COLLOQUIUM PAPER

Branches from the same tree: The case for integration in higher education

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The nature of work is changing rapidly in the digital age, increasing the demand for skills in specific disciplines. Across the United States and beyond, this evolution has led to an increased emphasis on science, technology, engineering, and mathematics (STEM) education at every level. Meanwhile, at US institutions of higher education, the proportion of undergraduate students who earn a degree in the humanities is declining. However, while the public discussion often pits the disciplines against one another, the sciences, arts, and humanities are—as Albert Einstein once wrote—"branches of the same tree" [(2006) *The Einstein Reader*]. They are mutually reinforcing. Therefore, the best way to prepare the next generation for the future of work, life, and citizenship is to provide broad, holistic educational experiences that integrate the STEM disciplines with the arts and humanities. A new study from the Board on Higher Education and Workforce of the National Academies of Sciences, Engineering, and Medicine bolsters the case for such an approach, finding considerable evidence that the mutual integration of disciplines leads to improved educational and career outcomes for undergraduate and graduate students.

integration | education | STEM | humanities | arts

We live in a period of massive, accelerating change, perhaps among the most profound in history. Digitization, artificial intelligence, machine learning, nearly universal personal digital communications, and other technologies are disrupting companies, reshaping industries, and transforming economies around the world. As these transformations take place, we are grappling, as individuals and as a society, with the immense challenges and opportunities that they present.

The Challenges of the 21st Century

Among the most pressing of these challenges is the question of how rapid technological progress will affect the future of work in the 21st century. For example, a McKinsey Global Institute study published in December 2017 estimated that between 400 and 800 million jobs could be displaced by automation by 2030 (1). Obviously, this is a frightening prospect for workers whose livelihoods are at risk. It also creates a serious concern for society as a whole. Indeed, at a time of deep and persistent economic inequality, large-scale job losses fueled by automation threaten to exacerbate economic and social dislocations.

It is true, of course, that some economists expect automation to have a net positive impact on employment in the long term. Even if they are right, however, there is no question that the new jobs created by emerging technologies will require more advanced skill sets than the jobs that disappear. In the United States, up to one-third of the workforce may need to acquire new skills to find or retain employment, the McKinsey study found (1). Meanwhile, as the demand for workers with advanced training in science, technology, engineering, and mathematics (STEM) rises, many employers are already struggling to find qualified employees.

What these trends suggest is that, as the nature of work changes, the nature of education must also change if the United States hopes to keep pace with an advancing reality—or with other countries. In fact, while the United States remains a powerful force for innovation and scientific progress, there are already troubling signs that we are falling behind. In the most recent international assessment, 15-y-old American students ranked 24th in the world in science and 38th in math (2).

These numbers reflect a failure not of our students but rather of our institutions. Today, many children are stuck in a system that is not adequately meeting their educational needs or preparing them to succeed in the evolving workforce. This includes higher education. A 2017 Gallup survey found that barely half of students (53%) at 4-y colleges and universities believed that their degree would lead to a good job after graduation; just over a third (34%) believed that they would leave school with the skills and knowledge required for success (3).

Over the past decade, these challenges have become almost impossible to ignore. Across sectors—business, government, academia, and philanthropy—many leaders have been pushing hard to ensure that students receive increased exposure to STEM disciplines from the moment their schooling begins—and even before. At the same time, the rapidly shifting demands of the digital age have ignited debates about the fundamental purpose of higher education and the value of a postsecondary degree.

In many ways, these discussions are already having a significant, positive impact on what—and how—the next generation is learning in school. Today, millions of Americans are getting hands-on STEM experience as part of their K-12 education, from taking coding classes to participating in robotics competitions. Furthermore, when students enroll in higher education, they are increasingly being encouraged to pursue degrees in computer science, engineering, and other STEM disciplines, which are widely seen as the surest paths to success.

Mutually Reinforcing Disciplines

Considering the monumental global challenges facing our world—including climate change, health inequalities, food scarcity, and many others—it is clear that the STEM disciplines have never been more important. We need scientists, technologists, and innovators to expand the scope of human knowledge and to use that knowledge to invent the solutions that will advance humanity's progress in this century and beyond.

The emphasis on STEM education is, therefore, an essential one. It is not, however, sufficient in itself. STEM curricula must

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be part of a broad education that includes the arts and humanities, as well as the social sciences. These disciplines hold enormous intrinsic value for individuals and society. Equally important, they have an indispensable role to play in preparing the next generation to meet the challenges and opportunities of the future, as I will explain. Accordingly, our emphasis on STEM must not come at the expense and the exclusion of the arts and humanities.

Unfortunately, in some cases, that is precisely what is happening. In April 2018, for example, the University of Wisconsin at Stevens Point made national headlines when the school proposed the elimination of 13 majors in the humanities and social sciences, including English, philosophy, and political science. The proposal, administrators explained, was motivated by a desire to expand or create degree programs in fields with "demonstrated value" and "clear career pathways," such as computer information systems and environmental engineering (4).

This is an extreme case. However, the public conversation about higher education often leaves the impression that, in the digital age, only the STEM disciplines are valuable. Moreover, there is evidence that many students are internalizing that message. In fact, between 2006 and 2015, the humanities suffered a 20% decline in the proportion of undergraduate degrees awarded, according to the American Academy of Arts and Sciences (5).

However, despite this trend, my primary concern is not the overall number of students who choose to major in the STEM disciplines versus the arts and humanities. The problem is that students who are focused on a given discipline tend to receive little meaningful exposure to others. It is true that there are many excellent cross-disciplinary programs at colleges and universities across the country, including the Science, Technology, and Society programs that a number of schools offer. However, these are the exception rather than the rule. In most places, most of the time, the STEM disciplines and the arts and humanities are studied in silos and not in tandem. This does a disservice to our students and our society, for a reason best articulated by Albert Einstein.

In 1937, Einstein wrote, "All religions, arts and sciences are branches of the same tree. All these aspirations are directed toward ennobling man's life, lifting it from the sphere of mere physical existence and leading the individual toward freedom" (ref. 6, p. 7).

As this makes clear, Einstein viewed science and the arts and humanities as deeply connected. It should not surprise us, then, that he also had a great passion for music. In fact, he often played Mozart sonatas on his violin while trying to work out a theory, and he even credited music with contributing to his greatest scientific achievement (7). "The theory of relativity occurred to me by intuition," he once explained, "and music is the driving force behind this intuition" (ref. 8, p. 90).

Einstein was hardly alone in his view of the sciences, arts, and humanities. American history is filled with figures who, like Einstein, excelled across disciplines. Benjamin Franklin was not only a statesman; he was also a scientist. Thomas Jefferson was not only a political revolutionary; he was an architect and inventor, as well. Ada Lovelace, the mathematician and writer—now recognized as the world's first computer programmer—described her work as "poetical science" (9).

There are similar examples today. Fabiola Gianotti, the Italian particle physicist and Director-General of CERN, the European Organization for Nuclear Research, is also an accomplished pianist. In March 2018, Gianotti echoed Einstein's view of the disciplines in an interview with the *New York Times*. "Too often, people consider science and the arts completely decoupled, compartmentalized," she said. "To me, they are not different things. They are both the highest expressions of creativity, of curiosity, of the ingenuity of humanity" (10).

Of course, these are all extraordinary figures. However, their combination of interests and talents does not, in my view, make them outliers. Rather, I believe, as Einstein did, that the sciences, arts, and humanities are fundamentally connected. More than that, they are mutually reinforcing.

Pitting the disciplines against one another, as the public discussion tends to do, presents our students—and, for that matter, our academic institutions—with a false choice. With that in mind, I believe that it would be a huge mistake for higher education to push students into silos where they learn specialized skills at the expense of attaining a familiarity with multiple disciplines. We do need specialists. However, we can, at the same time, provide them, and all students, with a broad, holistic education that integrates STEM with the arts and humanities, reuniting them and reinforcing the connections between them.

A Growing Body of Evidence

The argument for integrated learning is supported by a growing body of evidence.

This past May, the Board on Higher Education and Workforce of the National Academies of Sciences, Engineering and Medicine made one of the most significant contributions to this important conversation by releasing a study entitled *The Integration of the Humanities and Arts with Sciences, Engineering, and Medicine in Higher Education: Branches from the Same Tree*. I was privileged to serve as chairman of the study committee, which was made up of scholars as well as leaders in higher education and industry, representing a diverse range of expertise in the arts, humanities, social sciences, natural sciences, engineering, and medicine.

As a committee, we were tasked with "examining the evidence behind the assertion that educational programs that mutually integrate learning experiences in the humanities and arts with science, technology, engineering, math, and medicine (STEMM) lead to improved educational and career outcomes for undergraduate and graduate students" (ref. 11, pp. 2, 17). We found considerable evidence that it does (Fig. 1).

Integration of the Arts and Humanities into the STEM Disciplines. To begin, the study provides numerous examples of how STEM-focused students benefit from an integrated education.

Specifically, the committee determined that "integration of the arts and humanities into STEM courses and curricula" is "associated with positive student outcomes, including higher order thinking, creative problem solving, content mastery of complex concepts, enhanced communication and teamwork skills, and increased motivation and enjoyment of learning" (ref. 11, p. 111). These skills—especially communication and teamwork—are becoming increasingly valuable as the nature of work evolves. This suggests why a growing number of employers are touting the benefits of integration, as I will explain below.

Integration, however, does not only help STEM students develop these so-called "soft skills." In fact, the arts and humanities can also facilitate the development of highly complex knowledge in the STEM disciplines. The study notes that "a comparative study of an undergraduate neuroscience course (Jarvinen and Jarvinen, 2012) found that students who were required to apply their understanding of neurotransmission through the creative activity of making a 3- to 5-min film significantly outperformed those who learned the concept from more conventional approaches" (ref. 11, p. 112; see also ref. 12).

The logic behind these results is both straightforward and, I would argue, compelling. "The process of creating helped [students] reduce the complexity of the scientific concept to its most salient features," the study explains. "Conveying scientific content with accuracy requires deep understanding of the concepts being conveyed. This depth of knowledge comes from internalizing information and constructing it into a form that is unique and coherent to the individual" (ref. 11, p. 112).

There is also significant evidence that integration increases student motivation and engagement. In one study (13), the Olin College of Engineering allowed students to choose between taking an introductory material science course taught by an engineering

Key Recommendations from the National Academies Consensus Study
The Integration of the Humanities and Arts with Sciences, Engineering, and Medicine in Higher Education:
Branches from the Same Tree

The charge to this committee was to examine the evidence of the impact of educational experiences that integrate the humanities and arts with the sciences, technology, engineering, mathematics, and medicine (STEMM) on both undergraduate and graduate students in terms of learning and career outcomes. After considering multiple forms of evidence, the committee found that certain approaches to the integration of the arts and humanities with STEMM are associated with positive student learning outcomes, including, but not limited to, written and oral communication skills, teamwork skills, ethical decision making, critical thinking and deeper learning, content mastery, general engagement and enjoyment of learning, empathy, resilience, the ability to apply knowledge in real-world settings, and indicators of improved science literacy. Though additional research is needed, the committee concluded that the available evidence is sufficient to urge the support and evaluation of courses and programs that integrate the arts and humanities with the natural sciences, social sciences, technology, engineering, mathematics, and medicine in higher education. Therefore, we recommend the following:

Support for Integrative Approaches

Institutions should work to develop and implement new models and programs that integrate the STEMM fields, the arts, and the humanities, and sustain existing efforts that have shown promise.

Faculty, administrators, and scholars of higher education should consider new designs for general education that incorporate integrative approaches that help students make meaningful connections between their general education and specialized courses.

Federal and private funders should recognize the significant role they can and do play in driving integrative teaching, learning, and research. They should lead in supporting integration by prioritizing and dedicating funding for novel, experimental, and expanded efforts to integrate the arts, humanities, and STEMM disciplines and for the evaluation of such efforts.

Evaluating Integrative Courses and Programs

Institutions and employers should collaborate to better understand how graduates who participated in courses and programs that integrate the humanities, arts, and STEMM fields fare in the workplace throughout their careers.

Faculty and administrators should work with scholars of higher education and experts in the humanities, arts, and STEMM fields to establish agreement on the expected learning outcomes of an integrative educational experience and work to design approaches to assessment.

Faculty, administrators, and scholars of higher education should employ multiple forms of inquiry and evaluation when assessing courses and programs that integrate the humanities, arts, and STEMM fields, including qualitative, quantitative, narrative, expert opinion, and portfolio-based evidence.

Removing the Barriers to Integrative Approaches

Faculty, administrators, and accrediting bodies need to identify and mitigate constraints (e.g., tenure and promotion criteria, institutional budget models, workloads, accreditation, and funding sources) that hinder integrative efforts in higher education.

Faculty and scholars of higher education working to facilitate integrative curricular models should initiate conversations with the key accrediting organizations for STEMM, the arts, and higher education to ensure that the disciplinary structures and mandates imposed by the accreditation process do not thwart efforts to move toward more integrative program offerings.

Fig. 1. Key recommendations from the National Academies Consensus Study.

professor or an integrated materials science–history course that was cotaught by engineering and history faculty. While the classes were structured similarly, the study found that students who enrolled in the latter course were more motivated and engaged than their peers in the nonintegrated class (13).

In addition to the benefits of integration within a given course, curricular integration—in which STEM students take classes in the arts and humanities—leads to similar outcomes. As evidence, the study points to examples from Texas A&M University and the Colorado School of Mines, where first-year engineering students who enrolled in integrated programs that included English courses and humanities concepts, such as ethics, "boasted higher retention and graduation rates, stronger critical thinking skills, increased subject matter competence in their science and engineering courses, and improved communication skills" (ref. 11, p. 120).

Integration of STEM into the Arts and Humanities. It is important to note that the benefits of integration flow in both directions. The

National Academies study cites several ways in which students who are focused on the arts and humanities can benefit from exposure to the STEM disciplines.

Many of the current efforts to integrate STEM into arts and humanities are geared toward promoting basic science and technology literacy. This includes courses that aim to make the STEM disciplines "more accessible, relatable, and engaging for students by grounding this knowledge in real-world contexts and demonstrating the impact of STEM on society throughout history and in our everyday lives" (ref. 11, p. 123). The study identifies the popular University of Virginia class "How Things Work" as an example of a course that has enabled arts and humanities majors to attain a basic understanding of physics.

In our rapidly changing world, it should be self-evident that everyone—including students in the arts and humanities—has a great deal to gain from literacy in science and technology. However, that is not the only benefit. As the study notes, integration can also provide artists and humanists with new tools and perspectives to bring to their work.

For example, Worcester Polytechnic Institute has offered a class called "Making Music with Machines and Musical Robotics" (among other integrated courses) in which students explore how technology can be used to design new musical instruments. Similarly, the study notes that projects at the MIT Media Lab include "research on the power of virtual reality to enable new methods for storytelling, engagement, and empathy" (ref. 11, pp. 130–131).

From Integration to Employment. There is one more conclusion from the National Academies study that I want to address: the ways in which integration improves students' job prospects. As mentioned above, integration contributes to creative problem-solving, communication, and collaborative skills that, as the committee found, are increasingly valued by employers.

"Given the need for innovation in modern economies, employers know that a variety of employee talents are essential to the competitiveness and growth of their organizations," the study states. "But recent surveys of employers reveal that they see talent as more than deep technical expertise or familiarity with a particular technology. They also are looking for well-rounded individuals with a holistic education who can comprehend and solve complex problems embedded within sophisticated systems that transcend disciplines, understand the needs, desires, and motivations of others, and communicate clearly" (ref. 11, p. 42).

The committee approached this question from multiple angles. We considered what skills employers rate as most important. We reviewed a textual analysis of 25 million job postings. We looked at a survey of MIT alumni, who collectively indicated, as the study reports, that they "rely more heavily on communication, teamwork, and interpersonal skills throughout their careers than the specific technical and engineering skills that they learned as undergraduates" (ref. 11, p. 44).

Meanwhile, employers report strong dissatisfaction with the results of current educational approaches. "Employers also reported that many recent college graduates have not achieved the kinds of learning outcomes that they view as important," the study says. "This is especially the case for applying knowledge and skills in real-world settings, critical thinking, and written and oral communication. In these areas, fewer than 30% of employers think that students are well prepared. More than 80% of employers feel that colleges and universities need to improve in helping graduates gain cross-cutting skills and knowledge" (ref. 11, p. 46).

The Path to Integration

These findings reaffirm my long-held belief in the value of a broad, holistic education. Indeed, as former Harvard President Drew Faust has argued, "The best education is the one that cultivates habits of the mind, an analytic spirit, a capacity to judge and [to] question that will equip you to adapt to any circumstance or take any vocational direction" (14).

For America's institutions of higher education, the challenge now is finding ways to provide the integrated learning experiences that will do exactly that. To that end, the National Academies study put forward 16 specific recommendations. They include developing and implementing new curricular models of integration; hiring faculty with the ability to teach integrated courses; and collaborating with graduates and employers to gain more insight into how the benefits of integration extend into students' careers.

At the same time, we must recognize that there is no one-size-fits-all approach to realizing this vision. Students have different strengths and will take different paths toward their goals. Likewise, different institutions will need to make decisions that suit their different roles. Much of this work will happen at liberal arts colleges and research universities. However, given the critical role that community colleges play for millions of American students—both as a springboard to a 4-y degree program and as a direct path into the job market—we must continue to invest in them and include them in discussions about the future of education. This is also true of vocational education programs, whether for young people or for workers who have been displaced by automation or market forces.

The changes that I and many others are calling for will no doubt meet with skepticism and even resistance. Parents and students with understandable concerns about future employment may not believe that a holistic approach is the best path to a successful career. There may also be some resistance from academic departments, as well as from faculty members who are in charge, as they should be, of designing curricula.

A healthy debate, of course, is a necessary part of the process. The conversation should be robust, because the stakes are so high. Above all, we need to acknowledge the ways in which higher education is failing today's students while seeking new ways to ensure that we are preparing the next generation for the challenges of work, life, and citizenship in the 21st century.

Conclusion

The 19th-century French physician Armand Trousseau once said, "Every science touches art at some points—every art has its scientific side; the worst man of science is he who is never an artist, and the worst artist is he who is never a man of science" (15).

Of course, we would include women in that formulation today, but Trousseau's larger point still holds true. Each in its own way, the sciences, arts, and humanities all heighten our collective understanding of ourselves and the world we live in. Therefore, when we fully separate the disciplines—when we isolate complementary fields of knowledge—we limit their ability to advance human progress.

As I argued at the outset, the growing emphasis on STEM education at all levels, including higher education, is necessary if we hope to solve the global challenges that humanity is facing. However, we will never solve the world's thorniest problems with science alone. It will also require a great deal of collaboration, communication, and creativity. It will require the arts and humanities.

Today, leaders in higher education have a choice to make. They can continue to put the disciplines in academic silos, depriving students of the ability to become more well-rounded members of society. Alternatively, they can work to provide students with an integrated education that treats the sciences, arts, and humanities as "branches from the same tree"—and they can allow the tree to grow and flourish.

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