Robert Reeves, University of Maryland, Baltimore County
Robert Reeves graduated Magna Cum Laude in 2009 with a BS degree in Chemical Engineering from the University of Maryland, Baltimore County. He will finish his MS in Chemical Engineering also from UMBC in May 2010 and will begin his career with OSIsoft, LLC. He has been working on the INSPIRES program for the last year.

Julia Ross, University of Maryland, Baltimore County
Julia Ross is Professor and Chair of the Chemical and Biochemical Engineering Department at the University of Maryland, Baltimore County. Her technical research interests are in the area of cellular engineering. In particular, her work focuses on bacterial adhesion to physiological surfaces. In addition, she maintains an active research program in curriculum development with a focus on workforce development. She is also the 2007 recipient of the ASEE Sharon Keillor Award for Women in Engineering Education.

Taryn Bayles, University of Maryland, Baltimore County
Taryn Bayles is a Professor of the Practice of Chemical Engineering in the Chemical and Biochemical Engineering Department at UMBC, where she incorporates her industrial experience by bringing practical examples and interactive learning to help students understand fundamental engineering principles. Her current research focuses on engineering education, outreach and curriculum development.
A Novel Approach to Professional Development

Abstract

The INSPIRES project (INcreasing Student Participation, Interest, and Recruitment in Engineering and Science) stemmed from an NSF-IMD grant and focuses on developing engineering curriculum to introduce high school students to the engineering design process. Curriculum features include professionally produced video segments, a large culminating open-ended engineering design challenge, online content with interactive animations, an online mathematical simulation, and a variety of hands-on activities. One module included in the curriculum is Engineering in Health Care: A Hemodialysis Case Study, which has been used successfully for the past four years. Data has shown that the curriculum is effective at increasing student interest and learning engineering design and science content.

Initially, we have focused on developing the curriculum and teacher Professional Development (PD) was limited to just two days. With the support of an NSF-DRK-12 grant and by partnering with the Education Department, we are currently working to enhance the PD program for the high school teachers. The new PD program threads the use of the INSPIRES curriculum with deepened content, practice instruction, and reflection. The morning sessions focus on deepened content, taught by engineering faculty modeling pedagogical “best practices”. This was followed by teachers going through the section of the curriculum that paralleled the content lesson, including hands-on activities and the online module. In the afternoon sessions, the teachers applied their new found technical and pedagogical knowledge as they taught the curriculum to students enrolled in the Upward Bound program. While teaching, the teachers were videotaped and observed. After the lesson each day, the teachers reviewed videotapes and highlighted what went well and what needed improvement. Together, the teachers and PD facilitators provided constructive criticism on how to improve the delivery of the curriculum. This provided a unique type of feedback that most teachers had not received before. In July 2009, this PD program was piloted with 12 pre-engineering/technology high school teachers using the Engineering in Health Care module. This module was chosen because of its proven success and available student learning data compiled from previous years.

All of the teachers who attended the PD program last summer plan to implement the Health Care module in their respective class rooms during the 2009-2010 school year. Student learning data will be collected and compared to past years data to quantify the success of the PD program.

Background

INSPIRES Curriculum

The INSPIRES curriculum, funded by the National Science Foundation, has been developed and continues to be expanded to increase recruitment of students in STEM-related fields. This program serves to combat the trend of declining engineering enrollment within the
U.S. The curriculum aims to accomplish this goal by developing curriculum that exposes students to the engineering design process through real-world engineering design challenges and using iterative, inquiry-based learning pedagogical methodology. The INSPIRES curriculum is designed to specifically target three Standards for Technology Literacy set by the International Technology Education Association (ITEA):

Standard 8: Students will develop an understanding of the attributes of design.
Standard 9: Students will develop an understanding of engineering design.
Standard 11: Students will develop abilities to apply the design.

The curriculum currently consists of five modules that use real-world problems within several disciplines of engineering to teach students about the design process. Each module takes the same general structure. A pre-module assessment is given to obtain a baseline of the knowledge possessed by each student. Then the students watch a short video of an engineer discussing the real-world problem that the module targets, the challenges that must be overcome to find a solution, and how the solution can benefit society. Afterwards, the students form groups of three to five people and are given a mini-design challenge that relates to the overall problem. They are given approximately one hour to use the predetermined supplies to develop a solution that meets the constraints and goals of the mini-design challenge. This serves as an introduction to the design process. Over the next several class periods, the students participate in a combination of online lessons and simulations, threaded with classroom demonstrations and hands-on activities illustrating and reinforcing the online contents. After the students are exposed to all the necessary concepts, they build a device that serves as a solution to the main design challenge. Over the course of multiple class periods, the students go through the design process, until a final design is reached. The students take the post-assessment test to determine how much they learned from the module. Last, the module is ended with another mini-design challenge aimed at ending the module on a fun, stress free note that leaves the students excited about engineering.

Engineering in Health Care

The focus of this year was the Engineering in Health Care: A Hemodialysis Case Study module. In this module students are introduced to a patient suffering from kidney disease, which, along with her doctor, explains how hemodialysis works and has benefited her life. The students are challenged to design a mock hemodialysis system that is subjected to constraints, such as costing below 50 dollars and removing at least 2.5mg of waste (yellow dye) from 500 ml of simulated blood in five minutes of operation. The opening mini-design challenge is to separate one cereal from a mixture containing a variety of cereals. The students then go through an assortment of hands-on activities, demonstrations, animations and computer simulations that teach them about the principles involved in hemodialysis including diffusion, porous membranes, and fluid flow. The simulations systematically integrate each principle and explore how manipulation of each variable effects a hemodialysis system's efficiency. The students then apply their new-found knowledge to build and test their hemodialysis systems, using the steps of the design process.
Before implementing the Engineering in Health Care module for the first time, the high school teachers were required to participate in a two day professional development (PD) workshop. The focus of this workshop was to introduce the teachers to the contents of the module. The teachers spent the majority of each day going through the module while the facilitators guided them, answered any questions, and provided the teachers with deepened background about the concepts. On the first day, the teachers participated in the introduction, mini design challenge, hands-on activities, and started the online content lessons and simulations. On the second day, the teachers finished the online portion of the module. Then the main culminating project, building a hemodialysis system was reviewed. The goal, constraints, and “bragging rights” were explained and examples of past projects were shown. Next, the teachers completed the closing mini-design challenge. The training ended with a 45 minute session with experienced teachers to provide guidance on how to implement the curriculum in the classroom.

To judge the effectiveness of the module, the students took a pre and post-assessment. The assessment was comprised of both multiple choice and free response questions that evaluated each student’s knowledge pertaining to the scientific principles involved in hemodialysis and the engineering design process. Fourteen questions about the scientific principles and eight about the engineering design process were evaluated in both the pre and post-assessment. The questions were developed by the IMD INSPIRES team (which consisted of engineering faculty, graduate students and high school technology education teachers). Examples of the questions asked can be found in Appendix A. Past data has shown that this module has been successful at increasing the students understanding of the underlying scientific principles and the engineering design process.

![Figure 1: Student learning data for Engineering in Health Care module during 2006-2007 school year. Mean assessment scores ± standard error of the mean (n=158).](image-url)
Figure 1 illustrates students improved both their scientific and engineering scores after participating in the Engineering in Health Care model. The data chosen includes only the teachers implementing the module for the first time. Since it will be compared to the data generated during the 2009-2010 school year, which contains only teachers new to the module. The science scores went from $63.6(\pm1.8\%)$ to $78.8(\pm1.5\%)$ and the engineering scores went from $27.2(\pm1.0\%)$ to $42.3(\pm1.4\%)$. The statistical significance of these increases was analyzed with a one tailed t-test, and the p-values for the science and engineering sections were $4.0\times10^{-22}$ and $5.0\times10^{-30}$ respectively. This indicates that there is a significant increase in the student’s knowledge after participating in the module that cannot be accounted for simply through experimental variation, indicating after participation in the module the students possessed more knowledge on the subjects of interest.

**Professional Development Course**

After collecting the student learning data for several years and receiving positive results, the focus shifted to improving the PD training course. There were several aspects of the two day training course that needed to be further developed. First, the Engineering in Health Care module is estimated to take 20 classes of 45 minutes periods (15 hours). This implies two seven hour days, including lunch and instruction, is insufficient to cover all the material necessary in a manner that the teachers will fully understand and absorb it. For example, the teachers had to forgo designing and building their own hemodialysis system and in place were simply shown working examples. However, the design process is one that is learned best by doing, not seeing. Another aspect of the PD training that was missing was a substantive pedagogy curriculum. The lack of time also forced the facilitators, which included engineers only, to refrain from providing a formal time period for the teachers participating in the PD training to practice teaching what they had learned. Consequently, the teachers did not have the opportunity to test, evaluate, and revise their understanding of the module before implementing it in the classroom.

With the support of an NSF-DRK-12 grant and by partnering with the Education Department, the focus for this year was to enhance the PD training coupled with the Engineering in Health Care module to further increase its efficacy and ease of implementation for the high school teachers. The structure of the PD training was changed dramatically. It moved away from a passive transmission style to an active inquiry-based process, just like the engineering design process and the actual module.

The length of training increased to three weeks of seven hour days. Days were broken into three distinct sections. In the morning section, the facilitators exposed the teachers to the course content and pedagogical methodology. This builds on past PD courses that have shown an inquiry-based structure combined with a focus on pedagogy is an effective means to increase teachers understanding and preparedness of K-12 engineering curriculum.\textsuperscript{3,4} This intertwining of inquiry-based learning and pedagogy has served as an excellent start to bridging the gap between engineering content and effective teaching strategies. However, like any engineering design project, the iterative process of field testing and refining to create the best possible design is needed. Another novel aspect of the PD training was added to provide this iterative step and an opportunity to further solidify the new material. In the afternoon section, the teachers were
given a chance to teach the module contents to students enrolled in the Upward Bound Program and then assessed each of their own and peers performances.

**Figure 2: Schematic of the general structure of each day in the PD course.**

**Morning Section**

The morning session was formatted in such a way that the teachers were introduced to the course content using the same, inquiry-based pedagogy that was intended for them to use in their classrooms. The general outline of the Engineering in Health Care module was followed, but it was also threaded with lessons that focused on extending the teachers technical and pedagogical knowledge. To meet the needs of this extended focus, in addition to the engineering facilitators, several education facilitators were added, including one with a strong background in biology.

The first day of the morning session began just as it does for the students. The teachers took the pre-assessment and were introduced to the main design challenge, designing a hemodialysis system. As an introduction to the subject, a Know, Want to Know, Learned (KWL) table was used to generate subquestions for the driving question, “What is hemodialysis?” An example of a subquestion that arose is “How does hemodialysis clean blood?” By generating this list of subquestions, the activities throughout the module are able to be anchored to these subquestions as answers that the participants arrived at through their own hands-on experiences during the module. As the subquestions are answered, the information can be added to the “Learned” section of the KWL table as a visual reminder of the event that each question is anchored to. Ideally, by the end of the module, all of the subquestions will have been answered, leading to a thorough understanding of the driving question. The importance of this step was discussed with the teachers and was recommended to be used as an opening tool, for not just the main design topic, but also any of the subtopics within the module.
The teachers then participated in the opening mini-design challenge, where they were tasked to build a device to separate one type of cereal from a mixture of cereals. In addition to discussing how the activity related to the design process and the idea of filtration, the teaching side of the activity was discussed as well. The suggested grading rubric, which is provided in the teachers manual and is based off of the ITEA standards for evaluating engineering design challenges, was discussed in detail and the teachers were given the opportunity to voice their concerns and input. This was vital, because grading an engineering design is not as clear cut as other projects and many of the teachers initially felt uncomfortable with it before the discussion. In the previous two day PD training course, this type of discussion would have been limited to remain on schedule.

The next pedagogical method the teachers were introduced to was what is called an “artifact.” An artifact is an idea or object that relates to the course content in some manner. At the end of each part of the module, the participants were required to present an artifact relating what they learned. These artifacts are to be explained by the participants about how they relate to the concept, critiqued, and revised to act as a formative and summative assessment. To serve as a reminder, these artifacts can be put on display somewhere in the classroom, physically anchored on the concept they represent (i.e. on the KWL table). This process serves as an opportunity to apply the concepts learned and reinforce the ideas. Last, artifacts brings clear closure to the lesson.

For example, one of the hands-on activities is called, “Visualizing Dialysis.” The activity starts by placing a dialysis membrane filled with simulated blood containing mostly red dye and a smaller portion of yellow dye into a cup of water. When the dialysis membrane is placed in water, only the yellow dye diffuses through the membrane because the red dye molecule is too large to fit through the dialysis membrane’s pores. At the end of the activity and subsequent discussion of the scientific phenomena occurring, the teachers were asked to bring in an artifact that illustrates the concepts demonstrated in this activity. The next day teachers brought in artifacts such as teabags and coffee filters.

The technical lessons included topics such as kidney function, mass transfer, diffusion, and fluid flow. The hands-on activities were threaded within the technical lessons. After each technical lesson and subsequent hands-on activity, each participant had to write a take away sentence describing the main point of the lesson. This was also suggested for use as a pedagogical method to be applied when teaching the students. For example, one of the hands-on activities explores the temperature effects on diffusion. A drop of food dye is placed in ice water and hot water to compare the rates of diffusion. The consensus for the take away sentence was that diffusion increases with increasing temperature.

After the in depth look at the course contents, the teachers went through the online part of the module that goes over above mentioned technical concepts. A facilitator went through the online content with them and acted as a guide to make the connections from the hands-on activities to the online animations and simulations. The teachers revisited their take away sentence from each concept lesson and discussed how they were illustrated in each simulation. This was used to reinforce the technical concepts while putting them in the context of the hemodialysis simulations.
The one sentence summaries of each concept were also used to introduce another pedagogical strategy, the use of a reflections notebook. At the beginning of the module, each participant is given a notebook to keep a record of their progress and understanding of the material. In key areas, the teachers can use this as a way to get the students to organize and record the information in a concise way they understand. The reflection activity can also be used to foster a discussion on the topic by asking students to read their take away sentence of the topic and then discussing their conclusions.

After completing the online course contents, the teachers had an opportunity to apply their knowledge and experience the design process by designing and building their own hemodialysis system. This is one of the most important changes of the PD training course. The design process is an engaging process where some problems (and therefore learning opportunities) simply cannot not be predicted and must be gained from first hand participation. This gave the teachers an opportunity to not only apply the design process, but also gave them the opportunity to evaluate and refine their knowledge of the technical concepts as well. When problems arose during the students’ development of their hemodialysis systems, the teachers also have the experience to be able to relate to them and help move past the issue.

Each group was given the opportunity to test their project multiple times. After the final testing period, each group explained their design to the rest of the class and reflected on what went well and what needed to be changed. This further fostered the mind set required for the evaluation part of the design process. Another unexpected benefit was that the teachers were able to indentify common areas where the students may have trouble. After identifying these areas, the teachers prepared short lessons to help the Upward Bound Students meet these challenges in the afternoon sessions.

Afternoon Section

In the afternoon section, the teachers taught the module contents to students enrolled in the Upward Bound Program. The goal of the Upward Bound Program is to encourage high school students from low-income families whose parents do not possess a bachelor’s degree, to strive to go to college. There were three classrooms, each containing approximately 12 upward bound students. The teachers remained in the three groups from the morning section, each taking a classroom. Each teacher had an opportunity to teach the class individually. They were required to plan the lesson and prepare their lesson plans (i.e. Supplemental PowerPoint presentations) and incorporate the pedagogical methods used in the morning section. In the parts of the module that did not include a formal lecture, such as during the mini-design challenge, all teachers circulated the classroom to assist the students when needed, taking on the role of not only a teacher, but also a collaborator.
The purpose of this aspect of the PD training was to provide the teachers with a platform to practice teaching the module using the new pedagogical methods. This opportunity was unique because it provided an environment that allowed the teachers to focus solely on teaching. In each teachers respective classroom, their focus will have to be divided between several factors such as getting the materials ready (i.e. computers), grading, attendance, and so on. Also, it forced the teachers to test the limits of their understanding of the material while simultaneously helping to solidify what they have learned through repetition. Through teaching the material, the teachers were able to identify areas they did not understand fully while the resources, the facilitators, are still present to help resolve these discrepancies. Last, this experience gave the high school teachers the confidence to teach the material with new pedagogical strategies and aimed to remove the stresses associated with the trying something new, making for a smoother implementation process for all parties involved.

During the Upward Bound teaching session, the teachers were also videotaped. This aided the final element of the PD training each day, reflective critique. Each group of teachers reviewed the videotapes and compiled a set of clips that illustrated what was done particularly well and what needed improvement (called a “missed opportunity”). This exercise was used to make the teachers actively evaluate their performance. After the teachers in each group were done putting together their clips, everyone came together and each group presented their clips. At this point, the clip was used as a tool to further enforce what was taught in the morning session. After positive clips, the teachers and facilitators had a short discussion on what worked well. After clips that illustrate examples of teaching events that could be improved, the other teachers and facilitators offered their advice and constructive criticism. This was also important because, despite all being technology education teachers, they came from a diverse range of backgrounds ranging from retired engineers to a U.S. naval officer to a former physical education teacher. This means advice was drawn from people with a vast range of experiences. Through free discussion, the best ideas naturally came into focus, just as in brainstorming during the engineering design process.

**Results and Conclusions**

**Student Learning Data**

The student learning data is currently being collected from eleven of the high school teachers, with an estimated total of 900 high school students participating in the Engineering in Health Care module. The student’s learning was quantified with the same pre and post-assessment used to collect the data in Figure 1 in order to be able to compare this year’s data to
past year’s data. Thus far, data shows that the module has increased the students understanding of the scientific and engineering design concepts.

**Figure 3:** Student learning data for Engineering in Health Care module during 2009-2010 school year. Mean assessment scores ± standard error of the mean (n=45).

Figure 3 shows the science scores went from 51.6(±2.3%) to 77.5(±2.5%) and the engineering scores went from 49.9(±2.6%) to 65.7(±2.4%). This data represents 45 students taught by 2 teachers. All of the students were in the 9th or 10th grade. The statistical significance of these increases was analyzed with a one tailed t-test, and the p-values for the science and engineering sections were 1.1e-12 and 1.9e-8 respectively. This indicates that there was a statistically significant increase in the student’s post test scores.

Next, the percent difference between the pre and post-assessment data was compared to the percent difference of the data from the 2006-2007 school year. In the 2006-2007 school year, teachers participated in the two day PD training course and in the 2009-2010 school year, the teachers participated in the three week PD training course.
Initial results suggest students who had teachers from the three week PD performed better than those who had teachers in the two day PD course in the scientific principles evaluation. The increase was statistically significant, with a one-tailed, unpaired t-test returning a p-value of 3.7e-4 when compared. There was relatively no change in the increase of the student's understanding of the engineering concepts when using the new PD structure, with a one-tailed, unpaired t-test returning a p-value of 0.39. With these results, it is apparent the new PD course more effectively prepared the teachers to teach the scientific principles, but could use refining with respect to engineering principles. This information will be used to refine the contents of next the summer 2010 PD course. The results will continue to be updated as more student data from the other nine teachers becomes available and is processed.

Teachers Preparedness and Attitudes

Another aspect used to judge the effectiveness of the updated PD training was the teacher’s preparedness and attitudes towards the Engineering in Health Care module. To quantity this, an external evaluator extracted this data from the teachers who participated. The teachers were given an in depth survey before and after the PD training.
Table 1: Teacher Ratings of the Importance, Preparedness, and Frequency of Implementation of Strategies Tied to Effective Science and Technology Instruction. Shaded cells indicate a statistically significant pre/post differences (p<0.05).

<table>
<thead>
<tr>
<th>Importance</th>
<th>Prepared</th>
<th>Implementation</th>
</tr>
</thead>
<tbody>
<tr>
<td>1=Very Important to 5=Not at all Important</td>
<td>1=Well Prepared to 5=Not at all Prepared</td>
<td>1=Always to 5=Never</td>
</tr>
<tr>
<td>Pre Post</td>
<td>Pre Post</td>
<td>Pre Post</td>
</tr>
<tr>
<td>Make connections between science and engineering</td>
<td>1.17 1.25</td>
<td>2.08 1.33</td>
</tr>
<tr>
<td>Have students participate in hands-on activities</td>
<td>1.08 1.08</td>
<td>1.50 1.17</td>
</tr>
<tr>
<td>Engage students in inquiry-based learning</td>
<td>1.00 1.09</td>
<td>2.17 1.33</td>
</tr>
<tr>
<td>Write reflections in a notebook or journal</td>
<td>1.83 1.58</td>
<td>2.08 1.58</td>
</tr>
<tr>
<td>Do design exercises with constraints</td>
<td>1.17 1.08</td>
<td>1.67 1.33</td>
</tr>
<tr>
<td>Work on solving real-world problems</td>
<td>1.33 1.08</td>
<td>1.83 1.42</td>
</tr>
<tr>
<td>Engage students in open-ended problem solving</td>
<td>1.17 1.08</td>
<td>1.75 1.58</td>
</tr>
</tbody>
</table>

Table 1 shows the results of a survey given to the teachers before and after the PD training course. The results are encouraging. There was a statistically significant improvement in the teacher’s opinion of their level of preparedness and ability to implement the module in the majority of the categories. There was less of a change in the teacher’s opinions of the importance of each category, but this is due to the fact most categories received strong pre-rankings. The largest average improvement was in the implementation category with a change of -0.84. This result was particularly encouraging because one of the main goals of the modified PD course was to increase the ease of module implementation, thus encouraging more teachers to participate in the program and exposing more students to STEM-related fields. Another result that was encouraging was that the teachers unanimously agreed they would recommend the PD training to their colleagues.
Module Improvements

The extended PD training not only benefited the teachers, but also served to improve the Engineering in Health Care module. Working side by side with the high school teachers provided an opportunity to get real time feedback for the entirety of the module, both communicated by the teachers and observed by the facilitators. This collaboration between the teachers and facilitators proved to be invaluable and catalyzed changes within the course content. For example, the original Engineering in Health Care module contained a section on osmosis. The teachers pointed out that it was not a concept directly pertinent to hemodialysis after they had been able to teach the material. This may have been a concern that teachers have had in the past, but without real time feedback produced through the opportunity to teach during the PD training, the concern may have never come to the researcher’s attention. Their concerns, coupled with the researchers seeing the module implemented in its entirety, catalyzed an evaluation and subsequent conclusion that the osmosis section did not have a strong connection to the overall theme of the module and it was removed. Changes of this nature serve to strengthen the focus of the course content through a collaborative effort between the researchers and teachers and further increase the ease of implementation in the classroom.

Sustainability

While the contents of the three week PD course were all very useful, to increase the sustainability and reach of this PD structure, the results are being used to determine what was most effective and what can be cut. The goal is to make the PD training as effective as possible, while minimizing the resources needed. The three main features of the course (inquiry-based learning, focus on pedagogy, teaching and evaluating performance) proved to be an effective combination, increasing the teacher’s confidence in the course, the student’s scores, and inducing changes in the module itself. However, some specific aspects of the course certainly appeared to be more useful than others.

One important aspect of the PD course was fostering a collaborative environment between the researchers and teachers. It was greatly beneficial to incorporate time for the teachers to discuss their thoughts and ideas on pedagogical methods after going through a particular activity in the module. Each teacher comes from a different background and brings different experiences to the group. By allowing the teachers to collaborate, it serves to allow the best ideas to rise from the sums of the group’s knowledge. The collaboration set up during the PD training did not stop at the end of the three weeks either. Several teachers have remained in contact through email, giving each other advice on how to most effectively implement aspects of the module. Three teachers commented on the external evaluation that better knowledge of their colleagues provided a rich source to draw upon. One way to shorten this exercise is to plan collaborative time periods after areas of particular importance and difficulty instead of after every activity.

Another aspect that proved beneficial was the extended lessons taught for each scientific principle. The teachers clearly had a strong understanding of the scientific principles, and it was likely part of the reason the student’s science scores increased in comparison to the 2006-2007
school year. However to shorten the PD training course, while not abandoning this aspect, instead of teaching the extended lessons PowerPoint presentations could be made for each topic and included in the supplementary materials. Another option would be to record a short lecture and add it to the teacher resources portion of the website coupled with the module.

One aspect that requires more intensive logistics, but was highly beneficial and helped the teachers grow was providing an opportunity to teach and then evaluate their performances. In fact, one of the suggestions given on the external evaluation was to have more time with the students and there were no negative comments about it. To satisfy this suggestion and reduce the time needed, the teachers could teach the students in longer sessions, reducing the time needed each day to get situated and back on track. Also, an abridged version of the module could be taught, cutting out items such as the pre and post-assessment since the student’s grades are not being evaluated. This aspect was important and is worth including for several reasons. First, it provides the teachers with an environment where they can try new pedagogical methods without the fear of it not working out as well as hoped. The video evaluation allows them and others to decide how to improve the new techniques. By making the teachers aware of their own pedagogy, it starts the process of identifying what areas they could improve on. Just like in the design process, this iterative process noticeably improved the teacher’s pedagogy as the PD course progressed. The teaching sessions also allow the teachers to gain confidence in the module, making them more likely to implement in the classroom. While not all facilitators have access to the Upward Bound Program, there are other options. One option that may be more reasonable is to have incoming freshman required to stay on campus for the summer for reasons such as a scholarship bridge program to participate in the module. This can serve to build a relationship between the freshmen in the scholarship program, while retaining this aspect of the PD course. Without this aspect, an opportunity for teacher growth and to further solidify their understanding of the module would not be realized.

**Future Work**

By coupling the student learning data and the results of the teachers feelings about the updated PD training course, necessary changes will be made to further refine the effectiveness of the program. The structure of the PD training course will also be applied to other modules in the INSPIRES Curriculum.

**Acknowledgements**

The funding provided by the National Science Foundation ESIE-IMD and DRK-12 programs is gratefully acknowledged, as well as the participation of the Upward Bound Program students.
References


Appendix

Appendix A. Sample Questions from Pre and Post-Assessment

The picture to the left shows two regions separated by a membrane. Initially, the left-hand side contains water with two sizes of molecules present and the right-hand side has only water.

As time passes, the molecules will move. Which of these pictures shows a system in equilibrium assuming that the membrane is permeable to all species?

On the plots shown below, the x-axis is the independent variable and the y-axis is the dependent variable. What type of relationship between x and y is shown with the plotted data? Match the following terms to the appropriate plots by dragging each item from the left hand column and dropping it on an item in the right hand column. You may undo a selection by clicking on the scissors next to each match line.

[Make up to 3 matches.]

Inverse Relationship
No Relationship
Direct Relationship
The sum of the atomic weights of the atoms that constitute a molecule is:
- Gram-mole
- Energy
- Pore Size
- Molecular Weight

A thin, pliable sheet of material that is often semi-permeable.
- Membrane
- Dialysate
- Polymer
- Surface

A measurement of the amount of fluid transferred from one position to another over a period of time.
- Volumetric Flow Rate
- Velocity
- Hemodialysis
- Equilibrium

Agree or disagree with the following statement and support your argument.

"The engineering design process yields a single unique solution to a problem."