

## Introducing Problem-Based Learning in a Materials Science Course

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### Abstract

The advantages of problem-based learning (PBL) have been enumerated in the literature. In this work, the author presents his own experience in introducing PBL in a Materials Science course. In particular, several distinct problems will be identified for the interested teachers to implement. Materials science teachers can readily adapt such problems in their classrooms depending on available resources. Finally, a discussion of the author's evaluation of the educational experiment and any lessons learned/future recommendations are also included.

### Introduction

PBL is championed in the literature as one of the best methods for enhancing the learning experience of students<sup>1,2</sup>. The reason behind this is that in PBL, the problems are typically open-ended and do not possess a unique answer just like real-world problems and opposite to packaged textbook problems. In PBL, the student is pretty much left on his/her own, or in groups, and is asked to invoke his/her best "engineering" judgment to solve a problem or a set of problems. By its nature, PBL often involves that the student integrates a suite of previous knowledge, to a greater or less extent depending on the problem(s) at hand. This of course involves a considerable amount of thinking, which really is the nucleus of invention, and is in sharp contrast to traditional end-of-the-chapter problems for which the student expects to find the answer normally in the chapter!

Materials science and engineering is typically a major undergraduate course for many engineering majors (e.g. mechanical, civil, chemical, nuclear, aerospace, manufacturing, etc.). Such a course, at many universities, typically involves a lecture component and a companion lab component (although sometimes the lab portion of the class can be taken by the student independently, but following, the lecture component). In either of the last two formats, the main reason that the lab is an integral part of such a course is that materials engineering has traditionally been a hands-on type profession that lends itself to easy visual understanding of matter around us. And the saying "seeing is believing" cannot be more true than in materials science/engineering education especially given the fact that experiments in this field are very well established and relatively easy to perform provided average facilities/equipment at an institution.

In materials science education, there have been attempts reported in the literature to enhance the educational experience of students<sup>3-7</sup>. However, most reported efforts typically revolve around computer use through enhanced graphics, animations, virtual experimentation, etc., which are again factory packaged. However, it is not common to come up with open-ended problems, i.e. PBL, and let the students on their own define what the problem really is and solve it within some given guidelines, especially problems that involve hands-on type work. In this paper, the author attempts just that by providing here a list of small project/assignment ideas that serve as PBL experiments a materials science/engineering teacher can possibly assign to his/her students (depending of course on available resources). We also discuss some of the issues related to both the execution and successful completion of such PBL experiments.

## Project Assignments

A list of the projects assigned to students, *as is* from the class, is provided here below for interested teachers to utilize or adapt to their teaching:

- 1- Using Brinell hardness indenter:
  - a) Investigate the hardness of bobsled and skeleton runner material using lateral and longitudinal sections.
  - b) Investigate edge effects on hardness.
- 2- For a piece of copper of bulk size, polish and etch it, and then investigate microhardness close to the center of the grains and progressively closer to grain boundaries until indenting on top of them.
- 3- Using Brinell hardness, investigate hardness of aluminum to show the effect of:
  - a) indentation spots' separation
  - b) thickness of indented sheets
- 4- Using impact testing, show the effect of temperature on toughness and fracture surface appearance of steel specimens.
- 5- Using Pro/E (SolidWorks or any other 3D CAD software), construct three-dimensional models of FCC and BCC unit cells (sectioned and un-sectioned). Rotate them in GIF animations.
- 6- Using Pro/E (SolidWorks or any other 3D CAD software), construct three-dimensional models of HCP and Rhombohedral unit cells (sectioned and un-sectioned). Rotate them in GIF animations.
- 7- Using plexiglass or wood hard spheres, construct sectioned models of FCC and BCC unit cells.
- 8- Build two models of a tilt boundary (Figure 4.8 in the textbook by Callister, 2003); one with  $\theta=5^\circ$  and the other with  $\theta=10^\circ$ .
- 9- Use a tensile testing machine to test the strength of different types of paper tissue (namely toilet, facial and towel paper) and determine if it meets TAPPI standards.
- 10- Use a digital camera and determine the time exponent for diffusion of blue or black ink in water.
- 11- Build a model that would be used repeatedly to illustrate dislocation slip and the impingement of dislocations on a free surface (like a sliding deck of cards).

- 12- Establish a stress-strain curve for rubber band elasticity and determine its tangent modulus at zero strain.
- 13- Determine Poisson ratio for a piece of Aluminum.
- 14- Determine the effects of temperature on the ductility of rubber bands of some fixed brand and type.
- 15- Determine the flexural strength of Alumina or ceramic tile (marble for example).

Some notes on the above project assignments are in order. First of all, the students were for the most part on their own, and the instructor did not provide much guidance. Second, all of these projects were chosen because they were considered to be neither time-consuming nor costly in materials and supplies (students were given about a month and a half to complete their projects). Third, each of the projects was considered to be a very heavy homework assignment in grading (equal to about 4 homework assignments in weight) and students knew about that from the very beginning. Note again that these projects were not part of the lab portion of the class but rather of the lecture portion. Fourth, the projects were picked such that the existing departmental facilities/equipment were capable of handling any usage demands/needs from the student groups that they might foresee necessary to accomplish their projects.

There were 45 students in the class and the instructor wanted to divide the students in nominal groups of three. Hence the fifteen projects presented above. Right after the project assignments, every student group was asked to give the teacher back a filled-out “team contract” (see the contract in the **Appendix**). At the end of the semester, one class day was declared as a “Poster Day” whereby every student group had to develop a poster, along with any other visuals including developed computer animations, to showcase their work to their peers and other students/faculty/staff in the department. The students were made aware of the Poster Day when the project list was first provided to them.

### **Some Project Results**

To give the reader a flavor of some of the results generated by the projects, we show here few figures from these projects. Figure 1 shows a sectioned computer-generated unit-cell of a BCC crystal structure. This hard-sphere model was generated using the 3D CAD software Pro/Engineer. This is called a sectioned model since only portions of the cell’s atoms that completely lie within the cubic domain are shown in the figure. The students also generated an un-sectioned model (picture not shown here) where such atoms were left intact without sectioning. Figure 1 indeed does not represent a still image but rather a computer animation (a GIF animation) that can only be displayed as a still on paper but shows its true self in a web browser for example. Other GIF animations that are shown here as still images are Figures 2 and 3, which show an un-sectioned model of a HCP unit cell and a sectioned Rhombohedral unit cell, respectively. These two were generated using the 3D CAD software SolidWorks. Other projects were more experimental in nature and it is thus harder to show images from the results of these projects although many of them posted pictures on their posters. It was thus easier to obtain the three figures here from their respective groups since they readily had available computer files to lend the instructor.

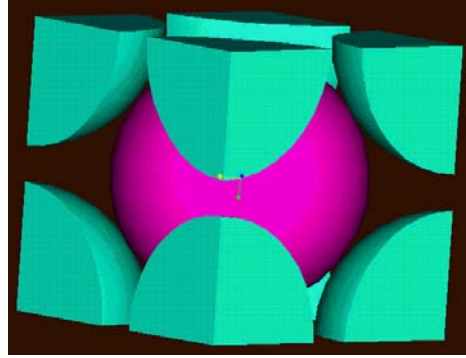


Figure 1. A sectioned computer-generated model of a BCC unit-cell.

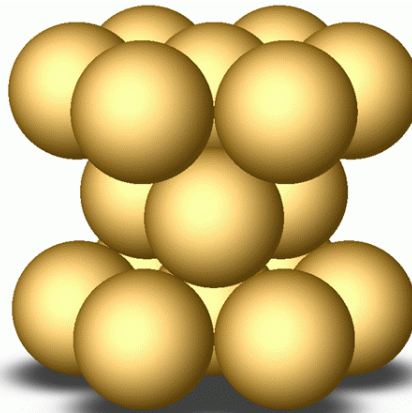


Figure 2. An un-sectioned computer-generated model of a HCP unit-cell.

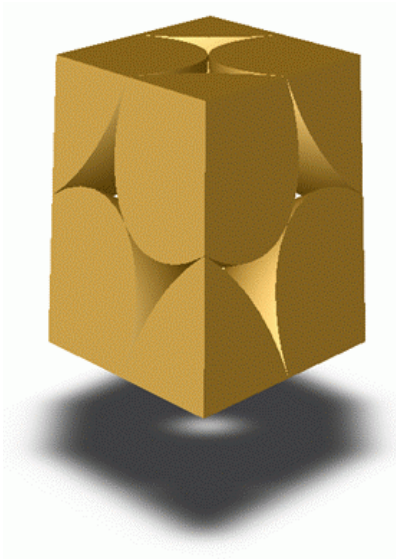


Figure 3. A sectioned computer-generated model of a Rhombohedral unit-cell.

## Discussion

First, it has to be pointed out that students were allowed to pick a project from the list on a first-come first-serve basis. The instructor did not impose projects on any group of students. Second, the reason why the students were not provided much guidance from the instructor was because that is the whole idea behind PBL in general. Students, therefore, had to search through literature, textbooks and other sources to accomplish on their own the tasks assigned to them. They have to understand the problem very well on their own and then tackle it with whatever means appropriate. Third, time and cost were two very important factors in choosing projects on the list as neither was meant to be a burden on the students. After all, the students were doing these projects in addition to regular homework assignments and one other credit hour of lab work. Fourth, the above list serves only as a starting point for interested teachers wanting to implement something similar in their classrooms. The projects in the list can either be modified or other projects can be thought of along parallel lines to existing ones. Fifth, it has to be emphasized that the selected projects for the class were things not typically covered in any great detail in the classroom, if any whatsoever. Indeed this a main idea behind PBL is that there is almost never enough time in the classroom to explain a lot of good topics, *especially* in materials science and engineering, but this way the student gets to learn few things in depth on their own time/effort. Sixth, part of the reason behind certain project selections was to drive students to use knowledge gained from pervious courses. For example, projects #5 and #6 build on 3D CAD modeling knowledge that the students learned about in the past year or two in other classes. Other projects also build on knowledge gained from the lab portion of the current materials class (but still doing different things than in the lab). Hence, the students are doing in essence one more extra lab but totally on their own without any guidance from a Teaching Assistant. Seventh, the GIF animations generated by the students can be used by the teacher in future class demonstrations of crystal structure, i.e. they serve as excellent teaching aides. These animations are also ideally suited for web content and display. Eighth, the team contract is a measure exercised by some educators to avoid or manage conflict between team members in the case they arise. Lastly, the Poster Day has generated a lot of enthusiasm and interest from the students, faculty, and staff in the department, as it was widely announced and open for everybody.

## Conclusions

The PBL experiment overall was perceived a success. The students provided, in general, positive verbal feedback about it. Perhaps some sort of written feedback, e.g. surveys, would have been better for assessment of the effectiveness of the experiment but that would be left for future endeavors. It is important when assigning such projects that the conditions of performance, including deadlines and expectations, are clearly communicated to the students as much as possible. Although this is also true about other types of assignments, it is more relevant in PBL because of its open-ended nature. It also helps a lot that the teacher meets with the groups, once or better twice, before the project deadline to make sure that they are on track to accomplish their tasks. This would eventually make it a happier and more successful experience for all.

## References

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Dr. Khraishi currently serves as an Assistant Professor of Mechanical Engineering at the University of New Mexico. His general research interests are in theoretical, computational and experimental solid mechanics and materials science. He has taught classes in Dynamics, Materials Science, Advanced Mechanics of Materials, Elasticity and Numerical Methods. For the last two-three years he has engaged himself in the scholarship of teaching and learning.

## Appendix

### ME370 (Materials Science and Engineering) Project Team Contract

Complete the following table to collectively define the responsibilities of each member to the total team and the team's responsibilities to its individual members.

<b>Individual Members' Responsibilities to the Team</b>	<b>Team's Responsibilities to the Individual Members</b>
1.	1.
2.	2.
3.	3.
We the undersigned agree with these responsibilities lists for our team:	