8F. [The Basics of Making](https://engineeringunleashed.com/card/1823) Syllabus, Learning Outcomes, and Assessment



Figure 8F.1 – The Basics of Making topics ([PowerPoint file](https://fit.instructure.com/files/43167851/download?download_frd=1) slide 8; [ref.](https://engineeringunleashed.com/card/1823); [[32](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Ref_8_32)])

The Basics of Making (Figure 8F.1 for v. 1; Table 8F.1 for v. 2; [PowerPoint file](https://fit.instructure.com/files/43168059/download?download_frd=1) slide 169; [Video Link](https://fit.instructure.com/files/44138321/download?download_frd=1) at time index = 00:08:16; [[32](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Ref_8_32)]) bundles all skills necessary for students to be able to design and build capstone design projects and/or become productive researchers, with the KEEN mindset development interspersed at almost every stage, as highlighted in the hyperlinked KEEN cards.

Unlike most engineers, chemical engineers have no required build-and-test projects. They have no required CAD, circuit building, and/or testing experiences. Aerospace Engineering Professor Daniel Kirk said in 2018, "Imagine what our senior design projects would look like if our students actually knew this content as freshmen." I added at the same time, "This class ought to be an elective for graduate students as well if we want to increase the quality of our research projects." For years, I spent three or four hours per week teaching what I consider basic engineering skills to my research students, instead of teaching them the skills that are going to take my research to prominence at the national and international level. If I and others could delegate this to a general engineering course, then it should make all faculty and students more productive.

So, what would the syllabus for this new maker class look like (Table 8F.1; [PowerPoint file](https://fit.instructure.com/files/43168059/download?download_frd=1) slide 169)? First of all, students should be exposed to National Instruments LabView if they have not been exposed any computer programming already. This is a much easier way to learn computer programming due to its visual object-oriented programming approach, appearing very much like a circuit diagram. Students should get a [crash course](https://fit.instructure.com/courses/629658/assignments/5223357) ([external link to exercise](https://fit.instructure.com/courses/629658/assignments/5223329); [internal link to another section](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#LabView_HW_text)) in common variable types, if-then-else statements, while loops, and a little bit of data acquisition and control hardware. Then once they have learned LabView, then they can reinforce that with Python ([external link to exercise](https://fit.instructure.com/courses/629658/assignments/5223331); [internal link to another section](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Python_HW_text)) and G code ([external link to exercise](https://fit.instructure.com/courses/629658/assignments/5223225); [internal link to another section](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#G_code_generation)). G code is the primary computer language used by 3D printers, laser cutters, and machine shop tools.

There used to be a lab that I had incorporated into Florida Tech's Materials Lab course that got taken out in recent years. In this lab, students had to wire a light bulb circuit ([external link to exercise](https://fit.instructure.com/courses/629658/assignments/5223443); [internal link to another section](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#light_bulb_text)). You are probably wondering, “What does that have to do with materials?” That is why it got removed from that course. However, not having that experience left a gaping hole in an engineer's skill set, and thus it was later added to the new Basics of Making course curriculum instead. In this new course, students should also learn about a variety of sensors, as well as motor and robot controls, eventually building up a student's skills toward what is necessary to build research test stands like my tissue engineering test bed.

Table 8F.1 - The Basics of Making v. 2

[Questions and Issues Sheets:  A Quick Way to Define Projects](https://engineeringunleashed.com/card/2000) [[16](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Ref_8_16)]

[Computer Programming for Makers:  LabView, Python, C++, and Arduino](https://engineeringunleashed.com/card/1790) [[33](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Ref_8_33)]

[Wiring, Soldering, and Wiring Diagrams - How to Teach Them to non-ECE's](https://engineeringunleashed.com/card/1983) [[34](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Ref_8_34)]

Electrical Circuits and Arduino

[Using a Journal and Patent Literature Search to Demonstrate Curiosity and Connections via Information Integration](https://engineeringunleashed.com/card/2769) [[35](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Ref_8_35)]

CAD Drawing

Stepper, Servo, and DC Motor Control

Editing of CAD Drawings Prior to 3D Printing

3D Printing

Laser Cutting

Combining All Prior Maker Skills into the Bucknell Speaker Box

[Process Flowsheeting, Piping & Instrumentation Diagrams (P&ID's), and Plumbing](https://engineeringunleashed.com/card/651) [[36](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Ref_8_36)]

Printed Circuit Boards (PCB's)

Virtual Reality, Augmented Reality, & Advanced Visualization

[Electrochemical Concentration Measurement Using a Multiplexed Potentiostat](https://engineeringunleashed.com/card/2075) [[37](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Ref_8_37)]

[Celebration of the 3C’s: A Showcase for Makers](https://engineeringunleashed.com/card/821) [[13](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Ref_8_13)]

8Fa. Prerequisites

Students need to be able to take numerical derivatives, perform integration, and do some curve fitting. With regard to chemistry, hopefully students have learned a little bit of spectroscopy in General Chemistry 1, preferably with the Vernier LabQuest. It would be nice if they have also learned some chemical reaction kinetics and equilibrium constants in General Chemistry 2. Those are encouraged, but not absolutely required. From [Materials Science and Engineering](https://fit.instructure.com/courses/620422/assignments), students ought to know about the electrical properties of different classes of materials. Computer programming proficiency in any language is helpful, but the Basics of Making course enables one to learn National Instruments [LabView](https://fit.instructure.com/courses/604044/assignments/5079689) and Python programming basics with two in-class hours and about 6-8 hours of self-paced homework exercises; any first year undergraduate should be able to handle this without difficulty. Knowing some PowerPoint is definitely expected. If a student has taken a basic circuits class, that will help, but if not, the Basics of Making course will enable you to learn it quickly. CAD drawing is also highly encouraged, but you can learn that quickly as well via a set of [OnShape](https://cad.onshape.com) [tutorials](https://fit.instructure.com/files/45146529/download?download_frd=1) [[1](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Ref_8_1)] as recommended by Bucknell's Margot Vigeant. If a student has learned mass, energy, and/or momentum balances, that is highly desirable. Prior background in process flowsheeting and piping and instrumentation diagrams (P&ID’s) is also a major plus, but that can be learned from this book.

Until now, there has been no maker “textbook” for this, and while there have been some courses, primarily at Bucknell [[1](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Ref_8_1)], Georgia Tech [[6](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Ref_8_6)], and Lawrence Tech [[5](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Ref_8_5)], that have components that have been merged into The Basics of Making course on which this textbook is based, no one has combined all aspects of making into one course, let alone a textbook on the subject.

8Fb. CHE/BME 4568: The Basics of Making Syllabus

**2019-2020 Catalog Data: The Basics of Making.** After a brief review of the basics of computer programming, CAD drawing, and circuit breadboard prototyping, this class will emphasize the use of Arduino microcontrollers and LabView for sensors, data acquisition and controls, followed by 3D printing with a final project competition with 3D printed wearable sensors.

**Credits & Contact Hours:** 3 Credits, 13 lectures (50 mins.), 30 labs (110 mins.)

**Required or Elective or Selected Elective:** Technical Elective.

**Prerequisite and Co-Requisite Courses:** Calculus 2 prerequisite AND junior standing in one’s major (not to be confused with junior standing purely based on the number of credits). Typically, this is cross-listed with graduate offerings (CHE 5568/BME 5568), with the major differences for honors students or graduate students being implementation of more controls and of a project management requirement

**Prerequisite and Co-Requisite Topics:**

1. Mathematics - Numerical derivatives and integrals, and curve fitting
2. Chemistry (preferred) – spectroscopy (Gen Chem 1), chemical reaction kinetics (Gen Chem 2), equilibrium constant (Gen Chem 2)
3. Materials Science (preferred) – electrical properties
4. Computer Programming (preferred) - proficiency in any language
5. General Engineering – PowerPoint, basic circuits (preferred), CAD drawing (preferred, in any software package)
6. Chemical Engineering (preferred) - mass and energy balances (CHE 2101), process flowsheeting and piping & instrumentation diagrams (CHE 1101)

**Textbook (T) and References (R):** (R) J. R. Brenner, Compilation of relevant topics at

 <https://fit.instructure.com/courses/604044/>

**Instructor**

Dr. James R. Brenner Office: OEC 256 Phone: 321-749-3437 Email: jbrenner@fit.edu

**Topics Covered and Associated Time:**

1. National Instruments LabView Programming Basics: Common variable types, If/Then/Else, Do and While Loops, Data Acquisition and Control (DAQ) hardware (1 week)
2. Same programming concepts in C++ for Arduino and G Code for 3D printing (1 week)
3. Wiring a light bulb circuit and soldering (1 lab hour)
4. Intro to breadboard circuit concepts in TinkerCAD Circuits (1 lab hour)
5. Wiring breadboard circuits using Arduinos: Blinking LED, resistor circuit, resistor/capacitor & introduction to Arduino programming (2 lab hours)
6. Arduino/LabView DAQ for temperature, liquid level, pH, electrical conductivity (EC), dissolved O2 (DO), oxidation reduction potential (ORP), mass, and flow rate (1 week)
7. Arduino/LabView servo and stepper motor control (1 week)
8. Concentration monitoring using a CheapStat potentiostat (1 week)
9. LabSmith microfluidic flow kit - assemble & test (1 week)
10. CAD drawing (2 weeks incl. fall break)
11. CAD to .stl and 3D printing, including G code modification (2 weeks)
12. Assembly of a fully instrumented bioreactor with automated feeds, aforementioned sensors & controls, stepper-based syringe pumps, etc., with instruction in and integration of prewritten computer code for mass and energy balance closure, process control, and hazardous operability (HAZOP) analysis (2 weeks of lab + 3 lectures)
13. Student design, parts fabrication, and assembly of prototype (remainder of labs in course)
14. Final project explanation, with emphasis on Kern Entrepreneurial Education Network (KEEN) goals of [curiosity](https://www.youtube.com/watch?v=o82MADReofI&feature=youtu.be) [[38](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Ref_8_38)], [connections](https://www.youtube.com/watch?v=p0Wc1PIeXPo) [[39](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Ref_8_39)], and [creating value](https://www.youtube.com/watch?v=GM8d1UL0a1g) ([[40](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Ref_8_40)]; 2 lectures), as well as multidisciplinary teamwork survey and expectations
15. Poster/demo contest for function & creativity to engender entrepreneurial mindset (in lieu of final exam)

**Class Schedule:** Common Lecture: Monday 8-8:50 AM;

 Labs (WF 8-10 AM; F 1-5; M 9-11 and WF 10-11)

**Grading**: Grades: 90, 80, 70, etc. Quizzes: 20%; Homework: 24%; In-class assignments: 12%; Lab Report: 4%; Performance of, meeting of minimal requirements for, and complexity of customized wearable sensor: 12%; Poster presentation of customized wearable sensor: 12%; Final report on customized wearable sensor: 16%.

Graded Work

HW 1 - Kit identification (textbook section; [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223325))

HW 2 - Questions and issues sheet for project (textbook section; [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223327))

HW 3 - LabView programming basics (textbook section; [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223329))

HW 4 - Python programming basics (textbook section; [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223331))

HW 5 - KiCAD wiring diagrams (textbook section; [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223333))

HW 6 - CAD drawing (textbook section; [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223335))

HW 7 - Meshmixer Prep (textbook section; [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223337))

HW 8 - Data acquisition, mass & energy balance closure, process control & HAZOP analysis

 (textbook section; [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223339))

In Class Grade 1 - LabView programming basics (textbook section; [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223357))

In Class Grade 2 - Light bulb circuit (textbook section; [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223443))

In Class Grade 3 - Arduino programming basics (textbook section; [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223237))

In Class Grade 4 - Soldering of Load Cell ([textbook section](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Section_10D_Soldering_Load_Cell); [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223413))

In Class Grade 5 - SpeakerBox - Soldering of LED's ([textbook section](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Section_10E_Soldering_Bucknell); [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223419))

In Class Grade 6 - Temperature Sensor - Arduino ([textbook section](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Section_10F_Temperature_Sensor); [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223429))

In Class Grade 7 - Load Cell - Arduino ([textbook section](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Section_10G_Load_Cell_Arduino); [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223369))

In Class Grade 8 - Arduino pH data acquisition and calibration

 ([textbook section](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Section_10H_pH_sensor_Arduino); [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223381))

In Class Grade 9 - Total dissolved solids (TDS; [textbook section](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Section_10I_EC_TDS); [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223299))

In Class Grade 10 - Stepper, servo, & DC motor ([textbook section](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Section_10L_Stepper_Servo_DC_Motors); [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223421))

In Class Grade 11 - G code programming basics ([textbook section](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Section_10M_G_Code); [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223225))

In Class Grade 12 - Microfluidic flow & lab-on-a-chip ([textbook section](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Section_10O_Microfluidic_Flow); [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223373))

In Class Grade 13 - Editing of .stl Files with Meshmixer/Inkscape

 ([textbook section](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Section_10Q_Meshmixer_Inkscape); [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223295))

In Class Grade 13 - Arduino/Bluetooth Robot Control ([textbook section](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Section_10T_Arduino_Robot); [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223239))

In Class Grade 14 - Laser engraving of Bucknell Speaker Box top (textbook section;

 [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223359))

In Class Grade 15 - 3D printing of Bucknell Speaker Box feet

 ([textbook section](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Section_10R_Speaker_Box_Feet); [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223229))

In Class Grade 16 - Assembly of Bucknell Speaker Box

 (textbook section; [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223417))

In Class Grade 17 - Electrochemical Concentration Monitoring

 ([textbook section](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Section_10S_Electrochemical_Conc); [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223301))

Quiz 1 - pH data acquisition and acid/base titration (textbook section; [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223379))

Quiz 2 - CAD drawing (textbook section; [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223351))

Quiz 3 - Computer programming & control (Honors only; textbook section; [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223263))

Lab Report 1 - Includes CAD drawing, 3D printed object, printing parameters, assessment of fit of machine screws into printed holes, any necessary revisions, and assessment of any necessary revisions (textbook section; [Canvas course section](https://fit.instructure.com/courses/629658/assignments/5223355)).

Project Outcome 1 - Questions and issues sheet for end-of-semester project

Project Outcome 2 - Motivation and value proposition for end-of-semester project

Project Outcome 2 - 3D-printed part for project

Project Outcome 3 - Assembly of end-of-semester project

Project Outcome 4 - Hand-drawn sketches of end-of-semester project

Project Outcome 5 - CAD drawing(s) of end-of-semester project

Project Outcome 6 - 3D-printed parts of end-of-semester project

Project Outcome 7 - Assembly of end-of-semester project

Project Outcome 8 - Evaluation of multidisciplinary teamwork effectiveness

Project Outcome 9 - Curiosity as number of hours spent on project in making environments

Project Outcome 10 - Connection of content from multiple courses and integration/synthesis of

 different kinds of knowledge, as assessed in the end of semester final

 project report

Project Outcome 11 - Value created as assessed by combination of student, faculty, and general

 public feedback during the poster presentation and performance evaluation

Performance of Final Project Prototype (textbook section; Canvas course section)

Poster Presentation of Final Project Prototype (textbook section; Canvas course section)

Final Report on Final Project Prototype (textbook section; Canvas course section)

8Fb.1 – Online Learning, Homework, and Quizzes

Students will have a highly varied set of prerequisite experience prior to starting this course, regardless of major or class standing. Students should be encouraged to do as much of the assignments 8Fb.1.1 – 8Fb1.4 prior to starting the course as possible.

8Fb.1.1 – [Downloading and Installation of Software, Videos, etc.](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Downloading_and_Installation)

8Fb.1.2 – [CAD Drawing Online Learning](https://fit.instructure.com/courses/629658/assignments/5223253)

8Fb.1.3 – [3D Printing Online Portion of Certification](https://fit.instructure.com/courses/574158)

8Fb.1.4 – [Laser Engraving Online Portion of Certification](https://fit.instructure.com/courses/574154)

8Fb.1.5 – [HW 1 – Identification of Kit Items](https://fit.instructure.com/courses/629658/assignments/5223325)

8Fb.1.6 – [HW 2 – Questions & Issues Sheets for Group Project](https://fit.instructure.com/courses/629658/assignments/5223327)

8Fb.1.7 – [HW 3 – National Instruments LabView Computer Programming](https://fit.instructure.com/courses/629658/assignments/5223329)

8Fb.1.8 – [Quiz 1 – National Instruments LabView Computer Programming](https://fit.instructure.com/courses/629658/assignments/5223379)

8Fb.1.9 – [HW 4 – Python Computer Programming](https://fit.instructure.com/courses/629658/assignments/5223331)

8Fb.1.10 – [Project Report – Literature Review & Business Case](https://fit.instructure.com/courses/629658/assignments/5223367)

8Fb.1.11 – [HW 5 – Introduction to KiCAD for Wiring Diagrams](https://fit.instructure.com/courses/629658/assignments/5223333)

8Fb.1.12 – [HW 6 – CAD Drawing](https://fit.instructure.com/courses/629658/assignments/5223335)

8Fb.1.13 – [HW 7 – Meshmixer or Inkscape for Editing .STL Files](https://fit.instructure.com/courses/629658/assignments/5223337)

8Fb.1.14 – [HW 8 – Data Acquisition, Mass & Energy Balance Closure, Process Control, &](https://fit.instructure.com/courses/629658/assignments/5223339)

 [Hazardous Operability (HAZOP) Analysis](https://fit.instructure.com/courses/629658/assignments/5223339)

8Fb.1.15 – [Quiz 2 – CAD Drawing](https://fit.instructure.com/courses/629658/assignments/5223351)

8Fb.1.16 – [Project Report – CAD Drawing, 3D Printing, Fit & Finish](https://fit.instructure.com/courses/629658/assignments/5223255)

8Fb.1.17 – [Quiz 3 – Computer Programming & Control Quiz](https://fit.instructure.com/courses/629658/assignments/5223263) (Honors Program/Grad Version)

8Fb.2 – [Lecture Content](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Section_9_BasicsofMakingLectures)

8Fb.3 – [Lab Content](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Section_10A1_BasicsofMakingLabs)

Before the semester starts, go [here](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Downloading_and_Installation) to download necessary software.

8Fb.3.1 – [National Instruments LabView In Class Assignment](https://fit.instructure.com/courses/629658/assignments/5223357)

8Fb.3.2 – [Wiring a Light Bulb Circuit](https://fit.instructure.com/courses/629658/assignments/5223443)

8Fb.3.3 – [Arduino Blink](https://fit.instructure.com/courses/629658/assignments/5223237)

8Fb.3.4 – [Soldering of Load Cell to Load Cell Shield](https://fit.instructure.com/courses/629658/assignments/5223413)

8Fb.3.5 – [Bucknell Speaker Box Soldering of LED’s](https://fit.instructure.com/courses/629658/assignments/5223419)

8Fb.3.6 – [Temperature Sensor – Arduino](https://fit.instructure.com/courses/629658/assignments/5223429)

8Fb.3.7 – [Load Cell Sensor – Arduino](https://fit.instructure.com/courses/629658/assignments/5223369)

8Fb.3.8 – [pH Sensor – Arduino](https://fit.instructure.com/courses/629658/assignments/5223381)

8Fb.3.9 – [Electrical Conductivity / Salinity Sensor - Arduino - Total Dissolved Solids (TDS)](https://fit.instructure.com/courses/629658/assignments/5223299)

[8Fb.3.10](file:///C%3A%5C%5CUsers%5C%5Cjbrenner%5C%5CDownloads%5C%5Cbasicsofmakingtextbook12052023.doc%22%20%5Cl%20%22Section_10J_Martin_Gallagher) – Martin Gallagher lecture on a full body virtual reality (VR) suit; discussion of finer

 aspects of 3D printing; 3D scanning, including turntable photography; VR glasses,

 particularly for biomechanics projects; 3D Vista software vs. Matterport for 3D virtual

 modeling tours; LiveFace; Vinyl cutter

8Fb.3.11 – [3D Printing](https://fit.instructure.com/courses/574158) and [Laser Cutting](https://fit.instructure.com/courses/574154) Group Training

8Fb.3.12 – [Python Computer Programming](https://fit.instructure.com/courses/629658/assignments/5223397)

8Fb.3.13 – [Stepper, Servo, and DC Motors](https://fit.instructure.com/courses/629658/assignments/5223421)

8Fb.3.14 – [Arduino & Bluetooth Motor Control of Robots](https://fit.instructure.com/courses/629658/assignments/5223239)

8Fb.3.15 – [Microfluidic Flow & Lab-on-a-Chip Devices](https://fit.instructure.com/courses/629658/assignments/5223373)

8Fb.3.16 – [3D Printer Configuration and Subsystems, G-Code, and Conversion of CAD to .STL](https://fit.instructure.com/courses/629658/assignments/5223295)

8Fb.3.17 – [3D Printing of Bucknell Speaker Box Feet](https://fit.instructure.com/courses/629658/assignments/5223229)

8Fb.3.18 – [Laser Engraving of Bucknell Speaker Box Top](https://fit.instructure.com/courses/629658/assignments/5223359)

8Fb.3.19 – [Electrochemical Concentration Monitoring](https://fit.instructure.com/courses/629658/assignments/5223301)

8Fb.3.20 – [Editing of .STL Files with Meshmixer/Inkscape](https://fit.instructure.com/courses/629658/assignments/5223295)

8Fb.3.21 – [Bucknell Speaker Box Construction & Wiring](https://fit.instructure.com/courses/629658/assignments/5223417)

8Fb.3.22 – [Bluetooth/Arduino Speaker Box Configuration](https://fit.instructure.com/courses/629658/assignments/5223239)

8Fb.4 – End-of-Semester Project

 [HW 2 – Questions & Issues Sheets for Group Project](https://fit.instructure.com/courses/629658/assignments/5223327)

[Project Report – Literature Review & Business Case](https://fit.instructure.com/courses/629658/assignments/5223367)

[Project Report – CAD Drawing, 3D Printing, Fit & Finish](https://fit.instructure.com/courses/629658/assignments/5223255)

[Poster Presentation - Project Performance & Complexity](https://fit.instructure.com/courses/629658/assignments/5223307)

[Poster Presentation of Project](https://fit.instructure.com/courses/629658/assignments/5223305)

[Final Project Report](https://fit.instructure.com/courses/629658/assignments/5223317)

Students are expect to spend approximately ten hours per week in a standard three credit lecture course, but closer to twenty hours per week in a senior design class or in The Basics of Making because much of the additional time is spent on topics that should have been mastered much earlier in their careers. I work 80 hours per week pretty consistently. Professors think that everyone else is just as neurotic as they are. Professors are almost by definition workaholics. They somehow think that everyone is a workaholic, too, even when they are not. Is that fair? It probably is not, but it is the professor's expectation. Exceeding your boss' expectations is how you get noticed. If you want to be a professor and you are working less than 70 hours per week, you will not succeed. The concept of the forty hour work week is foreign to faculty members. It just is not possible to achieve what they think needs to be accomplished in that short a period of time. When people ask me how much I work, I tell them about a movie from 1999 called Pirates of Silicon Valley [[41](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Ref_8_41)] and how Steve Jobs distributed "90 Hours A Week And Loving It" T-shirts [[42](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Ref_8_42)] to his Apple employees.

**8Fc. Learning Outcomes of Basics of Making Course**

**Relationship of Course Outcomes to Student Outcomes:** See following assessment matrix. KEEN outcomes as delineated by Estell *et al*. [[12](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Ref_8_12)] have been included.

**Course Outcomes:** Upon completion of this course the students will achieve the outcomes as

1. Computer Programming - 90% of students will demonstrate the ability to write and/or modify computer code in both LabView and in Arduino.

2. Wiring/Soldering - 100% of students will be able to safely construct a circuit containing soldering, butt splicing, and heat shrinking.

3. Arduino- and LabView-Based Based Circuits - 100% of students will successfully connect an Arduino to their computers and to a breadboard, and communicate with their circuit with both Arduino and LabView software.

4. Arduino- and LabView-Based Data Acquisition, Sensors, Motors, and Controls - 70% of students will properly calibrate a pH meter. 80% of students will successfully control a stepper motor-based syringe pump to titrate an acid with a base. 90% of students will read a thermocouple's temperature in an ice water bath and control both stepper and servo motors outside of class.

5. Concentration Monitoring and Potentiostats - 80% of students will calibrate electrical conductivity (EC)/salinity probes BEFORE an in class lab. In lab, they will compare their "home results" with those of a commercial potentiostat

6. Microfluidic flow - All students will construct a LabSmith microfluidic flow kit and demonstrate the lack of mixing in laminar flow.

7. CAD Drawing - 90% of student groups and 70% of students will successfully prepare CAD drawings for a wearable sensor and a cylindrical or rectangular prismatic object with machined holes during homework and quizzes, respectively.

8. 3D Printing - All students will successfully print an object, vary at least two aspects of the G code printing parameters, and assess both the effects of those parameters and the fit of machine screws into the holes associated with their prints.

9. Fabrication of Wearable Sensors - All student groups will 3D print at least one component of a customized wearable sensor as part of an end-of-semester project.

10. Poster Presentation and Demonstration of Wearable Sensors - All student groups will present a poster as part of the end-of-semester project on the design and fabrication of a customized wearable sensor, with 80% of the sensors will communicating data via USB and 40% communicating wirelessly.

11. Multidisciplinary Teamwork - 90% of students will be able to function properly in multidisciplinary teams as assessed by self, team, and faculty evaluations of their performance as being "acceptable" on the end of semester project.

8Fd. Assessment of the Basics of Making Course



Table 8Fd.1 show how the course's seventeen course objectives (row #'s) align with ABET and KEEN student outcomes (column #'s). Open diamonds and solid diamonds denote whether those objectives are lightly or strongly addressed, respectively.

If a program fails [ABET](https://www.abet.org) accreditation [[43](file:///C%3A%5CUsers%5Cjbrenner%5CDownloads%5Cbasicsofmakingtextbook12052023.doc#Ref_8_43)], at least that program will be terminated. If multiple programs at a university fail, then the university would probably go out of business. If an invididual university program gets what is known as a concern, then that usually does not even merit an interim report. If a program gets a weakness, that means that either the program will have to go through a follow-up visit related to that in two or three years or at least an interim report. If the program has more than a weakness, that program is often closed.

At this point, there is no official KEEN accreditation. Inclusion of this KEEN accreditation alignment matrix is included to encourage adoption of this course and textbook into engineering curricula.

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