

Integrating Spreadsheets into an Introductory Materials Course

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Introduction

We hardly have to encourage students to use the latest software for many of their course assignments, personal business, entertainment, and all the other things our computers can do for us these days. It is clear that they are not reluctant to jump in and teach themselves how to use these new tools. It seems, however, that this may not be the case for less trendy or entertaining software such as programming languages, databases, and spreadsheets, even when it can really help them in their studies. In the case of spreadsheets, few students in our department had ever used them in their engineering courses. This seemed surprising since spreadsheets are so easy to use, are ideal for performing routine calculations and plotting data, and a spreadsheet application has probably been on every personal computer they have ever used. Normally this would not cause any concern except that many of our students continued to do much of their work using handheld calculators and pencils and were still drawing their graphs by hand, while at the same time they'd never consider writing the text of their papers and laboratory reports without using a wordprocessor.

A critical and challenging part of an on-going project to develop spreadsheet modules for use in the materials science and engineering curriculum is finding the best way to introduce these into existing courses. This paper describes an effort to integrate spreadsheets into a sophomore-level introductory materials science course.

Why Spreadsheets?

While spreadsheets have been around for many years, dating back to the late 1970s and early 1980s when the availability of programs such as VisiCalc and Lotus 123 alone justified the purchases of the hardware, the engineering student and instructor today have many more options for mathematical and number-crunching software. TKSolver, Maple, MatLab, Mathematica, and others offer powerful modeling and equation-solving capabilities. FORTRAN and C++ are well known examples of programming languages that are widely used in modeling and numerical analyses and which are often taught in undergraduate courses. Spreadsheets, like word

processing software, are not actively taught in engineering courses, not because they are not useful, but because students can usually learn them on their own.

The advantages of using spreadsheets in classroom situations include ease of use and easy learning curve and the grid arrangement of spreadsheet cells lends itself to learning a host of skills such as working with arrays, thinking in terms of data as objects, organizing and presenting information in tables, and taking an overall structured approach to solving engineering problems. In many cases their main advantages may be their low cost and availability means they can be inserted into practically any course with little or no additional investment of money, by the department or the student, or distraction from the principal subject being taught.

Integrating Spreadsheets into an Existing Course

Recently developed spreadsheet modules have been used in several undergraduate materials science courses, including an upper division materials characterization course, a kinetics of materials course, and an introductory materials science course, ENG-45. Given the large number of students taking ENG-45, that it is taught four times each year, and that it is a lower division course that has a laboratory component, it received the most attention in our efforts at integrating spreadsheets into this course.

ENG-45, Properties of Materials, is a 4-unit lower division course that is taught during all three quarters of the academic year plus summer session. Enrollment is typically 90-130 each quarter except summer, and is taken by students from all majors. The laboratory portion of this course consists of four experiments. Each begins with a discussion session where the instructor, usually a teaching assistant, helps prepare the students to do the experiment, the laboratory session where they all do the experiment, and finally a written formal report. These laboratory activities offered many opportunities to employ spreadsheets in all phases of each experiment.

In the past we (myself and eight teaching assistants) tried simply encouraging students to use spreadsheets by demonstrating how they can be used to organize and plot their data, by using an automated (macros) spreadsheet to import and plot their data, by exporting data to a spreadsheet-friendly format, and by showing them how we personally had used spreadsheets in various projects. Each quarter a few students showed an interest and we provided additional support for them, but most stuck with their calculator and pencil methods, contradicting our notion that students are quick to adopt new technologies.

A few years ago we introduced a spreadsheet-based experiment dealing with the ionic bond ¹, forcing them to use spreadsheets in their first experiment. In this experiment students calculated lattice energies and forces for NaCl-type compounds and then extracted properties such as lattice spacing, elastic moduli, and melting points. This exercise involved creating tables, simple numerical techniques, plotting the data, finding minima, etc. As a result the teaching assistants

were thoroughly convinced that knowing how to use spreadsheets could really help the students, but still few students took advantage of their new skills in subsequent experiments or in preparing their reports.

During the past year additional spreadsheet exercises were written into the students' laboratory manual and became a required part of each experiment, appearing in all three phases:

- Preparation Students are given exercises to complete before they come to the laboratory to do the experiments. These exercises are typically sample calculations that help them understand the equations they'll use in the laboratory, or compiling data similar to that they will be generating.
- Experiment Spreadsheets become secondary in this phase, but may be used to compile and organize data in group experiments and to import data and generate plots. In many cases, the spreadsheets they created before coming to the lab are adapted and expanded to include the experimental results.
- Reports Students are given a number of recommendations on how to analyze and present their data, including using simple spreadsheets to help compare measured versus reference data, etc.

Descriptions of how these are done in each experiment are described in the appendix. Copies of the preparation and recommendations handouts can be downloaded from the course's web site at www.matsci.ucdavis.edu/matscilt/eng-451/eng-451.htm.

Other than these additional spreadsheet-based assignments, little additional time was spent teaching the students how to use spreadsheets. The first experiment provided an opportunity to help the students as they built their first large spreadsheet, but even that was after they had a chance to experiment on their own doing the preparatory exercise.

Assessment and Outcomes

Students taking ENG-45 were surveyed at the beginning and end of the fall 2003 quarter to gauge their expertise using computers and spreadsheets, and how effect our efforts were in teaching them how to use spreadsheets to solve engineering problems and how it helped them learn the course material.

Profile of Student's Experience Using Computers – The survey given at the beginning of the quarter dealt with five issues:

Spreadsheet Experience and Expertise	Spreadsheets used (Excel, Quattro Pro, etc.), level of expertise (beginner, intermediate advance, and expert), how they have use spreadsheets in the past (homework, job, research, high school), how often spreadsheets are used in current course work, and how much help does the student think he/she would need to complete a spreadsheet-based homework assignment
Experience Using Other Applications	Other types of applications used (wordprocessors, databases, CAD, etc.) and which ones the students feel they are proficient at.
Experience With Programming Languages	Which languages they have used, what types of projects they worked on, and how many hours of programming they have done.
Experience with Computers in General	How old they were when they started using computers, how many years they have been using computers and whether they consider themselves ordinary users, advanced users, power users or experts at using computers.

The students were asked these same questions in the first category (spreadsheet experience and expertise) at the end of the quarter. The number of surveys completed were 116 at the beginning of the quarter and 97 at the end of the quarter.

The students' responses to questions of experience with spreadsheets and computers are shown in the charts in figure 1. These results show that nearly all of the students have used Microsoft Excel, but most also consider themselves to be beginners (can write simple formulas and create basic charts). A third of the students have never used spreadsheets in course work while only a few, less than 10%, use them routinely. The average age when our students started using computers for other than games and entertainment was 12 and they have been using computers for an average of 7-8 years. When asked to write a simple formula using spreadsheet syntax two-thirds did not do it correctly. Consistent with this, two thirds said they would need some help using spreadsheets for course work. The number of students not providing answers to specific survey questions, shown as N/R in the charts, was less 0 to 5%, consistent with the 6%

who indicated that they had never used spreadsheets.

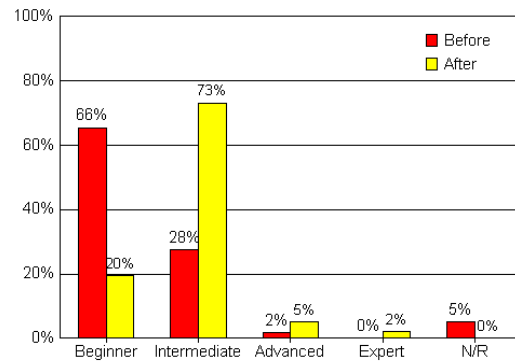
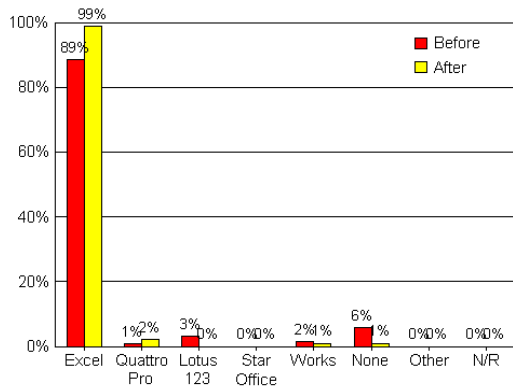
In summary, the typical student had 7-8 years of experience using computers and had used Excel but not enough to be able to do some basic calculations.

Improved Spreadsheet Skills – At the end of the quarter the results were quite different. The number of students who considered themselves spreadsheet beginners had dropped from 66 to 20 percent while the number who felt they could write complicated formulas, import data, perform moderately difficult numerical analyses, and create any type of chart (intermediate) had increased from 28 to 73 percent, nearly tripling. In addition, the number who felt they wouldn't need any help with spreadsheet-based course work almost doubled to 48 percent while the number who felt they would still need a lot of help had dropped from 9 to 2 percent. In terms of general spreadsheet skills, the improvement was substantial.

Specific Skills Learned and Broader Impact – The survey at the end of the quarter included 10 additional questions that address specific skills and broader outcomes. These questions were phrased in such a way that the responses “Agree” and “Strongly Agree” indicated desirable outcomes. The issues addressed in this part of the survey included:

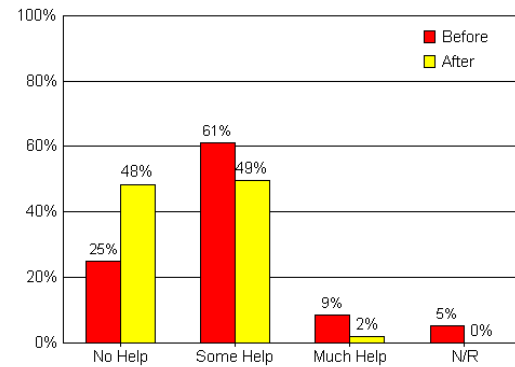
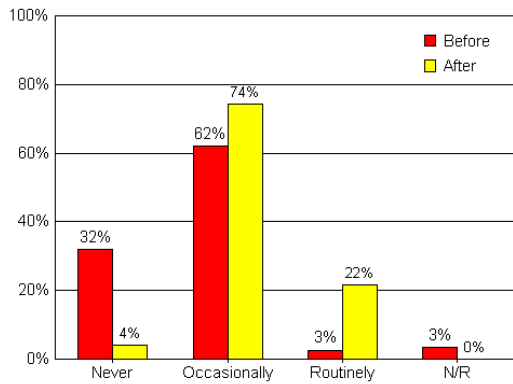
Using Spreadsheets in Engineering Courses	Compiling data and creating charts, perform simple calculations, perform more sophisticated numerical analyses, importing data, copying and pasting objects to other applications
Learning Materials Science	Gained a better understanding of basic concepts, provided tools to be able to explore more advanced materials topics, helped generate more informative and effective laboratory reports.
Broader Impact	Organizing and presenting data, illustrating concepts, solving engineering problems, handling data from experiments, likelihood of using spreadsheets in other engineering courses, and spreadsheets becoming a normal part of all materials science courses.

Figure 2 shows the responses to the two questions which address broader impacts and long term goals of this effort along with the totals from all questions, indicating that an overwhelming majority agreed with each of the statements in their surveys, reflecting outstanding success in this effort.



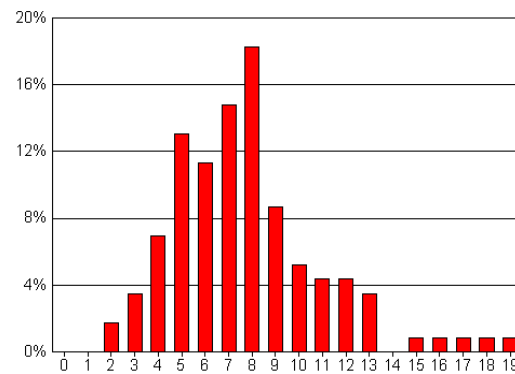
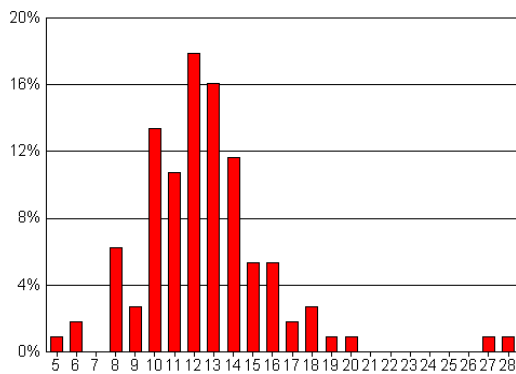
A. Spreadsheets students have used.

B. Students' spreadsheet skill level.



C. Frequency that the students use spreadsheets in their course work.

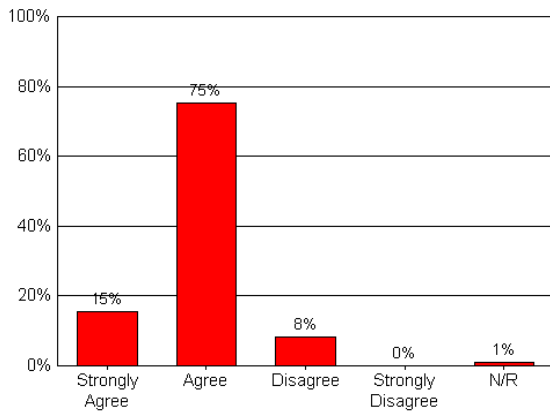
D. Students who feel they'd need help completing a spreadsheet-based homework assignment.



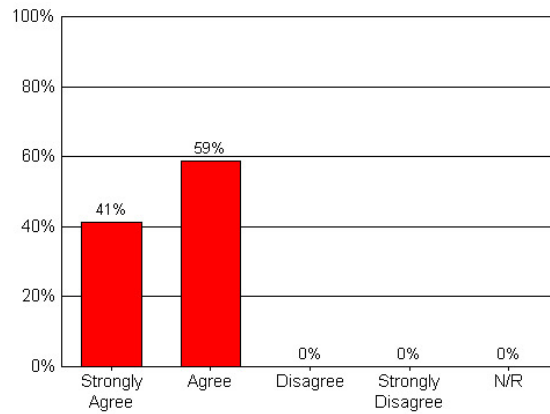
E. Age when the students started using computers.

F. Years the students have been using computers.

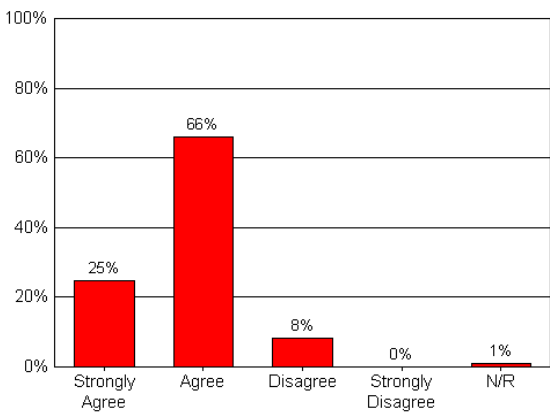
Figure 1 Students' responses to questions about their experiences and expertise with spreadsheets and computers.



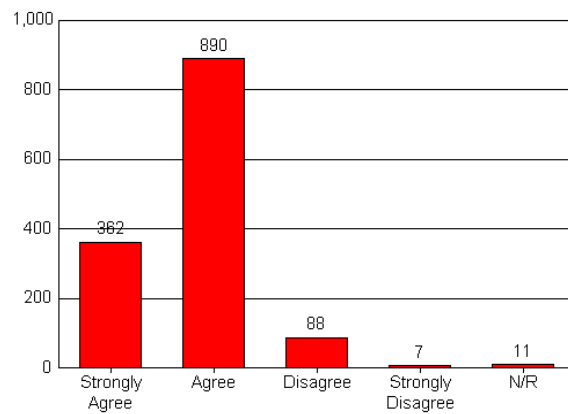
A. Ability to use spreadsheets to solving engineering problems.



B. Ability to handle data from experiments.



C. More likely to use spreadsheets in the future.



D. Totals from student responses to all questions about specific skills learned.

Figure 2. Responses from survey questions dealing with specific skills and broader outcomes.

Figure 2D summarizes the students' responses to a number of questions asking about specific skills the students learned, including writing formulas, creating tables and plots, cutting and pasting data and objects, importing data, using numerical techniques, and using spreadsheets to illustrate concepts, organize and present data, solve engineering problems and handle data from experiments. These involved too many questions to present individually here, and are simple the sum of the responses from each question. The results were consistent for each question, with an average of 26% indicating that they strongly agreed and 64% agree that they learned these skills.

Finally, figure 3 shows the teaching assistants' combined responses to a survey they were given at the end of the quarter. These statements given in this survey were:

1. The spreadsheet exercises used in the preparatory exercises and the laboratory experiments improved the students' overall understanding of the subject.
2. The instructions given in the spreadsheet exercises were clear and easy to understand by the students.
3. The spreadsheet skills required by these exercises were within the grasp of your students.
4. The overall level of difficulty of these exercises was appropriate for these students.
5. Based on feedback from the students, they are now more likely to use spreadsheets to solve engineering problems.
6. Based on your experiences with these exercises, you will be more inclined to use similar exercises in classes you teach in the future.

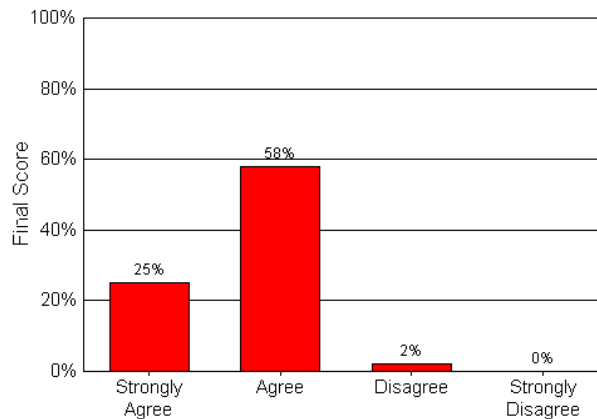


Figure 3. Summary of the results from surveys of the teaching assistants asking about the effectiveness of the spreadsheet exercises in improving student learning.

Like figure 2D the results shown in figure 3 are the sum of the responses to all six questions, and the results were consistent, considering the small sample size, for each question. Overall, these results illustrate what the teaching assistants have been reporting for the past year and a half, that our efforts to integrate spreadsheets into this course are producing positive results in terms of the students learning of materials science and their ability to handle a wider variety of problems using their new skills. Comments the teaching assistants offered in their surveys included:

- Even though some students may have complained at first they really learned a lot, that the extra effort was really worth it.
- By the end of the quarter the students felt more comfortable using spreadsheets. As with any software it seems the hands on approach is the best way to learn.
- I thought the pre-lab exercises were too easy, outside of the first one.

Conclusions

Early efforts to get students to start using spreadsheets in their laboratory work and when preparing their reports did not get far until spreadsheets were fully integrated into the course. Once we had them using spreadsheets in all phases of the experiments they began to see how easy spreadsheets were to use and how useful they actually were. Many students indicated in the surveys that they would be more likely to use spreadsheets in future courses, which was the principal objective of this effort and a few even expressed their appreciation on the surveys (figure 4). Surveys being what they are, the real measure of the effectiveness of this effort will come when they take my upper division materials characterization course.

A student's handwritten note at the bottom of a survey. The text reads "Thank you for your assistance. 😊 NO, thank you." The note is written in black ink on a white background. There is a horizontal line above the text, and a small vertical line above the word "NO".

Figure 4. One student's note at the bottom of the second survey.

Matlab and similar software could also be integrated into these courses, based on this experience to be effective the students must use them throughout the quarter and the instructor will probably need to set aside time to learn how to use this software. Spreadsheets, on the other hand, were relatively easy to integrate into this course due to the low learning curve, which meant that we did not have to allocate additional time, other than a brief introduction at the beginning of the first exercise and a Word and Excel notes sheet the teaching assistants wrote, to teach the students how to use spreadsheets. Our efforts remained focused on the materials science.

References

1. Mike Meier, Ionic Bonding, An Introduction to Materials and to Spreadsheets, Proceedings of the National Educator's Workshop, NEW-Update 1999, pp.151-166, (1999)

Bibliographic Information

Michael L. Meier received his B.S. in Materials Engineering from North Carolina State University in 1979 and his M.S. (1986) and Ph.D. (1991) in Materials Science and Engineering from the University of California, Davis. In 1993 he returned to UC Davis where he is now the director of Materials Science Central Facilities, a materials characterization facility, and is very active in outreach efforts and developing the laboratory teaching program.

Appendix

This appendix describes each experiment used in ENG-45 and how spreadsheets are used in the preparation, the laboratory session, and when preparing the reports.

Experiment 1 – Ionic Bonding

Students use spreadsheets to calculate the lattice energies and forces for NaCl-type compounds, to plot the curves, and to derive basic properties such as ionic spacing, elastic moduli, and melting point. Once their spreadsheet has been validated for KCl they use their spreadsheet for another compound.

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| Preparation | Students are asked to perform preliminary calculations of the minimum lattice energy, ionic spacing and density. This familiarizes the students with the equations they'll use during the modeling experiment. |
| Experiment | The experiment involves building, validating and then using a spreadsheet to model ionic bonding. Students are also taught how to keep their work organized and understandable by a reader. |
| Report | Students copy and paste graphs into their reports and are encouraged to create bar charts to illustrate the agreement between their results and published results. |

Experiment 2 – Mechanical Properties

Students perform tensile and hardness tests on four different alloys to learn more about basic mechanical properties.

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| Preparation | Students are asked to look up selected mechanical properties for several alloys and illustrate them using a bar chart. This familiarizes the students with the typical range of values for these properties and provides them with a spreadsheet and graph they can use in their reports. |
| Experiment | The experiment involves tensile and hardness testing. Results from the tensile tests are exported as ASCII text (*.txt) files which the students can, but are not required to, import into a spreadsheet for further analysis and plotting. |
| Report | Suggestions are made on ways to compile and present the results from the experiment, including extending the original bar chart to include their alloys and additional properties. |

Experiment 3 – Equilibrium Phase Diagrams

Students melt 10 gram samples of Bi-Sn and record the cooling behavior, noting the transformation temperatures and using them to construct an equilibrium phase diagram.

- Preparation Students are asked to make a spreadsheet version of their data sheets (lists times, temperatures, compositions and other data to be collected during the experiment) and to fill it in with values they expect to record during the experiment. They are also asked to import data from the class web site and plot a reference phase diagram.
- Experiment The data logging software saves the data in a spreadsheet-friendly comma-separated variable (*.csv) format.
- Report Students are encouraged to import their raw data, plot selected cooling curves, and cut/paste them into their reports. They are also told how to add their transformation temperature data to the phase diagram they created in the preparation exercise.

Experiment 4 – Recovery, Recrystallization and Grain Growth

Students revisit mechanical testing while tensile and hardness testing six brass samples that had been annealed to affect recrystallization and grain growth. Once the mechanical testing is done they examine the microstructures.

- Preparation The students are asked to plot the strength, hardness, and ductility of a range of heat treatments for this brass (the data are in the appendix of their laboratory manual). Similar trends are expected in the experiment they will do.
- Experiment The stress-strain data from the tensile tests are exported as ASCII text (*.txt) files, while the mechanical properties (yield and tensile strengths, ductility, etc.) are analyzed and tabulated during the laboratory session. Students may work together on a spreadsheet that tabulates and plots this data.
- Report Students are encouraged to adapt the plot they made in their preparation exercise to show the trends in the various properties measured in this experiment.