STEMstory: integrating history of technology in science & engineering education

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Abstract

STEM students face general education requirements in humanities as a part of their degree programs. Many students believe these courses are of little value to their education and career goals. Policy discussions at all levels of government has politicized history education. History curriculum focusing on societal and political developments seems obscure to the high school or undergraduate STEM student. STEMstory focuses on engaging STEM students by examining history general education courses through the lens of history of technology. The study proposes curriculum for a U.S. history survey course focusing on progress in science and technology incorporating best practices in fusing liberal arts and engineering in curricular and co-curricular activities. The curriculum proposal includes innovative approaches that intentionally promote development of professional, non-technical skills and focuses on student retention. It supports efforts on and studies of integrating engineering with general education. The curriculum parallels coursework in U.S. history and includes units on: technology and culture, technology in early America, transportation and industrial revolutions, the Second Industrial Revolution, the communication revolution, technology in war and Depression, Age of Space and Science, the Information Age and biotechnology, and Romanticism, techno-phobia, and technology failures.

> *History has to be rewritten in every generation, because although the past does not change, the present does. ... Each generation ... rescues a new area from what its predecessors arrogantly and snobbishly dismissed as the lunatic fringe.*
> - John Edward Christopher Hill.

Introduction

How many teachers hear such comments from their students? The following remark by a graduate engineer with a successful career designing and constructing transmission lines for an Oklahoma electrical utility may sound familiar to many history and humanities professors:

> I always loved math and physics, where I have to remember just the basics and I can derive everything else with logical thinking. I mean, my memory is bad...I cannot remember all the dates and who came where, when etc. That is why; when I was a student, I hated history. I always thought why I would learn about what war was fought in what age and who did what when it has nothing to do with my life.

The professional engineer went on to suggest, “You can make a difference if you tell it like its story so that it sticks in your mind, and makes it interesting.” For many years while serving as a history instructor at a community college I frequently heard similar statements from the best students in STEM fields.

Education has undergone a revolution in a generation. Many of us learned handwriting in grade school, read *Dick and Jane* primers, performed calculations on a slide ruler, studied mechanical drawing, and took vocational courses in carpentry, metalworking, or car shop. Teaching and learning today often happens online with advanced educational technology. Humanities and soft-skills have taken a backseat teaching to the test. CAD drafting systems produces renderings for projects. Standards-based education nearly obliterated vocational education in the late-20th century but CareerTech has reemerged today as pre-engineering, information technology, entrepreneurship, and culinary arts.

The purpose of this paper is to present a new history curriculum incorporating the history of technology for STEM students at our community and technical colleges that speaks to their academic and career interests. The paper demonstrates how history of technology fulfills outcomes expected of our graduates, how technological achievements since the Scientific Revolution parallel our own United States history, and how history about invention and culture engages STEM students. This monograph provides a course outline with units that tell the story of technology. Finally, this paper presents data derived from when this curriculum was "test driven" as a part of a university philosophy and history of science. The curriculum proffered encourages community and technical colleges to incorporate such a course either as alternative to general education requirements for history or as a requirement for STEM graduates.

Rational for Research

Renewed interest in STEM and Career-Technical Education

In his 2015 State of the Union Address, President Obama described a Minneapolis couple, Rebekah and Ben Erler, and their journey out of the family's economic difficulties in wake of the Great Recession. Their success, he said, was partly through retooling and career retraining at their local community college. The president called on Congress to lower the cost of community college to Zero so that two years of college becomes as free and universal in America as high school is today "for everybody who is willing to work for it." His administration is continuing to emphasize STEM programs to educate scientists, engineers, and technicians for the purpose of renewing U.S. technological and manufacturing prowess. The STEM careers are the most competitive, pay out the most, and sustain the middle class American Dream while prolonging U.S. economic hegemony and rebuilding its industrial base and infrastructure [13], [24].

During the 2016, presidential primary season contenders for both the political parties' nominations repeated an emphasis on career and technical education as a part of their education agenda. A Republican presidential aspirant sparked a debate among philosophy professors when he asserted, "Welders make more money than philosophers. We need more welders and less philosophers [25]."

Do STEM students "hate" history?

Even within the social sciences, there is a bias against history. As these fields evolved from normative to behavior theory after World War II, they increasingly emphasized statistics, economics, and decision analysis. Dwight Waldo, a political scientist who played a defining role in modern public administration, remarked with regard to history: ". . .public administration was born of the conviction that historical as well as legal studies of government are narrow, bookish, and sterile. . .Why try to reconstruct the Roman administrative system – it failed, didn't it [32], [8]?"

What is the cause of students' lack of interest in history? Why is a subject that fascinates pupils in fifth grade is found boring by senior year? Is it a situation prompted by the old joke that "half the history teachers in the nation have the same first name: 'Coach' [9]? Is it due to the prevalent high school history pedagogy consisting reciting names and dates on tests? Could it be to STEM students' inclination to seek quietly for eternal truths about Nature, using Nature's own incorruptible methods of disinterested experiment and incontrovertible mathematics?

Alternatively, perhaps James Loewen's [18] criticism of canonical American history, *Lies My Teacher Told Me: Everything Your American History Textbook Got Wrong*? For students the study of history is confusing because of historical problems with randomness, probability, and uncertainty, or as Donald Rumsfeld commented:

> …as we know, there are known knowns. These are the things we know. There are known unknowns; that is to say we know there are some things we do not know. But there are also unknown unknowns -- the ones we don't know we don't know. And if

> one looks throughout the history of our country and other free countries, it is the latter category that tend to be the difficult ones [7].

Adding to student confusion are historians' debates about what really happened. Both Napoleon and George Orwell agree, "History is written by the winners." Accurate figures and objective accounts of what happened often do not exist. Each party in a historic controversy has its own version of the history it writes. Is it fact or is it propaganda?

History on trial

Adding to STEM learners' confusion is the political conversations, or near wars, over history. Historian Alan Brinkley observed, "You can name virtually any field of history and find revisionists. There were New Deal revisionists, Lincoln revisionists, Eisenhower revisionists [4]."

In 1994, the revisionists' isolation sparked a sensational controversy over the proposed National History Standards, created by UCLA historians under a National Endowment for the Humanities grant. The Standards sought to engage students with exciting materials allowing students "to exercise their own judgment… and understand that there are multiple perspectives [11]."

That fall, before the UCLA researchers' findings were published, the former NEH Chair, Lynne V. Cheney launched a preemptive strike in the *Wall Street Journal*'. Mrs. Cheney's op-ed piece sparked an October Surprise firestorm just weeks before Newt Gingrich's Republican Revolution. Throughout the ruckus, Mrs. Cheney maintained, "students who learn their history according to these national standards…wouldn't be aware that George Washington was our first president…wouldn't know that James Madison was the father of our Constitution [5]."

In August 2015, the Republican National Committee condemned a "radically revisionist view of American history…[and] emphasizing negative aspects of U.S. history while minimizing positive aspects." The RNC accused APUSH guidelines of differing "radically from almost all state history standards [26]."

Echoes of the History Standards row have reverberated for twenty years. Republicans on the Texas state Board of Education delayed implementation of APUSH for a year claiming it violates a 2013 law prohibiting Common Core in Texas schools. Texas Lt. Gov. Dan Patrick charged APUSH brings Common Core into Texas "via the back door [31]."

Colorado's second-largest district school board directed a similar APUSH review following a takeover by conservatives in 2013. The board directed AP history curriculum taught in the Denver-area district must promote "citizenship, patriotism, essentials and benefits of the free-market system" and not "condone civil disorder, social strife or disregard of the law [12]."

In Oklahoma, Common Core critics turned their opposition on Advance Placement history. Legislation was introduced directing the state Board of Education to review course guidelines and bar the use of state funds for AP history courses [16].

Enough about educational politics. Is it any wonder, with history curriculum debates at the national, state, and local levels, STEM learners are both dazed and confused with the subject? History of technology promises to bridge the gap over what is history and its relevance while providing a narrative of "individuals and events that greatly shaped our nation's history" so important to policy makers in our Red States [22].

What is History of Technology and why is it relevant to STEM education?

History of technology is a new field in the study of history. The field originated from a broader social and intellectual historiography following the demise of progressive history in the postwar age [10].

It is an interdisciplinary area of history, as well. The field is a history of technological devices and processes: the invention, the inventors, and how it worked. In addition, the history of technology places technology in the context of history and technology's relationship to politics, economics, science, the arts, and the organization of production, and with the role it plays in class differentiation in society. That field of research involves the entrepreneurs who invested in these inventions and created organizational structures to bring those products to the consumer, the workers whose labor manufactured those devices, toxic byproducts from their processes, and technology and women [28].

The field surfaced in the 1950s from the investigation of "technological determinism". This is a debated term coined by the American economist and sociologist Thorstein Veblen and based on a theory conceived of by Karl Marx about the "forces of production" and their role in creating a social order [3]. Marx [19] had a technologically driven context for history stating, "the hand mill gives you society with a feudal lord, the steam mill, society with the industrial capitalist."

The history of technology is interdisciplinary with links to economic history and history of science. The study interacts with environmental history, gender history, business history, and labor history. Treads of each of these historical fields run through each technological development. History of technology is further divided by each technological field: biotechnology, civil engineering, communication, computing, consumer technology, electricity and electronics, energy, materials science, measurement, medicine, military technology, nuclear, physics and astronomy, and transportation. Each field has its own history and each field is further divided into subsets. New historical subdivisions are emerging as we speak in the fields of quantum computers, nanotechnology, bioengineering, nuclear fusion, drones, superconductivity, and artificial intelligence [20].

Interdisciplinary science studies.

Similar studies of history of science, technology, and society as Peter Novick [23] observed "a more general breakdown of agreement on the meaning of the past" that was occurring in the postwar period. George Sarton [27] is considered the father of history and philosophy of science with the publication of his nine volume Whig history of great men and great ideas in the march of progress.

During the interwar years, history of science was not without its detractors. The history of science was dominated by "proto-historians" – scientists from various scholarly and intellectual traditions whose methods were questioned by professional historians. The Carnegie Institution's president, Vannevar Bush, a hard science enthusiast who helped create the military-industrial complex, saw little value in humanities and social sciences. Bush once commented: "I have a great reservation about these studies where somebody goes out and interviews a bunch of people and reads a lot of stuff and writes a book and puts it on a shelf and nobody ever reads it," Bush canceled funds for Sarton's journal *Isis* on the history of science and culture [34].

Sarton's protégé, I. Bernard Cohen, was the first doctorate in the new discipline. After 1945, top American universities instituted graduate programs in history of science. The big advance in the field occurred with Thomas Kuhn's [17] study. This work held the history of science was less a linear progression of discoveries, rather the concept of scientific paradigms – an open-ended framework upon which subsequent work is structured.

Beginning in the late 1960s, U.S. and British established a number of interdisciplinary programs designed to address relevant issues left unaddressed by traditional disciplines. The first development was science studies, a branch of sociology, dealing with the social conditions and effects, and the institutional origins of modern scientific activity [2].

The science, technology, and society (STS) field was another product of 1960s ferment. STS intended to be more "activist" than its earlier academic cousins were. STS programs consist of historians, anthropologist, political scientists, and sociologists who examine how social, political, and cultural values. In turn, how do these values affect scientific and technological research and innovation? Finally, how does the research and development process affect those values?

Early on, STS addressed the "governmentisation" of science due to the Cold War [30], and "cultural, social, and political implications of Big Science" drastically changed the major features of science in the postwar era [33].

A final interdisciplinary approach is the field of science, technology, and public policy (STPP) studies programs introduced at universities in the early 1970s. Again, the premise that modern democratic societies require citizens informed about science and technological issues drove the development of STPP programs. Universities intend program graduates armed with professional skills, including a command of quantitative

and qualitative methodologies, become future leaders in government science and technology policy development [30].

History of technology and STEM curriculum outcomes.

The study of the history of technology fulfills several of the performance standards of the STEM National Career Cluster. The career cluster developed by the National Association of State Directors of Career Technical Education Consortium, an organization of career tech leaders. They provide a broad overview for each Career Cluster, including Essential Knowledge and Skills, the types of educational topics studied within a particular Career Pathway, and a listing of sample Career Specialties or occupations. The Consortium's relevant performance elements include

- Understanding the role of STEM in society.
- Applying the process and concepts for the use of technological tools in STEM.
- Applying the knowledge learned in the study of STEM to provide solutions to human and societal problems in an ethical and legal manner.
- Analyzing the impact that science and mathematics has on society.
- Applying critical thinking skills to review information, explain statistical analysis, and to translate, interpret and summarize research and statistical data.

Outcomes and Course goals

After completing a history of technology course, the student will:

- Understand major technological innovations and transformations in U.S. history and their effect on society.
- Identify and evaluate major controversies about technological change.
- Analyze the history of technological change through written assignments.
- Demonstrate knowledge of technological change through class discussion and exams.
- Fulfillment of relevant performance standards fashioned for the STEM career cluster [21].

Course Outline

1491 – 1607: Discovery & exploration
- Age of discovery
- Improvements in navigation
- Printing and publishing
- Agricultural advances

1607 – 1754: Colonial America
- Pre-industrial America
- Artisans & ironmongers
- Plantation economy
- Slave and indentured labor
- Age of sail

1754 – 1800: Revolutionary Age
- First Industrial Revolution
- Steam engine
- Factories & mills
- Luddites & Romantics

1800 – 1844: Early Republic
- Market Revolution
- Canals & turnpikes
- Steamboats
- Railways

1844 – 1877: Manifest Destiny, Civil War & Reconstruction
- Transcontinental railroads
- Maritime technology
- Coal & steel
- New South

1865 – 1889: Gilded Age
- Closing the frontier
- Agricultural revolution
- Urbanization, industrialization, & immigration
- Labor movement
- Water & sanitation
- Bacteriology
- Business organization
- Petroleum age

1890 – 1942: Progressive Age
- Second Industrial Revolution
- Communications Revolution

War & technology
Women in the workforce
Atomic energy

1943 – 1980: The Thirty Glorious Years
Computer age
Modern medicine
Age of space & science

1981 – Present: Postmodern Era
Environment & Ecology
Bioengineering
Nanotechnology
Ethics and technology failures

Testing the History of Technology in the Classroom

Last year presented an opportunity to "test drive" the history of technology curriculum in the classroom. The curriculum was incorporated in the team-teaching effort of an honors course at a four-year university. A case study description of the teaching experience and response by the students presented below.

The honors course, Philosophy and History of Technology (HON 2013), was offered at the University of Tulsa (TU) during the fall semester 2017. TU offers such courses to students in the TU Honors Program, a cohort program of students who receive honors scholarships and live in a designated honors dormitory on the university campus. The honors students enroll in four seminars studying ancient history, medieval and Enlightenment studies, philosophy and history of science, and modernity.

The course and teaching environment

HON 2013 enrolled eighteen students who were sophomores. The majority have majors in the College of Engineering and Natural Sciences, two are nursing students, three are majoring in computer sciences, and one has a major in the College of Business and another in political science.

The location of the class was in a small classroom on the second floor of Oliphant Hall, a mid-century modern classroom building that houses the departments of Languages and of Biological Sciences. The room is primarily a language classroom decorated with maps, posters, and pictures of France and Africa. The students sat three each at seven round tables in the room that was equipped with a white board, screen, and overhead projector.

HON 2013 was a team-teaching effort of this researcher with another instructor who is a professor of physics and university vice president for research. The physics professor/college administrator taught the first half of the class focusing on philosophy of science. He also assigned a research paper and a blog site the students were complete for their final grades. This researcher/instructor taught the second half of the course and employed the history of technology course outline.

The first week of the history of technology curriculum dealt with an overview of periods covered in the outline. The second week included a guest lecture on the agricultural revolution presented by a M.B.A. graduate student from Oklahoma State University–Tulsa. The students also watched a short World War II U.S. government propaganda film *Hemp for Victory* concerning the wartime production and use of hemp. The third week this instructor lectured on petroleum age history and particularly on the Oil Crisis of 1931 and its effect on the economy of Oklahoma. The final week included a guest lecture by media studies Professor Ben Peters on the information age, with focus on research from his recent book *How Not to Network a Nation: The Uneasy History of the Soviet Internet.*

Survey of participants

Students received an assignment to submit blog postings in response to the following questions:

1.) What was your Interest in history before this course and what previous history courses have you been enrolled in at TU? In high school?
2.) In class November 15th, you were introduced to the history of technology STEMstory curriculum. Do you believe this is a good alternative to traditional U.S. history courses?
3.) What are your thoughts on the periodization of U.S. history of technology as presented in the STEMstory curriculum?
4.) In the November 15 lecture, which period/era interested you the most? Why? Did you hear adequate information on that subject?
5.) Please provide any feedback you feel might be helpful in future presentations of the STEMstory curriculum.

Fourteen of the students responded to the questions contained in the survey. The fact the students were participants in the TU Honors Program gave a different perspective for history of technology curriculum designed for primarily for STEM students at community and technical colleges. The responses from Honors students reflected a favorable experience toward history classes taken in secondary school and in the Honors seminar. Several learners had AP history courses in high school, while one had completed only an eighth grade world history class.
The lone political science major was the most enthusiastic about studying history citing an "interest in colonization and how government originated…how political parties originated and other areas such as finance policies, interest groups, and court cases." He listed a number of AP classes he took in high school in addition to history and political science courses taken since he matriculated at TU.

On the other hand, another student was less enthusiastic, while understanding the importance of history, "can't say I have a lot of personal interest in it." A student who "loved history in high school" enrolled in an honors women's studies course as well as Queer Theory/Queer Lives history course.

The students surveyed were interested in the history of technology curriculum. The group was evenly divided among those who believed STEMstory was well suited as a stand alone course for the STEM-minded because it "captivates interest for STEM students" and "its direct connection to business, gender, economics, military areas cannot be overstressed."

Another student applauded the stand-alone STEMstory curriculum viewing it as a "great idea. Not everyone goes to college…for trade school students, this is a much more of a good use of time than a general history course."

Respondents who had a greater interest in history and government preferred history of technology integrated into traditional survey courses especially "concerning political and social movements that shaped history."

The third question on the survey concerned how the curriculum was presented in lecture over time and within the larger context of history. A student agreed with Kuhn's (1962) contention that science and technology was less a linear progression of discoveries an open ended framework stating "the reality is that technology develops fluidly, and not periodically."
Some respondents claimed the course outline presented was confusing and more of a timeline was needed. The course outline has been revamped in this paper that places technological discoveries and development within established era framework of U.S. history.
Every student surveyed found subjects in the history of technology that peaked their interest. Subjects that were mentioned spanned the spectrum of history from the first Industrial Revolution to "technological advances as with equipment in surgery, CAT scans, MRI scans, X-rays etc."

Several students expressed interest in developments since World War II. Discussion of this period of course came at the end of the lecture "that wasn't covered extensively due to lack of time." The computer age and contemporary issues such as ethics were mentioned. A student thought their favorite era was the Cold War which "is mostly skipped over in every history class." The student wanted more emphasis on "innovation and secrecy during that time which is never really covered in any class."

Finally, the lecture delineating the history of technology was well-received by the students in HON 2314. A student suggested including "some examples of how a certain technology or invention is used in modern times, just so that students will be able to relate to it and really grasp how important technology and STEM are in everyday life." Another suggested "a more distinct structure (perhaps a clear time line that is referenced periodically)". This improvement of the periodization was updated for this paper.

Opportunities for further research

Investigation of the history of technology in the United States as a general education course presents several research opportunities.

One area of research is curriculum development for courses in the history of technology. Bibliography, course materials, textbooks, chapters, audio-visual materials, and lesson plans are necessary to guide instructors and students in teaching and learning.

A second research opportunity is a study of how success or failure in history as a general education course affects student retention. Such a study is important because higher education institutions are facing declining enrollment, tuition increases, and cuts in public funding. One area of research current being conducted is studying the use of growth

mindset strategies for freshmen composition courses. There have several studies about implementing these strategies in basic math courses.

Another area of inquiry is the incorporation of ethnic and cultural references in STEM education. Retired astronaut John B. Herrington [15] conducted research on the motivation and engagement of Native American students in a NASA-sponsored summer STEM program on the Duck Creek Indian Reservation in the high desert of Idaho and Nevada. Commander Herrington found indigenous students were more enthusiastic when presented information on traditional tools and techniques used by their ancestors long before the introduction of western STEM disciplines [14].

A final area of research is studying civic engagement among STEM students who have completed history of technology courses. The focus of inquiry might be participation in afterschool organizations such as debate club or Model United Nations, involvement in civic and political activities, and association with technical student organizations.

Conclusion

This purpose of this paper is advocacy for including the history of technology – the STEMstory – as part of the engineering and other STEM field education. This essay maintains that STEM students, particularly those right out of high school and enrolled in community and technical colleges are not engaged by traditional history courses required for graduation in their fields. A real opportunity is lost to provide historical contexts for students that are invaluable for citizenship in a democratic society.

This paper presented a background on history of technology as an interdisciplinary study, a course outline based on innovation and invention using a traditional periods of U.S. history, and feedback from presenting the history of technology curriculum as part of a university honors program seminar on scientific enterprise. The feedback from the students buttressed the argument for developing such a curriculum for STEM studies at community and technical colleges. This study presents an outline of related research opportunities in the areas of history of technology curriculum development, student retention, STEM and cultural traditions, and the efficacy of history of technology general education courses in the civic engagement of STEM students.

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