Curriculum Development

The learning outcomes for Day 5 included discussion of the use of concept maps and narrative in curriculum design.

Activities:

- The use of concept maps and narrative was presented as means for supporting deep learning and student engagement.
- Students worked on curriculum development.
- Students discussed the use of technology in the classroom during lunch.

Day 6 – Curriculum Development

The intended learning outcomes for Day 6 focused on curriculum development.

Activities:

- Students worked on curriculum development.

Day 7 – Working Construction Site

The intended learning outcome for Day 7 was to have the teachers experience a working construction site.

Activities:

- Students took a field trip with two destinations. The cohort visited the Scibelli Enterprise Center at Springfield Technical Community College for a presentation by the Entrepreneurial Institute, STCC's nationally known small business incubator, to learn about the free programs offered to SPS students linking innovation and entrepreneurship. The second part of the field trip was a visit to a construction site at Bay State Medical Center in Springfield, MA where a large, state-of-the-art, LEED-certified wing was under construction. A tour from the project foreman was extremely enlightening for the group; all aspects of construction were discussed, including "green" building, LEED certification, computerization of plans and drawings, construction planning, structural features of the building, materials, foundations, soils, and construction challenges.

Day 8 – Curriculum Development, Concept Mapping, Future Plans

The intended learning outcome for Day 8 was to review the basic engineering concepts of load, material, and geometry and make important connections in the context of concept mapping, as well as discuss sharing lesson plans and the future of the learning community.

Activities:

- The plank bridge used to being the discussion of engineering concepts was used to illustrate the concept of bending and the affect of material and geometry on bending resistance.
- Teachers worked in groups to develop curriculum.

- Teachers had group discussions regarding how the workshop content could be incorporated into their classrooms, in addition to formulating a “wish list” for future activities and workshops.
- A post-evaluation was administered.

Follow-Up

A workshop follow-up was held on Saturday, December 12th at Smith College. Eleven of fifteen (one teacher left the District) teachers attended. The objective of the follow-up was to learn if and how teachers had incorporated any of the workshop teachings into their curriculum. Activities included small group discussions, a roundtable discussion or “reporting out” of ways in which workshop learning had been, or was going to be, used in the classroom, and a tour of the new Ford Hall Science and Engineering Center at Smith with an emphasis on learning about sustainable design features used in the building.

Findings

In terms of content knowledge, it was clear from the pre-assessment for content and the observations of course instructors McGinnis-Cavanaugh and Ellis that the teachers did not have command of the fundamental engineering concepts that they were teaching. Misconceptions abounded in basic knowledge; for example, confusion existed about concepts like tension and compression as well as the difference in the tensile strength of structural steel as compared to concrete; incorrect applications of fundamental physics – Newton’s Laws, for example, were prevalent, as was a lack of understanding in higher order concepts like shear, bending, and torsion. It was difficult to determine if teachers were comfortable teaching the material in the targeted strands; while there was seemingly adequate “usage” of terms such as tension and compression, stress and strain, etc., the learning activities showed that a truly deep understanding of the concepts was rare. Progress with the use of concept mapping exhibited an improvement in the understanding of the relationships between material, load, and geometry, although not altogether satisfactorily. The post-assessment responses showed significant improvement over the pre-assessment responses, but, again, this was not deemed entirely satisfactory for the cohort.

Open-ended pre- and post-assessment questions were administered to the teachers. The responses to these questions were independently evaluated by McGinnis-Cavanaugh and Ellis using the scoring rubric shown in Appendix B. On average, response scores went up 83% and 60% (see Appendices B and C) on questions 1 and 2, respectively, showing significant improvement in both the understanding of both basic mechanics concepts and educational theory with regard to student engagement. The assessment questions were as follows:

1. A gymnast stands on a balance beam. Explain in your own words how the beam responds to the loading depicted in the illustration (i.e. the gymnast is the loading).
2. You are considering using an activity in your class that has been developed to teach the engineering design process and construction engineering. In this activity students follow instructions provided by the teacher to build a catapult out of Popsicle sticks,

glue and rubber bands that can launch a grape. They then use the catapult to launch grapes across the classroom and measure the distance traveled.
What is your opinion of the educational value of this activity? What would be key points for the teacher to consider in using it most effectively? Explain.

Appendix D shows one teacher's pre- and post-assessment responses. The post response to question 1 showed a clear gain in the understanding of fundamental engineering principles and the mechanics of beam bending. The pre response was limited to a discussion of applied and resisting forces. In contrast, however, the post response was more sophisticated in that it related load, geometry, and materials – a clear application of concept mapping – and correctly incorporated mechanical properties such as ductility, elasticity, plasticity, and yielding. Beam action was correctly described and concepts such as load path were discussed. On the whole, the post response showed a "bigger picture" understanding of engineering concepts and higher order consideration of these concepts.

The post response to question 2 indicated a new sensitivity to the issue of gender as well as to expanding engagement for all students with re-framed approaches to the presentation of the material. While the pre response showed that this teacher considered the catapult activity to have "super education value" before consideration of the use of conceptual frameworks and narratives for making engineering concepts relevant to a group of diverse learners, the post response did indicate reflection upon these issues and was promising in that a more inclusive approach and more relevant application and analysis of the project.

In general, teachers exhibited various levels of receptivity to changing their teaching approach to foster deep and meaningful learning. Some were definitely more open to new ideas and methods than others. Many teachers loved the various hands-on activities for their students – the testing machines were a huge hit – although some still indicated strong tendencies to rely too much on "kit" type projects as an ultimate outcome rather than a tool to engage students in a broader context on the given topic.

Unique to this workshop was the equipment allowance allotted each teacher. Consistent with the belief that each teacher is an expert in their own classroom, most of the grant funds targeted for workshop equipment and supplies at the teachers' individual discretion. Interestingly, only eight teachers have ordered equipment as of this writing. Teacher equipment purchases to date consist of the following:

- Roller coaster kits
- "Building Homes of Our Own" software (residential architecture)
- Air compressor (for rocket launches)
- Lego catapult kits
- Lego Maglev Vehicle kits (three teachers, three individual orders)
- Assorted DVD's and books; miscellaneous equipment such as scales, stopwatches, analog multimeter

Overall, teacher feedback indicated a high level of satisfaction with the workshop on everything from content to logistics, and clearly conveyed an eagerness from teachers to put into practice what they learned when they return to the classroom. A sampling of feedback comments follows:

> *"High level of intellectual challenge. We were engaged as thinkers and contributors and challenged to think about concepts. Also, there was a humanistic/cultural component that was surprising - the content, to me was fresh and new and engaged me - from construction site to research on cognition. The professors were wonderful teachers and guides, and the colleagues were top notch!"*
>
> *"I learned ways to be able to reach students regarding the idea that engineering involves more than the traditional notion of facts and figures. This workshop showed me ways to make engineering concepts more complete by incorporating then into a meaningful social context."*
>
> *"I have learned how to think about and approach concepts differently to help students develop a deeper understanding of engineering as a whole."*
>
> "*The overarching themes of this workshop - sustainability, engineering as a creative process, the effect of cultural values - will all be reflected in my classroom."*

Consistent with our belief that *listening* to teachers is critical to the formation of a strong partnership and a meaningful community of learners, the workshop began with an "appreciative inquiry". This exercise clearly indicated that teachers want the best possible learning experience for their students; this was reflected in the themes that they as a cohort deemed important and relative to their experience and mission.

The activity called for teacher partners to ask each other the following questions designed to elicit best and most valued learning experiences:

- Best Experience: Reflecting on your experience as a teacher/learner, tell me a story about one of the high point experiences of "transformational learning". Looking at your entire experience, recall a time when you felt most alive, most involved, most capable or most excited about your learning. What made it a successful experience? Who was involved? Describe the situation/event in detail.
- Values: What are the things you value deeply; specifically, the things you value about yourself, your work and your school:
  - Yourself: Without being humble, what do you value most about yourself – as a human being, a friend, a parent, a citizen, and a teacher?
  - Your work: When you are feeling best about your work, what do you value about it?

  - Your school**:** What is it about your school (workplace) that you value? What is the single most important thing that your school has contributed to your life?
- Three Wishes: If you had three wishes for yourself, your workplace and the world what would they be?

Partners aggregated the responses and the teachers completed "energy diagrams" to determine the themes with which they identified. The five main themes below were selected based upon the frequency of teacher responses; all express the teachers' overall desire to improve student success and their own professional environment:

- "Children need help in discovering their own value" (faith in the future)
- "Hands-on activities"
- "Expectations of excellence, room for excellence"
- "General desire to improve the learning environment"
- "Environment of high level of involvement of staff & students"

Figure 7. Teachers identify common themes, strengths, and desires with "energy diagrams".

Post-Workshop

The workshop follow-up was held on Saturday, December 12th at Smith College. Eleven of fifteen teachers attended. Teachers began the morning in small groups discussing if and how they had implemented the workshop lessons in their curriculum. A roundtable discussion was held so that teachers could "report out" on what their group discussions.

In addition to the discussion portion, the cohort toured Ford Hall, Smith's new state-of-the-art, "green" engineering building at Smith College. The tour was revealing in that the topic of "green" building was engaging for the teachers, consistent with the ongoing workshop theme of sustainability. Many insightful questions were asked of the Capital Projects Manager leading the group along that line, indicating an overall active interest in and awareness of sustainability From the workshop and the follow-up came many teacher requests for future workshops, development of curricula, collaboration with peer teachers and STCC and Smith College, in addition to equipment requests and the like. For example, teachers asked for

- Teacher observations and "swapping" between Technology/Engineering teachers, from school-to-school or from class-to-class within the same schools where more than one Technology/Engineering teacher is assigned
- Coordination and collaboration for lesson plans
- Integration of Technology/Engineering strands with other subject areas
- Group activities and/or an Engineering Fair, either in school or between schools
- More collaboration between middle schools and STCC and Smith
- More testing machines for the tension/compression testing activity
- More "hands-on activities" for students (like the file-folder bridge activity)
- A "dream space/lab"

For future workshops, teachers requested more professional development along the same line as the summer 2009 workshop, with future sessions to include students to some degree along with a "bring a buddy" program to spur team teaching, especially between disciplines. More field trips were requested, as was a focus on green technology. In fact, it was suggested that the common themes of sustainability and educational theory for deep and meaningful learning be woven through any workshop offering for any subject area or strand.

Finally, and most importantly, the cohort requested a "community of learners" in the form of an electronic learning community that would provide or insure that, in their own words:

- Everything is posted – workshop materials, presentations, etc.
- Record of experiences
- Sharing of lesson plans
- Sharing of learning strategies and theories
- An "idea bank"
- Book discussion
- Classroom management tips
- Emails/links/updates

Has there been any evidence of success? One teacher emailed the following as the school year began with an inventive application of the use of narrative for a standard boat building project:

> *"…As a matter of fact, I wanted to share with you that the work we did with you this summer forced me to research a little bit about boat building (remember we were struggling with the concept of kids coming in with a plastic bottle and calling it a boat...we also had worked on trying to come up with good, real life story to hook the kids into building something) Well, one thing that I found was an eccentric environmentalist (David de Rothschild) actually has built a boat out of plastic bottles to bring attention to the plight of the polluted Pacific Ocean. He is planning an 11,000 mile trip across the Pacific in a catamaran type of boat being supported by clear plastic bottles. the name of his boat is Plasticki . So now we have a real motivating story for our boats, and here is part two that I'm trying to convince Burt of...maybe we could have an afterschool program or something where we could attempt to make a Plasticki2 and to test it we could launch it on Porter Lake with who else but Mr. Freedman paddling it! Still toying with the idea but I think it could be fun …"* Katie Orellana, ECOS

Another teacher spoke at the follow-up session of "making it all inclusive" when it comes to gender and race, and "considering all aspects of a project", i.e., social impact, ethics, gender bias, and sustainability when presenting material to his students. He mentioned a discussion that took place in the summer workshop concerning a rocket launching project that he and many other teachers use frequently. In the context of "re-framing" this type of project for deep and meaningful learning, we discussed why the rocket launch itself – the competition to see how far the rocket can go – was inherently gender biased. Teachers vigorously argued this point, stating that girls frequently excelled in this project, often outdoing their male counterparts. Did the girls find the activity meaningful or engaging in any way? To engage them, it was argued, a broader context for that type of project was necessary. To help teachers and students broaden that context, we suggested incorporating discussion on the space program – the politics and cost of space exploration, the cost-benefit ratio, and ethics – use of resources vs., for example, the development of helpful products and the advancement of research and discovery – as a way to enhance the meaning and relevance of the activity. The teacher indicated his approach to teaching activities like the rocket launch had changed because of the workshop.

Future Plans and Challenges

Success indicators thus far demonstrate the formation of a strong partnership between SPS, Smith, and STCC, especially in light of the very successful first professional development summer workshop. Overall, evidence of increased teacher content knowledge and teachers "buying in", i.e., using conceptual frameworks and narratives for making engineering concepts relevant SPS middle school students, has been documented in evaluation and assessment.

Future challenges include sustaining the overall momentum of first workshop experience and engaging all technology/engineering teachers in SPS in upcoming workshops and other activities. Meaningful curriculum change vs. standardized testing is a priority, as is developing and sustaining a meaningful online learning community among teachers. Full activation of the project website, which can be found at http://www.engineerstomorrow.com/index.html, will facilitate the introduction of the online learning community. Outreach to successful learning communities has been made for advice in engaging teachers in this effort and maintaining their participation by making the site useful and meaningful for them. Also in process is the formation of an equipment “lending library” to be administered by the Instructor Resource Teachers at SPS and inventoried on the project website. In addition, the logistics of putting Smith and STCC students into SPS middle school classrooms, as requested by our workshop teachers, are being worked out. To bolster all of these efforts, investigation into the feasibility of STCC and Smith engineering students in the classroom is also planned, as well as enhanced collaboration between SPS, STCC, and Smith College. A clearer definition of roles and the logistics of student transportation are currently being considered.

Three summer 2010 workshops have been planned. Two will address the Construction Technologies strand (including the related strands of Materials, etc. and Engineering Design) and will be structured such that new participants will attend the first and returning participants will attend the second. Hence, the new participant session will be similar to the 2009 session but will be limited to mechanics (that is, educational theory, gender issues, diversity, etc., will not be included in this session); a study of engineering ethics will be included. For returning teachers, a continuation of the summer 2009 workshop in terms of basic mechanics with discussion of more advanced topics like shear and torsion in addition to tension, compression, and bending will be conducted. Materials will be discussed in greater detail, and material testing of steel and concrete will be included. Tall buildings will be discussed. A transportation component will also be included.

Open to all teachers, the third workshop session will deal with artificial intelligence (AI) and will look at the possibility of intelligent machines and the limitations of machines and computers. Hands-on activities will include talking to chatterbots (AI programs designed to engage in conversation).. A possible bio-engineering component will be included. A highlight of this session will be coordination with the STCC Summer Robotics Camp for SPS middle-schoolers; this was a request of the summer 2009 cohort and has been very well-received by both SPS and the STCC Robotics Camp faculty. This integration will allow the workshop teachers to “test” new approached and curriculum on “real” students. Hopefully, it will also allow some outreach to both SPS students and parents, as parent participation is a hallmark of the STCC Robotics Camp.

Common to all sessions will be a common-themed lunch session to include all participating teachers. Teachers may meet as one group or in breakout groups. Topics will include educational theory, diversity, and meeting all learners’ needs. Returning teachers may be part of presentation team. Again, in response to teacher comments and requests, the workshops will weave the common themes of educational theory for deep and meaningful learning and sustainability throughout all content. As always, ideas for further strengthening the Partnership and keys to meaningful and successful online learning community for teachers will also be discussed.

Conclusion

A partnership between the Springfield Middle Schools (SPS), Springfield Technical Community College (STCC), and Smith College has been funded through an NSF MSP-Start Partnership Grant. "Drafting a Blueprint for Teaching Tomorrow's Engineers Today" is a partnership program designed to foster deep and meaningful learning of engineering concepts among SPS Middle School Technology and Engineering teachers, as well as collaboratively develop active learning methods leading towards deep learning for improved student success. The overall goal of the grant is to enable teachers to reach and inspire students typically outside of the engineering "pipeline". To that end, a workshop was held in summer 2009 to provide professional development for sixteen SPS Technology/Engineering teachers. Learning outcomes for the workshop were developed to promote deep and meaningful learning of basic engineering concepts for targeted strands of the Massachusetts Science and Technology/Engineering Curriculum Framework as well as introduce educational theory to enhance STEM engagement for all students.

The workshop was successful in improving concept knowledge and educational theory according to post-assessments and preliminary feedback from teachers. Recognizing the importance of context in both effective engineering and in the learning process, teachers learned the fundamentals of engineering mechanics through hands-on activities that they could use in their own classrooms and within a variety of contexts that included the design process, an ethics case study, and the history and aesthetics of bridge design.

Evidence exists to support the partial achievement of learning outcomes, but more work is needed. SPS has expressed the need for continued professional development for any of the Technology/Engineering strands, and a renewed focus on curriculum changes, fully supported by SPS, is underway. Three summer 2010 professional development workshops have been planned. A website has been launched to establish an effective and useful online learning community as well as expand outreach.

Can standards be interpreted in such as way as to promote deep and meaningful learning based on education theory and the learning sciences? Can an interdisciplinary approach result in improved teacher content knowledge, improved student performance on standardized testing, and increased student engagement in STEM? What curricular enhancements can stimulate interest in STEM for underrepresented students? Can engineering and the liberal arts stimulate girls' interest in STEM? Is this a model that can be replicated in other grades or in other districts? Plans to answer these questions by strengthening and expanding the Partnership are being considered as the Partnership prepares for a full MSP proposal later this year. Outreach to well-established MSP projects, like the Boston Science Partnership and others, will be valuable in formulating effective long-range plans for an effective and sustainable relationship between SPS, STCC, and Smith College leading to improved student engagement, access, and success.

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[3] Ellis, G.W., Rudnitsky, A. and Silverstein, B. (2004) Using Concept Maps to Enhance Understanding in Engineering Education. International Journal of Engineering Education 20 (6) 1012-1021.

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Appendix A: Needs Assessment Results

Below you will find response frequencies (N=19) to the SPS teacher needs assessment administered during January 2009. This table is formatted in way to compare responses by each of seven major learning strands contained in the Technology/Engineering grades 6-8 curriculum frameworks. Following the table are open-ended comments.

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
You have a strong content knowledge in this area						
1. Materials, Tools, and Machines	5.3%	36.8%	36.8%	5.3%	10.5%	5.3%
2. Engineering Design	10.5%	26.3%	31.6%	5.3%	21.1%	5.3%
3. Communication Technologies	5.3%	26.3%	36.8%	26.3%	0.0%	5.3%
4. Manufacturing Technologies	0.0%	26.3%	36.8%	10.5%	15.8%	10.5%
5. Construction Technologies	36.8%	10.5%	31.6%	5.3%	10.5%	5.3%
6. Transportation Technologies	10.5%	36.8%	31.6%	10.5%	5.3%	5.3%
7. Bioengineering Technologies	0.0%	10.5%	31.6%	31.6%	10.5%	15.8%
When an average SPS student completes middle school, they have a sufficient content knowledge in this area						
1. Materials, Tools, and Machines	0.0%	0.0%	42.1%	5.3%	36.8%	15.8%
2. Engineering Design	5.3%	0.0%	36.8%	10.5%	31.6%	15.8%
3. Communication Technologies	0.0%	10.5%	26.3%	15.8%	31.6%	15.8%
4. Manufacturing Technologies	0.0%	5.3%	26.3%	21.1%	26.3%	21.1%
5. Construction Technologies	0.0%	26.3%	26.3%	10.5%	21.1%	15.8%
6. Transportation Technologies	5.3%	21.1%	26.3%	10.5%	15.8%	21.1%
7. Bioengineering Technologies	5.3%	0.0%	15.8%	26.3%	21.1%	31.6%
You are comfortable teaching this subject area to your students						
1. Materials, Tools, and Machines	10.5%	36.8%	26.3%	0.0%	26.3%	0.0%
2. Engineering Design	22.2%	22.2%	27.8%	5.6%	22.2%	0.0%
3. Communication Technologies	5.6%	33.3%	16.7%	22.2%	16.7%	5.6%
4. Manufacturing Technologies	5.3%	26.3%	10.5%	36.8%	15.8%	5.3%
5. Construction Technologies	21.1%	36.8%	10.5%	15.8%	10.5%	5.3%
6. Transportation Technologies	15.8%	21.1%	36.8%	10.5%	10.5%	5.3%
7. Bioengineering Technologies	0.0%	15.8%	15.8%	36.8%	21.1%	10.5%
You would find professional development in this area beneficial (assuming high quality PD in content and delivery)						
1. Materials, Tools, and Machines	57.9%	42.1%	0.0%	0.0%	0.0%	0.0%
2. Engineering Design	57.9%	42.1%	0.0%	0.0%	0.0%	0.0%
3. Communication Technologies	73.7%	26.3%	0.0%	0.0%	0.0%	0.0%
4. Manufacturing Technologies	63.2%	36.8%	0.0%	0.0%	0.0%	0.0%
5. Construction Technologies	57.9%	31.6%	5.3%	5.3%	0.0%	0.0%
6. Transportation Technologies	52.6%	36.8%	10.5%	0.0%	0.0%	0.0%
7. Bioengineering Technologies	78.9%	21.1%	0.0%	0.0%	0.0%	0.0%

Please add any additional comments related to your needs/concerns/issues and how this grant may be able to help you:

- Tools for the classrooms are desperately needed as well as training on how kids can use them safely.
- I just moved from many years in elementary school to middle school, so I have very little experience so far. I'm interested in any PD to help me build knowledge, help me meet students' needs, and to build our school's STEM program.
- Time to attend PD has been my biggest challenge. They always look interesting but I always have conflicts.
- I have trouble with Manufacturing and Bioengineering - not so much Design and Construction.
- Any professional development would be beneficial.
- Engineering and Technology would be/is more interesting to students because it offers concepts that are practical - construction, transportation etc., as compared to pure academics. Shop is "hot" however it’s not offered.

Below you will find response frequencies (N=19) to the SPS teacher needs assessment administered during January 2009. This table is formatted in way to show teacher responses for each of seven major learning strands contained in the Technology/Engineering grades 6-8 curriculum frameworks. Following the table are open-ended comments.

---

1. **Materials, Tools, and Machines -** Central Concept: Appropriate materials, tools, and machines enable us to solve problems, invent, and construct.

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
a. You have a strong content knowledge in this area	5.3%	36.8%	36.8%	5.3%	10.5%	5.3%
b. When an average SPS student completes middle school, they have a sufficient content knowledge in this area	0.0%	0.0%	42.1%	5.3%	36.8%	15.8%
c. You are comfortable teaching this subject area to your students	10.5%	36.8%	26.3%	0.0%	26.3%	0.0%
d. You would find professional development in this area beneficial (assuming high quality PD in content and delivery)	57.9%	42.1%	0.0%	0.0%	0.0%	0.0%

2. **Engineering Design -** Central Concept: Engineering design is an iterative process that involves modeling and optimizing to develop technological solutions to problems within given constraints.

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
a. You have a strong content knowledge in this area	10.5%	26.3%	31.6%	5.3%	21.1%	5.3%
b. When an average SPS student completes middle school, they have a sufficient content knowledge in this area	5.3%	0.0%	36.8%	10.5%	31.6%	15.8%
c. You are comfortable teaching this subject area to your students	22.2%	22.2%	27.8%	5.6%	22.2%	.0%
d. You would find professional development in this area beneficial (assuming high quality PD in content and delivery)	57.9%	42.1%	0.0%	0.0%	0.0%	0.0%

3. **Communication Technologies -** Central Concept: Ideas can be communicated though engineering drawings, reports, and pictures.

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
a. You have a strong content knowledge in this area	5.3%	26.3%	36.8%	26.3%	0.0%	5.3%
b. When an average SPS student completes middle school, they have a sufficient content knowledge in this area	0.0%	10.5%	26.3%	15.8%	31.6%	15.8%
c. You are comfortable teaching this subject area to your students	5.6%	33.3%	16.7%	22.2%	16.7%	5.6%
d. You would find professional development in this area beneficial (assuming high quality PD in content and delivery)	73.7%	26.3%	0.0%	0.0%	0.0%	0.0%

4. **Manufacturing Technologies -** Central Concept: Manufacturing is the process of converting raw materials (primary process) into physical goods (secondary process), involving multiple industrial processes (e.g., assembly, stages of production, quality control).

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
a. You have a strong content knowledge in this area	0.0%	26.3%	36.8%	10.5%	15.8%	10.5%
b. When an average SPS student completes middle school, they have a sufficient content knowledge in this area	0.0%	5.3%	26.3%	21.1%	26.3%	21.1%
c. You are comfortable teaching this subject area to your students	5.3%	26.3%	10.5%	36.8%	15.8%	5.3%
d. You would find professional development in this area beneficial (assuming high quality PD in content and delivery)	63.2%	36.8%	0.0%	0.0%	0.0%	0.0%

5. **Construction Technologies -** Central Concept: Construction technology involves building structures in order to contain, shelter, manufacture, transport, communicate, and provide recreation.

1. **Construction Technologies -** Central Concept: Construction technology involves building structures in order to contain, shelter, manufacture, transport, communicate, and provide recreation.

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
a. You have a strong content knowledge in this area	36.8%	10.5%	31.6%	5.3%	10.5%	5.3%
b. When an average SPS student completes middle school, they have a sufficient content knowledge in this area	0.0%	26.3%	26.3%	10.5%	21.1%	15.8%
c. You are comfortable teaching this subject area to your students	21.1%	36.8%	10.5%	15.8%	10.5%	5.3%
d. You would find professional development in this area beneficial (assuming high quality PD in content and delivery)	57.9%	31.6%	5.3%	5.3%	0.0%	0.0%

2. **Transportation Technologies -** Central Concept: Transportation technologies are systems and devices that move goods and people from one place to another across or through land, air, water, or space.

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
a. You have a strong content knowledge in this area	10.5%	36.8%	31.6%	10.5%	5.3%	5.3%
b. When an average SPS student completes middle school, they have a sufficient content knowledge in this area	5.3%	21.1%	26.3%	10.5%	15.8%	21.1%
c. You are comfortable teaching this subject area to your students	15.8%	21.1%	36.8%	10.5%	10.5%	5.3%
d. You would find professional development in this area beneficial (assuming high quality PD in content and delivery)	52.6%	36.8%	10.5%	0.0%	0.0%	0.0%

3. **Bioengineering Technologies** - Central Concept: Bioengineering technologies explore the production of mechanical devices, products, biological substances, and organisms to improve health and/or contribute improvements to our daily lives.

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
a. You have a strong content knowledge in this area	0.0%	10.5%	31.6%	31.6%	10.5%	15.8%
b. When an average SPS student completes middle school, they have a sufficient content knowledge in this area	5.3%	0.0%	15.8%	26.3%	21.1%	31.6%
c. You are comfortable teaching this subject area to your students	0.0%	15.8%	15.8%	36.8%	21.1%	10.5%
d. You would find professional development in this area beneficial (assuming high quality PD in content and delivery)	78.9%	21.1%	0.0%	0.0%	0.0%	0.0%

Please add any additional comments related to your needs/concerns/issues and how this grant may be able to help you:

- Tools for the classrooms are desperately needed as well as training on how kids can use them safely.
- I just moved from many years in elementary school to middle school, so I have very little experience so far. I'm interested in any PD to help me build knowledge, help me meet students' needs, and to build our school's STEM program.
- Time to attend PD has been my biggest challenge. They always look interesting but I always have conflicts.
- I have trouble with Manufacturing and Bioengineering - not so much Design and Construction.
- Any professional development would be beneficial.
- Engineering and Technology would be/is more interesting to students because it offers concepts that are practical - construction, transportation etc., as compared to pure academics. Shop is "hot" however it’s not offered.
- Any new knowledge I can acquire is a welcome endeavor

Appendix B: Scoring Rubric for Summer 2009 Content Assessment

Summer Professional Development Workshop in Technology and Engineering

July 13-16 and 20-23 at Smith College

Participant Learning Assessment Scoring Rubric

Please fill in teacher code below

Teacher Code ☐☐☐ - ☐☐☐
1 2 3 4 5 6

Scorer:

○

○

○ Other: ________________________________

3. A gymnast stands on a balance beam. Explain in your own words how the beam responds to the loading depicted in the illustration (i.e. the gymnast is the loading).

Criteria	Not Addressed 0	Minimal 1	Basic 2	Solid 3	Advanced 4	Score 0-4
Addresses issues related to loading	Response contains no mention of loading.	Response indicates a minimal understanding of issues related to loading.	Response indicates a basic understanding of issues related to loading.	Response indicates a solid understanding of issues related to loading.	Response indicates an advanced understanding of issues related to loading.	
Addresses issues related to geometry	Response contains no mention of geometry.	Response indicates a minimal understanding of issues related to geometry.	Response indicates a basic understanding of issues related to geometry.	Response indicates a solid understanding of issues related to geometry.	Response indicates an advanced understanding of issues related to geometry.	
Addresses issues related to materials	Response contains no mention of materials.	Response indicates a minimal understanding of issues related to materials.	Response indicates a basic understanding of issues related to materials.	Response indicates a solid understanding of issues related to materials.	Response indicates an advanced understanding of issues related to materials.	
Integrating concepts together	Response does not integrate concepts of loading, geometry, or materials at all.	Response includes minimal integration of loading, geometry, and/or materials.	Response includes basic integration of loading, geometry, and materials.	Response includes solid integration of loading, geometry, and materials.	Response includes advanced integration of loading, geometry, and materials.	

4. You are considering using an activity in your class that has been developed to teach the engineering design

process and construction engineering. In this activity students follow instructions provided by the teacher to build a catapult out of Popsicle sticks, glue and rubber bands that can launch a grape. They then use the catapult to launch grapes across the classroom and measure the distance traveled.

What is your opinion of the educational value of this activity? What would be key points for the teacher to consider in using it most effectively? Explain.

Criteria	**Not Addressed 0**	**Minimal 1**	**Basic 2**	**Solid 3**	**Advanced 4**	**Score 0-4**
Addressing any potential gender or other biases in the activity	Does not address any potential gender or other biases in the activity.	Only minimally addresses any potential gender or other biases in the activity.	Does a basic job addressing any potential gender or other biases in the activity.	Solidly addresses any potential gender or other biases in the activity.	Advanced response addressing any potential gender or other biases in the activity.	
Addressing if the activity relates to learning outcomes	Does not address how/if the activity relates to learning outcomes.	Only minimally addresses how/if the activity relates to learning outcomes.	Does a basic job addressing how/if the activity relates to learning outcomes.	Solidly addresses how/if the activity relates to learning outcomes.	Advanced response addressing how/if the activity relates to learning outcomes.	
Addressing contextual issues such as ethics, politics, sustainability, etc.	Does not address contextual issues.	Only minimally addresses contextual issues.	Does a basic job addressing contextual issues.	Solidly addresses contextual issues.	Advanced response addressing contextual issues.	
Addressing current issues in engineering education—such as globalization, professional skills, innovation, etc.	Does not address current issues in engineering education.	Only minimally addresses current issues in engineering education.	Does a basic job addressing current issues in engineering education.	Solidly addresses current issues in engineering education.	Advanced response addressing current issues in engineering education.	
Addressing issues related to deep learning—such as engagement, addressing prior knowledge, framing understanding, metacognition, etc.	Does not address issues related to deep learning.	Only minimally addresses issues related to deep learning.	Does a basic job addressing issues related to deep learning.	Solidly addresses issues related to deep learning.	Advanced response addressing issues related to deep learning.	

Appendix C: Summer 2009 Workshop Pre- and Post-Assessment Results

Summer Professional Development Workshop in Technology and Engineering

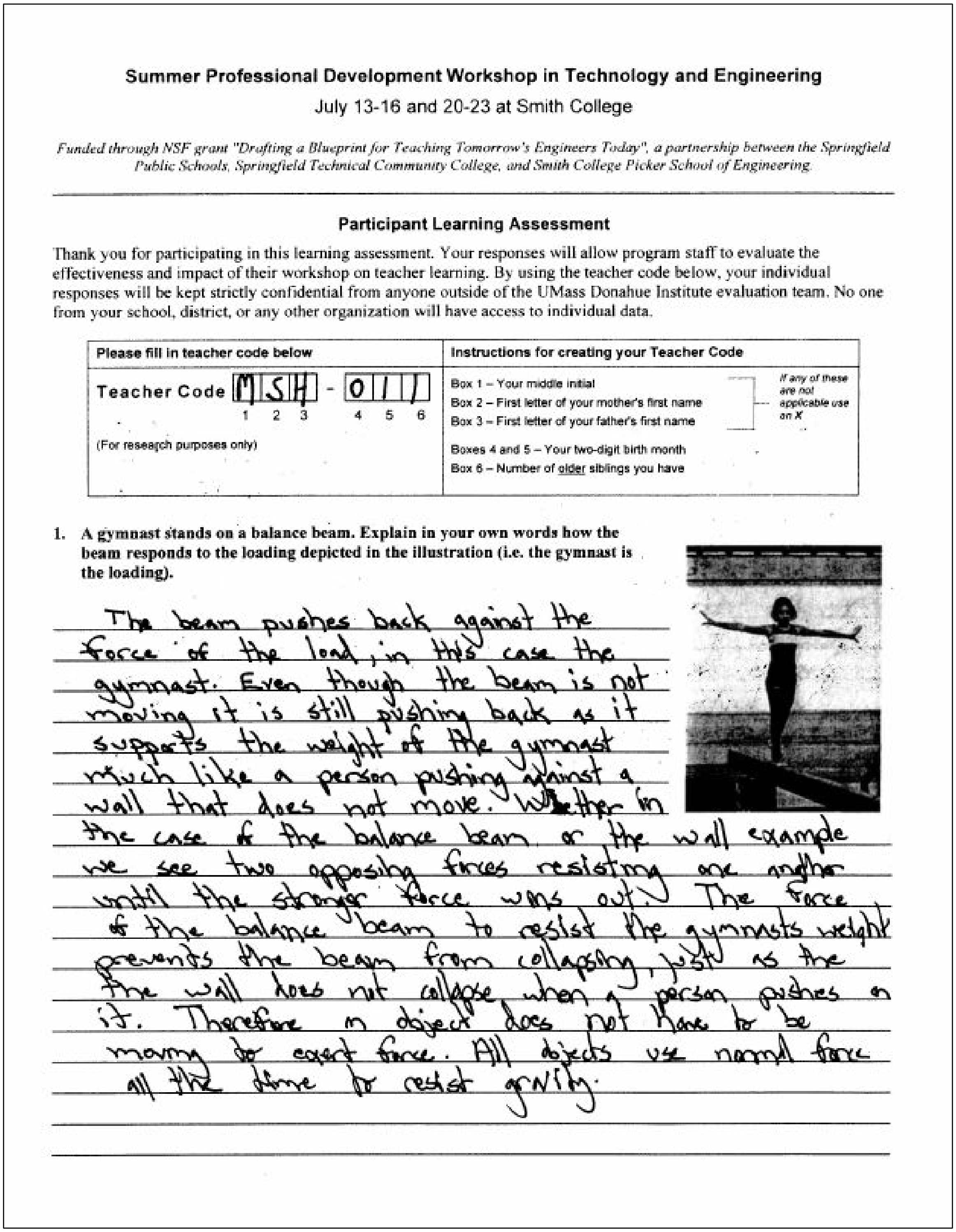
Pre and Post Content Assessment Results

Of the 15 teachers with both a pre- and post-assessment, 73% increased their overall scores based on Scorer 1 while 100% increased their scores based on Scorer 2. Scores improved slightly better on Q.1 compared to Q.2.

Comparison of Pre- and Post-Scores on 2009 Summer Workshop Content Assessment

	N	Scores Went Down (-)	Stayed the Same (=)	Scores Went Up (+)
Total Score (Combined Q.1 & Q.2)				
Scorer 1	15	20%	7%	73%
Scorer 2	15	0%	0%	100%
Total	30	10%	3%	87%
Question 1				
Scorer 1	15	7%	27%	67%
Scorer 2	15	0%	0%	100%
Total	30	3%	13%	83%
Question 2				
Scorer 1	15	40%	33%	27%
Scorer 2	15	0%	7%	93%
Total	30	20%	20%	60%

Appendix D: Summer 2009 Workshop Pre- and Post-Assessment Answer Sample



Summer Professional Development Workshop in Technology and Engineering

July 13-16 and 20-23 at Smith College

Funded through NSF grant "Drafting a Blueprint for Teaching Tomorrow's Engineers Today", a partnership between the Springfield Public Schools, Springfield Technical Community College, and Smith College Picker School of Engineering.

Participant Learning Assessment

Thank you for participating in this learning assessment. Your responses will allow program staff to evaluate the effectiveness and impact of their workshop on teacher learning. By using the teacher code below, your individual responses will be kept strictly confidential from anyone outside of the UMass Donahue Institute evaluation team. No one from your school, district, or any other organization will have access to individual data.

Please fill in teacher code below	Instructions for creating your Teacher Code
Teacher Code M S H - 0 1 1 1 2 3 4 5 6 (For research purposes only)	Box 1 – Your middle initial Box 2 – First letter of your mother's first name Box 3 – First letter of your father's first name *If any of these are not applicable use an X* Boxes 4 and 5 – Your two-digit birth month Box 6 – Number of older siblings you have

1. A gymnast stands on a balance beam. Explain in your own words how the beam responds to the loading depicted in the illustration (i.e. the gymnast is the loading).

The beam pushes back against the force of the load, in this case the gymnast. Even though the beam is not moving it is still pushing back as it supports the weight of the gymnast much like a person pushing against a wall that does not move. Whether in the case of the balance beam or the wall example we see two opposing forces resisting one another until the stronger force wins out. The force of the balance beam to resist the gymnasts weight prevents the beam from collapsing, just as the the wall does not collapse when a person pushes on it. Therefore an object does not have to be moving to exert force. All objects use normal force all the time to resist gravity.

2. **You are considering using an activity in your class that has been developed to teach the engineering design process and construction engineering. In this activity students follow instructions provided by the teacher to build a catapult out of Popsicle sticks, glue and rubber bands that can launch a grape. They then use the catapult to launch grapes across the classroom and measure the distance traveled.**

   What is your opinion of the educational value of this activity? What would be key points for the teacher to consider in using it most effectively? Explain.

I've actually done this exact activity, only we launched marshmallows not grapes. The educational value of the activity was superb! The kids got to brainstorm, build, test, design, redesign, and share feedback. The teacher should consider things such as collaborative learning groups for students to benefit from each other. Other things such as pictures of catapults, bilingual instructions, and previous knowledge of the students should be considered. The teacher should include a lab report and launch contest that values both distance and accuracy so students can have multiple roads to success.

Summer Professional Development Workshop in Technology and Engineering

July 13-16 and 20-23 at Smith College

Funded through NSF grant "Drafting a Blueprint for Teaching Tomorrow's Engineers Today", a partnership between the Springfield Public Schools, Springfield Technical Community College, and Smith College Picker School of Engineering.

Participant Learning POST Assessment

Thank you for participating in this learning assessment. Your responses will allow program staff to evaluate the effectiveness and impact of their workshop on teacher learning. By using the teacher code below, your individual responses will be kept strictly confidential from anyone outside of the UMass Donahue Institute evaluation team. No one from your school, district, or any other organization will have access to individual data.

Please fill in teacher code below	**Instructions for creating your Teacher Code**
Teacher Code M H S - 0 1 1 1 2 3 4 5 6 (For research purposes only)	Box 1 – Your middle initial Box 2 – First letter of your mother's first name Box 3 – First letter of your father's first name *If any of these are not applicable use an X* Boxes 4 and 5 – Your two-digit birth month Box 6 – Number of older siblings you have

1. A gymnast stands on a balance beam. Explain in your own words how the beam responds to the loading depicted in the illustration (i.e. the gymnast is the loading).

The beam responds to the dynamic load of the gymnast by pushing up against her weight. The top of the beam is being compressed while the bottom of the beam is in tension. These forces are being distributed across the beam to the legs and finally the floor. The geometry and materials that comprise the beam are designed to handle such dynamic loads through their shape and composition. The beam is ductile enough to flex under her weight without breaking. The metal legs of the beam also have some flex but are more than strong enough to handle the load. The stress strain relationship is linear in this model and shows that the stress provided by the dynamic load does not create enough strain to make the beam yeild.

When the gymnast gets off the beam it will return to its initial shape, because it is within its elastic limit. No plastic damage has been done. The beam will be able to be used again and again because the properties of loading, geometry, and materials have all be applied correctly.

2. You are considering using an activity in your class that has been developed to teach the engineering design process and construction engineering. In this activity students follow instructions provided by the teacher to build a catapult out of Popsicle sticks, glue and rubber bands that can launch a grape. They then use the catapult to launch grapes across the classroom and measure the distance traveled.

What is your opinion of the educational value of this activity? What would be key points for the teacher to consider in using it most effectively? Explain.

The teacher should think about why they are asking students to build a catapult. They may ask questions about when catapults were invented, and what were they used for. The teacher may ask students to brainstorm new ways to use a catapult today. This will get all the students involved, even the ones not interested in building a catapult. Now the educational value is enhanced because the activity has a story and a social context.