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STEM or STEAM?: the Critical Role of Arts in Technology Education (and the Critical Role of Art in Technology)

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STEM or STEAM? The Critical Role of Arts in Technology Education (and the Critical Role of Art in Technology)

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Abstract

This paper outlines the interdependency between arts and technology, and explains the absolute necessity of keeping them together in our education systems. While arts and humanities can be successfully taught without technology, technology greatly enhances learning, and more technology is connected to arts in some way than any other use. According to PwC Chief Executive Luke Sayers, science, technology, engineering and mathematics (STEM) are the solution to our workforce and growth challenge. Deckers suggests that all the levels of Maslow's Hierarchy exist in order to get us to the highest level where decisions are made according to aesthetics. Both STEM and (with arts added) STEAM offer the requisite knowledge and skills that make graduates attractive to employers, while also providing these students with the capacity to make knowledge transferrable to other subjects and tasks. This prepares them for lifelong learning and bestows the capacity for adaptability, essential in the twenty-first century job market. Retention of arts and technology are both imperatives in a higher education. A liberal education develops social responsibility and the practical skill set including communication, analytical, and problem-solving skills, and a demonstrated ability to apply knowledge and skills in real- world settings.

Keywords: STEM; STEAM; arts; technology education; humanities; graduate attributes

Introduction

I remember a conversation at a conference with several retired American teachers who had begun to teach in the late 1960s, and the one thing that stood out was the program they identified as “Writing Across the Curriculum”. The idea that technology universities should eliminate liberal arts, because we cannot prove causality between liberal arts education and innovation, reminds me of what those teachers discussed. Basically, the program required some writing assignments in every course from first grade through high school. It was thought that this would help students develop writing and speaking skills while aiding their learning in various other subjects.

After doing some research I find that this idea has survived. Not only are primary and secondary schools using it, but many universities have also added it, especially Information Technology / Management Information systems (IT-MIS) universities. IT/MIS curriculum is sometimes very limited in focus to just what is needed for the central career skills in IT/MIS, and students may not acquire the needed skills for a balanced education aimed at career development and life enhancement (Merhout & Etter, 2005). It is a common complaint in technological universities and in companies that these students lack adequate language and speech skills (Plutsky & Wilson, 2001). One very interesting statistic is that more liberal arts graduates go on to postgraduate work in STEM than undergraduate STEM honours graduates (Seymour & Hewitt, 1997).

The liberal arts program is interdisciplinary, with differences in the particular subjects but generally covering the humanities (art, philosophy, religion, literature and the classical languages, speech, theatre, music and other languages); social sciences (history, psychology, law, sociology, politics, gender studies, anthropology, economics, geography, business informatics); the natural sciences (physics, chemistry, botany, zoology, astronomy etc); and

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the formal sciences (logic, statistics and mathematics). It can apply to just one subject (Haidar, 2014).

STEM curriculum educates students in Science, Technology, Engineering and Maths. STEAM adds Art to the other four disciplines, extending STEM by inclusion of a focus on innovation and design. Whether STEM or STEAM, these are interdisciplinary, applied processes with a project methodology. Modern jobs require a great deal of technological knowhow, but there is still a need for communications skills and even for a connection to other disciplines, because most companies using high technology do business with companies within other domains. Most jobs require a balanced set of skills (Gobble, 2019). So, for the future employer, liberal arts education, even if limited to communications subjects and introductory classes across the spectrum, would produce a more attractive new employee. “A liberal arts education has always helped students develop the disciplined yet vibrant habits of mind that allow them to respond usefully to what is new in our culture” (Frost & Olsen, 2006, p. 22). This paper aims to illustrate the importance of combining technology and art in education, and makes a case for STEM education being upgraded to STEAM.

Rationale

For the technological university, including liberal arts may be seen as an additional expense, and an unnecessary expenditure of student time and energy. However, it is worth noting that the inclusion of liberal arts provides a diversion for students from what can become a mind-numbing study routine with some very repetitive subjects. The difference between the subject types relieves the monotony, making the technology less grinding and more attractive (Milekic, 2000). It is possible that the intangibles of art and humanities require a different kind of thinking and complement the type of reasoning required for technology. Marcoux found that the inclusion of arts and humanities actually activates the brain in the areas devoted to learning, and that there are some areas that fail to develop unless arts and humanities are taught (Marcoux, 2013). However, technology brings new teaching and learning strategies to the arts with its display power, along with the possibility for hands-on manipulation by students, making them more real, and drawing the student into the creative process. Milekic considers them interdependent (Milekic, 2000).

In Ireland, the Technical Universities (TU) Bill of 2015 makes provision for TUs that "engage in industry-focused research" with a "focus on science and technology programmes that are vocationally and professionally oriented…with an emphasis on programmes at levels 6 to 8 and industry-focused research…" and "play a pivotal role in facilitating access and progression particularly through relationships with the further education and training sector" (Technological Universities Policy, 2019). For the student, liberal arts provide a form of relief from intensive technological study and also a broad connection to the why of technology. However, connecting new skills and technology to the real world is something left out of an education that does not include liberal arts. Some universities have added project based STEM in the first two years along with liberal arts in order to make those connections and create lifelong learners driven by passion, which is more constant than that driven by need (Cervini, 2003). This creates a bridge between liberal arts and technology. Another bridge is sometimes forged by creating interdisciplinary studies programs, combining arts and STEM subjects into the STEAM curriculum that prepares students for the challenges peculiar to the twenty-first century. Taylor (2016) describes these outcomes as creating "critical consumers, creative and ethically astute citizens, innovative designers, good communicators and collaborative decision-makers" (p. 89) in response to the global,

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multicultural interconnected society these students face in the real world. According to Taylor, this speaks to the wholeness of the individual.

Background

In the 1980s many educational institutions removed liberal arts in preference to STEM, but industry protested the lack of problem-solving skills in graduates. Some citizen groups and political action groups noticed that new graduates were disconnected from the community. Anders (2015) suggests that although liberal arts graduates may not start out at the higher levels of pay that STEM graduates earn, the skills they develop could be the ticket to executive suites, especially the higher middle management, where there is a paucity of talent. This is reinforced by Schneider & Sigelman (2018) who stated that "while graduates' earnings and employment prospects start out slowly relative to graduates in other fields, liberal arts graduates will experience a more rapid increase in earnings as the value of their education manifests" (p.3). A number of authors, including Roth (2017), Stross (2017) and Anders (2015), have championed the liberal arts education as one that does not become obsolete. Technology education is great until the technology changes, and then those experts among employees have to learn the new technology. Not only does a liberal arts education provide life skills and skills transferable to other areas, but it also makes such graduates well suited to the peripheral and adjacent positions created by obsolescence-prone technological innovation, including the newly emerging "rapport sector" (Godfrey, Aubrey, & King, 2010). The pace of technological change is a governing force for the demand in STEM education, but STEM graduates without a liberal arts background do not necessarily have the adaptive skills provided by a broad liberal arts education. These include critical thinking and problem solving, research, communications, cultural sensitivity, leadership and team building, interpersonal skills, ethical boundaries and the reasoning and ability to integrate knowledge from a plethora of sources (Zakaria, 2015).

How Liberal Arts Education Links to Adaption to Technological Change

Technology does not generally change as planned obsolescence, but simply evolves very quickly. The technological push for change comes from a combination of factors in the analogue world; when Goldstein (1989) did his study, change was significantly slower than it is now. Subsequently, at the beginning of the twenty-first century, STEM was seen as a saviour for businesses who were clamouring for graduate with these skills. Students were assured that STEM would provide a guaranteed employability for them. So, this previously shrinking population rebounded, though retention through STEM studies only improved a little. Many liberal arts schools added STEM to provide for their students and attract new ones.

Specialization quickly becomes obsolete in today's working world, as things change constantly. Controlling technological change is seemingly not possible in view of all the forces acting upon it, so adaptation to change is necessary. When businesses adopt new technology, hiring all new people who know the technology is not a practical option, so re-training of current employees is generally required. Re-training employees constantly is an expensive necessity, and businesses need all the help they can get. This is where employees with liberal arts education shine. Zakaria (2015) insists that a liberal arts education must teach students how to learn, first and foremost. In addition to knowing how to learn, the liberal arts students know how to separate fact from fiction, a skill that is becoming more important in this age of digital faking, hacking, cybercrime and rapid change. While companies need protection against the first three, managing change is a pivotal aspect of

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innovative development and economic growth. Stein (1995) defines technology as "technological systems of complementary resources and pieces of knowledge" (p.38) . In looking at the pace of technological change when the systems do not change, technology remains as it is. However, change is fast becoming the rule. Each innovation incites development in all directions, geometric expansion of the new ideas, like fractal geometry, with each new development seeding more. It more than primes the pump, it feeds the power plant (Pilzer, 1990).

Skills Provided by a Liberal Arts Education

The fast development of new technologies requires new skills in response. That technology skills become obsolete on a regular basis is the nature of innovation. The entire spectrum of technological development and obsolescence is market driven, partly by the vendors and partly by the consumers (Stein, 1995). Price mechanisms improve the price/performance ratio and supporting technologies will survive, becoming the new generators of technological change. Finally, induced technology change is produced by government regulation in response to population demands, such as those aimed at climate-change control. For example, energy use and waste-control regulations from various governments are changing the cost to consumers of energy and plastic, and this is driving innovation in these areas (Newell, Jaffe, & Stavins, 1999).

Liberal arts are often thought of as useless knowledge, not having any practical application (Raposa, 2015). However, although this may appear as useless knowledge for its own sake, it is really a net of knowledge and skills designed to make sense of any new changes in the world of its holder (Taylor, 2002). Businesses are still learning how to adapt to technological change (Smith, 1992). When gaming started pushing computer development technology, companies responded to this new market, developing faster, better and smaller machines. Businesses benefitted by the new technology and quickly learned to take advantage of it. However, there was a desperate need in businesses for workers who were technically literate, so schools responded, and industry even created special schools to fast track technology students. This worked to fill the void until the next paradigm change.

Stein (1995) suggests that there are a variety of forces that control the adjustment to technological change and that an actual change agent is valuable, since some of the forces mentioned are sometimes in conflict (McKinley & Zielinski, 2019). They refer to author Britt Andreatta, stating that “our brains are biologically wired to resist change”. Ordinary staff react according to how they believe the change will affect them. Middle managers may need to attend to their staff and not get personally tangled up. Leaders need to engage their people and manage conflict without becoming part of it, especially where it involves those directly affected by the change in technology. Those with a liberal arts background can more easily learn whatever replaces the old. They can become change champions and help others to transition. This is illustrated by *Table 1* below which shows the changing nature of liberal education ("AACU ", 2019).

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Table 1 Liberal Education from 20th to 21st Century (Borrowed from "AACU" 2019)

	Liberal Education in the Twentieth Century	**Liberal Education in the Twenty-First Century**
What	• intellectual and personal development • an option for the fortunate • viewed as non-vocational	• intellectual and personal development • a necessity for all students • essential for success in a global economy and for informed citizenship
How	through studies in arts and sciences disciplines ("the major") and/or through general education in the initial years of college	through studies that emphasize the Essential Learning Outcomes across the entire educational continuum—from school through college—at progressively higher levels of achievement (recommended)
Where	liberal arts colleges or colleges of arts and sciences in larger institutions	all schools, community colleges, colleges, and universities, as well as across all fields of study (recommended)

Defining and Assessing the Value of a Liberal Arts Education

As defined by the Association of American Colleges and Universities (AACU), a liberal education is an approach to learning that empowers individuals and prepares them to deal with complexity, diversity, and change. It provides students with broad knowledge of the wider world (e.g., science, culture, and society) as well as in-depth study in a specific area of interest. A liberal education helps students develop a sense of social responsibility as well as strong and transferable intellectual and practical skills such as communication, analytical, and problem-solving skills, and a demonstrated ability to apply knowledge and skills in real-world settings (AACU, 2019).

The liberal education is a preparation for flexible, knowledge-based careers and includes education aimed at developing general intellectual capacities, plus a beginning specialization which would equip the student for further learning in situ (Karimi, Manteufel, & Peterson, 2015; Marra *et al*., 2012; Watkins & Mazur, 2013). A major question among university attendees is how they might prepare for the future in a world of rapid change, especially as it changes at least every decade. Keeping up with that requires one to be flexible and to know how to learn, as going back to formal education is generally not an option (McPherson & Schapiro, 1999). About the time that McPherson and Shapiro were questioning the best way to insure employability for graduates, the game was changing. The number of technical, maths and science students graduating was falling; while non-maths and science graduates were ill-equipped for technological employment, the economy was moving towards a technological base, even in non-technology companies. Technology was becoming more than a product, but was a tool for other product design, manufacture and distribution. Purely technical students could not bridge the gaps between technology and all the other kinds of products, and liberal arts students just did not have the technical background to step right into the breach.

As far back as the 1970s-1990s interested parties were debating the effects of our move toward an information society. It was often predicted that only technical honours graduates would be able to find jobs, and that technology would make such rapid changes as to leave liberal arts in the dust (McPherson & Schapiro, 1999). Of course, the economy was in danger from the weakness of technical and scientific literacy among liberal arts graduates, and conversely, the weakness in soft skills among technical graduates. Neither sort could fill the job openings adequately (Gobble, 2019). Many institutions and even companies, themselves, have responded by creating interesting solutions for this double-edged reality.

Designing a Workable and Effective Compromise

Gobble (2019) asserts that technology is defined as focusing on the human-made world – unlike science, which focuses on the natural world. Technology takes nature as it is understood and uses the information to produce effects and products that benefit mankind.

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So, science alone simply does not connect to the culture that it tries to understand and educate, while technology must connect, because that is its purpose, to help create new products for companies and to make things work better for people. Because people are there in the equation, liberal arts must be there in order to make it work, because people and their needs cannot be truly understood using only maths and hard science. One needs things like psychology, philosophy and sociology, the soft sciences, to begin to understand humankind and language arts are required in order to translate the understanding into strategies for the designers and technologists.

By the beginning of this millennium, the basic liberal arts education of a general introductory level of a wide range of subjects, plus a major subject of study and a generally complementary minor plus electives, was the pattern for 37.6% of graduates (Gobble, 2019).This model is still working, but the aims have changed, from imparting knowledge of facts to the ability to transfer that knowledge and apply it to current problems. Transferring knowledge is, in essence, new learning, and that is what is needed. Both companies and universities are redesigning their plan for education and re-education. Federal programs in the United States are aimed now at developing scientifically literate citizens and reducing the maths and science phobias among undergraduates. One might think that developing more rigorous programs for STEM majors would be a better spend, but an ethnographic study of Seymour and Hewett (1997) showed that improving the learning experience for majors and liberal arts students also goes further to attract and retain STEM graduates.

Curriculum reform is the response of many institutions of learning, both liberal arts and technical. Few would eliminate technology from the curriculum, since technology is an integral part of our lives, across societies and economies in most places on earth. With the high demand for technically and scientifically savvy graduates at the turn of this century, technical schools popped up everywhere. However, they were first seen as simply trade schools, and have only begun to come into their own of late. A mistake they should not make is to eliminate liberal arts, as this connects the technology to people and society, and business and governments, in short, the real world (Yager, 2002). An understanding of science is also a necessity in many jobs these days, but curricula cannot be simply organized around science either. Therefore, we need a blend of science, technology and liberal arts, including soft sciences (Dezure *et al*., 2002). This can be accomplished with curriculum reform in both liberal arts and technical schools, and it can be accomplished in industry by providing additional education for employees.

STEM Versus STEAM

Liberal arts universities are adding STEM to their curricula and STEM universities are adding liberal arts to theirs (Bevins, 2011; Kang, 2019). They should neither be separate disciplines, as you cannot be completely educated for today's world without both. They give to each other. Technological tools enhance human talent, but also help shape their thinking, while the reality reflected in liberal arts teaches the student how to see (Yager, 2002). Beyond this, liberal arts colleges are changing the traditional discipline-specific science education reforms, combining the domain knowledge with problem-based activities designed to apply the domain knowledge as it is acquired, thus making it more real and supporting cognitive retention (Guenther, Johnson, & Sawyer, 2019). This experiential learning creates an environment of self-development for students.

Some liberal arts schools are taking this one step further and initiating STEAM instead of STEM, (Science, Technology, Engineering, Arts and Maths) (Blickenstaff, 2005; Metcalf,

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2010; Miller & Wai, 2015). This strategy was first tried to counteract the tide of attrition of STEM graduates (almost 50% attrition) (Ehrenberg, 2010; Rask, 2010). By adding arts to the curriculum, IT universities can help STEM students acquire communication and leadership skills, while liberal arts universities can add the technical skills foreseeably required in industry (Kang, 2019). A STEAM program combines these and connects the arts to STEM subjects, thereby allowing students to develop the ability to change horses as needed on the job (Chao, Butler, & Ryan, 2003; Kang, 2019). Preparedness issues and application of active learning methods are also good tools to provide for students in STEM (Tai *et al*., 2006).

The Benefits of STEM

Strategies for learning arts and STEM range from innovative instruction using technology or active experiential learning. However, understanding how people learn is an intrinsic need for change. Learning by doing (experiential), discovery-based learning with problem-solving emphasis, collaborative and cooperative learning, research and writing to learn, service learning in and outside of academia plus learning via various uses of technology are all being researched while they are used (Gobble, 2019). All such learning strategies are valid and work well for many people. As we go through our formal schooling, we need to learn which strategy works best for us. In that way we will be prepared for making change. STEM courses are important and should get special attention. However, it is not about how to teach but more about how it actually happens and how and why particular interventions are more successful than others. This especially affects the more diverse student body members. STEM education to be successful must be personal (Talanquer, 2014).

A liberal arts strategy often results in the students learning how they best learn, since the subjects are varied in the extreme (Schatz, 2017). They learn ways to connect the varied subjects and adapt their study habits to make sense of the combinations. There may be a need for different strategies for learning the varied subjects. Introductory classes with built-in help strategies can go a long way toward retention of students, especially STEM students who can find themselves overwhelmed if their secondary school left them ill-prepared (Rask, 2010). In addition, there are several other programs aimed at making STEM subjects more connected to reality and helping students acquire a deeper understanding of what they learn by taking part. (Becker & Park (2011) note that STEM students are on the decline.)

One very successful strategy just recently becoming popular is the implementation of educational research within STEM programs. It began with such research in physics in order to identify the learning problems within the degree program, and has since been used in mathematics also. Both Alan Schoenfield and Ed Dubinsky used cognitive psychology in mathematics and physics education in order to identify the sub concepts that students need to acquire in order to understand STEM concepts and design in more investigative project-based learning. The Bio QUEST philosophy and ChemLinks programs are a collaborative system of intellectual activities of problem-posing, problem-solving, and the persuasion of peers (the "three P's" of science education). All of these in liberal arts universities, where research is generally easier to do, benefit greatly from computer technology to provide simulations and tools to engage the students. Further use of educational research in all the STEM classes, basically action research, is revealing ways to improve STEM teaching and learning (Nelson, 2013; Walker & Loots, 2018).

In order to accommodate the working learners, technology has developed many different ways to deliver continuing education at various costs to institutions, companies or students. Many companies provide on-site training or finance other methods of learning new skills.

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Opportunities to complete post-secondary education are no longer limited to attending live classrooms but can be done at any time in the privacy of the students' homes via video conferencing or even using interactive learning environments provided by schools or industry (Bevins, 2011).

Conclusions

So, with all of this available, why do technological universities still need to offer liberal arts? The short answer is "retention". If they want to keep their STEM degrees, they need to provide those liberal arts that make sense of the more concrete majors. The flexibility the graduates gain is definitely worth the cost in time, money and trouble. That these graduates will have all the offerings on line after graduation is great, but they will be far better able to take advantage of this with the help of the soft skills gained from liberal arts. STEAM is definitely the way to go in liberal arts institutions; keeping liberal arts in STEM universities and creating some kind of cooperative blending would greatly enhance the education of students and help them succeed in their future careers. A good strategy for all schools might be to develop introductory classes across the entire spectrum of arts and science to make sure that graduates have a balanced education and life skills. Otherwise we will continue to see STEM graduates who can reprogram the software in an automobile but cannot change a tire, and arts graduates with the soft skills needed in middle and higher management but lacking the requisite technical abilities that would make them attractive to potential employers. As so eloquently stated by Werth (2003. p.40):

> It is about learning to see the world in new ways, from new perspectives—about breaking free of preconceived views, typically static and one-sided, and adopting a broader stance in which multiple views can be ascertained and accepted simultaneously. In this regard a metadisciplinary perspective is invaluable.

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