Materials Science Course for Non-Majors: An Exercise in Experiential Learning

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Teaching Materials Science courses can be difficult. Teaching Materials Science courses to non-majors can be even more difficult, but teaching Materials Science courses to freshmen non-majors who have no chemistry or engineering background can be extremely challenging. The students in the Mechanical Engineering Technology (MET) program in the Purdue School of Engineering and Technology at IUPUI are required to take an introductory Materials Science course their very first semester. Lacking the basic chemistry and engineering mechanics fundamentals, most of the concepts presented in this course are completely foreign to the students. The absence of the fundamentals coupled with the students’ naiveté about materials, products, and processes requires a slightly different approach in the classroom.

The MET program is a manufacturing based curriculum that emphasizes mechanical design, processing, and analysis. The information the students receive in the materials course will be encountered again in several of their major classes, but more from a design or manufacturing standpoint. The students need something they can relate to now because it is uncommon to have the foresight and understanding of how all this academic information will be important and utilized in the future. To help the students maximize their learning in the classroom and begin to understand the complexity of the manufacturing industry, various activities, laboratories, and tools have been developed for this Introduction to Materials course. These ideas were developed to engage the student in this course and help them obtain a deeper understanding and appreciation of the material world than they would get with a traditional lecture format. This paper discusses the strategies and tools used to present various materials concepts to the students along with the guided activities and laboratory experiments performed by the students.

Introduction

Young children are very inquisitive and they want to figure out how and why everything works. It’s during this time in their lives, just after they have a firm command of the language until they are about 5 or 6 years old, that children are the most curious and want to explore their world. Children will test things out, take things apart, put them back together again, and repeat the process over and over again. Children learn by active
exploration, repetition and the many activities they experience. As adults, we are able to learn in other ways, but the best way to retain and understand information is not very different from when we were young.

One of the best ways to learn something new is to experience it. This is not a new concept, in general; it just hasn’t always been applied in the college classroom. Many hours are spent enduring lectures which have been shown to be an inefficient means for students to retain the information. Several academic units have adopted a more active learning environment for their students by incorporating real-world activities into the curriculum. These efforts enable the students to better understand the material they are learning. Examples of such majors include: Medicine, Dentistry, Education, Geology, Foreign Language, and others. Hands-on or experiential learning is also very common in the Engineering Technology fields, but there is always room for improvement.

Background

The Purdue School of Engineering and Technology at Indiana University Purdue University Indianapolis has two degree programs that are considerably manufacturing oriented; Mechanical Engineering Technology (MET) and Computer Integrated Manufacturing Technology (CIMT). Each of these programs requires first semester freshmen students to take an Introduction to Materials course. The course covers the areas of polymers, ceramics, metals, and composites. Within each of these areas several topics are covered including chemical composition, physical behavior, properties of the materials and more. The course is a three credit hour course consisting of a two credit hour lecture and a two credit hour lab each week for sixteen weeks.

While it’s desirable for students coming in to IUPUI to have already taken courses in chemistry and physics in high school, it is possible for a student to pursue a degree in MET or CIMT without having taken either. Also, since there are no pre-requisites for the materials course, being a first semester course, it is a common occurrence that students have no background for this type of course at all. This creates additional work for the instructor if the student is to understand the content and derive useful meaning from it.

The situation is no longer one where the instructor can explain atomic bonding because the students have to first understand what an atom is, what an atom is made of, how this relates to the periodic table of elements, what an element is, and then finally how atoms can then bond together to make something useful. The key is to work diligently at finding “something useful” that interests the students or at least piques their curiosity enough to make them want to learn more and understand the concept. The best way to do that is to engage the student and either allow their past experience to help guide their learning or create new experiences for them to foster new learning.

Engaging the Student

The transition from high school to college is one that presents many challenges for students. There are new rules, new expectations, new faces, and so many of the first year
students are very unsure of their new environment. These insecurities often manifest themselves as students who are very hesitant about participating in class discussions. Finding new ways to engage the students becomes critical. It is also important to create an environment where students are comfortable participating in group and class activities.

At the beginning of each semester, the students are given a confidential survey and a pre-course exam. The survey enables the instructor to identify the educational background of each student while keeping the instructor impartial to all students. The survey also tries to ascertain the interests of the class members so that they can be used in lectures and discussions. This is also very important as freshmen tend to be rather timid and quiet during lectures and forcing the students into giving this information to the entire class would be very embarrassing. The pre-course exam is given to evaluate the educational background of the students and help the instructor understand the educational need of the students with respect to the learning objective of the course. From that point forward, creating an environment where students are interested, motivated, and comfortable is very valuable in experiential learning activities. Any tool that can be used to assist in this process is recommended. Some of the tools utilized in the Introduction to Materials class are described below.

**Learning Tools**

**Scavenger hunt** – During one of the first few meetings, the class is broken down into groups. Each group is given a bag, a sheet of paper, and a pen. The sheet of paper has the four materials families that are to be covered during the semester (metals, ceramics, polymers, and composites) and nothing else. The groups have 45-60 minutes to search far and wide for as many items as possible that will fit into each category. The teams must write the items down on the piece of paper or place it in the bag if it will fit. Extra points are given for items fitting inside the bag. At the end of the time, the teams return and present their findings to the class. Extra points are also given for originality or complexity. The hunt counts as an assignment grade and teams can also be graded on their effort.

This process makes the students take a different view of their surroundings. Now, it isn’t the place they’re completely used to and generally take for granted, it’s a new place filled with products made from many different types of materials and those materials are very important for supporting our way of life.

**Writing down instructions** – One of the most difficult tasks a student must do is write laboratory reports. Although necessary and important for developing the students’ communication skills, it can be perceived as rather dull and frustrating at times. This process becomes more challenging for instructors when the students writing the lab reports have never written lab reports before. One of the most difficult sections for students to write seems to be the laboratory procedure and equipment section. A couple of related activities have been developed to aid in this area.
In one activity the student must give instructions and in the second they must follow them. For giving instructions, each student is given the “simple” chore of writing down the instructions for a specific task. (How to tie a shoe, How to make a peanut butter and jelly sandwich, etc.) When everyone is finished, a couple of volunteers are gathered to test out the instructions in real life. The outcome is that it is much more difficult to write exactly what you mean than you think it is and so care must be taken when writing down laboratory procedures.

For following instructions, the instructor creates a “procedure” that must be followed without the student knowing or asking anything about the goal. The idea is for the instructor to give bad instructions, thus making the students confused and needing to ask questions. The students then have to work together to rewrite the instructions, clarifying all confusion. This process helps the students identify good and bad ways of writing instructions.

**Why not vs. why** – regardless of how well an instructor feels they have led a discussion toward a desired concept, asking the question “why” will always result in an unexpected answer. For a student with no real understanding of a topic, asking “why” or giving an open-ended question can be very intimidating because the connections may not be there just yet. Sometimes it’s easier to drive a point home by creating the ridiculous and then asking the students – why not?

To make a point about impact properties of various materials, ask the students how many hammers they’ve seen made from glass. While intuitively they know that it is ridiculous for a hammer to be made from glass, they have to come up with some valid reasons why it shouldn’t be done. Then move to another ridiculous material, such as EPS, and continue the process. It doesn’t take long for the students to understand the concept and make the connections about materials and their impact properties.

**Experiments and Demos** – The students perform eight lab experiments during the course of the semester that require a formal written report. This is a great way for them to see what is happening and get some experience with the equipment. While this tool is nothing new, it still plays a very important role in experiential learning. Examples of experiments that are performed during the semester include: Exploring Physical Properties, Exploring Mechanical Properties, Metallurgical Specimen Preparation, Heat Treat and Hardness, Jominy Hardenability, Impact Testing of Polymers, Anisotropy in Wood, and Performance of Adhesives.

While most of the activities performed during the laboratory experiments are guided, leaving some room for student curiosity and exploration can also lead to additional learning and comprehension. One example of this is given in the Performance of Adhesives lab. The objective of the lab is to determine the bonding performance of various adhesives with respect to bond orientation (shear and tension) and materials bonded (metals, plastic, wood, and combinations). Once the basic requirements of the experiment are met, the students are also able to utilize their own adhesive-material
combination. The challenge is to see if any group can come up with a combination that is stronger than any of the standard specimen for the experiment.

Since the students do not perform a lab experiment every week during the semester, there are occasions where a demonstration by the instructor can take place. Demonstrations do not give the students the opportunity to do the work for themselves, but it can be used as an opportunity for the instructor to show the students something a bit riskier – something that will make a visual impact. Going back to the glass hammer example, a bit of liquid nitrogen comes in handy for making glass “bouncy balls.”

Another easy example that is often pictured in materials textbooks is to examine the thermal shock resistance of Pyrex vs. ordinary glass, or thick glass vs. thin glass. Some ice, an electric heating plate or a torch, a standard glass bowl, and a Pyrex bowl is all you need. By placing the ice inside the bowl and heating the outer surface of the bowl with the heating plate or torch, the standard glass bowl with crack but the Pyrex bowl will not.

**CD Lab manual** – A multimedia version of the lab manual was created to address the visual learning process more directly. Regardless of how well instructions are written, there is always room for interpretation error if the person is not familiar with the procedure. Since the students in this course are completely unfamiliar with all the equipment and procedures, it is very easy for them to get confused with the instructions in the lab manual. To help address this issue, videos were taken of the lab procedures being performed, saved as .avi files, and incorporated onto a page along with text procedures. Now, the students have access to a visual reference for the procedure as well as written instructions. Still photographs of the equipment are also available so that the students can identify the equipment before they perform the experiment and they can incorporate the name, manufacturer, and model number information in their lab reports.

**The Magnitude of Manufacturing** - Many people take for granted the amount of materials we consume each year. We talk about recycling, green design, and other topics of this nature, but this really doesn’t drive home the urgency of the situation. To give students an eye-opening view of how much material we use, they are given an exercise requiring them to search the internet to find the answers to some manufacturing questions. Other questions may be answered from their own experience. Here are some examples:

- How much does the average car weigh?
- What portion of that weight is made from metal? Polymers?
- Approximately how many cars are produced in the U.S annually?
- Where do these materials come from?
- Are they a renewable source?
- How many rolls of toilet paper does your family buy a week?
- How many people are in your family?
- How many (on average) rolls of toilet paper does each person use a week based on the above 2 questions?
- How many people are there in the United States?
How many rolls of toilet paper would we consume per year based on the number of rolls/week each person uses in your family?

Mind Trap® - Mind Trap® is a game by Pressman® that asks questions or presents scenarios that try to make you think “outside the box.” There is always some catch or trick or even obvious explanation as an answer, but the general tendency for people is not to “think”, but just say whatever seems logical. The goal is to answer the questions correctly or accurately explain the outcome of the scenario and progress around the game board. While the questions and scenarios do not necessarily have to deal with materials, the game is a very useful tool for getting students to think about ideas from a different perspective. Rather than playing an entire game, the question cards can be used as a way to grab the students’ attention or make a transition to a new topic. Offering bonus points to the students that correctly answer the question can motivate the students to participate also.

Additional activities are used and many more can be incorporated into the classroom to enhance the learning process for the student and make the class more enjoyable for everyone involved.

Results

Incorporating these engaging activities into the Introduction to Materials course made a difference in the students’ performance on exams during the first semester trial. As a baseline indicator for each semester, as previously described, a pre-course exam is given during the first week of classes. The scores on this test are consistent over a 3 year period. Exams given during the semester, in partial fulfillment of the students’ final grade in this course, are also consistent over a 3 year period even with some variation in the class. The scores are consistent even though other changes were made in the class. For example, the book for the course was changed to a new author with a different content layout in the Fall of 2000 and then updated to a new version for the Fall of 2001. Also, rotating the experiment schedule for the different groups was tested as well. However, the lecture plus lab format was consistent and unchanged during this timeframe and so were the exam scores. Summary of this data is presented in Table 1.

Prior to utilizing the new material in the fall of 2002, the course consisted of lecture and experiments only. While the class still has a lecture component to it, the format has changed. The other activities are incorporated as breaks, “attention getters”, “eye-openers”, group activities, and the students respond positively to them. On a semester-to-semester comparison of test scores, the students doing the extra activities perform slightly better on exams than those with the traditional lecture and laboratory combination during the previous 3 years. The class average test data can be seen in the Table 1 and Figure 1 below.

As a measure of student satisfaction in the course since the extra activities were added, the course evaluations have improved also. This data is included in Table 2. The scale for the evaluations is from 1 to 5 with 1 being the lowest score and 5 being the highest.
As more and more activities are developed and incorporated into the class, and improvements are made to the current activities, it is expected that additional student improvement will be seen before reaching a maximum.

**Average Student Performance on MET 141 Exams**

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<th>Fall 2002</th>
<th>Fall 2001</th>
<th>Fall 2000</th>
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<tbody>
<tr>
<td>Pre-exam</td>
<td>36.5</td>
<td>37.1</td>
<td>35.2</td>
</tr>
<tr>
<td>Test 1</td>
<td>83.5</td>
<td>76.5</td>
<td>75.7</td>
</tr>
<tr>
<td>Test 2</td>
<td>76.7</td>
<td>72.4</td>
<td>73.1</td>
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<tr>
<td>Final Exam</td>
<td>82.6</td>
<td>75.7</td>
<td>76.8</td>
</tr>
<tr>
<td># of students</td>
<td>20</td>
<td>25</td>
<td>24</td>
</tr>
</tbody>
</table>

Table 1: Student Performance as an Indicator of Experiential Model Success

![Student Performance on MET 141 Exams](image)

Figure 1: Student Exam Scores Improve After Incorporating Experiential Learning Activities

**Student Evaluation Summary for MET 141**

<table>
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<th></th>
<th>Fall 2002</th>
<th>Fall 2001</th>
<th>Fall 2000</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall Course Evaluation</td>
<td>4.15</td>
<td>3.72</td>
<td>3.8</td>
</tr>
<tr>
<td>Student Satisfaction Rating</td>
<td>4.19</td>
<td>4.06</td>
<td>4.08</td>
</tr>
<tr>
<td># of students</td>
<td>20</td>
<td>25</td>
<td>24</td>
</tr>
</tbody>
</table>

Table 2: Student Evaluation Data as an Indicator of Experiential Model Success
Figure 2: Student Evaluation Scores Improve After Incorporating Experiential Learning Activities

Conclusions

Incorporating these activities into the classroom is not always simple. A lot of planning, preparation, several trial runs, internet searches, and more may be necessary. It can also be very difficult to keep these activities going. It’s much easier to stand in front of the classroom and lecture as has been done in the past. However, in the interest of the students, their understanding of the material, and their continued desire to learn, it is better to teach outside the box and engage the students in some experiential learning.

Bibliography

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2. Department of Mechanical Engineering Technology web page at IUPUI, [www.engr.iupui.edu/met](http://www.engr.iupui.edu/met)

Biographical Information
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