2017

Philosophical and Educational Perspectives on Engineering and Technological Literacy, IV

John Heywood
Trinity College

Suzanne Keilson
Loyola University, Maryland

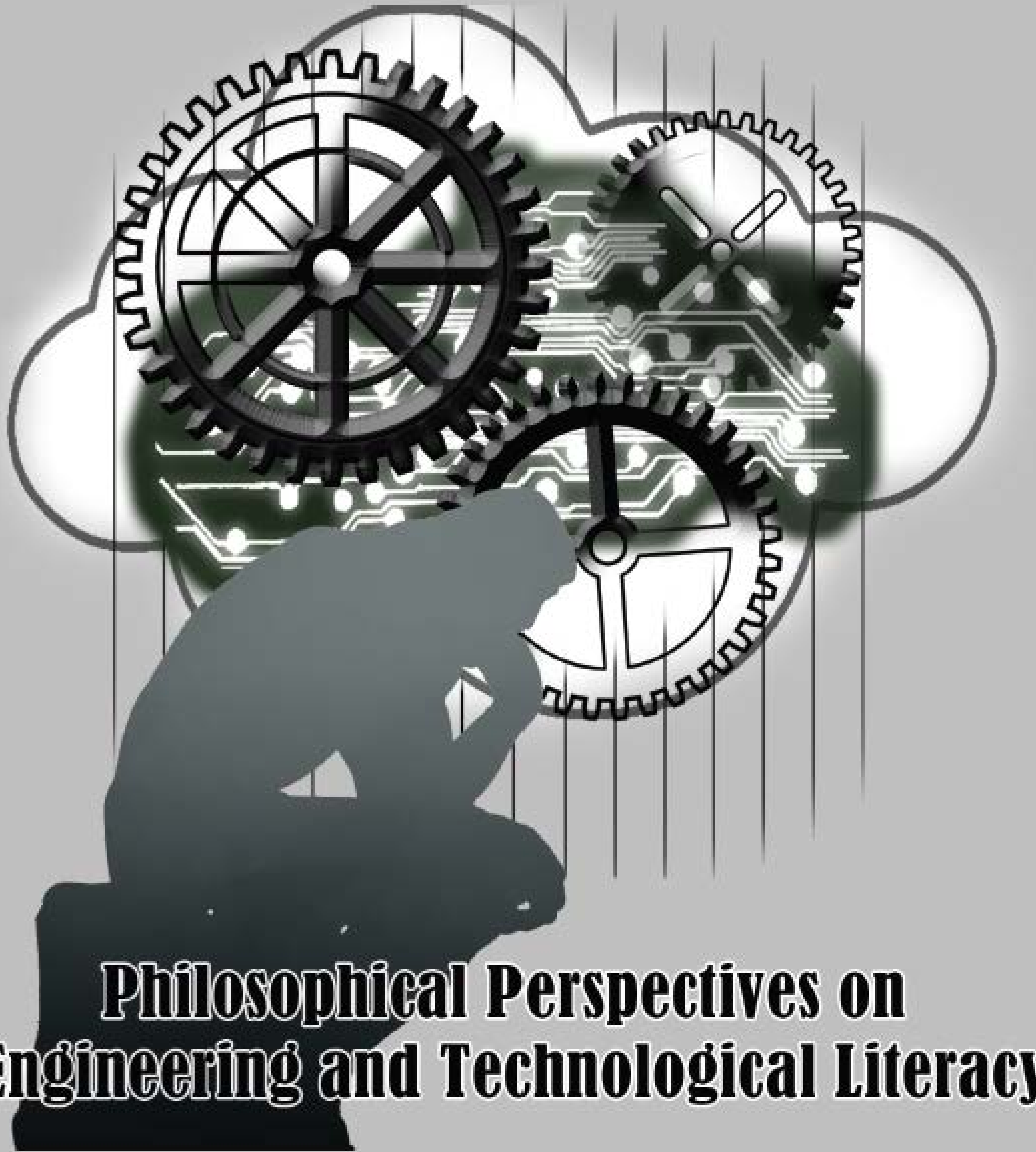
Aaron Krawitz
University of Missouri

Sheila Tobias

James Trevelyan
University of Western Australia

See next page for additional authors

Authors
John Heywood, Suzanne Keilson, Aaron Krawitz, Sheila Tobias, James Trevelyan, Alan Cheville, John Krupczak, Tom Siller, Mani Mina, David E. Drew, and Sergey V. Sychov



Philosophical Perspectives on Engineering and Technological Literacy

Philosophical Perspectives On Engineering And Technological Literacy, IV

Prepared for the Technological and Engineering Literacy & Philosophy of Engineering Division of the American Society for Engineering Education

Editor:
Alan Cheville

Cover and Figure 1 of philosophy and Engineering by Peter Frezza, from Gannon University, Erie, PA.

CONTENTS

Contents

Preface 1
Anchoring Article: Why Technological Literacy and for Whom? 2
A New Schema for STEM Literacies 10
Scientific vs. Technological Literacy 12
Comment on John Heywood's paper: *Technological Literacy and for Whom?* 13
Literacies of Entrepreneurship and Value Creation 14
Technological Literacy without Proficiency is not Possible 17
Unfinished Business for the ASEE TELPhE Division And Other Engineering Educators 19
Why and For Whom as Historical Reflection 22
Moving the Needle From Literacy to Knowledge 24
Technological Literacy and Global Society 26

Preface

In this fourth edition of *Philosophical Perspectives on Engineering and Technological Literacy*, the divisional publication of the Technological and Engineering Literacy and Philosophy of Engineering (TELPhE) Division of ASEE, is trying a new format. Over the years members of the division have noted that many of us keep coming back to the annual ASEE conference year after year not only for the technical papers, but the deep and wide-ranging conversations that crop up organically and spontaneously at the conference like flowers in the desert after a rain. This may be an appropriate metaphor since within our own academic institutions the opportunities to have wide ranging conversations with others who have similar interests in the larger questions that underlie engineering education are often difficult to start or hard to find.

Such conversations matter; dialog is fundamental to the practice of both philosophy and literacy. It is a truism to say that we learn through interacting with others and refine our own ideas by sharpening them against those of others. However the practical reality of a conference is to at least not lose money and that of today's academic life is to publish one's work. In conjunction, however, these have the effect of steering academic writing towards papers and presentations rather than free ranging dialog. For TELPhE, a group focused on the ideas and narratives that underlie the learning of engineering, it is not clear that such outward facing, many-to-one, ways of communicating are by themselves meeting the Division's needs. As Mark Twain is alleged to have said, "*Let us make a special effort to stop communicating with each other, so we can have some conversation*."

This edition begins with an anchoring paper, John Heywood's *Why Technological Literacy and for Whom?* which was presented at the 2016 ASEE Annual Conference and Exhibition in New Orleans, Louisiana. In this paper Professor Heywood's intent was "raise questions about the intent of technological literacy in society at the present time." Following the ASEE conference a call was put out to all members of the TELPhE Division asking for short responses to Professor Heywood's paper. These responses, in random order, follow the anchoring paper. Unlike more traditional journals each author was free to comment in the style and form they best saw fit; instruction for style and formatting were minimal to non-existent. The author's papers have been left mostly "as is" with only consistency between fonts, layout, and similar issues addressed. In cases where a title was not provided by the author one was inserted; apologies to the authors in advance.

It is hoped that this form of "dialog journal" will enable a wider ranging conversation within TELPhE that spans not only those who can attend the ASEE conference and whom stumble in to conversation, but also those whose time, circumstance, and resources don't give them opportunities to attend. The larger goal of this format is to stimulate ongoing dialogs and capture them in ways that are both readable and archival.

Alan Cheville

Editor

Anchoring Article: Why Technological Literacy and for Whom?

John Heywood, Trinity College, Dublin

The purpose of this paper is to raise questions about the intent of technological literacy in society at the present time. Unfortunately at an international level there is no clear perception of what technological literacy is whereas in the United States there has been a substantial debate about the need for people to be technologically literate. At the same time there is a tension between those who assume that technological literacy means "learning to compute," and those who believe it is about the relationship of the outputs of computing to society. The response in American engineering higher education seems to have been the teaching of engineering topics to persons not taking engineering. More generally there is interest in courses in "Technology and Society."

Krupczak and other members of the TELPHE Division of the American society for Engineering Education have distinguished between technological literacy and engineering literacy. One approach is to distinguish between the "process" of engineering and its "product" technology. While useful in engineering education at school level and in higher education it is no wonder that the public continue to be confused about the differences between engineering and technology. Krupczak and his colleagues not that "the term engineering is not treated systematically by any of the technological literacy standards which must be to the detriment of engineering, and those wanting to develop engineering standards.

Attempts to show how engineering and technology interact inevitably lead to models that conflate the two literacies and shows them to be embedded in the philosophy that derives them. The model shows no disconnect between the designer and the user; they have joint responsibility for its use.

At the same time these models have been developed without clear reference to the audience for which they are intended. Audiences that are readily identifiable are the general population, the liberal arts undergraduate population, professionals such as lawyers, teachers, medics, and the undergraduate engineering population. The purpose of this study is to provide a limited examination whether there is a community of scholarship that is relevant to every group that is divided by the extent of knowledge and skill required for a particular audience. Recent controversial activities undertaken by General Motors and Volkswagen high light the importance of such an examination. An engineering view of technological literacy is inadequate for the task it is expected to do. An interdisciplinary approach is clearly necessary.

Introduction

The purpose of this article is to raise questions about the intent of technological literacy in society at the present time. It may be regarded as complementary to, or an extension of the paper defining technological and engineering literacies presented by Krupczak et al.[1] at the 2012 annual conference of the American Society for Engineering Education, and this writer's response in 2014.[2]

There is no international movement or organization at the political level (e.g OECD) that argues that every person should be technologically and engineering literate. Given the impact of technological change on such diverse things as the workforce and personal values this is surprising. But internationally strong movements have ensured that language, numerical and scientific literacies are well discussed. In consequence there is considerable agreement that students should have minimum competency in the use of their own language (literacy) and basic arithmetic (numeracy). In consequence primary (elementary) and post-primary schools are required to ensure their products are literate and numerate. Politicians compare the relative performance of one country against another on tests that they regard as valid (e.g.PISA).

Arguments have also been made that everyone should have a basic knowledge of science and more recently technology. It is generally assumed that it is the responsibility of the system of schooling to provide for the development of these literacies. In the United States "standards" have been adopted for the subjects of the school curriculum including technology. At an international level it is by no means clear what technological literacy is perceived to be or what purpose it is to serve. This is not true of the United States where there has been much discussion as Krupczak et al.[1] have summarised.

The National Academy of Engineering (NEA) undoubtedly influenced some universities to take technological literacy seriously when it published "*Technically Speaking: Why all Americans should know more about Technology*" in 2002, and "*Changing the Conversation: Messages for Improving the Public Understanding of Engineering*" in 2008. Thus in the last decade the American Society for Engineering Education has created a Division for Technological Literacy separate to its division for k-12 education that suggests that technological literacy has a role to play in higher education. In higher education several courses with that intention have been reported. Paper sessions at the ASEE annual conferences have revealed that in the US the minor course might be a useful structure for teaching technological literacy to non-engineers.[3] There have been a variety of presentations on the teaching of engineering topics to persons not taking engineering. The range of topics offered is illustrated by some of the presentations at the 2013 annual conference shown in exhibit 1. Only one of the presentations came from outside the US, in this case, The University of Buenos Aires. The programme inadvertently highlights one of the dilemmas facing those who would promote technological literacy namely, that it is all too often taken by members

Application of peer-reviewed journal articles for enhancing technological literacy (Brooks, R.M., Cetin, M., Kavuturu, J and Al-Maghrabi, M-N).

Demonstration of electrical principles in the classroom by hydraulic analogues (Graff, R. W and P. R. Leiffer).

Waves of engineering: using a mini-wave flume to foster engineering literacy (Lyman-Holt, A. L and L. C Ribichaux).

Simulating interest in technological and engineering literacy using multidimensional desktop virtual reality framework (Chandramoudi, M and G. R. Bertoline).

Using heavy metal music to promote technological and socio-cultural understanding (Kirkmeyer, B. P)

Using scale models to promote technological literacy (Loendorf, W.R., Geyer, T. L and D. C. Richeter).

Gadget Avalanche. A technological literacy course for novice adults (Lichini-Colbry, K and D. Colbry).

Information and communications technologies literacy of the University of Buenos Aires engineering students (Clua, O and M. Feldgen).

Exhibit 1. The title of some of the papers presented at the Technological Literacy Division sessions at the 2013 Annual Conference of the American Society for Engineering Education. A complete session was devoted to problems in the assessment of technological literacy.

of the public to mean information technology (IT) combined with artificial intelligence (AI) where IT is taken to mean learning to compute. But, as is well understood, the problems promoted by IT and AI are large and cannot be ignored, particularly as they impact on the professions.[4] It is nevertheless a basic tension in the promotion of technological literacy, and its relief may be helped by the distinctions that Krupczak et al.[1] have made between engineering and technological literacy. The need for acceptable distinctions is never more apparent.

Distinctions between engineering and technological literacy

The distinctions that Krupczak et al.[1] found between engineering and technological literacy led the Technological Literacy Division seek to incorporate engineering literacy within in its title. They sought to define by examples the differences between the two (see exhibit 2). One approach offered by Krupczak et al. was to distinguish between the two literacies as process and project which is the approach adopted here. Technologies are the products of the process of engineering. If that is in anyway correct, then while useful to engineering educators in school and higher education it is no wonder that the public is confused about the differences between “technologists” and “engineers,” and no wonder the media tend to use the term “technologist” more often than they do the term “engineer.” The thinking is easy- “Technologists make a technology.” Worse there is tendency to substitute science and scientists for technology/engineering and technologist/engineer. Krupczack et al. reported that “the term engineering is not treated systematically by any of the technological literacy standards” which must surely be to the detriment of the understanding of engineering, as well as its image. Given that this statement includes the ITEEA 2000 Standards it is a matter of considerable consequence for the development of engineering studies in K-12, and supports those who wish to develop standards for engineering literacy.

It would be remiss not to mention the cognate study of “Technology and Society,” or the work of institutions such as the European Inter-University Association of Science and Technology, the IEEE Society on the Social Implications of Technology, and the Society for the History of Technology in this area of knowledge which often takes place in schools out-side of engineering as for example the departments of philosophy in universities in the Netherlands.

“A person who is technologically literate might have a knowledge of the systems of an automobile such as engine, power train, and brakes along with the basic principles underlying the functioning of these systems. This is knowledge of the product. Engineering literacy would include knowledge or ability to design, analyse or otherwise create the constituent components of the automobile.”

“An integrated circuit is a technological device. A person who is technologically literate might be able to describe an integrated circuit, describe what it is, and explain the general uses and importance of integrated circuits. An engineering literate individual would be more familiar with how an integrated circuit can be used as a means of connecting an abstract schematic design into a working physical object.”

Exhibit 2. Two of the examples given by Krupczak et al.[1] to illustrate the differences between engineering and technological literacies.

Technological and Engineering Literacy and Liberal Education

Attempts to show how engineering and technology interact inevitably lead to models that conflate the two literacies. Following an earlier study in which Heywood had argued that engineering was necessarily a component of liberal education[2] he argued, in a development of

Krupczak et al.s paper, that "the defining characteristic of liberal education was "enlargement of mind. This "enlargement" was achieved by the capacity to perceive inter-relationships between the areas that comprise "universal knowledge" as it is currently understood. It follows that consideration of the "product" (technological literacy) without consideration ofthe "process" (engineering literacy) is not a liberal education."[5] Using the model he had presented in the earlier paper (exhibit 3) he argued that the solution to engineering problems (the technology) required not only knowledge of engineering science and the mechanics of manufacturing but an understanding of the ways of thinking in such areas as law, management as it embraces the human and social sciences, and philosophy. As such the model conflates the two literacies thereby linking the practical with the theoretical and shows them to be embedded in the philosophy that drives them.

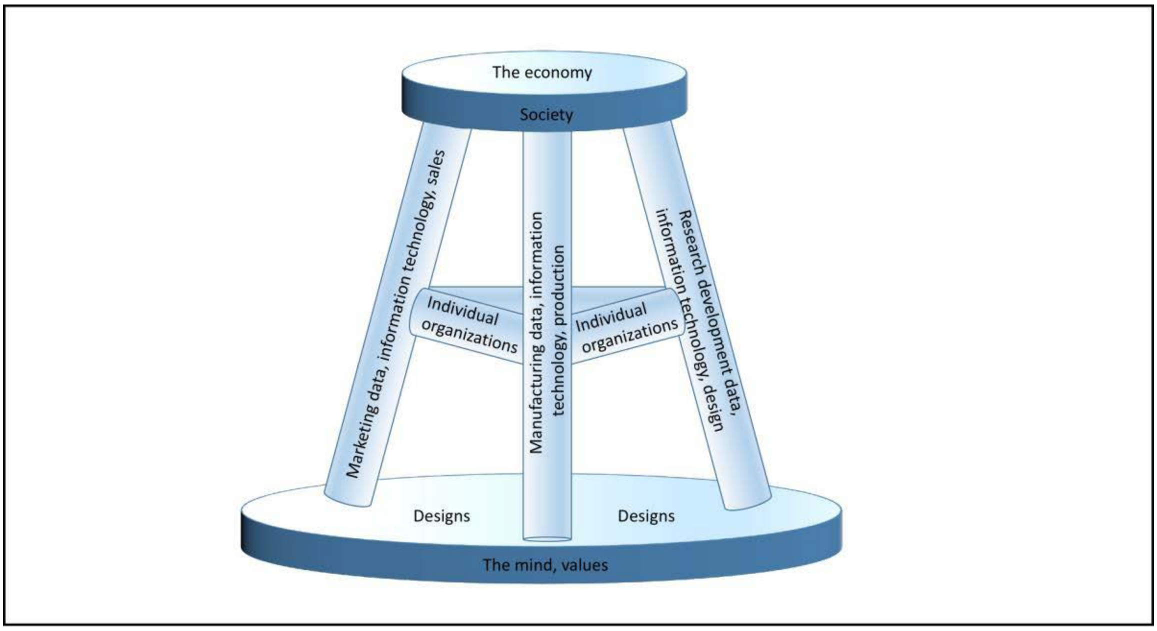


Exhibit 3

Philosophy, the engineer and the individual

That thesis and other developments in the philosophy of engineering education led the Division to embrace philosophy in its name at the same time as it introduced engineering literacy into its title. This has confused some members of the Division yet while any study of the process of producing a technology involves engineering it also depends on the values that drive the process as the model shows. There is no escape from philosophy. We all philosophize and we all have personal philosophies, and these drive our actions. The model does not indicate the effect of the socio-economic system on our belief systems although this could be remedied by drawing feedback lines through the legs of the stool from both the seat and the supports.

In the previous paragraphs the concern was with the understanding of what distinguishes technology from engineering – the technologist from the engineer, and with a reconciliation between the two literacies. The point to be added to this discussion is that the model shows no disconnect between the designer and the user (the engineer and the client), they are interdependent and carry a joint responsibility for what and how it is used, and by extension the public; hence the need for the public to be technologically literate.

The public exercise of responsibility

While co-responsibility places an obligation on both the designer and the user to consider the ethical implications of a design in action that commitment extends to the public for the simple reason that in most cases there will be many users. This point is illustrated by an editorial in *The Times*[6] written in response to the news are now being grown in sheep and pigs. The leader writer wrote "[b]ut the public must be wary of being lulled by technological optimism into forgetting the gravity of the problems raised by these methods. It is entirely legitimate to debate their use. Indeed it would be negligent not to" (see exhibit 4).

There is no point in public discourse unless its intention is public responsibility, the development of which is a major goal of liberal education. "Society itself requires some other contribution from each individual, besides the particular duties of his profession. And, if no such liberal intercourse be established, it is the common failing of human nature, to be engrossed with petty views and interests to underrate the importance of all in which we are not concerned, and to carry our partial notions, into cases where they are inapplicable to act, in short, as so many unconnected units, displacing and repelling one another."[7]

Since there is a need for ethics to be built into the design then users should be in a position to comment on the design for which they will also need to be engineering literate. This consistent with what Krupczak and his colleagues write about the NAE view of technological literacy was (exhibit 5).

> *"The potential rewards of this work are not merely tantalising. They are revolutionary. An effectively unlimited supply of organs for the mortally ill, cures for diseases written into bodies of newborn babies, new weapons in the last line of defence against cancer no doctor could ethically turn his or her back on such breakthroughs."*
>
> *"But the public must be wary of being lulled by technological optimism into forgetting the gravity of the problems raised by these methods. It is entirely legitimate to debate their use. Indeed it would be negligent not to."*
>
> *"Politicians, philosophers and above all ordinary citizens need to get to grips with an area of science that has developed beyond our present ability to assimilate it. It is imperative for a democratic society to determine its own future lest the job fall to technocrats and pressure groups."*

Exhibit 4. Extract from the 1st Leader "The origin of Species. Human-animal chimeras pose grave questions about the future identity of mankind. All the more reason to press on with the science. *The Times*, p 21, January 11th 2016.

> *"The NAE promotes technological literacy as a means by which individuals can function more effectively in modern technological society. This is consistent with E. D. Hirsh's general definition of "literacy" as information that is taken for granted in public discourse."*

Exhibit 5. Quotation from Krupczak et al.s paper on "Defining Technological Literacy."[1]

The dilemma of the audience and the curriculum

Of no less importance is the direction which the technocrats of Silicon Valley are taking us. One simple is example is the fact that we have been lulled into giving information to the big social media companies for free which leaves us open to greater control by the powerful.

The implications for the curriculum are profound. A detailed analysis of what these might be is not within the scope of this paper. However, in the light of this discussion it is necessary to focus, if only briefly, on the dilemma created for curriculum designers by the multiple audiences that need some form of technological and engineering literacy. Is there a community of knowledge that can serve these audiences? Or, do they have to be served by multiple pathways because the community of knowledge is so vast? The purpose of this paper is not to delve into the curriculum but to pose the problem in the paragraphs that follow.

It was pointed out that contextual models of the engineering process show that neither, engineering or technological literacy can be properly understood without reference to the other. At the same time these models when related to the curriculum have been developed without clear reference to the audience for which they are intended. Given that there are many possible audiences the content of the curriculum may have to differ considerably as between them. Audiences that are readily identifiable are the general population, the liberal arts undergraduate population, professionals such as lawyers, teachers, medics, and the undergraduate engineering population. The implications for the curriculum are profound. At one extreme, content arises from consideration of the impact of technology on society and individuals in particular. At the other end of the spectrum are the needs of non-engineers who have to deal with engineers and engineering in their everyday activities. Given this scenario it is possible to envisage two (or more) entirely different programs in technological literacy.

But there are in addition to dilemmas about content dilemmas about method. This may be illustrated by two recent scandals affecting automobiles-General Motors and Volkswagen.

General Motors had eventually to withdraw 30 million cars worldwide because some ignition switches had failed which had prevented the airbags from inflating. The company paid compensation for 124 deaths. It took a private lawyer from Georgia to pursue the company on behalf of a client to bring to light the problem: a decade passed before the Corporation began to recall call vehicles.[8] In the case of Volkswagen the US Environmental Protection Agency issued a notification of a violation of the Clean Air Act.[9] The Agency had found that during official testing, diesel engine vehicles had been programmed to reduce emissions of nitrogen oxide significantly below those emitted during real-road driving. The announcement reverberated around the world and the company had to withdraw millions of vehicles.

In the world of the Web firms that hold a lot of personal data have had to admit that there systems have been attacked.

The question that has to be asked is, “What should a member of the public do about a particular problem, if anything?” In order to answer this question, “What knowledge and cognitive skill does a member of the public have to have to make that decision?” These are quite difficult questions because the only action that a person seems to be able to take is not to buy one or other of these cars. There is little evidence that people will take such action: indeed, at the present time Volkswagen is beginning to restore the volume of sales in the

UK. This is a major problem for those who want the public to take the social media industry by the neck and seek payment for the information they currently get for free.[10] These are undoubtedly issues for technological literacy programmes.

Conclusion

This paper began with a description of developments in technological literacy as seen through the eyes of the Technological Literacy Division of the American Society for Engineering Education prior to 2015 when its name was changed. The focus of conference papers appears to have been on describing courses that enable the understanding of engineering principles.

Other papers have been concerned about assessment, and some have discussed the differences between engineering and science. It might be argued that these courses are rather more about engineering literacy than they are about technological literacy. The need to include engineering literacy in the name of the division is supported by Krupczak et al.'s report on the differences between (meanings of) engineering literacy and technological literacy.[1] Previous studies of the curriculum were used to support the inclusion of "philosophy" in the title but the notion of philosophy is extended to include the respondent perceived here as the "public." That respondent has as much responsibility for the value system that the engineers have that drive their engineering activities. This has considerable implications for the construction of curricular in technological and engineering literacy. The dilemma for those engaged in technological and engineering literacy is that their curricula have to meet the requirements of many audiences. The difficulty of developing a community of scholarship that meets the needs of all these audiences is illustrated by extreme examples of the questions that the public need to answer in deciding what action they ought to take in response to such happenings as the GM and Volkswagen automobile scandals. An engineering view of technological literacy is inadequate for the task it is expected to do. An interdisciplinary approach is clearly necessary

John Heywood is professorial Fellow Emeritus of Trinity College Dublin- The University of Dublin. He is a Fellow of ASEE and Life Fellow of IEEE with special interest in education for the professions and the role of professions in society. He is author of Engineering Education: research and development in Curriculum and Instruction.

References

[1] Krupczak, J., Blake, J. W., Disney, K. A., Hilgarth, C. O., Libros, R., Mina, M and S. R. Walk (2102). Defining technological literacy, *Proceedings Annual Conference of the American Society for Engineering Education.* Paper AC 2012-5100.

[2] Heywood, J (2014). Defining engineering and technological literacies within the framework of liberal education: implications for curriculum, *Proceedings Annual Conference of the American Society for Engineering Education.* Paper 8687.

[3] Krupczak, J., Mina, M., Gustafson, R. J., Young, J. E and S. VanderStroep (2012). Minors as a means of developing technological literacy programs at college level. *Proceedings Annual Conference of the American Society for Engineering Education.* Paper AC 2012-4696.

[4] Susskind, R and D. Susskind (2015). *The Future of the Professions. How Technology will Transform the Work of Human Experts*. Oxford, Oxford University Press.

[5] Heywood, J (2010). Engineering literacy: a component of liberal education. *Proceedings Annual*

Conference of the American Society for Engineering Education. Paper AC 2010-1505.

[6] *The Times*. January 11th 2016. Editorial.

[7] Newman, J. H (1852). *The Idea of a University. Defined and Illustrated*. 1923 Edition. London, Longmans, Green. p 168.

[8] General Motors ignition switch scandal. *Wikipedia*, the free Encyclopedia. 9th March 2016.

[9] Volkswagen emissions scandal. *Wikipedia*, the free Encyclopedia. 9th March 2016.

[10] Lanier, J (2013). *Who Owns the Future?* London, Allen Lane.

A New Schema for STEM Literacies

Suzanne Keilson, Loyola University Maryland
Department of Engineering
4501 North Charles Street
Baltimore MD, 21210

In response to the conference paper by John Heywood I would like to propose another way of thinking about the purposes of engineering and technological literacies. By organizing the question around learning aims, things that students need or should be able to know and do, the question of whether a particular topic falls under the umbrella of science or engineering or technology becomes less important than the outcome. Curricular or course design by an initial focus on learning aims and outcomes is called "backwards design". The distinction between process-focused engineering and product-focused technology as described by Heywood is important, clarifying, and useful, but we may need to take a more synthetic approach.

Schools still by and large deliver instruction by the unit of "courses". In disciplinary content areas, whether for majors or others, this is generally clear, but in the realm of skills, attitudes and dispositions it is often difficult to package learning into a single 3-credit course. They are the kinds of learning aims that need to be infused across a curriculum. As suggested by Heywood's article, the topics for engineering and technology are large and we would have many variants of a course to offer to various stakeholders. That is probably not feasible. Nor is it pedagogically sound to separate courses into homogeneous groupings by major, profession or other related criteria. It is far more challenging, but also potentially far more rewarding for both teacher and student to be in a diverse classroom tackling cross-disciplinary topics and issues.

I would like to suggest the following three learning aims for technological and engineering literacy to be offered throughout a general undergraduate education.

Teaching for Citizenship

This would involve ethics, politics, philosophy and the ways in which technological developments can impinge upon and challenge our understanding of moral reasoning. This would cover a range of questions from bioethics to corporate malfeasance to privacy. These decisions are not to be left to the technocrats alone and do need understanding of technical constraints and parameters. For example, a question that is much on people's minds with the advent of self-driving cars is how to embed ethical and moral reasoning into the product. This challenging question requires understanding the limits of what is currently technically possible, as well as entering into conversation about the legal understandings of product and personal liability.

Teaching for Living Skills and Competencies

This would include technological skills as basic manual life skills and conceptual understanding. This is an area that is practically non-existent on four-year campuses, except for the incursions of the maker movement. It is essential to our general flourishing, as the new ideas of "embodied cognition" point out. With these skills we can be empowered to make choices consciously and know how are machines work.

Our transactional economy has narrowed our skills and expertise to the point that we might not be able to survive outside of the complex infrastructures that support our lifestyles. In the developed world it makes sense to pay someone else for their time and knowledge rather than to acquire and execute skills that were once common. An appreciation and understanding of the infrastructures that support us is important for our roles as stewards and conscious consumers of technological products. This involves ethical reasoning about our obligations to the future and technological and engineering understanding of resource management.

Teaching for Employment Competencies

K-12 education spends a great deal of time on language arts, including conventions about the mechanics of formal writing. It takes time on task to master language, written and oral, to the level where one is considered educated. A similar imperative should push us to ensure that students, regardless of major, interests or ultimate paths, have necessary visual technology skills. This would involve teaching principles of visual composition, well known by the arts, adapted for presentation and charting software. Reasoning from graphs, constructing and presenting relevant displays are all primary learning aims for the developed urban 21-century workforce. Our students will be judged on the way they insert a picture into a document, as much as they are judged on basic punctuation. They will be judged to be illiterate and uneducated, no matter how good their underlying points or ideas. Under this umbrella general topics of usability and design can be introduced to all students to make them more aware of the current limits of human-machine interactions, whether in the home or at work.

Scientific vs. Technological Literacy

Aaron Krawitz, University of Missouri
krawitza@missouri.edu

Recently I had a total hip replacement. Being a materials scientist, I asked the surgeon: "Do you use metal on metal implants?" Fortunately, he said "No." If I were a humanist who had taken a Technological Literacy (TL) course, I would hopefully have learned to ask about pros, cons and unintended consequences in a technological procedure. Then, while convalescing, I watched a documentary on Rachel Carson, author of Silent Spring. She raised public awareness that DDT, for all its value in killing mosquitos and other pests, had serious negative effects on humans. The public, in the mid-20th century, had been convinced that technology was a force for good; that to question it was virtually un-American. If TL courses that taught how products engineered to help one kind of problem might create others were available 60 years ago, perhaps Carson's challenge would have been easier.

Prof. Heywood asks "why TL and for whom?" The first question has been identified and acknowledged for a generation now, in the US. Science literacy has been a part of US general education for generations, but it is not TL. Engineering is the application of science to society. TL deals with the products of engineering – their scientific basis and their impacts on society. Krupczak and his colleagues have argued for such courses as part of the liberal education of non-STEM students in the US. They have clarified how such courses could be distinguished from engineering literacy classes. I find their distinction useful since non-engineers, armed only with college algebra, cannot seriously deal with engineering practice. Still TL may be taught through surveys or more focused courses. A standardized syllabus is not our way.

Krupczak is operating in the US system of higher education, where "liberal education" beyond the student's major is delivered through the General Education portion of the curriculum, a series of elective courses with a range of subject areas: social science, science, English, humanities, etc. Thus, engineers must take humanities/social science and humanists must take some math and science, but not technology. What is being advocated is placing technological literacy into the mix, not as a curriculum, not as a major, not as a department, but as a course, an elective course in most cases.

I see two fundamental issues raised by such courses, neither of which have anything to do with Prof. Heywood's concerns. First, is the Gen Ed approach still valid? Should our curricula aim to broaden exposure? For me it was of significant positive personal consequence; as a faculty member, many of my colleagues thought such courses were a waste of time.

Second, enabling such courses requires a perceived benefit for teachers and administrators in Engineering. At research universities, such courses fly in the face of the fundamental realities: publications and research expenditures. This is how faculty is judged, as well as their deans. Will such courses recruit students to engineering? Generate research? Is there a professional payoff? Only if an institution promotes it as an advantage, and rewards accordingly.

Comment on John Heywood's paper: *Technological Literacy and for Whom?*

Sheila Tobias
sheilax@sheilatobias.com

Ask not for whom the bell tolls, it tolls for me! (with apologies to John Donne)

All this back and forth about technological vs. engineering literacy has one conspicuous omission: the learner. What does the learner want and need to know? How to capitalize on the learner's strengths and deal with the learner's limitations? How to excite, delight, empower and satisfy intellects that are – by definition – not like the instructors' own?

I am a graduate in "History and Politics" from one of the best universities in the U.S., who as a post-graduate found her way into German Politics, U.S. Civil Rights and Women's Studies, eventually being hired to adapt a formerly all-men's college to co-education. But it was only when confronted at that college with what I named "math anxiety" and "science avoidance," was I ready to conclude that, for large numbers of liberal arts majors, myself included, *knowing about* without having any idea of *knowing how* is one sure way to limit one's power to understand no less to change the world.

To be sure, my education included *exposure* to science, in my case an overview expertly guided by Thomas Kuhn and Leonard Nash. But though I was particularly interested in European imperialism, my history and politics instructors did not draw for me the links between the invention of vulcanizing rubber and the concurrent invasion of Malyasia (by the British), Vietnam (by the French) and Nigeria by Firestone. Maybe – I thought later – it was because my instructors were themselves technologically unschooled.

Much later, in midlife, exploring books like Daniel Hedrick's *The Tools of Empire: The Technological Basis of Imperialism*, Ivan Amato's *Stuff*, Dava Sobel's *Longitude*, Jennifer Conant's *Tuxedo Park* about efforts to start research on radar before the governments of the U.S. and Britain understood its potential, did all that history begin to make sense. I began to look around my personal library and realized that I'd had to discover for myself that politics and history were grounded in technological change. Even women's eventual emancipation was determined by technologies that had enabled in sequence: industrialization; birth control; and longevity.

So for me, as for Jim Duderstadt, technological literacy has to be grounded in the discipline of engineering. And until engineering educators let people like me "in" to how they think and what they think about….we will continue to vote wrong on issues that matter to the future of ourselves, our country and the planet.

Sheila Tobias is the author of a dozen books on math and science (Overcoming Math Anxiety, They're not dumb, they're different, The Hidden Curriculum: Faculty made Tests in College Science, Rethinking Science as a Career) and current history (Women, Militarism and War, What kinds of Guns are they Buying for your Butter? and Faces of Feminism: An Activist's Reflections on the Women's Movement.) She and her colleagues' collection of exemplary college and university courses about engineering and technology detailing how such courses came to be, is hosted by the Association and accessible at ASEE.sheilatobias.com

Literacies of Entrepreneurship and Value Creation

James Trevelyan, University of Western Australia
james.trevelyan@uwa.edu.au

Bill Williams, Instituto Politécnico de Setúbal

The Heywood paper makes a valuable contribution to the discourse of technological and engineering literacy. There are however two aspects that we believe are missing from the conversation so far: entrepreneurship and value creation.

Entrepreneurship

Is there a case for entrepreneurship to be considered as a part of liberal education curriculum? After its introduction into business school courses in the US in the 1940s it began to appear in management programs around the globe; over the last two decades (Katz, 2003) it has also been included in an increasing number of engineering courses and a number of studies have appeared in engineering education conferences and journals.

A justification for considering entrepreneurship as part of technological and engineering literacy can be found in the work of economists who developed complex economic models such as the Global Entrepreneurship Development Index (Ács, Autio, and Szerb 2014) that allow economists to investigate the effects of technology usage and other factors on economic growth, inequality, human life-span and health. The index has been shown to be a good predictor of the national economic growth of OECD countries and one of the components contributing to this model is the technological context of each country. Given that the data suggest that the technological context helps determine national growth, then technological literacy would appear to be important for political decision makers, engineers involved with technology and for citizens. Hence there may be a case for considering entrepreneurship as a component of both technological and engineering education.

Value creation

What is the value of engineering, the underlying purpose that motivates employment of engineers and even engineers themselves? There are and have been different answers depending on time and place, ranging from nation building to individual economic opportunity to a desire to make the world a better place. However, when most engineering careers involve employment with private firms it is perhaps troublesome that neither engineers nor their educators seem to have clear answers to this critical question.

Research on engineering practice has found that very few engineers working for private firms can clearly explain the economic value arising from their work (Trevelyan, 2012; Crossley, 2011; Singh, 2015).

There is scant mention of this issue in texts that introduce students to engineering. The authors have posed this question to engineering students on many occasions. It has not been easy for them to answer, and most responded hesitantly: “Innovate?” “Satisfy society needs?” and often “Solve problems?”

It is perverse, perhaps, that these same students had no such difficulty explaining the value of being a doctor: “Save lives” “Heal sick people” “Help people live longer and healthier”. Or a lawyer: “They get you out of trouble” “Provide justice, human rights”.

Why is this question so difficult across the engineering community?

Trevelyan and Williams (2017) point to an apparent gap in the philosophical foundations of engineering which could be an explanation for these observations. A review of business literature reveals that ‘value’ itself is a contested term with many different interpretations (Trevelyan and Williams, 2017). As reflected in contemporary engineering discourse, the business literature predominantly associates value creation with innovation and entrepreneurship. However this leads to an apparent contradiction because most engineers employed in work with only tenuous if any links with innovation and the business literature appears to be silent on the means by which these engineers are creating value. Trevelyan and Williams (2017) have argued that the non-innovative engineering work in which most engineers are employed both creates and protects value. They go on to contend that troubling aspects of contemporary engineering performance such as the appalling success rates in major engineering projects around the world could be associated with weaknesses in understanding engineering value creation. These weaknesses help to explain what is often referred to as sharp divisions between engineers and managers. Low success rates in major projects help to explain the disdain for engineers expressed in interviews of engineering enterprise CEOs by the first author.

These authors propose that engineers create or protect value in the following 10 ways:

1) Efficiencies
Engineers create value by seeking efficiencies, reducing the materials, energy, time and human effort needed to achieve a given result, reducing costs.

By providing accurate performance predictions, engineers can reduce the allowances to cover knowledge gaps and uncertainties known as design and safety factors. Reducing design and safety factors can lead to further significant savings in material, assembly and transport costs.

2) Product Differentiation
By designing products that provide improved buyer and end-user experience (product differentiation) engineers increase the use-value of products and services.

3) Innovation
Engineers create value for enterprises by innovating: finding new ways to achieve a given result that is better in some way than other known ways.

4) Performance prediction
Engineers provide sufficiently accurate technical and commercial enterprise performance predictions creating enough confidence for investors to provide the resources needed to make new products or provide new services.

5) Due diligence
By systematically checking designs and plans beforehand, and monitoring technical work for compliance with standards and specifications, engineers reduce both the real and apparent risks for investors, increasing the perceived value of an enterprise.

6) Community value creation
Engineers help enterprises co-create value in their communities through ethical behaviour, improved safety, community capacity building, identifying and conserving resources, reducing or eliminating detrimental environmental and social impacts, and remediating environmental damage. Developing the community that hosts an enterprise rewards both the enterprise and the community.

7) Reliable coordination
Reliable coordination within an enterprise improves the likelihood that the predicted product or service performance and quality will be delivered on time, safely, within the predicted budget and with acceptable environmental and social impacts. By doing so, engineers increase the value of the enterprise by aligning intentions with actions sufficiently well for investors to earn reasonable returns.

Beyond these seven ways that engineers contribute value, there are at least three ways in which engineers protect existing value: they help to prevent value from being reduced or destroyed.

8) Maintenance
Often referred to as engineering asset management or sustainment, maintenance engineering is critical in protecting existing value embodied in engineered products, systems and business processes.

9) Environmental protection
Engineers protect naturally endowed value by conserving both the renewable and non-renewable resources of our planet, our home.

10) Defence and security
Engineers provide many products and services that limit or prevent destructive behaviour by other people, thus protecting accumulated value represented by our society and its various cultures and civilizations.

Thus it could be argued that value creation is an important component of engineering literacy for the target groups set out in the Heywood paper. For engineers themselves, a clearer picture of the nature of engineering value creation would benefit their professional contribution and would benefit the enterprise in which they work. For citizens in general such literacy would contribute towards informed decision-making and participation in political process. Furthermore providing pre-higher education students and their parents with a more precise perception of the value creation and values of engineering work could help attract a larger and more diverse group of entrants to future engineering courses.

References

Ács, Zoltán J., Erkko Autio, and László Szerb. 2014. "National Systems of Entrepreneurship: Measurement issues and policy implications." *Research Policy* 43 (3):476-494. doi: 10.1016/j.respol.2013.08.016.
Crossley, Michael. 2011. "Business Skills in Engineering Practice."Bachelor of Engineering, School of Mechanical Engineering, The University of Western Australia.
Katz, Jerome A. 2003. "The chronology and intellectual trajectory of American entrepreneurship education." *Journal of Business Venturing* 18:283-300. doi: 10.1016/S0883-9026(02)00098-8.
Singh, Ravinderpal. 2015. "How do Engineers Perceive the Notion of Value: A Discussion of Value in Engineering Practice?"Bachelor of Engineering, School of Mechanical Engineering, The University of Western Australia.
Trevelyan, James P. 2012. "Understandings of Value in Engineering Practice." Frontiers in Education 2012, Seattle.
Trevelyan, James P., Williams B., 2017. “Identifying Value in the Engineering Enterprise” in The Engineering Business Nexus: Symbiosis, Tension & Co-Evolution, Editors Christensen Steen Hyldgaard; Delahousse Bernard; Didier Christelle; Meganck Martin; Murphy Mike, forthcoming Springer Press.

Technological Literacy without Proficiency is not Possible

Alan Cheville, Bucknell University
alan.cheville@bucknell.edu

John Heywood frames several dilemmas around how we educate individuals for the technological age we live in. These dilemmas include the difficulty of devising technological and engineering literacy for a breadth of audiences; understanding the relation between, and separate responsibilities of, the designer and the user; the fact that technology exists within a broader social milieu which requires a broad, liberal education; and the difficulties inherent to defining technological and engineering literature as separate from each other. I argue that while these are all challenges for engineering and technology educators, they arise from the larger question of what are the relative value of different forms of knowledge in a society that is reliant on a given level of technology for its survival?

Heywood correctly frames technology as a necessary form of knowledge in such a society, but seemingly equates technological literacy with knowledge of technology specifically, and knowledge itself more generally. At a surface level this is correct since the word "literate" means having knowledge of letters (i.e. the literature). However I argue this implies a limited definition of technological literacy by framing it as epistemic knowledge. From an etymological perspective the origin of "technology" is the Greek word *techne* which was one of Aristotle's five intellectual virtues along with *nous* (intellect), *sophia* (wisdom), *phronesis* (practical judgment), and *episteme* (knowledge of things which are unchanging). *Techne* was fundamentally different than *episteme* since it was a virtue developed by the act of making and thus related to artifacts that were made (came into being) rather than what existed naturally. Thus from an Aristotelian perspective the phrase "technological literacy" may be seen either as contradictory or as involving two related forms of knowledge. Despite today's belief in a divide between theory and practice, the latter definition aligns with Aristotle's views [1].

The relation between these two intellectual virtues can be clarified by moving beyond the Cartesian domain of thinking or knowing to include the domain of acting. In this case the phrase "technological literacy" should be expanded to "technological literacy and proficiency" since the root of "proficient" means to make progress or be useful. From this perspective it is not enough to be literate in technology, rather those who wish to be proficient in technology must also develop the skill to create, for as Aristotle says *techne* is concerned with those things "*whose origin is in the maker and not in the thing made*" [2].

Including both literacy and proficiency in a definition of technological education addresses many of the questions posed by Heywood as well as aligns with the view of Aristotle (and the Stoics) that both *techne* and *episteme* were needed for a virtuous life. For example, the difference between designer and user becomes a question of the degree of abstraction and proficiency. The designer has both the knowledge and skill to create a tool while the user, abstracted from the creation of the tool, may use the tool without full understanding of its originating technologies. Engineering is based on such abstractions since few, if any, engineers have mastered all the layers of given technology. However for the user to claim proficiency they must themselves create something and be able to generalize or abstract the process of creation. Including the framework of action also essentially eliminates the distinction between engineering and technological literacy discussed by Heywood since while there may be two knowledges, proficiency in use of a tool is a matter of degree and of the utility, appropriateness, or beauty of what is made. Without both literacy and proficiency the result will likely not be useful, appropriate, nor beautiful. Aristotle viewed mastery of *techne* as being able to describe the reason for decisions that underlie a craft which practically was evidenced by being able to teach it to others which seems to require proficiency.

If one's literacy in technology includes proficiency then as Heywood suggest the need for a liberal education is implicit. Goldman [3] points out that engineering, unlike science, is contingency based so a learner must be able to apply knowledge and skill in new contexts. The knowledge of context, contextual literacy, can arise from the inter-relation of knowledges which is in essence the liberal education Heywood espouses. Further, Goldman's principle of insufficient reason highlights that to act for the right purpose requires both gnosis and episteme [4]. A liberal education provides the learner knowledge of moral and ethical themes of human existence, supporting gnosis.

The question of broad audience is more difficult. While education can provide contextual literacy, proficiency requires not only the ability to choose the right purpose, but to be able to act in the right way. It may be argued that such skill must be gained through experience so that effectively teaching both technological literacy and proficiency requires students be exposed to a range of contexts and problems.

The difficulty with including proficiency along with literacy in a technical education is that the proliferation of, and inter-connection between, technologies is rapidly outpacing our ability to teach them. It is this tension between technological and educational capabilities that Heywood highlights in his commentary on the recent scandals involving the automakers VW and GM. In essence there is such a great distance between the esoteric knowledges and skills needed to design and build an automobile and that required to drive a car that no amount of emphasis on technological literacy and proficiency can span the gap. The increasing gap between the capabilities of technology and the capability of users of technology was captured by Ivan Illich in *Tools for Conviviality* [ref] which recognized that a technology that does not enable proficiency creates a "modernized poverty". It is for this reason that technological literacy and proficiency is an important issue for engineering since an inability to manage technology impoverishes all of us.

In conclusion Heywood's challenge to the Technological and Engineering Literacy and Philosophy of Engineering Division can be partially addressed by going beyond a focus on literacy as knowing (*episteme*) and including the idea of technological proficiency (*techne*). The inclusion of proficiency creates new issues, however, since neither the time nor resources for such a comprehensive education are available. While it is not clear how to address this dilemma, it is clear that more standardized education is not the answer. Rather educators could recognize that technology which supports instantaneous queries and communication means that we now all have not just the capability, but also the responsibility, to teach. Utilizing this capability requires we all learn to teach, to master some small aspect of both *episteme* and *techne*, and build communities in which these knowledges can be shared. A university education then is not simply about learning a body of knowledge, but about being able to connect to others who have knowledges and skills the learner lacks.

References

[1] Parry, Richard, "*Episteme* and *Techne*", *The Stanford Encyclopedia of Philosophy* (Fall 2014 Edition), Edward N. Zalta (ed.), accessed December 2016 at https://plato.stanford.edu/archives/fall2014/entries/episteme-techne/.

[2] Aristotle, "Nichomachean Ethics VI-4,"

[3] S. L. Goldman, "Why we need a philosophy of engineering: a work in progress," *Interdisciplinary Science Reviews*, vol. 29, pp. 163-176, 2004.

[4] B. Davis, "*Inventions of Teaching: A Genealogy*", Routledge, New York, 2009.

Unfinished Business for the ASEE TELPhE Division And Other Engineering Educators

John Krupczak, Professor of Engineering, Hope College, Holland, Michigan, USA.
krupczak@hope.edu

Professor Heywood's performs a great service by calling attention to unresolved issues regarding engineering literacy. Heywood points out that there is little in the way of official efforts to improve understanding of engineering by the general public and further, the concept has multiple audiences which may have different needs for distinct aspects of engineering knowledge.

Perhaps support for engineering as part of general education would be more enthusiatic if engineering educators could better define the specific utility of everyone knowing something about engineering and technology. Engineering is, after all, a profession that highly values utility and tangible benefit. Engineers then should be capable of identifying and communicating the substantive practical benefit of engineering as an element of general education.

Heywood's observations should also cause acceleration of efforts to define engineering literacy in measureable terms so that its presence in an individual can be identified. Again, this should not be an unfamiliar task for engineers who are trained to define in measurable terms the characteristics of acceptable solutions to imprecise and open-ended design problems. As Heywood points out, mathematically proficiency is universally accepted as an essential component of general education. This situation is possibly facilitated by the existence of quantitative measures which are taken as indicators of mathematical proficiency.

Additionally, we advocates of engineering literacy have yet to advance compelling arguments as to how an engineering literate public might have resulted in a different unfolding of high profile technologically-based problems such as the GM ignition switch or the Volkswagen emissions scandals as cited by Heywood. How would have an engineering literate populace resulted in a different, presumably better, outcome from these events? At the time of this writing we might add the Oroville dam issue in California to the list of public safety crises highly intertwined with technology.

As Professor Heywood points out, the question of curriculum is non-trivial. If engineering is an element of liberal education what specific engineering-based ideas should be included? To address this question recall that engineering students have a survival technique in problem solving of working backwards from the correct answer, and perhaps something of that practice might be employed here. One suggestion for research might be to inquire of those engineers whose career paths have led them out of engineering into positions in which they are making contributions in other spheres of activity. Engineering is well known for the fact that many formally trained as engineers are now fulfilling other responsibilities that may be also occupied by individuals with other types of formal training. All types of business and management are obvious examples but individuals formally trained as engineers can be found in law, health care, the arts, education, and government. Can these individuals shed any light on what specific aspects of engineering they have found particularly helpful as they have successfully navigated the responsibilities of jobs frequently held by other liberally educated non-engineers? Perhaps the experience of these erstwhile engineers can help to clarify the how, what, and why of engineering as an element of liberal education.

The Purpose of Technological and Engineering Literacy

Tom Siller, Colorado State University
1372 Campus Delivery
Colorado State University
Fort Collins, CO 80523-1372

In the paper: Why Technological Literacy and for Whom? [1], Heywood makes the case for a greater need for both technological and engineering literacy that are based on interdisciplinary approaches. He continues the earlier argument that these two literacies are not one in the same, but different literacies, with technology focusing more on outputs and engineering focusing more on process. In this response I would like to move the discussion further by considering the purpose of these literacies. The most common reason for promoting these two literacies is the need for the non-technologist to have a better understanding of technology. It is often posited that if the public has a better understanding of both the process and outputs, it will make better, more informed choices, e.g. the cases cited by Heywood (GM and Volkswagen). The logic of this argument seems sound and worth accepting. Herein I would like to postulate a different purpose for promoting these literacies: the development of a public that can influence more than the choice of competing technologies by also add purpose to them. This implies a closer partnership between technology and society.

As a starting point for the present argument it is valuable to return to the work of Jacques Ellul and his book The Technological Society[2]. Ellul takes a pretty pessimistic view of the technological society. In this work he attributes seven qualities to technology, one of which, autonomy, is the subject of the present argument. Most calls for technological literacy desire to have more people understand technology but not for the purpose of changing it –that is left to the technologists! This independence of technology from societal influence is a source of considerable discussion by Ellul. His concern is that all solutions are then technological [3]:

> *Automatism in technical choice is present insofar as technical rationality takes on a more or less automatic character and is assumed to be "the one best way" to make decisions that themselves become calculations (e.g., in cost-benefit analysis).*

This is a concern that has been shared by many over the years, probably reaching back to the industrial revolution. If this is true characterization of the technological world, then the proper role of literacy is for understanding. In Ellul's translated work [2] the statement is made:

> *Technique has become autonomous; it has fashioned an omnivorous world which obeys its own laws and which has renounced all tradition.*

This statement points out the root cause of the problem with the society Ellul portrays –viewpoints outside of technology are irrelevant. If tradition is to return to having a role in solving problems, then the non-technologist must become literate of engineering and technology. Constructive criticism comes from a foundation of understanding, not ignorance.

In conclusion Heywood's call for an interdisciplinary approach to engineering and technological literacy is well founded and worthy of support. If the autonomy so forcefully written about by Ellul is to be combated, and I believe it should be combated, then greater literacy is a place to start. But literacy should not be approached as a *window* for other intellectual traditions to peer through, but as a *door* to allow for greater movement between differing traditions. Then, in addition to creating a more literate society it may also lead to a more engaged society where technology no longer exists as an autonomous entity operating independent of society around it, resulting in solutions that reach beyond the technical.

References

1. Heywood, J., *Why Technological Literacy and for Whom?*, in *ASEE'S Annual Conference & Exposition*. 2016, ASEE: New Orleans, LA. p. 9.
2. Ellul, J., *The technological society*. 1st American ed. 1964, New York,: Knopf. xxxvi, 449 p.
3. Jonassen, D.H., *Engineers as Problem Solvers*, in *Cambridge handbook of engineering education research*, A. Johri and B.M. Olds, Editors. 2013, Cambridge University Press. p. 103-118.

Why and For Whom as Historical Reflection

Mani Mina, Iowa State University
mmina@iastate.edu

Being a part of the efforts regarding defining, promoting, and engaging in the areas of Technological and Engineering literacy for over a decade, the discussions and ideas in Professor Heywood's paper are familiar to me. I think it is of immediate importance to address the issues that he is bringing about. I would suggest that we treat this as a call for a discussion and debate on these fundamentally important issues. Professor Heywood is challenging us with thought provoking questions. The question of "why and for whom" has always been alive in our community. Each of our members and active participants in advancing and defining these areas have tried to find their ways, their perspectives, and their reasons about what they are doing. Most of us have been teaching classes in the area, and have been involved in defining approaches for curricular design, assessment, testing, and advancing the area. We can argue that most of our work has been academic.

The main reason for why this has been a more academic begins with the one historical question. Why should all students take liberal arts and general education? Many of us are engineering educators and this makes sense to us. However, why should student not also take technological and and/or engineering literacy classes, as requirement? Our lives in modern societies are full of gadgets, connectivity, wired and wireless engagements, communications tools, and even relaxation tools that are technologically advanced. The main question is, how are we allowing the infusion of so much technology in our lives without meaningful reflections and discussions on the ideas and different aspects and developments that the infusion brings about?

As educators in this area, we need to focus on how we got here? What have been the dominant trends and mentalities? What are the principles of the modern infusion of so much technology in our lives? If liberal arts expands our thoughts, logic, critical thinking, and empower us to think openly and examine facts and decisions, What would be the role of Tech literacy? Are we (and our students) tooled and trained to do the same with Technology and Engineering?

The main challenge is identifying for whom do we develop the education, lectures, and how would we design them? To understand technological development, growth, and to understand the dominant role of technology and engineering in our lives do we need new classes? How do we think about future generation making better decisions for implications and future growth? We need more than understanding in technology, engineering, civility, and liberal arts. We are facing difficult questions and difficult choices. That is why we need to have a more philosophical basis for wider range discussions.

I teach classes for engineering students as well as design students. It is important for both of the groups of learners to think deeper about how to develop new technology, how to gauge the complex societal and ethical issues of the technological decision-making, and how they impact on our lives and future generations.

Tech Tally, and Technically Speaking were national calls, demanding awareness and action. Many of us have been trying to define the domains, possibilities, and connectivity of all that we need to educate our students, and our nations. The last decades should be considered the transition from the "Romance" stage (borrowing Whitehead's ideas) to the "Precision". We need to work on moving from "Precision" to "Generalization". We tried many things, including defining and redefining our goals, visions, and efforts. How do we gauge ideas, examine new ideas and challenges? These are important issues for many of us. That is why a huge effort has been devoted to bring about a philosophical approach for logical debates and discussion in this area. It is time to ask deeper questions, and address issues of concern of different stakeholders. It is time to have a national as well as international dialog. I think the paper by Professor Heywood is a call for such a dialog. John Heywood initiates the dialog and let us continue.

Moving the Needle From Literacy to Knowledge

By David E. Drew
profdaviddrew@gmail.com

John Heywood's paper (2016) raises critical issues about differentiating technological literacy from engineering literacy. This is an important distinction, but I believe there needs to be a second epistemological analysis. Otherwise, "literacy" is assumed to be an acceptable, even laudable, goal. Words matter and striving for literacy may simply be setting the bar too low.

Granted, for some people "engineering literacy" implies or includes the links to society, philosophy, law, etc. But most people have a more limited definition in mind, a definition like that proposed by Hirsch, and quoted by Krupczak et al (2012), "information that is taken for granted in public discourse."

Information scientists and philosophers often discuss a continuum: data to information to knowledge to wisdom. Literacy means being able to understand information—"minimum competences". And, yes, it is better to be literate than to be illiterate. But shouldn't we want students and others to acquire knowledge, not simply process information. This translates into being able to contextualize information. They must go beyond understanding how a device works to considering the implications of its use for society. Critical thinking is essential.

Fostering and developing critical thinking is a major goal of a college education. In a thoughtful examination of liberal education, Michael Roth adds that "Critical thinking is sterile without the capacity for empathy and comprehension that stretches the self" (2014, p. 184). Similarly, Heywood (2014) has defined liberal education as an "enlargement of mind"

With these issues in mind, Louis Bucciarelli and I (2016) have proposed that colleges and universities consider a program in Liberal Studies in Engineering. The goal would be to integrate more completely engineering education with the arts and humanities. Liberal arts courses would be the focus of this program; they would be infused with engineering principles, techniques, skills and examples.

Enlargement of mind, critical thinking, contextualizing technology all are about knowledge. While some perceive them as included in the term "literacy", I would argue that a new term is required. Building on Heywood's (2014) distinctions, we might differentiate consideration of the product ("technological literacy"), consideration of the process ("engineering literacy"), and contextual consideration of the implications ("technological knowledge" or perhaps "technological judgment") Regardless of the semantics, Professor Heywood's (2016) concluding statement is key: "An interdisciplinary approach is necessary."

David E. Drew holds the Platt Chair in the Management of Technology at the Claremont Graduate University. His book, STEM the Tide: Reforming Science, Technology, Engineering, and Math Education in America, is published by the Johns Hopkins University Press.

References

Bucciarelli, L. and Drew, D. (2015) "Liberal Studies in Engineering: a Design Plan" Engineering Studies, volume 7, issue 2-3, pages 103-122.

Heywood, J (2014). "Defining engineering and technological literacies within the framework of liberal education: implications for curriculum," Proceedings Annual Conference of the American Society for Engineering Education. Paper 8687

Heywood, J. (2016). "Why Technological Literacy and for Whom?," Proceedings Annual Conference of the American Society for Engineering Education. Paper#15624

Krupczak, J., Blake, J. W., Disney, K. A., Hilgarth, C. O., Libros, R., Mina, M and S. R. Walk (2102). "Defining technological literacy," Proceedings Annual Conference of the American Society for Engineering Education. Paper AC 2012-5100

Roth, M., Beyond the University: Why Liberal Education Matters. (New Haven, Yale University Press, 2013)

Technological Literacy and Global Society

Sergey V. Sychov. Saint-Petersburg, Russia, ITMO University
sergey.v.sychev@gmail.com

The problem raised in the article (Heywood, J. (2016)), concerning the necessity for the global society (or a society of a particular country) is to function in an efficient way, deals with the general purposes of education in the modern world. In order to form a balanced conception of the subject we need to clearly understand, as it was mentioned, the audience and purpose of education and the extent to which the audience has to be educated.

Two main purposes of liberal education can be underlined as:

1) a general understanding of principals of modern (and possibly upcoming) technological devices
2) a possibility to make qualified political decisions (supportive or discouraging) that is necessary for a society (liberal, democratic society and a state as general idea) to be a well functioning system.

These two principals, being a minimal requirement, put a limit on the general population understanding of technology to be qualified enough for making decisions on general processes. In this regard, the ability to design particular devises, that is mentioned as engineering literacy (Krupczak, J et al. (2012)), which is required for an engineering specialist and ability to operate device, is let to some professional and can be achieved with special training.

This general understanding of technology is not possible without knowing basic scientific principals and lows and without logic about how to combine different subjects and concepts in a clear scientific picture of the world around.

Though, for example, qualified decisions on renewable energy sources could be more effective if one understands that (as a result of the first law of thermodynamics) the average yearly flow of energy from the Sun puts a limit on a combined yearly production of all Earth's possible renewable energy sources (wind and wave power, solar energy, and renewable fuel sources).

Though, having in consideration,1) philosophical literacy, 2) scientific understanding of the world, 3) technological literacy and 4) engineering literacy we have to highlight the second and the third as being the core structures for developing an effectively working liberal society.

In this respect, philosophical literacy is more important for politicians, academicians and government executives than for the general population, whereas, engineering literacy mostly matters for a narrow group of specialists concerning with design and operation of technical systems which then are used by the general population.

Technological literacy is one of the most fundamental competences in the modern world but if it is taken alone, without logical connections to the basic scientific concepts behind technology and without solid understanding of ideas network in which this technology embedded, it will suffer a shallow mental incorporation, weak psychological interiorisation and dysfunctioning practical implementation.

Scientific literacy (or scientific view of the World) have to include principal understanding of the main scientific concepts and, what is more important, logic of relationships between them, the scale of phenomenon considered and how those basic concepts led to technologies of the modern world.