# AC 2011-2051: LEARNING FROM A TEACHER'S PERSPECTIVE

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# Learning from a Teacher's Perspective


## Abstract

In recent years, enrollment in STEM related fields has steadily declined. To combat this, the INSPIRES curriculum (INcreasing Student Participation, Interest, and Recruitment in Engineering & Science) was developed with the goal to increase student motivation to learn by incorporating real world engineering examples and interactive lessons into the class room. Included are hands-on activities, online animations and simulations and a team engineering design challenge which allows students to solve a real world engineering problem using creativity and commonly found items. The curriculum being used this year, "Engineering in Healthcare: A Heart Lung Case Study," follows a young girl who suffers from a heart defect which requires her to have open heart surgery to repair.

The INSPIRES project has evolved from creating curriculum to providing teacher Professional Development. The most recent step of this evolution has been to extend the teacher Professional Development (PD) from a two day workshop to a three week summer workshop. The new PD program has allowed for a more in depth cohesion of engineering content, pedagogy, and reflection. The PD program was split up into three distinct sections. In the mornings, the teachers were team taught the heart lung curriculum by experienced engineering faculty and inquiry-based pedagogical facilitators. In the afternoons, the teachers applied what they learned as they taught students that were enrolled in the Upward Bound program. While teaching, the teachers were videotaped and observed by the INSPIRES team. After each lesson, the teachers and the INSPIRES team reviewed the recordings and collectively provided constructive criticism to improve content understanding, teaching pedagogy and curriculum delivery.

Although this new PD program provides the teachers with more practice, this extension to INSPIRES project has a significant associated cost. Prior to attending the PD program, the teachers were videotaped teaching a class involving engineering design and they will also be videotaped this coming year while teaching the heart lung curriculum. The pre and post videos will be scored using RTOP (Reformed Teaching Observation Protocol). In addition, the teachers completed pre and post tests covering the curriculum content and fundamental concepts (unit conversions, design process, graphing, etc.). They were also required to complete pre PD, post PD and post curriculum enactment surveys on the Importance, Preparedness and Frequency of seven statements (making connections between science & engineering, engage students in open-ended problems, design exercises using constraints, etc.). The pre/post tests and surveys results are presented and are used to evaluate the effectiveness of the new INSPIRES PD program.

## Background

The INSPIRES (***IN**creasing **S**tudent **P**articipation, **I**nterest and **R**ecruitment in **E**ngineering and **S**cience*) program began as a NSF funded Instructional Materials Development project with the goal of creating curriculum modules (for high school technology education classrooms - the duration of each module is approximately twenty 45-minute lessons) which incorporate a real world design challenge, online content with interactive animations, hands on activities, an online mathematical simulation and culminates with the students designing, constructing, testing, evaluating and reporting on their design solution. The program bridges math and science content with engineering to better prepare students to pursue engineering or technology related careers. Between 2003 and 2007 there has been a decline of enrollments in engineering programs[1], in addition women and minorities are underrepresented in the science and engineering workforce[2], so programs with the same goals as INSPIRES help expose students to careers that involve studying science or engineering. The INSPIRES curriculum is designed to specifically target three Standards for Technology Literacy (8, 9 and 11) set by the International Technology & Engineering Educators Association (ITEEA) which focus on student understanding of engineering design & attributes and the ability to apply the design process.

Each module begins with a pre module online assessment to obtain baseline knowledge, interest and attitude possessed by each student. The students are then introduced to the design challenge by watching a professionally produced video which provides the real world context of the challenge and how the solution can benefit society. To introduce the students to the design process, teams of students are given a mini design challenge (which is related to the culminating design challenge) and are asked to provide a design solution in one class period. Over the next several class periods, the students participate in a combination of online content lessons threaded with classroom demonstrations and hands on activities illustrating and reinforcing the science content which relates to their design challenge. The students also work with an online mathematical simulation so that they can learn how key components will affect their design. After the students are exposed to the necessary concepts, the students go through the design process as they design, construct, test and evaluate their design – the students are allowed several class periods for this part of the curriculum. At the end of the module, the students take the post assessment to determine learning. The modules are designed to be low cost and utilize commonly available software in order to make the curriculum accessible to most school systems.

The INSPIRES curriculum module which was used this year was Engineering in Health Care: A Heart Lung Case Study. In this module students are introduced to a 13 year old patient, Tynisha, who was born with a heart defect which had to be surgically corrected. During this life saving surgery, Tynisha had to be placed on a heart lung machine. The students are challenged to design a mock heart lung system which has a variety of design constraints – the system has to maintain a biologically safe 'blood' (water is actually used) flow rate using one of the provided pumps, provide a functioning 750 mL reservoir (which acts as the lungs of the heart lung system) and cools the 'blood' between 5-8 $^{o}$C during the 15 minute testing period, all while minimizing system leaks and cost. The initial mini-design challenge is to create a system to transport 500 mL of water a distance of 6 feet in the shortest time possible, while minimizing leakage. The teams are provided tubing of varying diameters in two foot lengths, connectors, funnels, ties and empty bottles, for this mini challenge. Then the students go through an assortment of hands on activities, demonstrations, animations and computer simulations that teach them about the principles involved in a heart lung system, including fluid flow, heat transfer and how different pumps work. The mathematical simulation systemically integrates each principle and explores how manipulation of each variable affects the rate of heat transfer of a heart lung system. The students then apply their newly acquired knowledge to build and test their heart lung system, using the steps of the design process.

**Professional Development Workshop**

The original INSPIRES project did not focus on professional development – however, two day PD workshops were held to introduce technology education (and science) teachers to the new curriculum. Each workshop focused on a single curriculum module. The goals were to train the teachers to use the curriculum and to maximize the integrity of the implementation. Over the two days, teachers were given an overview of the module and then experienced the curriculum as students in the order and format it would be implemented in the classroom. The workshop activities included lecture style presentations, self-paced online tutorials and hands on activities, design challenges and demonstrations. Open discussion was integrated throughout the workshop in order to clarify content and address concerns of the teachers. While two days of PD was sufficient for some teachers to feel comfortable with the INSPIRES curriculum module, some teachers need extended training that focuses on content, pedagogical approaches and actual design & construction of the culminating design challenge.

With funding obtained from the NSF Discovery Research K-12 program, a three week Professional Development workshop was offered to in-service technology education teachers who were interested in using the INSPIRES Heart Lung module with their classrooms during the 2010-11 academic year. The three week PD workshop adapted the Threaded Professional Development (TPD) framework (which was previously developed for use with science inquiry) to a model appropriate with the context of the INSPIRES curriculum. The results of the three week PD workshop was compared to the two day workshop using the same INSPIRES curriculum Hemodialysis module has been previously reported[3]. In designing the three week

Professional Development workshop, we drew upon the latest professional development literature[4-11]. From this research base six core components of what constitutes 'high quality' professional development were found in multiple studies. These components include:

- Immersing participants (teachers) in inquiry, questioning and experimentation;
- Intensive and sustained support;
- Engaging teachers in concrete teaching tasks that integrate teacher's experiences;
- Focusing on subject-matter knowledge and deepening teacher content knowledge;
- Providing explicit connections between the Professional Development activities and student outcome goals; and
- Providing connections to larger issues of education/school reforms.

The PD workshop threaded the use of the INSPIRES curriculum (with a new Heart-Lung system module) throughout all components of the PD which include a content course, practice instruction, reflection, and post PD enactment. In addition to using the curriculum with the teachers, specific activities from the materials were used to illustrate key ideas or to serve as 'jumping off' points for discussions. In this instance the use of the materials allows the faculty to model pedagogical practices, a recognized professional development 'best practice'[10]. The teachers utilized these same strategies and materials as they formed small teams to plan and practice teach, the same curriculum to Upward Bound students in the afternoon sessions. In this situation, the curriculum materials are used as a mechanism to engage teachers in concrete tasks of teaching, assessment, observation, and reflection that illuminates the processes of learning and development, and grounds the professional development in inquiry, reflection, and experimentation that are participant-driven[11]. By threading the innovative materials throughout the entire PD workshop, the participants learned far more than just the mechanics of a new curriculum. In addition, a master teacher, who attended this extended PD workshop last summer and implemented the curriculum in her classroom during the 2009-10 academic year, also helped deliver the workshop. This provided invaluable insight and credibility to the INSPIRES team.

The teachers were videotaped during their Upward Bound teaching session, which aided the final element of the PD workshop, reflective critique. At the end of the teaching session each team of teachers reviewed the videotapes and compiled a set of clips which illustrated what was done particularly well and what needed improvement ('missed opportunity'). The critique focuses on specific pedagogical strategies (e.g. context, making meaning), and this reflection is done collaboratively by the teachers, engineering and education faculty. Based on the observed teaching behaviors, targeted instruction in pedagogy was provided.

Another added benefit of the extended PD workshop allowed each of the teachers to design, construct, test and evaluate their own heart lung system. The engineering design process is one that is best learned by doing rather than by seeing the solution. Another unexpected benefit was that the teachers were able to identify common areas where the students may encounter challenges during the construction of their design. After identifying these areas, the teachers prepared short lessons to help the Upward Bound students overcome these challenges in the afternoon sessions. After the final testing period of their design, each group explained their design to the rest of the workshop participants. This was followed by the engineering and education faculty members asking a series of probing questions regarding their design to ensure that understanding of each core engineering concept is based on the design criteria, contextual information and is grounded in science/math principles. This further fostered the mind set required for the evaluation of the design which the teachers then mimicked with their Upward Bound students.

## Results and Discussion

One of the goals of the professional development workshop was to build teacher knowledge and skills in areas needed to successfully implement the curriculum. As an initial step, the INSPIRES team and the external evaluation team generated a list of skill areas felt to be needed by teachers to successfully implement the module. The skill areas include:

- Pedagogy
- Engineering design process
- Comfort/skill with tools
- Math and science content knowledge

The evaluation and project teams developed measures for each of these areas. Teachers completed measures in all four areas at the beginning of their participation in the workshop and at the end of the workshop. As demonstrated below, during the PD workshop teachers made major increases in each of the areas (although, some more than others).

### Pedagogy

In order to judge the effectiveness of the PD workshop, teachers were asked to indicate their preparedness and attitudes of seven student-centered pedagogical strategies. To quantify this, the teachers completed surveys to indicate how important, how prepared and how often they had implemented each of the strategies during the 2009-10 school year. At the end of the PD workshop the teachers completed the same survey but now indicating how often they planned to implement each strategy during the 2010-11 school year.

**Table 1: Teacher Ratings of the Importance, Preparedness, and Frequency of Implementation of Strategies Tied to Effective Science and Technology Instruction***

| | **Importance** | | **Prepared** | | **Implementation** | |
|---|---|---|---|---|---|---|
| | 1=Very Important to 5=Not at all Important | | 1=Well Prepared to 5=Not at all Prepared | | 1=Always to 5=Never | |
| | **Pre** | **Post** | **Pre** | **Post** | **Pre** | **Post** |
| Have students participate in hands-on activities. | 1.08 | 1.00 | 1.25 | 1.17 | 1.67 | 1.33 |
| Engage students in open-ended problem solving. | 1.17 | 1.17 | 1.58 | 1.25 | 2.17 | 1.42 |
| Engage students in inquiry-based learning. | 1.25 | 1.00 | 1.64 | 1.17 | 2.18 | 1.27 |
| Make connections between science and engineering. | 1.25 | 1.17 | 2.00 | 1.25 | 2.17 | 1.58 |
| Work on solving real-world problems. | 1.33 | 1.17 | 1.67 | 1.25 | 2.42 | 1.50 |
| Do design exercises with constraints. | 1.58 | 1.00 | 2.00 | 1.08 | 1.83 | 1.25 |
| Write reflections in a notebook or journal. | 2.17 | 1.42 | 2.18 | 1.50 | 3.00 | 1.73 |

*Shaded cells indicate a statistically significant pre/post differences ($p<.05$).

As indicated in Table 1, the teachers came to the PD workshop feeling that all seven strategies were important, and felt that writing reflections in a notebook or journal and doing design exercises with constraints as statistically more significant at the end of the workshop. This result is not surprising since the teachers themselves completed the design challenge and were required to journal in their design notebooks during the workshop. The teachers also felt well prepared to implement each of the strategies and felt they were significantly better prepared to implement two of the strategies – making connections between science and engineering and doing design exercises with constraints. The most encouraging differences were in the implementation category – where teachers indicated that they planned to implement all seven strategies significantly more than they had previously. It is important to note that this is self reported data – the pre/post RTOP scored videos will help determine if the teachers actually implement these strategies. (At this time the RTOP scores have not yet been compiled since the majority of the teachers are just now implementing the curriculum in their classrooms, however, this analysis will be included in the conference presentation.) One of the current authors of this paper has previously used RTOP scored videos and has found statistical significant improvement in teacher inquiry-based pedagogy was demonstrated[12]. Follow up qualitative data in the form of journal entries were then used to determine which elements of the Professional Development program were considered as significant contributors to the gains in teacher inquiry-based instruction. Key factors included the use of curricular materials that provide concrete examples of inquiry-based lesson plans, the practice teaching and subsequent post-teaching reflections.

**Engineering Design Process**

Prior to their participation in the PD workshop, teachers were asked how they would describe the Engineering Design Process. Seven teachers (58%) included one or more of the seven steps of the INSPIRES' Engineering Design Process in their responses. After the workshop, all 12 teachers included one or more of the seven steps; the average number of steps included by each teacher increased from 3.3 to 5.2. Four teachers included six of the steps and three included all seven. As Table 2 indicates, at the end of the workshop teachers were much more apt to include "communicate the solution" in their description.

**Table 2: Teachers' Understanding of the Engineering Design Process**

| **The INSPIRES Engineering Design Process** | **Number of teachers including the step in their response** | |
|---|---|---|
| | **Pre-Institute** | **Post-Institute** |
| Identify and Define | 6 | 9 |
| Generate Ideas | 6 | 10 |
| Select Best Solution | 6 | 9 |
| Model the Solution | 6 | 9 |
| Evaluate the Solution | 6 | 9 |
| Refining (Iteration) | 5 | 7 |
| Communicate the Solution | 1 | 8 |

## Level of Expertise with Tools

Teachers were asked to rate their level of expertise in using different tools and performing various tasks that the INSPIRES team felt were needed to implement the heart lung module – the results can be found in Table 3. After participating in the PD workshop, teachers reported significantly greater expertise in 8 of the 11 areas. Not surprisingly, teachers came into the workshop with a great deal of experience in two of the areas; there was not a significant change in these areas (use of glue guns and use of common tools). Areas with the greatest increases, also not surprisingly, included coupling tubing of different diameters, sealing leaks, and working with pumps – which are all important in the implements of the heart lung system design challenge and the teachers had a significant amount of practice with these area during the workshop.

**Table 3: Teachers' Self-Reported Level of Expertise with Tools and Skills (1=Very High, 5=Very Low)**

| | Pre | Post |
|---|---|---|
| Using a glue gun/heat gun | 1.50 | 1.25 |
| Using common tools (i.e. screwdrivers, hammers, saw) | 1.75 | 1.58 |
| Wiring a switch** | 2.45 | 2.36 |
| Measuring volumes | 2.67 | 2.00 |
| Using a voltmeter/other meters | 2.75 | 2.08 |
| Using a soldering iron | 2.83 | 1.96 |
| Projecting from 3D to 2D (or vice versa) | 2.83 | 2.00 |
| Predicting gear movement | 2.92 | 1.83 |
| Coupling tubing of different diameters | 3.17 | 1.75 |
| Sealing leaks** | 3.18 | 1.91 |
| Working with pumps | 3.25 | 1.92 |

*Shaded cells indicate a statistically significant pre/post differences (p<.05).
**For these items, n=11

## Math and Science Content Knowledge

At the beginning and end of the PD workshop, teachers were asked a series of content questions about metric unit conversions and independent and dependent variables. During the workshop, nine teachers became more proficient at doing unit conversations, two remained at the same level, and one decreased (this teacher had 3 correct in the pre-assessment and only answered one correct of the 14 questions in the post-assessment). Pre-scores ranged from 93% to 7% with an average of 49%. Post-scores ranged from 100% to 0% with an average of 81%. With the exception of the one 0% score, the lowest post-test score was 79%. The items with the lowest percentage correct were kilometer to miles conversion (58% correct) and centimeter to meter conversion (42% correct). There was less change in teacher scores on the one multiple-choice and two open-ended items dealing with independent and dependent variables. Six teachers had no change in their scores, four increased their scores, and two decreased their scores. The average pre-score was 54% while the average post-score was 57%.

To quantify content learning during the INSPIRES curriculum the teachers (and students) were asked to complete the on-line content pre-assessment and post-assessments. Over the last few years, the INSPIRES team has observed that often the learning data was incomplete since many students do not complete the post assessment (or provide nonsense answers). This was also found to be the case with the teachers who attended the PD workshop. The learning data for 6 teachers (of a possible 12) was collected and evaluated and is displayed in Figure 1.

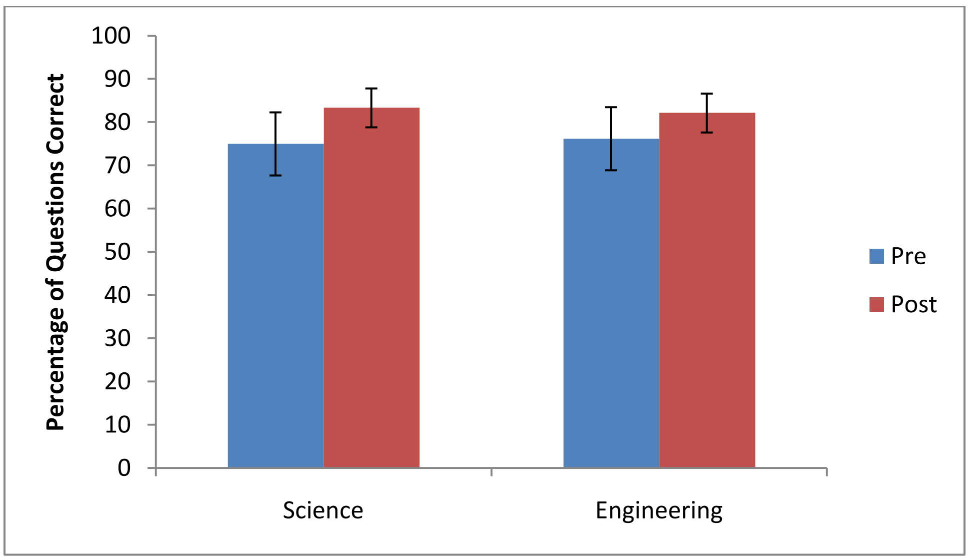


**Figure 1: Teacher learning data from "Engineering in Healthcare: A Heart Lung System Case Study" in the 2010 PD workshop. Mean score ± standard error for 6 teachers.**

Figure 1 shows that science scores went from 75 (± 16.67%) to 83.33 (± 11.78) and the engineering scores went from 76.19 (± 9.49%) to 82.14 (± 5.98). This data represents only six of the 12 teachers who attended the PD workshop. There was no statistically significant increase in the scores.

## Conclusions, Challenges and Sustainability

The PD workshop not only benefited the teachers, but it also served to improve the Heart Lung module. Working side by side with the high school teachers and Upward Bound students provided an opportunity to get real time feedback for the curriculum. This collaboration between the teachers, master teacher, facilitators, students and the external evaluation team proved to be invaluable and catalyzed changes and improvements within the course content. These changes serve to strengthen the focus of the content through a collaborative effort between the researchers and teachers and further increase the ease of implementation in the classroom.

In the last six years, our experience with high school technology education professional development workshops, we have encountered various challenges[13-14] which included:

- The wide range in technology education teacher backgrounds and experience levels makes it difficult to design a 'one size fits all' PD strategy. We acknowledge that a 'one size fits all' strategy may not be optimal given the diversity of teacher backgrounds, so a specific goal of our current work is to identify the characteristics of teachers who will benefit from extended PD.
- Many technology education teachers herald from vocational backgrounds and simply lack the fundamental mathematics and/or science skills necessary to easily implement engineering based curriculum (such as the INSPIRES curriculum).
- We have observed a general tendency to minimize or downplay the mathematical and simulations portions of the curriculum in a rush to build something.
- Through classroom observation, we have also observed that few teachers explicitly discuss the design challenge with students groups in the context of the scientific and mathematical concepts presented in the curriculum. The tendencies are problematic since we consider such integration of concepts to be a primary core skill that students need to develop. Many current technology education teachers appear to be weak in this type of integration skill.
- Teachers are often uncomfortable with the 'open-endedness' of engineering design (and the idea that there is not a single correct solution) and lack the experience in guiding students groups in open-ended exercises.
- Teachers consistently request help during implementation and need a high level of support that is not sustainable for engineering faculty.

As the results presented demonstrate, teachers made statistically significant gains in pedagogy (self reported), understanding of the engineering design process, comfort/skill with tools and math & science content knowledge. However the pre/post module online assessment in science and engineering content learning improvements were not statistically significant for the six teachers who completed the assessment.

While the contents of the three week PD workshop were useful to increase the implementation preparedness of the teachers in key strategies and design process knowledge, it has a significant associated cost. The results of the PD workshop are being analyzed by the INSPIRES team and the external evaluation team to determine what was most effective and what can be omitted. The goal is to make the PD workshop as effective as possible, while minimizing the resources needed. Next summer the INSPIRES team will offer two Professional Development workshops: a three week PD workshop similar to the ones offered for the last two years and a new three day PD workshop, a shorter more compact alternative which can ultimately be sustainable. This will allow comparison to be made, between the two workshops which utilize the same curriculum and workshop facilitators, on teacher comfort of implementation and impact on student learning; as we continue to identify the characteristics of teachers who benefit from extended Professional Development.


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