Summer Faculty Immersion as a Strategy to Diffuse Engineering Education Innovations: First Year Results

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Dr. Juan C. Morales is professor and department head of Mechanical Engineering at Universidad del Turabo. He also served as the ABET Coordinator of the School of Engineering until 2011 for the purpose of achieving the initial EAC accreditation of all the engineering programs at Universidad del Turabo. As ABET Coordinator, Dr. Morales had the privilege of working closely with the entire engineering faculty in the process of establishing a systemic and sustainable Outcomes Assessment Program. His current research explores innovations in the classroom and their diffusion.

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Abstract

This paper presents the first-year results of a five-year, externally-funded faculty development program, that is being conducted to develop the 35 faculty members of engineering and physics that teach full-time at Universidad del Turabo in Puerto Rico. The program impacts seven different faculty members per year. The initial effort took place in the Summer of 2012 with five faculty members from Mechanical Engineering, one from Industrial Engineering, and one from Computer Engineering. The program is designed to ignite systemic and sustainable change towards creating a classroom environment that engages students with authentic engineering real-world problems within an inductive teaching/learning environment. The overarching goal of the effort is to increase the graduation rates of engineering students at this Hispanic-serving institution. This model is a possible solution to a problem identified in the recent research literature: despite decades of efforts dedicated to the improvement of engineering education, and despite the many advances that have been well-researched and are readily available in the literature, the faculty are not readily adopting them because the time required to develop them exceeds substantially the normal course preparation. There are several positive indicators that the summer immersion program is working; however, it is still too early to determine if it has achieved “systemic and sustainable change”, and if there is an effect on retention rates, graduation rates, and employer satisfaction. The study has also uncovered two principal weaknesses that must be resolved: 1. insufficient time to cover all the course objectives, and 2. the need to better correlate exam content, grading schemes, and course objectives. Suggestions to improve these weaknesses are provided. In addition, the paper includes details of the structure of the summer program, the results of several surveys conducted to determine the perception of faculty and students, and examples of the innovations.

Introduction

The Summer Faculty Immersion Program (SFIP) strives to ignite and sustain innovative teaching practices in engineering and physics courses with the overarching goal of increasing the graduation rates of engineering students at Universidad del Turabo in Puerto Rico, a Hispanic-serving institution. The basis for the SFIP, and other supporting activities enabled by the Department of Education grant that supports it, have been established by Morales\(^1\). This section restates some of this material to provide the context for discussing the first-year results of the program.

The push for relevant learning experiences, as well as the need to acquire deep levels of conceptual knowledge, has been expressed by Litzinger\(^2\), who indicates “...that engineering education should encompass a set of learning experiences that allow students to construct deep conceptual knowledge, to develop the ability to apply key technical and professional skills
fluently, and to engage in a number of authentic engineering projects. Engineering curricula and
teaching methods are often not well aligned with these goals”. Also, in a recent article that
addresses the challenges of diffusing engineering education innovations, Borrego states that
“despite decades of effort focused on improvement of engineering education, many recent
advances have not resulted in systemic change”. In addition, the Research Council of the
National Academies’ report on transforming STEM education states that support is required to
implement “innovative SME&T course development that exceeds substantially the normal
course preparation commitment”. It also states: “The authoring committee recognizes that
implementing the visions of this report could require new funds or shifts in the allocation of
resources.” The lack of faculty time, and the lack of funding required for course development,
among other issues, are also mentioned by Borrego.

The SFIP addresses the issue of course-preparation time by concentrating the effort
during the summer (month of June), while the faculty members are free from their regular duties
of a typical semester. The issue of funding was addressed through a grant from the US
Department of Education which provides to each participating faculty member a $7,500 summer
stipend, a $2,500 budget to purchase educational materials, and a $2,000 travel budget to be used
for additional professional development. The stipend provides an incentive to ensure that the
faculty will concentrate their efforts only on course innovations during the month of June (no
summer teaching or research), and that the faculty will commit to the implementation of the
innovations in subsequent semesters. Funding runs through 2016 and the budget includes all the
faculty members from the School of Engineering. It also includes the physics faculty that are
responsible for the Physics I and II courses that are required for all engineering students. A total
of 35 faculty members will participate at a rate of seven faculty members per summer session.
The expected changes are systemic by virtue of including all the faculty members of the school.
In terms of ensuring faculty participation in the program, a survey by Morales showed that 96% of
the faculty were receptive to learning and adopting transformative teaching strategies that are
based on engineering education research results.

The course innovations consist of implementing active learning techniques, and the
inductive teaching/learning methodology. Active learning techniques may be used as an
alternative, or as a complement to the traditional lecture. Prince defines active learning in a
general sense as “any instructional method that engages students in the learning process”. It
strictly limits the definition to activities introduced in the classroom. Homework assignments are
not considered active learning under this definition, by virtue of being conducted outside of class
hours. Borrego defines “student-active pedagogies”, as follows: “Students are actively engaged
with course material in the classroom. Examples of classroom engagement include: performing
mini-experiments in the classroom and interpreting results, and working in pairs or groups to
address questions about the material and challenges posed by the instructor”.

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the faculty were receptive to learning and adopting transformative teaching strategies that are
based on engineering education research results.
The inductive teaching/learning methodology is best understood by contrasting it to the traditional deductive methodology. Summarizing from Prince and Felder\textsuperscript{7}, deductive learning typically goes through the following steps:

**Deductive Methodology (from generalities to specifics)**

1. The professor introduces a topic by presenting general principles and theories.
2. The professor uses the principles to derive the mathematical models.
3. The professor provides examples and applications.
4. The professor assigns homework to practice similar derivations and applications.
5. The professor tests the ability of the students to do similar things in exams.

A typical weakness of the traditional deductive learning methodology is that the usefulness of the general principles and theories being taught in class may not be evident. Typical questions a student could ask are “Why am I learning this material?”, or “Is this material practical and useful in real-world engineering applications?”. If the answers to these questions are not evident, students may lose interest and motivation in the class.

Citing from a medical journal\textsuperscript{8}, Prince and Felder\textsuperscript{7} state that “A well-established precept of educational psychology is that people are most strongly motivated to learn things they clearly perceive a need to know. Simply telling students that they will need certain knowledge and skills is not a particularly effective motivator”.

The inductive style of teaching is a preferable alternative for motivational purposes because it inverts the process, i.e., it uses specific applications to provide a context upon which general principles are then constructed. In this manner the perceived usefulness of the material is ensured. The steps in the inductive methodology are summarized below from Prince and Felder\textsuperscript{7}:

**Inductive Methodology (from specifics to generalities)**

1. The professor starts with specifics – a set of observations or experimental data to interpret, a case study to analyze, or a real-world engineering problem – of interest to the student, instead of starting out by presenting theories and principles (generalities).
2. A need arises to generate data, constraints, procedures, theories and principles to analyze the scenario and solve the problem.
3. Once the need-to-know is established, the professor presents the necessary information to develop the new knowledge, or the professor guides and assists students to discover it for themselves.
Several instructional methods are discussed in the paper, including inquiry learning, problem-based learning, and case-based teaching, among others. These inductive instructional methodologies “are all learner-centered (also known as student-centered), meaning that they impose more responsibility on students for their own learning than the traditional lecture-based deductive approach. They are all supported by research findings that students learn by fitting new information into existing cognitive structures and are unlikely to learn if the information has few apparent connections to what they already know and believe. They can all be characterized as constructivist methods, building on the widely accepted principle that students construct their own versions of reality rather than simply absorbing versions presented by their teachers.”

Patterson’s Using Everyday Engineering Examples (E3) in the Classroom, has also shown to improve the deep learning experiences of students. As the E3 name implies, everyday engineering examples that are familiar to students are used to provide the specific applications on which to build the inductive learning experience. The examples are chosen so that straightforward implementation of engineering principles is possible. Full lesson plans have been developed in Mechanics of Solids, Dynamics, Thermodynamics, and Fluid Mechanics. The lesson plans for the instructors are based on the Principles of the 5E’s: Engage, Explore, Explain, Elaborate, and Evaluate. The Engage phase presents the everyday example (skateboard, bicycle, stapler, etc.) to engage the students’ attention; the Explore phase starts discussing the engineering issues involved in the problem (forces, velocity, etc.) which may vary depending on the specific objectives of the lesson (one example may be used to illustrate several principles in several courses); the Explain phase brings in the general principles and theories required to solve the problem; the Elaborate phase uses actual data plus additional formulas and principles that may be required to solve the problem; the Evaluate phase incorporates exercises for the students to solve to show that they have understood the material.

In the E3 approach taken by Patterson the problems that are presented by the instructor are also solved by the instructor in an engaging manner to elicit student participation (active learning). The E3 approach may be defined as Structured, Guided-Inquiry Learning according to the Prince and Felder categories. It may also be defined as Problem Based Learning (PBL) with 100% scaffolding (support and guidance by the instructor). It is convenient to think in terms of PBL and the scaffolding concept since the degree of support and guidance (scaffolding) provided by the instructor is one of the variables that instructors may experiment with while trying out the innovations in the classroom.

An approach similar to E3, using 100% scaffolding, has been selected as the basis for the SFIP. This format intensifies the challenge faced by each faculty member as they transform their views on teaching during the SFIP. It forces them to think through the entire process from real-world example selection, to generating instructional objectives for each lesson, to making
assumptions, to selecting the most appropriate principles or theories to solve the real-world example problem, to solving the problem, and finally, to making the entire activity an enjoyable, relevant and engaging experience for everyone in the classroom. As their teaching careers progress, new real-world examples may be ideated which could be used for homework or exam problems, or to replace the ones used in the classroom.

Hypothesis of the Study

The hypothesis of the study is stated as follows: Systemic and sustainable change toward creating a classroom environment that engages students with authentic engineering real-world problems may be ignited by an intense one-month summer faculty immersion program in which faculty innovate two courses with inductive and active learning methodologies (with the commitment of implementing them) at a cost of approximately $10,000 per faculty member, which includes a summer stipend plus funds to purchase educational materials. If the transformation occurs, then the faculty should be able to sustain it by using the regular course-preparation time during the semester to gradually polish the real-world examples used in class, and to optimize the delivery of the inductive teaching/learning methodology.

SFIP 2012 Group Composition

The initial SFIP 2012 group consisted of the seven faculty members presented in Table 1. All seven faculty members hold Ph.D. degrees in their respective fields except for the Computer Engineering Assistant Professor who is currently finalizing his PhD dissertation. All the faculty members are involved in research to some degree. Some of the participants continued with their research commitments in July, immediately after finishing the SFIP in June.

Table 1: 2012 Summer Faculty Immersion Program – Participants’ Data

<table>
<thead>
<tr>
<th></th>
<th>Department</th>
<th>Rank</th>
<th>Years Teaching at U. Turabo</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Dr. E. Romero</td>
<td>Mechanical Engineering</td>
<td>Assistant Professor</td>
</tr>
<tr>
<td>2</td>
<td>Dr. D. Villegas</td>
<td>Mechanical Engineering</td>
<td>Assistant Professor</td>
</tr>
<tr>
<td>3</td>
<td>Dr. G. Carbajal</td>
<td>Mechanical Engineering</td>
<td>Associate Professor</td>
</tr>
<tr>
<td>4</td>
<td>Dr. M.C. Ruales</td>
<td>Mechanical Engineering</td>
<td>Associate Professor</td>
</tr>
<tr>
<td>5</td>
<td>Dr. Sundararajan</td>
<td>Mechanical Engineering</td>
<td>Full Professor</td>
</tr>
<tr>
<td>6</td>
<td>Dr. Santiváñez</td>
<td>Industrial and Management Engineering</td>
<td>Associate Professor</td>
</tr>
<tr>
<td>7</td>
<td>A. Alvear</td>
<td>Computer Engineering</td>
<td>Assistant Professor</td>
</tr>
</tbody>
</table>
Structure of the Summer Faculty Immersion Program

Preliminaries

Each faculty member reads and signs a sheet of requirements for the SFIP. It includes five principal items: (1) to have a full-time commitment to the SFIP during June (no summer classes and no research commitments); (2) to fully revise and innovate two courses and submit this deliverable at the conclusion of the program (end of June); (3) to commit to implement the innovations in subsequent semesters; (4) willingness to allow internal and external observers in the classroom; and (5) permission to use their work for any academic purpose such as sharing with other faculty members and using it in publications.

As a prerequisite (starting in 2013), each faculty member must complete a panoramic outline of each of the two courses before starting the SFIP in June (Table 2). The number of sessions used (30) corresponds to the number of times the class meets during the term. At Universidad del Turabo a term is defined as a 15-week semester and classes meet twice a week which results in 30 sessions. In total, 60 sessions are created (30 sessions per course). Each session must have at least one topic and some instructional objectives (a minimum of two or three). Table 2 may be used as a template for this exercise. The column labeled “Real-World Example” is left blank (will be addressed during the summer). If a topic appears to extend for more than one session it is simply repeated in the next session with perhaps different instructional objectives (or the same, depending on the case). The panoramic outline serves as the framework on which to transform the course. It forces each faculty member to take a broad and comprehensive view of the courses that they will address in the SFIP. At this stage there is no innovation. Setting the panoramic outline as a prerequisite leaves more time for innovation, a lesson learned during the 2012 SFIP session.

Table 2: Template used to create a panoramic outline of 30 sessions of 1.5 hours each (a prerequisite to start the SFIP in June)

<table>
<thead>
<tr>
<th>Session</th>
<th>Topic(s)</th>
<th>Instructional Objectives – By the end of this session students shall be able to:</th>
<th>Real-World Example</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td></td>
<td></td>
<td>(Leave blank until SFIP starts)</td>
</tr>
<tr>
<td>...</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>30</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
First week of the SFIP

The SFIP kicks off on the first week of June with a three-day, on-site seminar by the visiting external consultant (second author). Faculty members learn about the pedagogy of active learning and inductive teaching/learning methodologies. The seminar also includes a session on how to write effective instructional objectives. After the consultant leaves, he remains available for consultations by email or telephone to all the faculty members and the SFIP Director (first author).

Patterson’s E³ methodology is then presented to the SFIP group by the SFIP Director. Discussion of several E³ lesson plans take place. Afterward, the panoramic outlines prepared by each faculty member are discussed. This is followed by a review of the material prepared by previous SFIP groups, an example of which is shown in Figure 1.

**First innovation exercise.** Each faculty member is given time to select one session from their panoramic outline, to think of a real-world example that can be used in the classroom, and to prepare a session similar to the one shown in Figure 1. Each participant then gives a 10 minute presentation which is constructively critiqued by the group. At this point, emphasis is on ensuring that all the participants clearly understand the requirements and the expectations before starting the immersion period to create the 60 sessions.

A typical misconception noted in the 2012 SFIP group was thinking that a specific real-world example was to be used only as a demonstration piece without any formulations. The “engineering” of the real-world example must also be included. For example, pliers and wooden pegs may be handed out to students during the topic “frames and machines” in a statics course, not only to be used as a demonstration piece, but to determine the force applied to a wooden peg (an actual example that was presented at this stage in the 2012 SFIP session by Dr. Mary C. Ruales). The students will construct knowledge during the session that will allow them to identify if pliers are a frame or a machine, identify the different pieces, draw free body diagrams (FBD) of the complete device as well as the individual pieces, and select the necessary FBDs to solve the specific problem. With pliers in the hands of every student, the learning environment is enriched and students become engaged. Students may be asked, for example, where exactly in the jaws should the wooden peg be placed to maximize the clamping force on it?; where exactly should the hands be placed to maximize the clamping force?; or asked to pay attention to the sensations that they feel in their hand and to define the direction of the force vector on each finger; they are asked “how will you idealize the clamping force provided by your fingers?” Textbook figures of a “processed” problem usually show a single vertical force acting on the handles which is a suitable idealization; however, with the real pliers students acquire the real world experience of doing the idealization themselves. They are able to construct knowledge when they realize that several idealizations could be used; for example, a distributed force...
idealization of the entire hand, or several concentrated forces of different magnitudes and directions applied by each finger, or one equivalent concentrated load for the entire hand acting vertically, etc.). Students also construct knowledge regarding the accompanying assumptions, complications, and limitations of each idealization (model). These activates develop and improve their critical thinking skills. Having the unprocessed real-world object in hand, and coming up with the idealized models is one of the most enriching aspects of this methodology. In addition, students may be asked to measure the dimensions of the pliers with calipers or a tape measure as a preliminary step to drawing the FBD. Finally, using the FBD and the equilibrium equations, the students solve for the clamping force applied by the jaws to the wooden peg. Students may also be asked to determine the mechanical advantage of the device. Doing the “engineering” of the pliers in an active learning environment is what is sought, not just showing pliers as a demonstration piece of a “machine”. Each faculty member must be able to imagine an inductive teaching/learning session, sketch out the basic outline of the session, and then present it to the group as a broad outline by the end of the first week.

Once each faculty member demonstrates understanding of the requirements, the full immersion starts and each faculty member begins preparing the required 60 sessions as per Figure 1. Although physical objects are ideal for inductive teaching/learning, not all courses and not all sessions are apt to perform an exercise with a physical object similar to the pliers case presented above. Common sense and creativity must be used in such cases. For example, in an introductory programming course that was innovated in the 2012 SFIP, the instructor only used real-world scenarios rather than physical objects; for example, to teach the Do-Loop Until programming structure, students are first presented the unprocessed scenario of calculating the exam average per student of a population of $n$ students given that each student has three exam grades (step 1 of the inductive methodology). As an additional note, the introductory programming course has also started exposing students to the programming environment from the first day of class. Algorithms, flow charts and pseudo-coding are presented as “needs”, i.e., the required tools necessary to create a program (step 2 of the inductive methodology). Then, these are taught simultaneously with programming exercises (step 3 of the inductive methodology). In traditional programming courses that use the deductive methodology, algorithms and pseudo-coding are usually taught as preliminary course topics.

Other courses that were innovated in 2012 also used variations. For example, a course in probability and statistics for industrial engineering majors, also used many real-world case scenarios instead of physical objects. In fluid mechanics, a physical object (a 40-ft diameter ornamental water fountain) was used but it required a trip from the classroom to the fountain. The course topic was pump power. Arrangements were made to visit the machine room and to obtain the engineering drawings and specifications. Then, the required principles of fluid mechanics were used to calculate the required pump power to achieve the specified heights and mass flow rates. The results were compared with the actual pumps used in the fountain and
differences were discussed. In addition, videos of real world examples could also be used, as well as computer simulations. There is no limit to the variations that can take place. As long as unprocessed real-world examples are used within an inductive methodology (from specifics to generalities) to provide context and to engage students, then innovation is taking place.

Required facilities during the first week of the SFIP: The three-day kick-off seminar by the consultant requires a small classroom (minimum of 10 people) with audiovisual (AV) equipment capable of projecting power point presentations and videos. The AV equipment must include speakers to listen to the projected videos. In addition, a conference room with similar AV equipment is required throughout the entire month to conduct group meetings when required.

Typical workday during the first week of the SFIP: During the first week, the faculty meet from 8:00 am – 5:00 pm. The entire first week is spent as a group except for the preparation of the first inductive class session (to demonstrate understanding of the goals), which is carried out individually. The time dedication for development is 40 hours in the first week.

Second and Third weeks of the SFIP

Individually, each participant completes the transformation of the two courses, i.e., the preparation of 60 sessions (30 per course) as shown in Figure 1.

One group meeting per week is conducted, in addition to individual meetings between the SFIP Director and each of the participants, to ensure that progress is taking place.

More group meetings may be scheduled depending on particular circumstances, but these should be kept to a minimum to provide the required immersion time to transform the courses.

The external consultant remains available through email or by telephone to consult with any of the participants or the SFIP Director. The consultant is available to answer questions throughout the entire year.

Required facilities during the 2nd and 3rd week of the SFIP: Most of the work takes place in the professor’s office. Some of the work may also be done at home. The conference room is used for the group meetings and for individual meetings between the SFIP Director and the faculty members.

Typical workday during the 2nd and 3rd weeks of the SFIP: During the second and third weeks the 8:00 am – 5:00 pm regimen may be modified moderately as long as progress is achieved. The time dedication for development of the 60 sessions is 40 hours per week.
I. Topic: The Bernoulli’s equation, part 2
   1. The Bernoulli equation interpreted as an energy equation
   2. Main assumptions of the Bernoulli equation
   3. Energy grade line
   4. Hydraulic energy line

II. Instructional objectives:
   1. Apply the Bernoulli’s equation
   2. Represent the control volume
   3. Identify the restrictions for the Bernoulli’s equation

III. Real World Problem:
   Is it possible to estimate the discharging time of a container/tank filled with water?

IV. Design the class
   1. Brainstorming:
      o Is this a steady state problem?
      o Does the Bernoulli’s equation apply for transient process?
   2. One minute paper: write the main assumptions to solve this problem
   3. Lecture: Solve the problem and apply the Bernoulli’s equation
   4. Brainstorming:
      o How do we model the geometry of the bottle?
      o Where are the best locations for sections 1, 2 inlet/outlet?
   5. Activity: Fill the container with water and measure the discharging time
   6. Brainstorming:
      o Do the experimental values match the analytical results?
      o Why do you think the experimental and theoretical results are not the same?
      o What about a variable cross sectional area?
   7. Summarize: Ask the student if there is any question related with the topic developed in class
   8. Homework problem from lecture material

Figure 1: Typical Session Worksheet Developed during the Second and Third Week of the Summer Faculty Immersion Program
Fourth (Last) Week of the SFIP

Complete and hand in the required 60 sessions as per Figure 1.

The participants start putting together quotes for the educational materials required for their courses. The participants then meet and work with the Grant Coordinator to purchase the educational materials that they will use in class.

Final presentation. Each participant selects a session (as per Figure 1) for which the unprocessed real-world example is available (if it is a physical object, it must be used in the presentation), prepares a simulated class session, and makes a final presentation to the group. Active learning techniques are also included in the presentation and the SFIP group is used to simulate the student audience.

Participate in a closure activity at the end of the week where the stipend is handed out to each SFIP participant.

Required facilities during the 4th week of the SFIP: The same as for the 2nd and 3rd weeks.

Typical workday during the 4th week of the SFIP: Similar to the second and third week. In addition, the faculty members must meet with the Grant Coordinator to prepare the purchase orders of the educational materials. The time dedication continues to be 40 hours during this final week.

Initial and Final Survey to Students: Results and Discussion

Students answered an initial survey immediately after experiencing their first inductive teaching/learning experience. The initial survey recorded the first impression of the students. Students also answered a final survey so as to obtain their opinion after being exposed to several inductive learning sessions, and after taking several exams. The only difference between the initial and final surveys was the grammatical tense which was changed to the past tense in the final survey. Figure 2 integrates the questions and the aggregate results of the student survey.
Now that you have had one experience with inductive learning in the classroom, we ask you to please give us your opinion regarding this methodology. Please check the most appropriate column next to each question based on the following 5-point scale.

<table>
<thead>
<tr>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Disagree</td>
<td>Disagree</td>
<td>Neutral</td>
<td>Agree</td>
<td>Strongly Agree</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>No.</th>
<th>Question</th>
<th>Initial Survey n = 169</th>
<th>Final Survey n = 107</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>The inductive learning methodology creates relevance to the topics presented in class.</td>
<td>4.6</td>
<td>0.7</td>
</tr>
<tr>
<td>2</td>
<td>The inductive learning methodology is excellent and could be used in a large majority of engineering courses.</td>
<td>4.6</td>
<td>0.7</td>
</tr>
<tr>
<td>3</td>
<td>I think that with inductive learning I will achieve a deeper level of learning, i.e., that I will not forget the material as easily with the passage of time.</td>
<td>4.5</td>
<td>0.7</td>
</tr>
<tr>
<td>4</td>
<td>I think that I will do better in exams by learning with the inductive learning methodology.</td>
<td>4.3</td>
<td>0.9</td>
</tr>
</tbody>
</table>

The use of real-world examples in the classroom creates a rich learning atmosphere in which the instructor cannot control all the circumstances. Questions may arise which the professor may not be able to answer on the spot. Please answer questions 5 through 8 using the same 5-point scale:

| 5   | I will not feel a lack of esteem for the professor if the professor is not able to answer a question on the spot. On the contrary, I appreciate the fact that the professor is researching new methodologies to improve my learning experience. | 4.8 | 0.5 | 4.7 | 0.7 |
| 6   | I expect that the questions that were raised during class as a result of inductive learning should be answered before the end of the semester. | 4.7 | 0.6 | 4.6 | 0.8 |
| 7   | I am willing to search for additional information to answer those questions that were generated in class using the inductive learning methodology, i.e., the instructor should not shoulder the entire responsibility of answering them. | 4.4 | 0.8 | 4.4 | 0.9 |
| 8   | Points toward my final grade should be awarded for the effort I would undertake to answer these questions. | 4.3 | 0.9 | 4.4 | 0.9 |

Figure 2: Student Survey Questions and Results
Discussion of Student Survey Results

Regarding the difference in the number of participants in both surveys (n=169 vs. n=107; a difference of 62 students), it is noted that the initial survey includes all 11 courses in which the inductive methodology was used while the final survey includes only 9 courses. This accounts for 34 of the 62 students. Therefore, 28 students (not 62) did not answer it on account of being absent or because they had withdrawn from the course.

In general, all scores in both student surveys were above 4.0 in a scale of 5.0 which is considered to be at the excellence level in all the assessment instruments used at Universidad del Turabo. Based on having achieved the criterion of excellence, an argument may be made that, in general, students seem to be satisfied with the innovation. However, all the scores were slightly lower in the final survey than in the initial survey with two exceptions: Q7: “Willing to search for additional information...” received equal scores and Q8: “Points toward my final grade should be awarded for the effort...” received a higher score in the final survey.

The highest score in both student surveys (4.8, 4.7) was for question 5: “I will not feel a lack of esteem for the professor if the professor is not able to answer a question on the spot. On the contrary, I appreciate the fact that the professor is researching new methodologies to improve my learning experience”. The rich learning environment created by the inductive methodology could give rise to several question beyond the scope of the instructional objectives. It is positive that students are willing to accept that the faculty members may not have an answer on the spot for all their questions.

The lowest score in both the initial and final student surveys (4.3, 4.1 were for question 4: “I think I will do better in exams by learning with the inductive method”. These two results indicate that more thought must be placed on the type of examinations that are given when using this methodology. Further comments regarding this issue will be carried out in the discussion section of the faculty survey.

On a related issue to the exams, question 8: “Points toward my final grade should be awarded for the effort I would undertake to answer these questions”, received higher scores in the final survey (4.3, 4.4). Students seemed to have realized that it is a good idea for them to receive points toward their grade as a reward for researching an unanswered question from class (or similar task that spins off from the inductive approach).
Faculty Survey: Results and Discussion

The faculty survey was completed by each professor at the end of the Fall 2012 semester. The first of three parts consisted of 13 questions that were answered on the basis of 5-point Likert scales. The second part requested the faculty to list the most memorable inductive experiences that they experienced during the semester (no more than five). The third part of the faculty survey requested comments by the faculty to improve the SFIP.

All seven participants filled out the survey (n = 7). Figure 3 integrates the questions with the aggregate results of the first part of the survey.

Discussion of Results: First Part (of Three) of the Faculty Survey

This discussion begins with questions 12 and 13 which were aimed at quantifying the number of class sessions in which the innovations were put into practice in the Fall semester. As shown in the bottom of Figure 3, the Likert scale for questions 12 and 13 is linked to the number of sessions in which they used innovative methodologies [ (1) 0-5 lectures, (2). 6-10 lectures, (3). 11-15 lectures, (4). 16-20 lectures, (5). 21-27 lectures].

The 2.9 score in question 12: “The number of lectures in which I used inductive learning methodologies with a real-world application”, indicates that, on average, the inductive methodology was used on approximately one half of the sessions (11-15 sessions) throughout the Fall semester. It is noted that although the faculty members were required to develop the entire 60 sessions during the SFIP, they were allowed full freedom and discretion on how to deliver it during their actual courses. They were only required to make a commitment to implement the methodologies without any particular quota. The reasoning is that if the intense SFIP genuinely ignited a transformation in their views on teaching, then the innovations should flow freely in the classroom. A gradual adaptation is to be expected.

The 4.0 score in question 13: “The number of lectures in which I used an active learning methodology taught by Dr. Michael Prince (not necessarily inductive) in the summer seminar such as one-minute papers, collaborative learning activities such as “think-pair-share”, having students generate questions from lecture material, etc.”, indicates that active learning techniques (not necessarily inductive) were used in approximately two thirds of the sessions (16 – 20 lectures) throughout the semester. Active learning techniques are more easily implemented in the classroom.
For questions 1 through 11 please use the following scale:

<table>
<thead>
<tr>
<th>No.</th>
<th>Question</th>
<th>Avg. Score</th>
<th>Std. Dev.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Inductive teaching/learning provides relevance and context to what is taught.</td>
<td>4.9</td>
<td>0.3</td>
</tr>
<tr>
<td>2</td>
<td>Inductive teaching/learning is an excellent methodology and was effective in the courses I taught this semester.</td>
<td>4.1</td>
<td>0.5</td>
</tr>
<tr>
<td>3</td>
<td>The inductive teaching/learning methodology was effective in achieving deep learning of concepts in the courses I taught this semester.</td>
<td>3.7</td>
<td>0.8</td>
</tr>
<tr>
<td>4</td>
<td>Students perform better in the exams using this methodology than in the traditional (deductive) learning style.</td>
<td>3.5</td>
<td>1.2</td>
</tr>
<tr>
<td>5</td>
<td>I did not feel apprehensive or anxious when discussing the real world applications even though there was a good probability that students would ask questions relative to the application that I perhaps would not be able to answer.</td>
<td>4.9</td>
<td>0.3</td>
</tr>
<tr>
<td>6</td>
<td>Questions that were asked by students and not answered in class were followed up. All were answered either by myself or by students who found out the answer on their own.</td>
<td>4.3</td>
<td>0.5</td>
</tr>
<tr>
<td>7</td>
<td>Students showed disposition to search for answers to questions not answered in class.</td>
<td>3.8</td>
<td>1.1</td>
</tr>
<tr>
<td>8</td>
<td>I was able to figure out a good grading scheme to take into account extra work performed by the students that arose as a result of the inductive learning style.</td>
<td>4.4</td>
<td>0.7</td>
</tr>
<tr>
<td>9</td>
<td>I enjoyed the experience of using inductive learning activities in the classroom.</td>
<td>4.5</td>
<td>0.5</td>
</tr>
<tr>
<td>10</td>
<td>The summer faculty immersion program, including the seminar by Dr. Michael Prince, was effective in preparing me for teaching in this new style.</td>
<td>4.2</td>
<td>0.8</td>
</tr>
<tr>
<td>11</td>
<td>There is sufficient time to cover all the course objectives while using inductive learning.</td>
<td>2.6</td>
<td>1.0</td>
</tr>
</tbody>
</table>

For questions 12 and 13 use the following scale which is defined in terms of number of lectures. The maximum number of lectures has been set at 27, assuming that three sessions are used for examinations.

<table>
<thead>
<tr>
<th></th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
</tr>
</thead>
<tbody>
<tr>
<td>No.</td>
<td>0 – 5 lectures</td>
<td>6 – 10 lectures</td>
<td>11 – 15 lectures</td>
<td>16 – 20 lectures</td>
<td>21 – 27 lectures</td>
</tr>
<tr>
<td>12</td>
<td>The number of lectures in which I used inductive learning methodologies with a real-world application.</td>
<td>2.9</td>
<td>1.1</td>
<td></td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>The number of lectures in which I used an active learning methodology taught by Dr. Michael Prince (not necessarily inductive) in the summer seminar such as one-minute papers, collaborative learning activities such as “think-pair-share”, having students generate test questions from lecture material, etc.</td>
<td>4.0</td>
<td>1.3</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Figure 3: Faculty Survey Question and Results – First Part of Survey
This section addresses questions from the first part of the survey which is based on the typical five-point Likert scale shown at the top of Figure 3 (1. Disagree Strongly, 2. Disagree, 3. Neither agree nor disagree (neutral), 4. Agree, 5. Strongly Agree). It is the same scale that was used in the student surveys.

The 4.9 score in question 1: “Inductive teaching/learning provides relevance and context to what is taught”, shows that the faculty developed a strong appreciation for the relevance and context generated by using real-world examples in class as part of the inductive methodology. This result agrees well with the students’ opinion.

The 4.5 score in question 9: “I enjoyed the experience of using inductive learning activities in the classroom”, indicates that the faculty also enjoyed the experience of using this new methodology.

The 4.9 score in question 5: “I did not feel apprehensive or anxious when discussing the real-world applications even though there was a good probability that students would ask questions relative to the application that I perhaps would not be able to answer”, shows that the faculty felt very confident in class when discussing the unprocessed real-world applications. This is notable since this rich learning environment tends to generate questions outside the scope of the instructional objectives of the lesson, and perhaps outside of the comfort zone of the instructors. This is a very positive development as this issue was foreseen as a potential torpedo that could quash the SFIP initiative. Another positive development on this issue resulted from the student survey (question 5) which, as discussed previously, showed that students were very open to the initiative and forgiving with faculty in the case that questions generated during an inductive session were not answered on the spot.

The 3.5 score in question 4: “Students perform better in exams using this methodology than in the traditional (deductive) learning style” is the second lowest score in the first 11 questions of the faculty survey. It also has the highest standard deviation (1.2). This result indicates correlation with the students’ perception that the inductive teaching/learning methodology does not necessarily result in an improvement in exam scores (this question received the lowest score in the student survey, as discussed previously). While this is not entirely unexpected, it has become evident that exam content and grading schemes must be analyzed in more depth and perhaps redesigned. The idea is not to make the exams easier (to artificially inflate the grades) but to legitimately incorporate other aspects that the inductive methodology explores and strengthens, such as critical thinking, which are at the higher end of Bloom’s Taxonomy. One of the most attractive features of the inductive methodology, and of using Everyday Engineering Examples in the classroom, is that students are exposed to real-world applications that arrive in an unprocessed state, unlike textbook problems. So, for example, students could be asked to analyze similar unprocessed real-world applications in the
exam and be asked to make assumptions, choose idealizations (models), be asked to consider what information should be given as data of the problem, which variables should be measured, and which variables should be solved using mathematics and engineering principles — all with supporting arguments for their decisions. This approach mimics the way that real engineering problems are presented to, and solved by engineers in the real world. It is important to reward students with exam problems that address the same objectives that are explored in class (in addition to the typical textbook problems that are also very important). This issue will be addressed in future SFIP sessions by also requiring the faculty members to start designing the exams during the summer program. In addition, more research will be conducted with the objective of improving the correlation between examinations, grading schemes, and course objectives. The SFIP participants will continue to be tracked longitu

dinally with surveys to understand the evolution in the implementation of the innovations.

The 2.6 score in question 11: “There is sufficient time to cover all the course objectives while using inductive learning” indicates a weakness that must be addressed. There are two possible solutions and both can be worked on simultaneously. In the first place, the activities can be optimized with respect to time so that emphasis is placed on the issues that are most relevant to the class topics. For example, in the pliers case that was discussed earlier, the professor may opt to spend more time in the idealization of the forces applied by the hand rather than on measuring the dimensions. In the second place, more time must somehow be “created”. This may be achieved by flipping the classroom\textsuperscript{12} which is defined by the reference as follows:

\textit{Flip teaching (or flipped classroom) is a form of blended learning which encompasses any use of technology to leverage the learning in a classroom, so a teacher can spend more time interacting with students instead of lecturing. This is most commonly being done using teacher-created videos that students view outside of class time. The lecturing part may be achieved by having the students access a video outside of class.}

The videos may be prepared by each professor, or the professor may opt to use existing videos from other sources; for example, the use of Massive Open Online Courses (MOOC) platforms. The Coursera MOOC platform, for example, states the following\textsuperscript{13}:

\textit{Our (Coursera) platform offers universities the opportunity to move much of the traditional lecturing - required for conveying the necessary material - from inside to outside the classroom, in an online learning format that is, in many ways, more interactive and more engaging. By doing so, they open up space in the curriculum for the active learning strategies that are considerably more effective in increasing engagement, attendance, and learning.}

Additional efforts are required to resolve the time-management issue.
Memorable Examples: Second Part (of Three) of Faculty Survey

The participants were asked to list a few of the most memorable experiences that they experienced during the Fall semester while using the inductive learning methodology. The following is a partial list from all the members of the 2012 SFIP group with examples and a brief explanation of how they were implemented:

**IMEN 390 Probability and Data Analysis for Engineers: Dr. José Santiváñez**

- Tossing dice to check the outcome. Pass out dice to the students and work in pairs to determine the probabilities using addition rules of events both mutually exclusive or not. Use the experiments to build the concept of conditional probability.

- Real world scenario: Goferbroke Company: Should I drill for oil or should I not? Extension on the concept of conditional probability with a real world engineering scenario.

**MEEN 425 Design of Machine Elements: Dr. Visvanatha Sundararajan**

- Bearing selection for a skateboard that is brought to class. Students estimate the radial and thrust loads on the bearings based on experience riding the skateboard and using the concept of normal acceleration from dynamics. An estimate of bearing life is also carried out by students. Lecture on bearing selection. The most appropriate bearing for this application is selected and compared with the actual bearings of the skateboard. Discuss differences in the results.

- Spring design of a hole puncher (two-hole variety). Hole punchers are passed out to student pairs. What is the purpose of the spring? What is the material of the spring? What force is acting on each spring? Lecture on spring design and apply it to the hole puncher springs. Compare results with the actual hole-puncher spring. One-minute paper to write down issues that remain unclear to the students.

**MEEN 312 Kinematics: Dr. Mary C. Ruales**

- Crimping tool to determine its Grashof condition. Crimping tools are passed out to pairs of students. Using Think-Pair-Share, the students determine the purpose of the tool and how every piece moves. Lecture on the Grashof condition for 4-bar linkages and for linkages of more than four bars. Pairs of students then determine the mobility, the
Grashof condition, and its Barker classification. Work additional problems from the book.

- Bicycle brakes for graphical linkage synthesis. Bicycle is brought into class. Identify the parts of the brake system. Use Think-Pair-Share to determine and describe how the mechanism works. Lecture on synthesis; function, path, and motion generation; limiting conditions; dimensional synthesis. Students work in pairs to design a specific movement of the brake mechanism using two-position synthesis. Work additional problems from the book.

**MEEN 420 Heat Transfer: Dr. Gerardo Carbajal**

- How many modes of heat transfer occur during the heating process of an aluminum rod (L = 3 ft., D = 1/4 inch) by the flame from a lighter? Used in the second session to introduce the basic modes of heat transfer. The professor conducts the experiment with the lighter and the rod. Brainstorming is used to determine the heat transfer modes. Lecture on the conduction, convection and radiation modes. After each mode ask for a one-minute paper to write three real-world examples of each mode. Assign homework problems from lecture material. This same setup (lighter plus aluminum, steel and copper rods) is used in the third session to calculate the heat transferred from the flame to an aluminum, copper, and steel rods.

- Analysis of the heat dissipated from an electrical heater to the surrounding environment. Does the velocity of the surrounding air affect the heat transfer rate? Does the surrounding air temperature increase the heat transfer rate? Can this heater be modeled as a constant-surface temperature or constant heat flux? One-minute paper to sketch the local convective coefficient. Lecture on the calculation of the average convective coefficient. Think-pair-share to determine the average convective coefficient of a similar problem.

**MEEN 460 Control of Dynamic Systems: Dr. Edwar Romero**

- “The best approach was to have students work in pairs during class solving quick problems. This uncovered a number of misconceptions in the mathematics background and in statics (problems with free body diagrams and the sign convention) which typically delay the learning process (small obstacles seem to be a deterrent to understanding the principles). The work in pairs facilitated description of concepts by giving explanations in their own words until the concepts seemed to have gained “roots”. At the same time this delays the amount of course material that needs to be covered. Project-based or problem-based activities in pairs worked the best in class.”
ENGI 223 Intermediate Programming: Alcides Alvear

- Real world scenario: A bank charges $10 per month plus the following check fees for a commercial checking account (fees given in problem). Write a program that asks the number of checks written during the past month, then computes and displays the bank’s fees for the month. Input Validation: do not accept a negative value for the number of checks written. Brainstorm with the students on how to approach the problem. Lecture on checking numeric ranges with logical operators, validating user input and more about variable definitions and scope. One-minute paper for questions. Continue lecturing on comparing characters and strings, the conditional operator, and the switch statement. Solve the problem.

- Design an inventory class that can hold information for an item in a retail store’s inventory. The class should have the following private member variables (variables are given in the problem) and public member variables (variables are given in the problem). Brainstorm with the students on how to approach the problem. Lecture on structures as function arguments, returning a structure from a function. Solve the problem.

ENGI 318 Strength of Materials: Dr. Diego Villegas

- Stresses at the base of a drill bit due to combined loading (axial compressive load on the tip plus shear loading due to the circumferential friction on the drill bit). A hole is drilled on a concrete block brought into class. Students may participate in the drilling activity to feel the sensation of the loading condition. This real-world example is used in three sessions: introduction to combined loading, determination of principal stresses and stress transformations. Think-pair-share to sketch the free body diagram, estimate the loading, idealize the loading condition, and determine the state of stress. One-minute paper to write down issues that remain unclear.

- Normal stresses on a bicycle-brake cable. Bicycle brought into class. Think-pair-share to idealize the system, draw the FBD of the brake lever mechanism and cable, model the load applied by the fingers on the brake handle, estimate (or create an experiment) to determine the magnitude of this load, and then apply the equilibrium equations to determine the load in the cable. Then calculate the normal stress on the cable.

Faculty Comments: Third part (of Three) of the Faculty Survey

The third part of the faculty survey included a comment section with the following statement: “Please list strategies or comments to try to improve the Summer Faculty Immersion
Program. You may also comment on anything that did not work out well during the semester. Please comment and mention all the difficulties that you faced even if you do not have a solution to the challenging issue that you faced. A solution may appear in the future. At this point we are trying to focus on the challenges that we face on implementing innovative teaching methodologies.” The following is a partial list of comments, selected by the frequency with which they were mentioned or relevancy.

- There was unanimity in expressing that, although the inductive learning methodology provides relevance and context, there is a time-management issue. The faculty has had difficulty in covering all the course objectives. To try to ease the impact, some faculty members started handing out their class notes to the students to read as homework. In one case, part of the inductive activities, rather than the class notes, were assigned as homework to the students.

- Classrooms should be equipped with cabinets to store the real world examples used in class.

- Improve the topic/real problems to be presented in class. This will require additional time during the semester. (The regular course-preparation time during the semester is used to polish the innovation.)

- Inductive learning does not seem to fit every topic of the course.

- The number of W’s in class was reduced this semester (one participant commented on it).

Conclusions and Recommendations

The hypothesis of the study stated that “systemic and sustainable change towards creating a classroom environment that engages students with authentic engineering real-world problems may be ignited by an intense one-month summer faculty immersion program in which faculty will innovate two courses with inductive and active learning methodologies (with the commitment of implementing them) at a cost of approximately $10,000 per faculty member, which includes a summer stipend plus funds to purchase educational materials. If the transformation occurs, then the faculty should be able to sustain it by using the regular course-preparation time during the semester to gradually polish the real-world examples used in class, and to optimize the delivery of the inductive teaching/learning methodology.”

As it is only the first year of implementation, it is too early to determine if the SFIP will achieve “systemic and sustainable change” and whether the changes will have an effect on
retention rates, graduation rates, and employer satisfaction. However, there are some early indicators that have been arranged below as supporting arguments and counter arguments.

Supporting arguments

1. The faculty showed interest in the program. The 2012 SFIP session filled up very quickly and the 2013 SFIP session is already full. A survey performed in 2009 showed that 96% of the engineering faculty members at Universidad del Turabo were receptive to this type of initiative.

2. 100% of the faculty met the requirement of dedicating their efforts in June exclusively to the SFIP. Only two faculty members were absent for two days each (for valid reasons). The lost time was rescheduled.

3. 100% of the 2012 SFIP participants completed the assignment of innovating two courses. They all completed the 60 sessions (30 per course) by the end of June. The intensity required to carry out this deliverable is believed to be the primary catalyst for the transformation. If the transformation occurs, then the faculty should be able to sustain it by using the regular course-preparation time during the semester to gradually polish the real-world examples and gradually improve the delivery of the inductive learning methodology.

4. 100% of the faculty were satisfied with the kick-off seminar provided by the external consultant (4.9/5.0 score) and the SFIP experience as a whole (4.5/5.0 score).

5. 100% of the 2012 SFIP participants implemented changes in the courses they taught. Implementation has been gradual. Active learning techniques were used in 2/3 of the lectures while unprocessed real-world examples were developed inductively in 1/2 of the sessions.

6. The faculty enjoyed the process of implementing inductive teaching/learning in the classroom as evidenced by the faculty survey (4.5/5.0 score).

7. The switch to the inductive methodology was not stressful for the faculty. On the contrary, the faculty survey indicated that faculty felt confident using it (4.9/5.0 score). This is notable since the rich learning environment that is created tends to generate questions outside the scope of the instructional objectives of the lesson, and perhaps outside of the comfort zone of the instructors. In addition, the student survey showed that students did not feel a lack of esteem for faculty if they were not able to answer a
question on the spot (4.8/5.0 score). This combination of results makes for a powerful argument that there is a very rich atmosphere to bring about change.

Counter arguments

1. There is a weakness with respect to the amount of time required to cover all the course objectives when using inductive teaching/learning. Two possible solutions were discussed: (1) optimize the activities so that they take less time, and (2) somehow “create” more time. Fortunately, both can be addressed simultaneously. With respect to the first point – optimizing the activities with respect to time – this has begun to occur as the faculty continue gaining experience with the methodology and continue polishing the classroom delivery. With respect to “creating” more time, the discussion section concentrated on the concept of flipping the classroom (video lectures watched outside of class while class sessions are devoted to interactions between students and faculty). The videos may be prepared by each professor, or the professor may opt to use available videos from other sources; for example, the use of Massive Open Online Courses (MOOC) platforms. The Coursera MOOC platform, for example, states the following:

   Our (Coursera) platform offers universities the opportunity to move much of the traditional lecturing - required for conveying the necessary material - from inside to outside the classroom, in an online learning format that is, in many ways, more interactive and more engaging. By doing so, they open up space in the curriculum for the active learning strategies that are considerably more effective in increasing engagement, attendance, and learning.

   More research is required to solve the time-management issue. All the SFIP participants will be tracked longitudinally to determine the evolution of the time-management issue.

2. Exam scores are not improving with the inductive methodology. While this is not entirely unexpected, it has become evident that exam content and grading schemes must be analyzed in more depth and perhaps redesigned. The idea is not to make the exams easier (to artificially inflate the grades) but to legitimately incorporate other aspects that the inductive methodology explores and strengthens, such as critical thinking. One of the most attractive features of the inductive methodology, and the use of Everyday Engineering Examples in the classroom, is that students are exposed to real-world applications that arrive in an unprocessed state, unlike textbook problems. So, for example, students could be asked to analyze similar unprocessed real-world applications in the exam. They could be asked to state assumptions, choose idealizations (models), be asked to consider what information should be given as data of the problem, which variables should be measured, and which variables should be solved using mathematics
and engineering principles – all with supporting arguments for their decisions. This aspect, which involves critical thinking, also mimics the way that real engineering problems are presented and solved by engineers in the real world. It is important to reward students with exam problems that address the same objectives that are explored in class (in addition to the typical textbook problems that are also very important). This issue will be addressed in future SFIP sessions by also requiring the faculty members to start designing the exams during the summer program. In addition, more research will be conducted with the objective of improving the correlation between examinations, grading schemes, and course objectives. The SFIP participants will continue to be tracked longitudinally with surveys to understand the evolution in exam content and grading scheme used by the faculty.

3. Storage space for real-world examples used in class. Modifications to the physical space of the classroom are necessary; however, except for large applications (bicycles, for example), it may be solved easily by placing a few storage cabinets in all the classrooms and fill them at the beginning of the semester with the educational materials.

4. The price tag of $10,000 per faculty member to cover a summer stipend for the faculty plus a budget for educational materials. The initial impression may be that the price tag is high; however, it is noted that in order to participate in the SFIP faculty development program, the faculty is foregoing summer teaching, summer research or other activities that may be remunerated. Another consideration is that, if it is eventually shown that the immersion program is a solution to the problem of diffusing innovations in engineering education – a problem that has persisted for decades – the price tag may be considered a good investment (instead of a price tag), given the benefits that it generates. The program could be replicated in other engineering schools where the faculty members are receptive to teaching innovations.

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References


