STONY BROOK UNIVERSITY: NEW COLLEGE-WIDE TECH REQUIREMENT

Why Stony Brook? Why Now?

The new one-course Tech requirement for general education at Stony Brook University only went into effect in 2014, but was the result of five years of deliberation. According to Associate Provost David Ferguson, long-time Chair of the Department of Technology and Society, the Stony Brook Curriculum, as it is now known, *originated* in the “strong feeling” of the College of Engineering and Applied Sciences (CEAS) that *all* students should have an understanding of technology and most particularly “the role of engineering in the broader context of global problem solving.” Important for the telling of this story is that the CEAS itself wished to have a role to play in general education.

Ferguson, who serves on the implementation committee, recalled in a recent interview that the process was “smoother than expected.” Barely two years later, there are already over 20 new CEAS-initiated courses in the Tech area, along with Science/Technology Connections continued from the previous set of requirements (see below). These efforts were not without high-level endorsements by the then dean and associate dean of CEAS and were adopted enthusiastically by the new Dean, Fotis Sotiropoulos, who writes:

> In an era when exponential technological advances are driving innovation, economic growth, and societal prosperity…CEAS has recognized and responded to the need for a new educational paradigm…which cuts across traditional boundaries.

Imported into the new Tech requirement is the integration of student advising. Both university-wide and in an advising office within the College of Engineering and Applied Sciences, advisers are instructed to communicate to *all* students they come in contact with the value of being conversant in the tech areas. Their role is not just to impose the new requirement, but to have students understand the value of the “new curriculum” to their future studies and careers.

When asked “Why Stony Brook? Why now?” Ferguson who has been at Stony Brook a long time, points to the pioneering work of John Truxal, who was a member of the National Academy of Engineering and Dean of Engineering and Applied Sciences at Stony Brook over three decades ago. According to Ferguson, “What we see now is a *convergence* of Truxal’s work on technology and the liberal arts, and the unprecedented role that technology now plays in the 21st century.”

Stony Brook’s Tech requirement is compatible with SUNY Chancellor Nancy Zimpher’s emphasis on having all SUNY campuses broaden students’ engagement with Experiential Learning. Through the NSF-funded SENCER (Science Education for New Civic Engagements and Responsibilities), Stony Brook University plans to collaborate with other SUNY campuses.

TECH for non-majors:

AMS 103 - Applied Mathematics in Modern Technology
BME 200 - Bioengineering in Extreme Environments
BME 205- Clinical Challenges of the 21st Century
CIV 100 - Infrastructure
CME 201 - Sustainable Energy - Evaluating the Options
CME 240 - Introduction to Food Technology
CME 491 - Sustainable Future through Renewable Energy
CSE 101 - Introduction to Computers
CSE 102/ISE 102 - Introduction to Web Design and Programming
ESE 121 - Introduction to Audio Systems
ESM 150 - Materials of the Modern World
EST 100 - Designing, Producing & Presenting Multimedia Projects
EST 105- The Digital Generation: Leveraging Technology to Build 21st Century Skills
EST 106 - The Digital Generation: Creating a Professional Web Presence
EST 204 - Modern Digital Tech Infrastructure
EST 205 - Introduction to Technological Design
EST 207 - Interaction Design
EST 208 - Virtual Distance Foundations: Collaborating Across Boundaries in the Digital Age
MEC 104 - Practical Science of Things
MEC 105 - Everyday Science and Engineering

STAS (Science, Technology and Society):

BME 303 - Biomechanics (majors only)
BME 304 - Genetic Engineering (majors only)
CSE 301/ISE 301 - History of Computing
CSE 312/ISE 312 - Legal, Social, and Ethical Issues in Information Systems (majors only)
EEO 302 - Engineering Ethics and Societal Impact (majors only)
ESE 301 - Engineering Ethics and Societal Impact (majors only)
ESG 201 - Learning from Disasters
EST 200 - Cultural Technologies and Society
EST 201 - Technological Trends in Society
EST 291 - Energy, Environment and People
EST 320 - Communication Technology Systems
EST 325 - Technology in the Workplace
EST 330 - Natural Disasters: Societal Impacts and Technological Solutions
EST 355 - Preventing Weapons Proliferation
EST 361 - Technologies of Mass Destruction: The Gathering Storm
EST 391 - Technology Assessment
MEC 280 - Pollution and Human Health
WSE 242 - Society and Gender in Science and Engineering (WISE students only)

II Learning from Engineering Disasters

Gary Halada holds two degrees from Stony Brook University, a B.S. in physics, and a PhD in materials science and engineering, and inhabits two positions, which puts him at the intersection of engineering (Professor of Materials Science) and undergraduate education as Undergraduate Program Director of the B.E. in Engineering Science. Halada is an active researcher, where he studies corrosion and nuclear waste, which has involved him in a close examination of the three nuclear accidents (Chernobyl, Three Mile Island, and Fukushima). He has also assisted a number of companies in analyzing the causes of failures in products and in manufacturing. These close examinations have made him curious about how engineers look at risk, in contrast to the general public. At the time this interview took place, Halada was on his way to video the Hindenberg site in New Jersey where the famed dirigible disaster took place in 1938.

The video is for a course he has taught for some years now to ~122 undergraduates, half from engineering, half from other majors on campus, which he calls “Learning from Engineering Disasters.” He also regularly teaches a so-called Enrichment course for 40 freshmen on “Emerging Technologies: Fact and Fiction” and co-teaches a course, “Modes of Knowledge,” for all majors in the university Honors Program. In this latter course, he helps students analyze the human-made world around them through the lens of ‘value-sensitive design’ in which the values of engineers are seen as guiding their design choices and creations.

What enables Halada and several of his colleagues (including Jason Trelewicz see *infra*) to stretch his range of teaching and his students’ range of learning is the underwriting at Stony Brook (since 2014) of 20 “TECH” courses, and 18 more in “STAS”, science, technology and society. Some of the courses are not entirely new, but have re-engineered (sic!) learning outcomes, and so qualify. The thinking behind creating these new University-wide education requirements is the need to provide not just engineers but all graduates with a better understanding of the human-made world – a need seen as universal alongside learning outcomes in the arts, history, social and physical sciences. From the university’s *Current Policies and Regulations*, come operational definitions of the new parameters for courses to receive the TECH designation:

1. [Be able to] apply concepts and tools drawn from any field of study in order to understand the links between science or technology and the arts, humanities, or social sciences.

2. [Be able to] synthesize quantitative and/or technical information and qualitative information to make informed judgments about the reciprocal relationships between science or technology, and the arts, humanities, or social sciences

And from these directives have come two new interdisciplinary minors *within* Engineering, one in *Energy Science, Technology and Policy*, the other in *Nanotechnology Studies.* Both feature required courses, from different departments.

ESG 201, Halada's Signature Course

Halada begins by defining engineering disasters as spectacular and catastrophic failures of engineered systems, which impact the general public emotionally and viscerally. Their narratives, he explains, have become the background for societal perception of risk and for the course material. First, Three Mile Island, then Chernobyl, and now Fukushima have changed our belief in and our approach to nuclear power, despite the fact that the nuclear industry actually has a relatively strong safety record and may be a potential solution to reducing carbon emissions from energy production. The failure of the hurricane protection system in New Orleans had a comparable effect on how Americans view our institutions, our infrastructure and our vulnerability. “Psychologically,” he tells his students, “engineering failures trigger our fears and misgivings, impact how we vote and safeguard ourselves and our families, and may even influence our choices in education and careers.”

The course is developed around modules. Certain modules, such as “understanding engineering ethics” or “learning the importance of the engineering design process” highlight fundamental issues of engineering. Other modules are selected because they focus on a particular aspect of failure, including the engineering causes of failure, the engineering principles they illustrate and the systems-level issues related to the failure. In each case, Halada has his students derive the lesson a particular failure provides for engineers.

In addition to the Modules (see below) students are also provided with a list of other failures (some small, some spectacular) related to the overall topic of the module. In small groups, they develop their own risk analysis and probable causes of failure in relation to the complexity of the assigned example, from which discussions, they develop individual presentations.

I Table of Modules

Overarching concept	***Case study***	***Engineering concept***	***Broader/System concept***	***Notes***
Engineers and design needs	Highlight a design success	The role of engineers	Systems engineering	Overview lectures;
Failure and the tipping point	Bent Pyramid	Forces and stability	Evolution of engineering	Historical context; have demo of soil mechanics
Complexity and organizations	Titanic	Properties of steels	Haste makes disaster	Historical context: can film demo of field ultrasonic flaw testing; interview with ocean liner historian
Control of complex systems	Three Mile Island	Loss of control	Managing the failure; communications	Can discuss challenges of next generation nuclear energy
Assessing risk for complex systems	Challenger	Design flaw; temperature impact on materials	Engineering ethics	Can film live demo using impact tester, other materials testing techniques
Understanding risk and perceptions of risk in a historical context	Hindenburg	Probabilistic risk assessment; impact of scaling on design risk	Public perception of risk as impacted by current events, historical setting	Film from Hindenburg site; interview at on-site museum
Risk and changing environments	Katrina	Soil/hydrology/civil engineering	Piecemeal design; organizational failure	Can compare with Sandy, other local storm events
The energy/complexity spiral, and its impact on risk	Deepwater Horizon	High pressure design	Pushing the limits; value sensitive design	Can discuss new energy needs and risks (fracking)
Complexity and non-linear response	Great Pickle Works Wreck (Calverton, NY)	Vibration and mechanical failure	Failure due to maintenance	Can film at the disaster site (Peconic Land Trust site)
Failure modes and forensic engineering	Mianus River Bridge collapse (Connecticut)	Corrosion	Combinations of latent failures	Can film at site; can show live demo of field corrosion monitor; include interview with failure analyst
Complexity and ethics	C.W. Post arena collapse	Wind and snow loads	Engineering ethics	Can film at site (Westbury)
Design for reliability; learning from failure	Brockton Shoe Factory explosion; other examples from above list	Thermodynamics and material properties; design for reliability	Role of standards (ASME)	Role of professional engineering societies (ASME); include interview with engineers.

Putting Engineering into a Real-World Context

When asked what kind of analysis he wants his students to derive from the engineering failures he assigns them to study, Halada lists key concepts: First, that understanding what happened and why is never simple. Rather, it is a combination of factors, including but not always, extreme conditions that were either not anticipated or not adequately built into the system under review. The cause could also have been a material flaw, some part of the system having experienced too much stress. And of course the “human factor,” which is one of the key object lessons Halada wants his students to take from the course. This leads to a discussion of the “ethics of checking,” set up to keep engineers and users of their structures from missing things, being too lax. Pilots go through a check list before taking off that often includes getting out of their planes and “eye-balling” the landing gear and the tires. Surgeons are trained to color- tape the limb to be operated on to avoid cutting into the wrong limb.

The list of causes is longer still. A small unanticipated change in the environment of a structure or a system can cause a problem, and as systems become more complex, they can react in a non-linear way, which means they do not react proportionately. Twice the input may not double the output. Halada is at pains to compare and contrast how engineers and ordinary people regard risk. Students are asked to compare the sinking of the Titanic (which hit an iceberg) and of the Lusitania (which was torpedoed), each involving hubris of a different kind. There were signs on the dock from which the Lusitania was sailing that warned travelers that it was war time, and unseen dangers lurked at sea. Yet, they climbed on. But engineers themselves are not entirely rational and unemotional when they are attached to a project. Students are assigned a book called *Drilling Down* (which details the risks of deep-water drilling) co-authored by Joseph Tainter, an historian, who studies how societies collapse, and Tadeusz Patzek, a petroleum engineer. Students are instructed in the “energy/complexity spiral”: that increasing complexity in modern society requires more energy, which in turn leads to the creation of yet more complex technology to find, retrieve and transform energy resources to assess emerging technologies, from fracking to alternative sources. He also assigns reading from Sidney Dekker’s *Drift into Failure*, a book which describes how systems ‘drift’ toward failure through such processes as “normalization of deviance” – where events which once would have set off alarms and called for intensive corrective effort over time become accepted as the “new normal” both by engineers and by institutions. The foam falling from the external fuel tank of the Columbia space shuttle (which led to its catastrophic failure on re-entry) is one such example cited.

Student Assignments and Exams

As a professor of engineering, Gary Halada is used to giving students problem sets to solve. But with non-engineers he assigns case studies and asks students *in words* to summarize what they learned from it. He has students do group projects, working together to analyze a current disaster. Even where the information provided is incomplete, there's an object lesson for students to ferret out themselves. (Hurricane "Sandy" is of special interest to Long-Island residents.) Or where government laxity may be at fault (example: countries where building codes are not enforced).

The final individual assignment challenges each student to explore an energy technology, detailing its risks. But there is a group assignment, too, for groups of four students: to analyze a current disaster. For all of these assignments, Halada uses letter grading and develops rubrics for grading. There is no final exam in the course.

Impact on the Campus

Halada claims that some faculty remain a little skeptical about his Disasters course. But as one of a small number of engineering faculty at Stony Brook to have won the coveted SUNY Chancellor's award for excellence in teaching, Halada, is entirely trusted in his ability to connect engineering ideas with real-world examples, which fits well within the new TECH and STAS requirements for all majors. Recognizing this, the University and the College of Engineering and Applied Sciences have provided a small grant to support the development of a coming on-line version of "Learning from Engineering Disasters."

But beyond Halada, what are the chances of a groundswell at Stony Brook or in the SUNY system as a whole? Jason Trelewicz' new course for non-majors, may hold the key. Course enrollment in ESM 150, Materials of the Modern World more than *tripled* from 40 to 140, the second year it was offered.

III ESM 150 Materials of the Modern World

When, as we have noted, a Tech requirement was added to the undergraduate experience at Stony Brook University, the College of Engineering and Applied Science was tasked with developing new courses, depending on faculty interest, in teaching general ED students.

Jason Trelewicz is a materials scientist, who like Gary Halada, has an undergraduate degree from Stony Brook and a doctorate from MIT. Trelewicz has long had a vision of teaching materials science to non-majors, particularly because he believes materials science, more than any other sub-specialty of engineering, is especially appropriate for non-majors as it combines many STEM subjects into one discipline. And, indeed, the first time ESM 150, a course entirely of his own design, was offered in 2014, 40 students enrolled. In 2015, enrollment grew to 140 students. From the beginning, the course has attracted an especially wide range of majors or future majors, from physics to psychology. Trelewicz's aim is for students to emerge at the end of the course knowing more, much more, about the materials of their surroundings, from the steel used in bridges to the wood used in paper to electronic materials that have enabled the entire computing revolution.

The first year he taught the course, he assigned a classic materials science text, but by the second year had discovered *Stuff Matters: Exploring the Materials that Shape our Modern World* by Mark Miodownik (Houghton Mifflin, 2014). Miodownik presents the science Trelewicz wants to cover as a "tour" of the material world that the students inhabit. The textbook's chapter titles, which Jason adapts for his course schedule, are meant both to challenge and entertain, as well as to reassure a student who may have forgotten his or her high school chemistry (or have never even learned it). The textbook demonstrates that the science of materials is well within the non-major's ability to grasp, and, most important, as the Textbook advertizes, *stuff matters*! Each course topic is focused on understanding the functions of different materials. Following are some chapter titles and corresponding topic areas:

Indomitable; steel as a model high strength material
Unbreakable; carbon as an ultra-tough material
Immortal; biomaterials
Delicious; the materials science of chocolate

What surprises his colleagues in the College of Engineering and Applied Sciences *most* is that ESM 150 students end up making the connections *on their own* between tangibles and fundamentals, at their own pace and in their own way. In Trelewicz' view, many engineering undergraduates do not know (or appreciate) when choosing their major, the continuing salience of the periodic table in materials science. Trelewicz accomplishes this by making sure that the real-world questions posed percolate through the review of fundamentals. Some natural science students will be motivated to learn the periodic table, he knows from teaching them, because "It's there" (like Everest). For others, the motivation comes from trying to answer questions about a *particular material*, like steel:

"Why is a piece of steel strong?" "What even does 'strong' mean"? Or, "Why, if we find a way to bend it, will it break?" And what does 'break' mean, at the atomic scale?

The course is 15 weeks in duration, and will be taught every year going forward focusing on the topic areas taken directly from the syllabus and illustrated below.

Week	Class No.	Topic	Book Readings	Assignments
1	1	Course overview and introduction to the science of materials		
	2	Video: Exploring the Elements Part 1		
2	3	Video: Exploring the Elements Part 2		
	4	Atomic Bonding and the Periodic Table		Paper 1
3	5	Labor Day Break, No Class		
	6	Indomitable: Structure of Metals		Paper 1 Due
4	7	Structure of Metals	Part 1 Indomitable	
	8	The Strength of Metals		Paper 2
5	9	Unbreakable: The Many Uses of Carbon	Part 8 Unbreakable	
	10	Video: Making Materials Stronger		
6	11	Optical Properties of Materials	Part 7 Invisible	Paper 2 Due
	12	What is a Plastic?	Part 9 Refined	Problem Set 1
7	13	Invisible, Refined, and Imaginable	Part 6 Imaginative	
	14	Columbus Day: No Class		PSET1 Due
8	15	Problem Set and Exam Review		
	16	**Midterm Exam**		
9	17	Exam Solutions and Video: Making Materials Smaller		
	18	Marvelous: Foams and Aerogels	Part 5 Marvelous	Paper 3
10	19	Immortal: Biocompatible Materials	Part 10 Immortal	
	20	Video: Making Materials Smarter		
11	21	Composite Materials		Paper 3 Due
	22	Trusted: The World of Paper	Part 2 Trusted	
12	23	Fundamental: The wonders of concrete	Part 3 Fundamental	Paper 4
	24	Delicious: The Materials of Food Science	Part 4 Delicious	
13	25	Video: Making Materials Cleaner	Part 5 Marvelous	Paper 4 Due
	26	Visiting Lecture: Engineering Science Alumni		
14	27	Synthesis: Why Stuff Matters	Part 11 Synthesis	Problem Set 2
	28	Study Session and Group Discussion		
15	27	Visiting Lecture: Engineering Science Alumni		PSET2 Due
	28	Problem Set and Exam Review		

Course Assignments, Grading, Exams

ESM 150 requires a midterm and final exam and four short research papers that involve library research. At the beginning of the course, the assignments will be very specific.

As an example: “Pick an element off the Periodic Table, and discuss how it’s used in a particular material”; or “Describe a specific material and its properties.” The paper assignments during the second half of the semester instead aim to engage the student’s own perspectives and interests: “Analyze and reflect on particular chapters of the textbook,” or “How has a particular material impacted your own life, society as a whole?”

ESM 150 engages teaching assistants, all from Materials Science, to grade and to provide specific feedback on writing papers. Trelewicz, however goes over paper assignments and provides feedback on their work to the whole class, taking time to explain in detail what he is looking for and more generally what writing a research paper entails. He also handles questions in class about the problem sets, which provide the students with the opportunity to tackle conceptual problems related to specific materials discussed throughout the class. Not surprisingly, what he finds very different about teaching ESM 150 is the wider range of students’ backgrounds. Although some are science majors and therefore more familiar with the Periodic Table and basic chemistry, few have had any exposure to *materials science*. Thus, when in the second semester, they are introduced to applications, they become more actively engaged, willing to ask and answer questions even amongst themselves. Not surprisingly, they are particularly interested in substances found in their everyday environment.

Carry-Over to Engineering Instruction

From even just over one-year’s’ experience with ESM 150, Jason Trelewicz has imported some of his pedagogy to his standard Materials Science courses. He now shows videos of specific materials processes that he asks his engineering students to analyze as part of an upper division Advanced Materials Processing course (ESM 455). When he discusses ESM 150 with his fellow faculty on the College of Engineering and Applied Sciences’ Curriculum, Teaching, and Policy Committee, they are excited to see expanding knowledge of engineering being passed on to general education students. Few high school students have a working knowledge of engineering; even fewer are familiar with the vast field of materials science and engineering, and the rapidly growing job market for students with a skill set in one of the many sub disciplines of materials science. Faculty see Jason’s course, as he does: as a way to build new knowledge about science and engineering disciplines; to expose more students to technology and innovation; and most importantly to inspire students to think very differently about the world around them.