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# Creating a Minor in Materials for Engineering Technology Students

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# Creating a Minor in Materials for Engineering Technology Students


## Abstract

Purdue University Fort Wayne is located near a concentration of manufacturing industries, including automotive parts manufacturers, orthopedic implant manufacturers, medical tool manufacturers, copper wire mills, and steel minimills. Knowledge of engineering materials is critical for engineers working in these industries, so in 2015 the university's chancellor became interested in starting a materials program. Academic departments were asked to provide information and recommendations. As a metallurgist, I prepared a short report outlining five possible programs which could be created to satisfy industry's needs:

- A certificate program for materials laboratory technicians.
- A certificate program for practicing engineers.
- A B.S. materials degree.
- An M.S. materials degree.
- An undergraduate minor or double-major in materials.

I attached budget and staffing information, and recommended the least costly option, the minor in materials. Two academic programs developed minors to satisfy the need. The first was physics, which developed a minor in materials science and a concentration in materials science. The minor requires extra classes and is open to any student on campus, while the concentration is part of the B.S. physics degree and requires no additional classes.

The second academic program to develop a minor was mechanical engineering technology. The coursework provides the type of materials knowledge necessary for process engineers, manufacturing engineers, and design engineers. In 2017 I submitted paperwork to create a minor in engineering materials, having a different focus from the materials science minor offered in physics. Around this time, the university underwent a major structural change, splitting into two universities. All curriculum changes were put on hold for about a year and a half, during which time the title of the minor was changed to satisfy concerns from another department. The retitled materials engineering technology minor went into effect in fall 2019.

This paper discusses the need for a materials minor for engineering technology students, course development, selection of reference books and textbooks, my personal experiences teaching the new courses, student feedback from the new courses, collaboration with the physics and engineering departments, and development of a campus-wide course designator for materials courses in different departments and schools.


## Author's Note

This paper was originally accepted for the 2020 annual conference, but was withdrawn due to the COVID pandemic and subsequent shutdown. The current version includes updates from the past year.

**Background**

Purdue University Fort Wayne is located in Fort Wayne, Indiana, where the city's economic development bureau lists 7 key industries on its promotional literature: specialty insurance, medical devices & technology, vehicles, design & craftsmanship, logistics & e-commerce, food & beverage, and advanced materials [1]. The broader region includes two steel minimills, several wire mills, automotive parts manufacturers, a pickup truck assembly plant, recreational vehicle manufacturers, orthopedic implant manufacturers, defense plants, and many medical tool manufacturers. In 2015, the university's chancellor heard from regional business leaders that they needed more employees with a knowledge of materials. This demand is supported by employment data from the Bureau of Labor Statistics, which defines the "location quotient" of an occupation as its share of local employment relative to that occupation's share of national employment. The location quotient for materials engineers in Indiana is 1.49, or 49% higher than the national average. [2] Similarly, location quotients in Indiana for engineers in related fields that require a knowledge of materials are 1.22 for mechanical engineers, 1.42 for biomedical engineers, and 1.84 for industrial engineers. Some 75% of the graduates of Purdue University Fort Wayne work within the state, and 50% work in Fort Wayne and surrounding counties, so it makes sense to focus on regional needs

The chancellor asked faculty to recommend ways to increase materials education at the university. As a mechanical engineering technology faculty member with degrees in metallurgy and a decade of industrial experience in materials engineering, I suggested five options:

- A certificate program to train materials laboratory technicians in sample preparation, optical and electron microscopy, materials testing, and analysis.
- A certificate program offered through Continuing Education for practicing engineers.
- A 4-year undergraduate BS. degree in materials science or materials engineering.
- A Masters degree in materials science or materials engineering.
- A minor or double-major in materials for undergraduate engineering technology and engineering students.

A certificate program for laboratory technicians would have been too costly. Required resources would include 1 new full-time professor, 1 new materials laboratory technician, a metallography laboratory, and repairs to our tensile tester. Estimated equipment costs were $60k for startup plus $40k/year as the laboratory is developed, with an additional $60k startup costs if polymer laboratory skills are included. Since the annual department equipment budget for 5 academic programs is typically less than $15k, this proposal was a non-starter.

The Continuing Education certificate program would have required additional faculty, but probably not much laboratory equipment.

Offering a 4-year degree was not a good choice because at the time, only 1.7% of all B.S. engineering degrees in the U.S. were awarded in the materials field (materials science, materials engineering, metallurgy, polymer science, ceramics) [3], so the demand was low relative to other engineering majors. In 2015 there were 62 ABET-accredited B.S. materials degree programs at public and private institutions in only 32 of the 50 U.S. states; 18 of those 32 states offered the degree at only one institution, typically at the main campus of the land-grant university [4]. In comparison, 25% of all B.S. engineering degrees in the U.S. were awarded in mechanical engineering, from more than 340 ABET-accredited B.S. mechanical engineering programs in all 50 states. There is simply not enough demand for B.S. materials graduates to justify the cost, and it was unlikely that the Indiana Commission for Higher Education would approve this degree. In the years since the proposal was first presented, one of the two universities in Indiana with a materials program closed it down.

A Masters degree would have required additional faculty to teach very small classes; historically, the university has been shy about approving such faculty lines for cost reasons.

I recommended the minor in materials because the department had one full time faculty with a materials background (myself) and two adjunct faculty working as metallurgists in local industry. In addition, the Fort Wayne chapter of ASM International has more than 100 members, and I expected that we could find additional adjunct faculty to teach the occasional materials class in a specialized topic. Although the minor would require building a metallography laboratory, the costs would be considerably lower than developing a full-blown materials major.

The university administration did not make a decision, so in the absence of direction from above, both the physics department and the mechanical engineering technology program proceeded to create minors. The physics minor in materials science was designed for any student with a technical background, and includes the freshman-level *Materials and Processes 180* class which is taught by mechanical engineering technology faculty. There were no students enrolled in the physics minor in materials science as of November 2020.

The physics department also created a concentration in materials science, essentially using materials science courses as technical electives for physics majors. These students must choose a concentration among half a dozen choices. There were six physics students enrolled in the materials science concentration as of November 2020. The concentration requires these classes:

- Organic chemistry
- Introductory mineralogy
- Scanning electron microscopy
- Materials & processes (mechanical engineering technology course)
- Strength of materials (mechanical engineering technology course)
- Materials science laboratory
- Solid state physics
- Choice of 4 of 6 courses in semiconductors, optical & magnetic materials, thermal properties, electron microscopy, X-ray analysis, and scanning probe microscopy

The physics minor in materials science includes the courses in the concentration plus a couple of additional physics courses.

Concurrently, as an associate professor in the mechanical engineering technology program, I developed a materials minor focused on the needs of my students and local industry. Graduates of the mechanical engineering technology program typically become manufacturing engineers, process engineers, design engineers, or engineering managers. My students tell me that they are more interested in materials selection, materials processing, and failure analysis than they are in basic science. The industrial advisory committee for the mechanical engineering technology program includes senior employees of biomedical, steelmaking, automotive, and other industries, so their advice plus student feedback guided the choice of courses to be offered in the minor.

**What's in a Name?**

An early question was what to call the minor. A 2019 Google search of "materials minor" yielded a list of more than 50 distinct programs in the first 6 pages of the search. MSE is the most popular name for a minor in materials, comprising more than half of the programs.

- 27 Materials Science & Engineering (MSE)
- 11 Materials Science
- 8 Materials Engineering
- 2 Materials
- 1 Physics of Materials
- 1 Nanoscale Science & Technology
- 1 Renewable Materials

After evaluating the names of existing programs and considering that the students would focus on applications rather than on foundational science, I requested the name "engineering materials." Mechanical engineering and electrical engineering faculty members at the university vetoed this name because it lacked the term "technology," therefore implying that the minor was being offered by an engineering program rather than by an engineering technology program. We compromised on "materials engineering technology."

**Courses**

The mechanical engineering technology program includes two required courses in materials: a freshman-level *Materials & Processes 180* class which includes a mechanical testing laboratory, and a junior-level *Engineering Materials 381* class which goes into more depth. The minor includes two required courses:

- *Materials & Processes 180,* described above. This course serves as a prerequisite for the elective courses in the minor. The mechanical engineering program offers a comparable course, which is accepted as a substitute for mechanical engineering students wishing to enroll in the minor.
- *Materials Characterization 220,* a laboratory-based course that serves as a prerequisite for *Failure Analysis*. Although the laboratory did not exist when the minor was first proposed, I believed funding would be forthcoming from the university administration.

In addition, students must select four courses from a growing list of elective choices:

- *Introduction to Polymers 230*
- *Steelmaking, Forming, and Heat Treating 240*
- *Failure Analysis 310*
- *Biomedical Materials 320*

- *Corrosion Control 340*
- *Stainless Steels 350*
- *Lightweight Materials 360*
- *Engineering Materials 381*

**Textbooks**

Textbook selection is closely tied to Learning Objectives for each course, which are provided in course syllabi and in the Appendix of this paper.

The *Materials & Processes 180* and *Engineering Materials 381* courses have used Kalpakjian & Schmid's *Manufacturing Processes for Engineering Materials* [5] for many years. This textbook is a good fit for a curriculum designed to educate future manufacturing engineers and process engineers.

I had very little time to select a book for the *Steelmaking* course, so I compared *Steel Metallurgy for the Non-Metallurgist* [6] with *Steels: Processing, Structure, and Performance* by George Krauss [7]. The *Non-Metallurgist* text seemed too basic for this class, while the Krauss text was perhaps too advanced for undergraduate mechanical engineering technology students. Nevertheless, we used the Krauss text, and students learned how to read a more advanced book than they were accustomed to.

I drew on ASM International's *Understanding the Basics* book series for the *Corrosion Control 340* and *Lightweight Materials 360* classes because these books are written for practicing engineers, not experts in the topic. This series includes books on corrosion, lightweight materials, inspection of metals, alloying, soldering, joining, fatigue & fracture, metals fabrication, surface hardening, and phase diagrams. The books are available in print versions and as pdf e-books. Students can purchase books published by ASM for half the nonmember price, even if they are not student members, as long as the instructor informs ASM that the book will be used for a class. The beauty of *Corrosion: Understanding the Basics* [8] is that it looks at corrosion from a different point of view in each chapter, so after a few chapters the students can recognize common themes. The book would be even better if photographs were in color.

It was difficult to find a textbook for *Introduction to Polymers 230* that matches the needs of my students because most polymers books I reviewed focus heavily on organic chemistry and very lightly on properties and processing. A sister institution in another city uses a general introductory materials textbook for its polymers class, so the instructor uses a lot of supplementary material. A couple of weeks into the semester, I chanced upon Ulf Bruder's *User's Guide to Plastic*, [9] an inexpensive paperback written by a retired polymers engineer who has extensive processing and failure analysis experience. There is not enough detail in some sections, but the author makes liberal use of color photographs of parts and processing equipment, and provides practical recommendations on mold design, troubleshooting, etc. Students bought the book, and I modified the syllabus accordingly.

The ideal textbook to teach the *Failure Analysis 310* class to mechanical engineering technology students is Donald Wulpi's *Understanding How Components Fail* [10]. He wrote this book for practicing engineers who are not metallurgists, and it is full of practical examples of metallurgical failures in automotive and truck components. There is heavy focus on metallurgical failures involving fatigue loading, and very little information on sheet metal failures. I supplemented the content with other sources for failure analysis of wood, plastics, and composites.

I compared two candidate textbooks for *Biomedical Materials 320*. I first reviewed *Biomaterials: The Intersection of Biology and Materials Science* by Temenoff and Mikos [11], because it is widely used in U.S. biomaterials classes. This book is very strong on biology but weaker on properties, selection, and processing of materials. None of my students has taken a college-level biology course, and they would have been lost in this content. Instead, I selected *Introduction to Biomaterials* by Agrawal, Ong, Appleford, & Mani [12] because it focuses mainly on materials and applications, with less emphasis on biology. For half the cost, students get a textbook that better matches their academic background.

A student wanting to work in the aerospace industry asked me to teach a course in lightweight materials. I selected *Lightweight Materials: Understanding the Basics* [13], which is written for practicing engineers. The chapters are organized by material, except for a final chapter on materials selection. This book focuses on metals, intermetallics, ceramics, synthetic polymers, and composites, but does not include natural lightweight materials such as wood products.

ASM's *Stainless Steels for Design Engineers* [14] is a good fit for *Stainless Steels 350* to be offered in fall 2021. Like the *Understanding the Basics* series, it was written for practicing engineers. Major sections of the book include corrosion, alloy systems, processing, and industrial applications. I plan to draw on Harold Cobb's *The History of Stainless Steel* for supplementary material. [15]

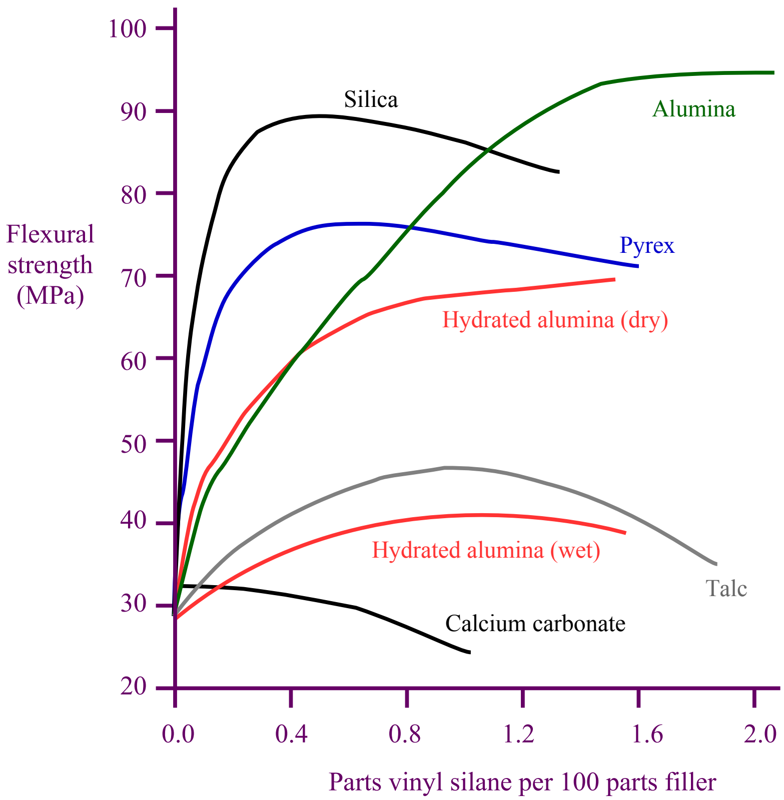
**Course Design**

I taught the *Steelmaking 240* course with very little notice. A faculty member accepted an offer to go on part-time retirement three weeks before the semester began, leaving a dozen students enrolled in a *Tool & Fixture Design* class but no professor. I offered to teach these students a course on steelmaking instead, and they agreed to serve as guinea pigs. Without the time to develop lectures, handouts, slideshows, etc., we developed a kind of flipped classroom approach. I assigned reading from the book, students submitted questions on the reading the day before our class meeting, I would type up responses, then we would sit around a large table and discuss answers to their questions. Each student was expected to provide at least three questions from the assigned reading. This approach was manageable for a class of 10 students, although answering 30 written questions twice a week was time-intensive. Weekly short quizzes ensured that the students would complete the reading.

I tried the same flipped classroom approach with *Corrosion Control 340* as an independent study class with one student, and it proved satisfactory. However, when I tried it with a class of 20 students, the students found it tedious and unsatisfactory. I was also answering twice as many questions as in the steels class. Nearly all students in the class said they would have preferred a lecture format, which I will use when the class is next offered in spring 2022.

The next semester I followed their advice with *Introduction to Polymers 230*. Our textbook was full of color photographs and strong on process control for polymer extrusion, but weak on mathematics and materials properties, so I used 16 lectures and 13 handouts to supplement the book content. The graph below is taken from a handout from a lecture on additives to polymers.

Redrawn from *Engineered Materials Handbook Vol. 2: Engineered Plastics Handbook,* ASM International, 1985, p.499.




Vinyl silane coupling agent improves bonding between filler particle and rubber matrix. For most filler particles, flexural strength increases as filler content increases.

I arranged for tours of a plastic extrusion plant and a plastic injection molding plant, both within 4 miles of campus. As it happens, we toured a poorly-run, dirty plant with obvious safety problems first, then we toured a well-run, efficient, modern operation where safety was clearly more important. Students noticed the contrast, and discussed it in class.

Six class meetings were set aside for student presentations on topics of their choice:

- Polymethyl methacrylate
- Epoxies
- Nylon
- Polytetrafluoroethylene
- Carbon fiber
- 3-D printing

This approach enabled students to work in groups to research polymeric materials, present their findings to the class, and submit a written report. This assignment meets ABET's requirements for demonstrating teamwork. Classmates evaluated the oral presentations according to a rubric and provided feedback to the presenters. I collated the feedback for each team and provided copies to the presenters. About a quarter of the class stopped attending once the student presentations began, so I resolved to include a student participation grade in any future class employing student presentations.

The *Failure Analysis 310* course in spring 2020 followed the same lecture and handout approach as the Polymers class. The initial proposal for this class called for a *Materials Characterization 220* prerequisite, but the university has been unable to provide funds to create the required laboratory, so I taught *Failure Analysis 310* without microscopes, using published case studies and personal stories from my industrial background as a failure analyst, rather than actual parts. The COVID pandemic shut down the university after spring break, but we were able to finish the book on metallurgical failures. I had intended to develop lectures on failure analysis of wood, polymers, and composites, but the campus shutdown meant I had to develop online lectures for other courses, so the Failure Analysis course ended shortly after spring break.

I taught *Lightweight Materials 360* in spring 2020 as an independent study for one student who needed a materials course to graduate with his materials minor in May 2020. The student read a chapter a week, then met with me to review his questions on the reading. Most of his questions were about topics not covered in introductory materials classes, such as the Bauschinger effect, skull induction melting, and shock reactive synthesis of powder metals.

The *Biomedical Materials 320* course in fall 2020 used the format from the *Polymers* class. I lectured through mid-November to the end of the textbook, then we had 7 student-led lectures at the end of the semester on topics of the students' choosing:

- Type 316L stainless steel
- Ti-6Al-4V
- Cobalt-chrome alloys
- History of prosthetics
- Bone screws
- Ultra-high-molecular-weight polyethylene
- Suture materials

A few students in this class work in the biomedical products industry, so the student-led lectures provided a platform for them to discuss personal knowledge of the industry.

The COVID pandemic resulted in several absences from class due to quarantine. I posted student presentations online, so all students had the opportunity to review the presentations and submit an evaluation form using a rubric, as in the *Polymers* class. However, this semester I made the evaluation an assignment worth a few points, to encourage participation. Also, I included questions from the presentations on the final exam. Due to pandemic restrictions, we were unable to tour any of the numerous biomedical products plants in the region.

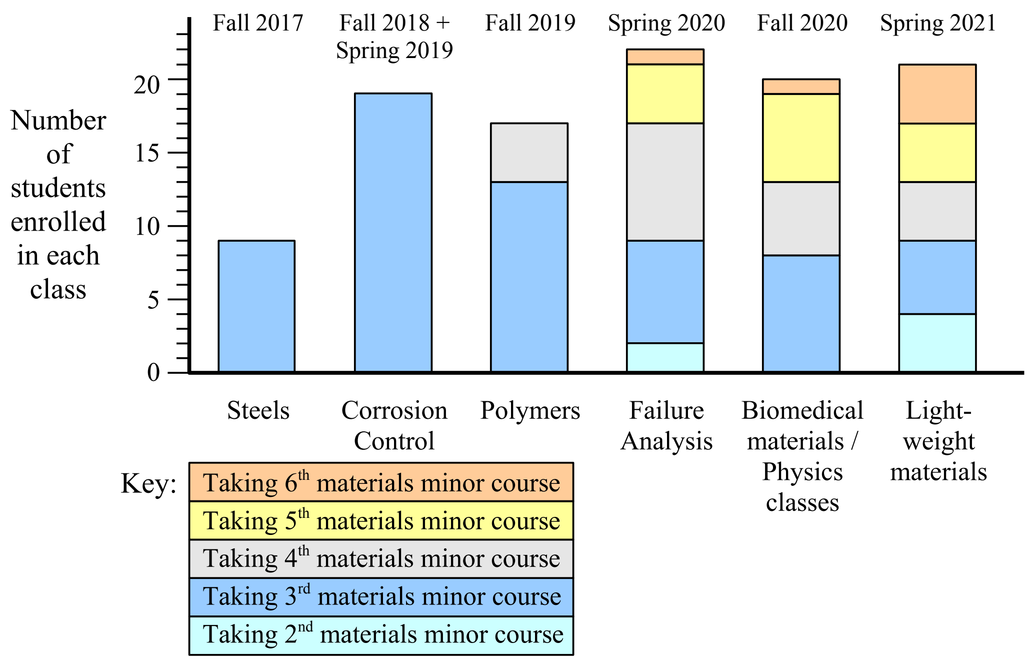
I taught *Lightweight Materials 360* in spring 2021 as a regular class. I used questions and feedback from my spring 2020 independent study student to guide the design of the lectures. I had asked the independent study student to imagine what it would be like to teach a course like this, so he wrote homework and exam problems for the course, along with his answers for these problems. The book is long enough to fill the entire semester, so there was no time for student presentations on special topics.

The next class in the series will be *Stainless Steels 350*, to be offered in fall 2021. I will spend part of the summer of 2021 developing the course. The book is about half the length of the *Lightweight Materials* book, so there should be time for student-led presentations at the end of the semester.

**Enrollment**

Since fall 2017, 67 distinct students have enrolled in at least one of the elective materials minor courses offered within the mechanical engineering technology program. These students had completed the introductory *Materials and Processes 180* class, which is a prerequisite for all of the elective courses in the minor. Most students had already completed the junior-level *Engineering Materials 381* class before taking elective courses in the minor, so their first elective course is the 3rd course in the minor.

The graph below shows enrollment in six materials minor elective courses. Color coding shows whether students were taking their second, third, fourth, fifth, or sixth course in the 6-course minor.




The 9 students who took *Steelmaking* in fall 2017 graduated that semester or the following spring, and did not take any additional materials courses. I was on sabbatical in spring 2018, and taught a 1-student Independent Study section of *Corrosion Control 340* in fall 2018 followed by a full class section in spring 2019. Four of the *Corrosion* students enrolled in *Polymers* in fall 2019, completing their second materials minor elective course. By spring 2020, more than half of the students in *Failure Analysis 310* had already completed one or more materials minor elective classes.

The first graduate of the materials minor completed his degree in spring 2020, with five more to follow in spring 2021. Two of these graduates used the physics materials courses as part of their minor.

As of November 2020, 14 students were enrolled in the minor, representing 6% of the 220 undergraduate mechanical engineering technology students. Since the materials minor courses can be used as Technical Electives, 34 students will have graduated by May 2021 with materials minor courses on their transcripts without completing the minor. The table on the next page illustrates progress of 67 students who have taken elective courses in the minor, with graduates (including students expected to graduate by May 2021) marked as “Grad – no minor” or “Grad with minor.” Note: the two leftmost courses are required in the mechanical engineering technology major; the remainder are elective courses.

This information is useful for planning the schedule of future classes. Since only one elective course is offered each semester, no student should be in the position of having already taken the scheduled elective course, and be left without the opportunity to finish the minor on time. All students from the *Steelmaking* class have graduated, whereas 4 *Corrosion Control* students, 5 *Introduction to Polymers* students, 9 *Failure Analysis* students, and 8 *Biomedical Materials* students have not yet graduated. Therefore, the next class that can be repeated is *Steelmaking*.

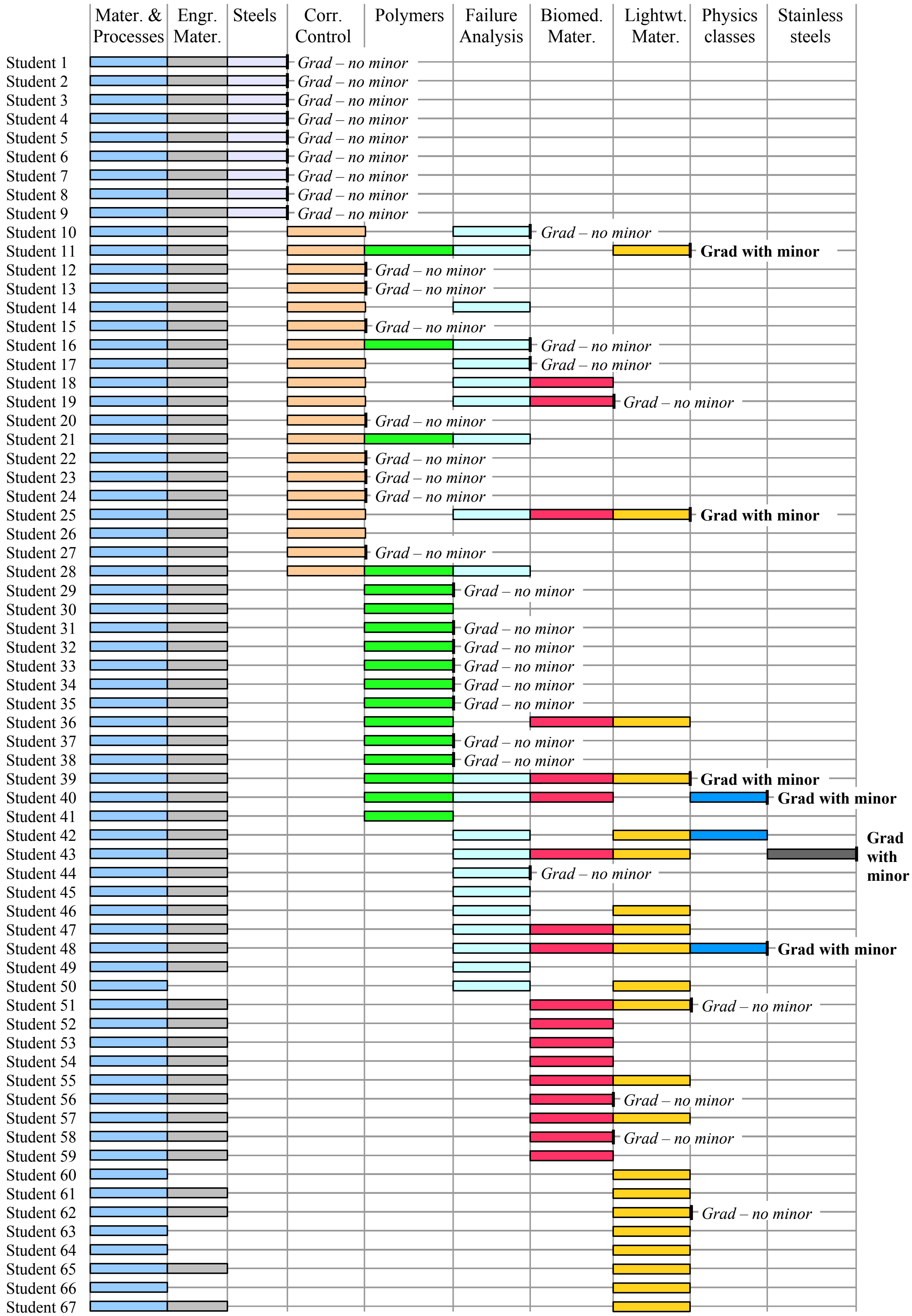
**Course Improvements**

The last question on the final exam in each course, for extra credit points, is “Discuss three ways to improve this course.” This question has proved to be a more useful tool for continuous improvement than standard institutional end-of-course surveys. As described previously, students in the two flipped classrooms (*Steelmaking 240* and *Corrosion Control 340*) strongly recommended using a lecture format instead – advice that I heeded in subsequent courses.

The *Steelmaking 240* students recommended finding a book that is better suited to mechanical engineering technology undergraduates. This search is ongoing.

The *Corrosion Control 340* students recommended supplementing the course with color photographs of corrosion specimens.

The *Introduction to Polymers 230* students suggested keeping the student presentations, and particularly enjoyed a slideshow I presented on polymers used in art restoration. This presentation included the reconstruction of a 700 lb. Italian Renaissance marble statue of the biblical Adam. The statue fell off its pedestal, shattering into thousands of pieces, which were successfully reassembled after years of careful work. Restoration included some interesting materials testing of pins and adhesives. The Metropolitan Museum of Art in New York has videos of materials testing and restoration work on its website. [16]



Mater. & Processes
Engr. Mater.
Steels
Corr. Control
Polymers
Failure Analysis
Biomed. Mater.
Lightwt. Mater.
Physics classes
Stainless steels
Student 1 Grad – no minor
Student 2 Grad – no minor
Student 3 Grad – no minor
Student 4 Grad – no minor
Student 5 Grad – no minor
Student 6 Grad – no minor
Student 7 Grad – no minor
Student 8 Grad – no minor
Student 9 Grad – no minor
Student 10 Grad – no minor
Student 11 Grad with minor
Student 12 Grad – no minor
Student 13 Grad – no minor
Student 14
Student 15 Grad – no minor
Student 16 Grad – no minor
Student 17 Grad – no minor
Student 18
Student 19 Grad – no minor
Student 20 Grad – no minor
Student 21
Student 22 Grad – no minor
Student 23 Grad – no minor
Student 24 Grad – no minor
Student 25 Grad with minor
Student 26
Student 27 Grad – no minor
Student 28
Student 29 Grad – no minor
Student 30
Student 31 Grad – no minor
Student 32 Grad – no minor
Student 33 Grad – no minor
Student 34 Grad – no minor
Student 35 Grad – no minor
Student 36
Student 37 Grad – no minor
Student 38 Grad – no minor
Student 39 Grad with minor
Student 40 Grad with minor
Student 41
Student 42
Student 43 Grad with minor
Student 44 Grad – no minor
Student 45
Student 46
Student 47
Student 48 Grad with minor
Student 49
Student 50
Student 51 Grad – no minor
Student 52
Student 53
Student 54
Student 55
Student 56 Grad – no minor
Student 57
Student 58 Grad – no minor
Student 59
Student 60
Student 61
Student 62 Grad – no minor
Student 63
Student 64
Student 65
Student 66
Student 67

Students in *Failure Analysis 310* were pleased with the textbook, but disappointed by the lack of a metallography lab and microscopes which could have been used for practical training. I share their frustration, and will continue to seek university funds to build the lab.

Most of the *Biomedical Materials 320* students recommended finding a textbook with less emphasis on biology, but one student who works in the biomedical industry thought the biology information was very important, and recommended invviting a teaching assistant from the biology department to lead a guest mini-lecture on basic biological principles. Since my own knowledge of biology is limited to a high school course I took in 1980, this is a very good idea. Students also asked for more show-and-tell examples of actual biomedical products. Given the numerous biomedical manufacturing businesses in the area, I would have offered two or three plant visits if it weren't for pandemic restrictions in fall 2020.

**Campus-Wide Materials Course Designator**

The chair of the physics department started a materials interest group, with faculty from physics, mechanical engineering technology, chemistry, and other sciences. Our intent is to share knowledge and resources, and perhaps write equipment grants to further materials study on campus. One of our first initiatives is to develop a new course designator for materials-related courses, regardless of academic department. The MATR designator begins in fall 2021, and will include one 3-credit and seven 1-credit courses offered by the physics department, and nine 3-credit courses offered by the mechanical engineering technology program. Eventually, the hope is to include materials courses offered by chemistry, biology, and mechanical engineering.

**Outcomes**

If success is measured by interest on campus, then the materials engineering technology minor is already a success. Courses are attracting repeat customers, as evidenced in the enrollment graph. Courses are reaching their enrollment limits, and additional students are admitted by exception. In future, the maximum class size will be increased to accommodate increasing demand.

If success is measured by marketability of graduates, then we only have anecdotal evidence of a student who used what he learned in *Introduction to Polymers 230*. During a job interview, he was able to solve a polymers problem that nobody at the company had been able to solve – and he got the job.

The department will monitor the success of the program through alumni surveys and feedback from the industrial advisory committee in coming years. If employers start demanding that graduates have the minor, we will advise students early in their academic careers to enroll.

**Conclusions**

Developing a new class every semester for several years in a row is time-consuming. In retrospect, I should have requested release time for course development.

Working with the physics department on common courses was rewarding, and should lead to partnerships with other departments interested in materials topics.

The most disheartening part of the process has been the lack of interest or support from the university administration, especially with respect to laboratory funding. Conversely, the most rewarding part has been the response from students. Classes are now filling well before the semester begins, and student feedback shows that students are genuinely excited about the courses.

Faculty wishing to start a materials minor at their instutition should consider these suggestions:

- Get input from your industrial advisory committee regarding the need for the minor, course selection, and possible funding for lab equipment.
- Obtain release time to develop the classes.
- Obtain firm commitments for lab funding in advance.
- Collaborate with departments that have some interest in materials, such as chemistry, physics, or biology – especially if they have lab equipment.
- If your institution is small, collaborate with another nearby institution. Perhaps each institution can teach half of the classes, and share students.
- When possible, take students on industry tours.
- If time allows in the semester, have students work in teams to research and present information on a special materials topic. Set up a rubric so the audience can evaluate each presentation, then collate the results and provide the evaluations to the presenting teams.

Although the initial driving force for materials minors on my campus came from local manufacturing industries, a materials minor could be developed on any campus, provided the faculty can show that graduates will benefit from this knowledge and expertise.

In future, I hope to attract students from other programs, such as mechanical engineering, to take the minor. I also hope to persuade more of my students to take the materials classes offered by the physics department.

## Appendix: Learning Objectives for each Materials Course

| | |
|---|---|
| *Materials & Processes 180* | By the end of this course, the student will have demonstrated knowledge and understanding of physical and mechanical properties of solids; equipment and techniques for determining materials properties; basic manufacturing processes for producing materials; and relationships between materials properties and design equations & concepts. In addition, the student will demonstrate the ability to write clear, concise laboratory reports which present data in tabular and graphical form. |
| *Materials Characterization 220* | By the end of the course, students will be able to prepare samples for materials analysis, conduct the analysis, and write engineering reports on the findings. |
| *Introduction to Polymers 230* | By the end of the course, students will have a basic understanding of polymer science, engineering properties of polymers, manufacturing techniques, and design concepts related to polymers. |
| *Steelmaking, Forming, and Heat Treating 240* | By the end of the course, students will understand the basic processes involved in making steel; how to modify properties through work hardening, alloying, and heat treatment; the link between microstructure and mechanical properties; and the economics of steelmaking and steel recycling. |
| *Failure Analysis 310* | By the end of the course, students will have the basic skills to plan and execute a failure analysis on a failed component. The final project will be a complete analysis, written report, and oral report on a broken part. |
| *Biomedical Materials 320* | By the end of the course, students will have an understanding of materials used in the medical industry and how these materials are selected and processed for making implants or surgical tools. |
| *Corrosion Control 340* | By the end of the course, students will understand the basic types of corrosion and degradation which occur in common engineering materials, including metals, polymers, composites, and reinforced concrete. They will also understand methods of corrosion testing, corrosion protection, and the economics of corrosion. |
| *Stainless Steels 350* | By the end of the course, students will have a basic understanding of stainless steels, including: metallurgy, corrosion theory, types of stainless steel, casting, thermal processing, forming, machining, surface finishing, welding, and industrial applications. |
| *Lightweight Materials 360* | By the end of the course, students will have a basic understanding of engineering properties and processing of lightweight materials, including aluminum alloys, magnesium alloys, beryllium, titanium alloys, titanium aluminide intermetallics, engineering plastics, structural ceramics, polymer-matrix composites, metal-matrix composites, and ceramic-matrix composites. |

*Engineering Materials 381* By the end of this course, the student will have demonstrated knowledge and understanding of heat treatment, composition, and mechanical processing of steel; properties of ceramics, polymers, and adhesives; processes for modifying materials properties; processes for producing and forming materials; surface treatments for improving resistance to wear, friction, and corrosion; and relationships between materials properties and design equations & concepts. In addition, the student will demonstrate the ability to write a research paper on materials.

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