**Nanotech HW Evaluation**

The homework exercises for the nanotechnology lecture is designed to be a gentle introduction to news items that described the research that formed the basis for each unit, long before there were any textbooks in the field.

With as much new content to grasp as there is, I formulated the questions originally as “talking points” for the lecture. Over the years prior to COVID, more formal lecture notes were developed, partly from the articles that were the sources of the homework questions listed in the weekXhorizontal.pptx files and partly from necessary “prerequisite” knowledge. Due to the interdisciplinary nature of the course however, such “prerequisite” knowledge cannot be presumed. Consequently, a summary of such prerequisite knowledge was merged into a lecture conducted at the beginning of the semester (prerequisitelecture.pptx), followed by reminders as necessary throughout the semester in weekXvertical.pptx and built upon to get a sufficient breadth of knowledge of the subject. As the homework is not designed for any meaningful depth, the answers to the homework are underlined, bracketed or circled in the news items. Consequently, scores on HW assignments should be 100%. Any scores below 100% meant that the student did not comprehend what he or she was reading. In some cases, that is not surprising, but when an ABET accreditor examines the consistently high scores on such homework, he or she should not be surprised. Consequently, there will also be only one reflection (this document) for all homework assignments.

**Nanotechnology Take Home Exam Questions and Issues Sheet (Q+I) Reflection**

The questions and issues sheet exercise is designed to provide a framework for defining both the technical and the non-technical issues thoroughly. Often this exercise is performed either individually or in teams. While students were permitted to work in teams on this part of the exam, most students did so individually. During the 2.75 hour weekly lectures, students need something to interrupt the monotony. Often, usually one to two time per lecture, students perform a short version of this routinely. After the course’s one very long exam, students work in teams on a literature review of their own choosing. The first task as part of that literature search after defining the search criteria is to generate a questions and issues sheet as a team.

Students who had taken CHE 1101 or CHE 3260 had performed an exercise before, whereas those who had taken BME 3260 or CHM 2002 as listed alternate prerequisite courses had not. That being said, the instructions are sufficient that even freshmen students can get an excellent score on this type of assignment. All students covered the minimum of 25 questions and issues. Students getting a poor rating on this assignment either ignored one of the nine categories (legal, regulatory, environmental, safety, health, social impact, quality, technical/engineering and economic), did not categorize their questions and/or did not bold-face the most important issues. In general, the students who had previous experience with this exercise averaged 4% better. This 4% was the standard deviation in the score for this assignment.

**Nanotech In-Class Portion of the Exam - Discipline-Specific Knowledge**

The in-class portion of the exam for the nanotechnology lecture does not include all of ABET’s broad scientific knowledge consistent with the goals of the ChE and BME programs, but it does satisfy more of that knowledge than any other course within the ChE and BME programs and it does include all of the necessary knowledge for the nanotechnology minor program. A student’s score on the in-class portion of this exam (total of 150 points) is as reasonable an assessment of the breadth of that knowledge. A score of 105-120 (a “C” on this test) is a poor, but adequate, understanding of the subject matter. A score of 121-130 represents an average understanding. A score of 131-137 represents a good understanding of the subject matter, and finally, a score of 138 or greater indicates a thorough knowledge of nanotechnology.

**Nanotech Excel / DataFit Take Home Exam Portion**

The ability to analyze data is one of ABET’s objectives. Though not a primary objective for this course, the ability to glean information from news items and journal articles and assess the validity of the materials analytical methods used to support the findings of those articles are critical. As an example, on this portion of the take home portion of the exam, students are expected to plot data using Excel for a capillary electrophoresis-based determination of the critical micelle concentration of a surfactant. As part of this, the students should see that there are two distinct linear regions in the data. The critical micelle concentration (CMC) is at the intersection of these two linear regions. Students use Excel to find the equations of those lines and preferably use Oakdale Engineering DataFit to determine the slopes, intercepts and the errors of these lines. Finally, students have to use DataFit to fit the following equation:

 ln CMC = A + B\*T + C/T, where T = Temperature

Students who had taken CHE 1102 learned these skills from me. Almost all students who had taken CHE 1102 had these skills further refined in CHE 3265. Some of the non-ChE students learned these skills for the first time in CHE 3265. Some BME students learned these skills from me in BME 4050 – Materials Characterization Lab in the prior semester. Some ChE students learned these skills from me in the prior semester during CHE 4553 – Materials Characterization Lab. BME students were supposed to learn these skills during BME 3261 – Biomaterials and Biomechanics Lab.

All of the chemical engineering students clearly achieved at least a “good” rating on the data analysis skills, as did the aerospace engineers who learned these skills in CHE 3265.

Some of the biomedical engineering students achieved either a good or excellent rating on these data analysis skills, but roughly 40%, including many BME master’s students who earned their B.S. degrees at Florida Tech earned unacceptable ratings. This confirms what Professor Diego Guarin-Lopez said anecdotally. This is an area that needs improvement. I recommend that BME students also take the one credit CHE 1102 course in future years as discussed in a 2021 BME faculty meeting to not only learn the data analysis skills, but also get an introduction to National Instruments LabView programming and some experience in solving problems requiring iterative solutions. This CHE 1102 course, plus more computer programming and CAD from my Basics of Making course and about one additional credit of content to be developed by Profs. Venkat Chivukula and Diego Guarin-Lopez of BME, will replace the MTH statistics course. I cover enough of the statistics that the students need, but nothing that they don't need.

**Nanotechnology - Comparison of Student Performance to Desired Course Outcomes**



**Nanotechnology - Comparison of Student Performance to Desired Program Outcomes**



**Materials Characterization Lab HW**

Students are permitted to work in groups to complete all homework assignments; this dramatically improves their success. Homework 1 expects students to process a TEM image using ImageJ. After some filtering processes to enhance the signal of the particles to the noise, students use ImageJ to determine the size of each particle. Then they dump the distribution of particles into an Excel file generated by the professor to bin the particles into logarithmically evenly spaced bins and make both probability density and cumulative particle size distributions. Generally, students struggle with this assignment and require the professor’s help to get through it. Success on this assignment is more or less binary. They either succeed or they don’t.

Homework 2 is meant to expose students to the plethora of materials analytical techniques, as well as assess their capabilities and limitations. Students take a long time to complete this assignment but are given enough guidance such that the average score on this assignment is over 95%.

Homework 3 introduces students to spectroscopic methods other than those that students get their hands on. As well, it provides insights into the physics of spectroscopy and the relationships of wavelengths and energies to the molecular orbital transitions. Students generally score over 95% on this assignment.

**Materials Characterization Lab 1st Exam**

The results for this are the same as those in the table in the next subsection on the next page, except that Course Objective 4 is not applicable.

**Materials Characterization Lab Final Exam – Discipline-Specific Knowledge**



**Materials Characterization Lab Final Exam – Ability to Analyze Data**

The ability to analyze data is one of ABET’s objectives. On the final exam, this was evaluated by the following problems:

1. Students had to plot data from a three-point Brunauer-Emmet-Teller (BET) pore volume/surface area experiment, fit the data to a straight line and determine the porous solid’s pore volume and surface area.
2. Given a set of Raman spectroscopy data, students were asked to calculate the wavelength of the most intense peak from its Raman shift.
3. Given Dynamic light scattering (DLS) data, students were asked to determine the log mean particle diameter and the polydispersity.
4. Most of the rest of the exam required students to qualitatively analyze microscopy data.

**Materials Characterization Lab – Ability to Conduct Experiments**

No class tests students’ ability to use a variety of experimental equipment more than this class. This is evaluated initially via a test on SEM, TEM, STM and AFM that must be passed with at least an 80% to be eligible to be trained on these pieces of equipment. This is similar to requiring a written driver’s test prior to being permitted to train behind the wheel. As part of each day’s in-class opportunity, the professor and teaching assistants award a participation grade for completion of acquisition of data for that day’s experiment. Examples of what data the students collect is in the [video recordings](https://fit.instructure.com/courses/265730/files/folder/Materials%20Characterization%20Videos), sorted by piece of equipment. In the official version of the course, these videos are also sorted in order of increasing difficulty. Further evidence is in the [SEM.zip](https://fit.instructure.com/files/43520893/download?download_frd=1), [SEM2.zip](https://fit.instructure.com/files/43521269/download?download_frd=1), [TEM1.zip](https://fit.instructure.com/files/43521039/download?download_frd=1), and [TEM2.zip](https://fit.instructure.com/files/43521171/download?download_frd=1) files. The decision by the BME program to require documentation for its electives was made during the Fall of 2020 after this course had started. While the aforementioned .zip files contain examples of student work, there are so many samples to document for so many students (~50) that it makes no sense to document this for every sample and every student. For each of the primary pieces of equipment (SEM, TEM, STM, and AFM), the ability to get an image on one of the early November samples acts as a pass/fail test as to whether the student is permitted to work independently on that piece of equipment; all students passed such a test.

**Materials Characterization Lab – Graduate Project**

Because of COVID and the TEM being down at the end of the semester, graduate projects were restricted to [SEM characterization of an array of porous polymeric foams](https://fit.instructure.com/files/43504855/download?download_frd=1). In addition to characterizing at least two samples each, students collaborated toward [development of synthesis-structure relationships](https://fit.instructure.com/files/43819789/download?download_frd=1) for the polymer foams.

**Materials Characterization Lab - Comparison of Student Performance to Desired Course Outcomes**



**Materials Characterization Lab - Comparison of Student Performance to Desired Program Outcomes**



**Nanotech Lab Quizzes**

The quizzes for CHE/CHM 1091 were traditionally either pre-lab or post-lab, depending on whether the goal of the quiz was to provide adequate materials characterization equipment respect (pre-lab), safety for syntheses (pre-lab) or comprehension (post-lab). Because of COVID, pre-lab content was upgraded to prerecorded Panopto videos for all of the materials characterization labs, and quizzes that had been done exclusively in-person were now either submitted via Canvas prior to class or done in-person. Scores were about the same as in prior years, with most students scoring 100% on the quizzes, with 90% or 75-80% occurring with 15% or 10% likelihoods respectively.

**Nanotech Lab Ethics Exercise**

Former Harvard Chemistry Department Head and inventor of both nanowires and nanowire-based virus detectors was arrested in January of 2020 for divulging DOD contract-developed data to the Wuhan Institute of Virology. Students are asked to define how they acquire knowledge, how they know what they know, their philosophy and how they will apply it to their life’s pursuit. In particular, they are asked to determine under what conditions they will or will not work. Student grades for this assignment are largely based on whether they complete the questions and justify their reasoning.

**Nanotechnology Lab Entrepreneurship Exercise**

To fulfill the Kern Entrepreneurial Engineering Network’s (KEEN’s) goals of fostering *curiosity*, making intellectual *connections* and *creating value*, this activity involves a brief literature, patent and company website review on a topic on the nanotechnology lecture or lab syllabus with a two Powerpoint slide summary of the technology and the field’s key players (the competition) and then one slide describing the concept for a product or service based on this technology, with emphasis on value creation over any possible competitors. Generally, the students require guidance on the literature review aspect and what separates the excellent work from average or poor work is the thoroughness, creativity and depth of insight in the literature review.

**Nanotech Lab Experiments**

Because of two faculty who helped me team teach this class in the past having moved on to better opportunities, this was the first time that I taught the entire class myself. The videos from the Materials Characterization Lab course in the fall were used as pre-lab content for most of the experiments that I had led in the past, and that worked well. Students were better prepared coming into class than in prior years. With the exception of one student group in each of two syntheses (not the same group for both), the students successfully executed all of the experiments, and now there are recordings of those for students in future years.

**Nanotech Lab - Comparison of Student Performance to Desired Course Outcomes**

All students achieved all of the desired course outcomes. This is not surprising as it is an elective course geared toward students who want to pursue the nanotechnology minor.

**Nanotech Lab - Comparison of Student Performance to Desired Program Outcomes**

As this is a class geared toward underclassmen, no program level outcomes are assessed as part of this class that are not better assessed in either Materials Characterization Lab or in the Nanotechnology lecture.

**The Basics of Making Justification**

Starting in 2013, several Florida Tech faculty began a tissue engineering initiative; Dr. Jim Brenner's part involved 3D printing of scaffolding. In 2015-2016, we lost three excellent grad students because of frustration over the lack of automation in this field. At that time, Dr. Brenner decided to focus his research on automation of the tissue culturing process. While others had automated feeding and waste removal, the only group that had automated the microscopic examination of the cells growing *in situ* was led by Wikswo and Cliffel at Vanderbilt. Though their method was being beta tested by LabSmith, it was far too costly for mass production. Dr. Brenner's research group began designing and building a prototype cell culture bioreactor; not long thereafer, Dr. Brenner realized that there was no one at our university, including himself, that all of the skills to do this. He needed postdisciplinary engineers, and he knew that he would have train them *en masse*.

Simultaneously with Dr. Brenner's change in research, several years ago, recent alumni from both the ChE and BME programs expressed a desire for more computer programming content and more "making" content (3D printing, laser cutting, sensors, data acquisition and control, etc.). Also during that time period, Dr. Dave Cannon, owner/inventor of Colloidal Dynamics' zeta potential analyzer and a founding member of the nanotech minor's advisory board, said that he would hire students who not only knew how to use equipment like his zeta potential analyzer, but more importantly, knew how to build one. Thus, a new course called The Basics of Making (CHE 4568 and soon to be CHE 5568, BME 4568, and BME 5568 after the CHE 4568 approval) was initiated to complete the training for our nanotech minor students. The next several paragraphs summarize how Florida Tech's Nanotechnology Minor helped several FIT CoES programs, most notably ChE and BME, satisfy the desires of these recent alumni and advisory board members.

Dr. Brenner then learned many of the skills that he did not already have at a Quantified Self workshop led Eric Meyer and Mansoor Nasir of Lawrence Tech at the 2018 Kern Entrepreneurial Engineering Network (KEEN) National Conference, on his own, and at the Bucknell KEEN BFAB for Faculty Workshop in July of 2019. Dr. Brenner had never done CAD drawing prior to learning OnShape for Bucknell's BFAB workshop. Now Dr. Brenner expects students to go through the tutorials at cad.onshape.com either before his innovative (and now often implemented at several other KEEN schools) Basics of Making course starts or at least early in the course; doing the tutorials counts as a homework grade and is even included now in CHE 1101. Students then must pass an individual quiz on CAD content, as well as do at least one CAD drawing per student in their end-of-semester project.

In 2018 Dr. Brenner became a beta tester of LabSmith's microfluidics educational kit. This kit essentially is a chemical engineering plant that you can hold in your hand and proved to be useful at teaching plumbing, electronics, data acquisition, microfluidics, and laminar flow.

He knew that he would have to teach stepper motors to the class as a prerequisite to automation of syringe pumps and 3D printers, but the automation of his tissue engineering test beds also required a retractable shield/dome so that microscope photos and load cell measurements of growing tissues could also be automated. He needed an efficient way to teach motors to non-mechanical engineers. He then recalled that in 2013 his daughter, now a biomedical engineer, took a Python programming class via the Florida Virtual School initially developed by Tucker Balch of Georgia Tech in which the final project was programming a Roomba vacuum robot. Students in the Basics of Making course go through a small subsection of that Python course as an in class lab and homework assignment; they must demonstrate that their code runs a Scribbler or BoeBot robot during the next lab.

The addition of online Python programming content was especially useful for his research students developing sensors for electrochemically measuring concentrations. Now Dr. Brenner measures four concentrations in each of his bioreactors, and thus he worked with Will Dickson of IORodeo to add a multiplexer capability to their inexpensive potentiostats. Now we have converted that research development to a two hour lab session for the course.

Though we used a combination of research projects, senior design projects, toys, and consumer products as choices for end-of-semester projects in the initial Basics of Making offering, for the next course offering, we will add selections from a book named "Open Source Lab" by Michigan Tech's Joshua Pearce. The ability of a Ph.D. research student to build or repair his/her own experimental setup or equipment is often the difference between whether that student graduates. The Basics of Making course is geared toward making all research students, both undergraduate and graduate, independent and is described in detail at <https://engineeringunleashed.com/card/1823> and in <https://fit.instructure.com/courses/551142>.

**The Basics of Making In Class Labs**

A list of experiments is available in <https://fit.instructure.com/courses/551142>. I assume that students have no background in any of the following, even though some of them do, of course.

a) Wiring

b) Soldering

c) Computer programming of any kind

d) CAD drawing

e) 3D printing

f) Laser cutting

g) Arduino-based sensors

h) Stepper, DC, and servo motors

While most students have previous experience in several of these skills, almost none of them have all of them coming in. The goal of the in class activities is to gain those skills. This is demonstrated as follows. Students are encouraged now to do the CAD and computer programming during the summer prior to the course.

a) Python programming is assessed by pass/fail completion of having a robot execute the code.

b) LabView programming is assessed by completion of a quiz after both an in class exercise plus a lengthy homework.

c) CAD drawing via a quiz and a requirement that each student draw his/her own project part.

d) 3D printing and laser cutting of the CAD-drawn project part

e) All other skills are assessed by completion of the project.

As these skills are assessed elsewhere, no separate documentation of the in class lab activities are included.

**The Basics of Making Homeworks and Quizzes**

The identification of kit items in HW 1 was mostly so that the faculty, teaching assistants, and students spent minimal class time looking for items. The HW 2 questions and issues sheet is the same kind of assignment described at the bottom of page 1 of this file and was meant to help students define both the technical and non-technical aspects for their end-of-semester project. The HW 6 Meshmixer prep was meant purely to ensure that when students got to lab class that they were ready to work; thus the results for that assignment were more or less pass/fail. The data acquisition, mass and energy balance, process control, and HAZOP analysis HW 7 was deemed to be too much for students to accomplish in addition to everything else for a three credit course being offered for the first time; it has since become an activity for students taking either the grad version or the honors option for this course. The F's are actually zeroes for those students who didn't do the work.



**The Basics of Making End-of-Semester Project (includes project performance and complexity, the poster presentation, the literature review and business case, and the final report)**



**The Basics of Making - Comparison of Student Performance to Desired Course Outcomes**



**The Basics of Making - Comparison of Student Performance to Desired Program Outcomes**

