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Whither engineering and technological Literacy? Cui Bono 2.

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Abstract

At the 2018 Business meeting of the Technological and Engineering Literacy/Philosophy Division (TELPhE) of the American Society for Engineering Education it was agreed that the author would continue to prepare a whitepaper on the future of the Division. As part of his study for the whitepaper the author responded [1] to nine comments in the Division's fourth handbook [2] on a previously published paper by him on "Why technological literacy and for whom? [3]

The principal axiom drawn from this analysis was that "the general aims or purposes of programs in engineering and technological literacy are far from clear, and in so far as they are declared or implicit, are a function of the audience to whom the course or program is directed".

In order to better understand the problem a comparative study is made with an innovative curriculum in liberal studies that took place in the UK, as they are roughly analogous. It confirms that any attempt to develop technological literacy as a discipline would require a substantive epistemological base. Without that base technological literacy can only continue to act as an umbrella that allows for content and method to be developed for the audiences to be served. In this respect TELPhE has significantly failed to consider the needs of the general public. It is evident that within the public there are different audiences with diverse needs, as for example, parents, journalists, and teachers. Mathematics is particularly problematic. The mathematics required for technological literacy is briefly considered, and reference made to a case study.

At the same time TELPhE has sponsored a number of innovations. Recent work suggests that an alternative curriculum may better meet the needs of a general higher education that is responsive to the changes in society being wrought by technology. Since the models that have been developed require different higher education structures TELPhE might consider initiating a substantive inquiry that answers the question - "What structures of higher education do we need to help us live in a technologically dominated society?

In order to further the debate within TELPhE three former Chairpersons of the TELPhE division (Carl, Hilgarth, John Krupczak and Mani Mina) offer their comments on the paper in a codicil at the end.

Introduction

At the 2018 Business meeting of the Technological and Engineering Literacy Division of the American Society for Engineering Education it was agreed that the author would continue to prepare a whitepaper on the future of the Division. As part of his study for the whitepaper the author responded to nine comments in the Division's fourth handbook on a previously published paper by him on "Why technological literacy and for whom? [1: 2: 3]

The principal axiom drawn from this analysis was that "the general aims or purposes of programs in engineering and technological literacy are far from clear, and in so far as they are declared or implicit, are a function of the audience to whom the course or program is directed".

It will be now be argued that the problem that faces the promoters of studies in technological literacy is analogous with that faced by the promoters of programs of liberal studies in Colleges of Advance Technology (CATs) in England and Wales between 1955 and 1966 (when they acquired university status). However, unlike the promoters of technological literacy who have to face at least three different audiences, the promoters of liberal studies had only to face one audience – the students in programs for the Diploma in Technology.

The Diploma in Technology

In 1965 the UK government created a National Council for Technological Awards (NCTA) to validate degree equivalent diploma programs in nine (subsequently 10) Colleges of Advanced Technology with the express purpose of increasing the supply of technologists (engineers, applied scientists and mathematicians) to industry. These Diploma programs were structured on the sandwich (cooperative) principle of integrated periods of study and training in industry. The most popular was six months in industry followed by six months in college in each of four successive years [4].

A requirement of the NCTA was that all students for their diplomas should have participated in programs of liberal study. This was reinforced in 1957 by a government edict that extended the idea of compulsory liberal studies to all levels of technical education even though much of it was part time study [5]. By 1962 it was seen that the development of literacy, that is the ability to read and write, was essential for the general education of all students. Thus, it was that in those colleges the term Liberal Studies came to be substituted by General Studies [6].

The 1957 Circular did not prescribe what a liberal curriculum should be but suggested five ways in which the curriculum could be liberalised. These were

(1) The inclusion of additional subjects.

(2) Broadening the treatment of technical and scientific subjects.

(3) Increase use of the college library, of seminars, of discussion groups, directed study periods, and projects; and in general the fostering of the tutorial relationship between teaching staff on the lines of that used in universities.

(4) The encouragement of corporate life in colleges, and the development of extra-curricular activities.

(5) The establishment of contacts with institutions abroad.

The Circular stated that "the mere addition of extra subjects will not by itself liberalize a course of technical study. Good teaching must demonstrate that these subjects have a content of fundamental interest and importance to students".

The discussion which follows is primarily concerned with items (1) and (2) as they developed in the Colleges of Advance Technology. It is particularly concerned with the philosophical assumptions and culture that underpinned the development.

Liberal/general studies were the subject of considerable R & D [7]. There were three major studies that focused solely on liberal studies [8; 9; 10], two of which were solely focused on the CATs [8; 9]. The third focused mainly on 34 Colleges of Technology with some CATs included. It produced insights that have had lasting significance [10]. In addition there were three major studies of CATs that included liberal education in their remit [4; 11; 12]. One of these studies by Laurence Davies, provided a substantial review of this R & D [8]. He argued that investigations into liberal studies should begin with an understanding of what liberal education is, and how it came about. Starting where he did with a dictionary definition of liberal education should demonstrate the validity of this analogical study for technological literacy.

Defining liberal education

Davies opens his argument with the *Oxford English Dictionary's* (he does not reference which version) definition of liberal education which brings us immediately to the problem of literacy and its meaning. The definition reads

"Liberal (of education), fit for a gentleman, of general literacy rather than of a technical kind".

But a short version of the dictionary with a Preface dated November 1963 reads

"*education*, i.e. directed to general enlargement of mind, not professional or technical":

In this definition there is no mention of literacy

But, following the first definition Davies identifies three dimensions that make up liberal education

"(1) A liberal education is not concerned with the application of skills or techniques as ends in themselves, but is more concerned with general purposes".

"(2) A liberal education is one fitted to a gentleman, and is perhaps a part of the training of a gentleman and hence an instrument of social aspiration"

"(3) A liberal education seeks to promote literacy and is therefore concerned with the language and culture which are part of our heritage".

From literacy to technological literacy; Knowledge, competency, proficiency and the control of technology

Davies adds a footnote which pointed out that Aristotle had indicated the relationship between the first two dimensions in his *Politics* Book VIII. But he goes no further, and does not seek to amplify the definition of literacy which in the same 1963 edition of the Dictionary is simply the "Ability to read and write". Thirty years later (1993) in *The New Shorter Oxford English Dictionary* literacy is defined as the "quality or state of being literate; knowledge of letters; condition in respect of education *esp.* ability to read and write". Examination of the term "literate" on the same page shows that while it also begins with "the ability to read and write" it extends the definition to "competent and knowledgeable in a particular area". By referring to "computer literate" it gives legitimacy to the more general use of the term as descriptor of other particular areas of knowledge, as for example, economics, maths and science.

Since competency implies proficiency it also implies proficiency in an area of knowledge, in this case technological literacy. This is the point that Cheville made in his comment on this writer's paper, although it would not seem to be an extension of the definition of literacy as he suggested [2]. But it also implies that technology is an area of knowledge that is similar to science, clearly it is not similar to maths or economics or English.

The 1993 edition of the dictionary first defines technology as "the branch of knowledge that deals with the mechanical arts or applied sciences". It is any number of subjects but it may also be a "discourse or treatise on (one of) these subjects". It is the former sense that is analogous with liberal studies in that it is a grouping of subjects whose coherence is self-evident and who claim to be disciplines. Similarly with science: the second definition of which in the 1993 edition of the Dictionary is "knowledge acquired by study: acquaintance with or mastery of a department of learning".

At school the minimum competencies thought to be essential for life in English and Maths have been designated as numeracy and literacy. Beyond that, however, there have been movements in England (1963) and America (1982) to develop cultural literacy to ensure that individuals have a knowledge of a wide range of specific facts without which a person will not be able to enjoy successful communication [13:14]. Thus, if to live in a society that is dominated by technology a person has to have a wide range of knowledge about technology, is technological literacy the means by which those facts are acquired? And, what contains the number of facts to be learnt? But to concentrate on facts is to ignore the question of competencies, that is, what competencies does a person require to be proficient in technological literacy? That is a central issue of this discussion.

As a matter of policy in the 1980's governments seem to have taken the view that it is a matter of the economic good that students should study technology in schools [15], and by 1992 a World Council of Associations for Technology Education had been founded. The conference proceedings associated with the founding of this organization, had the title "Technological Literacy, Competence and Innovation in Human Resource Development" [16].Yet, in this extensive report there are only two papers that mention technological literacy [17; 18]. Both authors are American; one, Michael Dyrenfurth is a member of ASEE. His definition was,

"Technological literacy is a concept used to characterize the extent to which an individual understands, and is capable of using technology. Technological literacy is a characteristic that can be manifested along a continuum ranging from non-discernible to exceptionally proficient. As such it necessarily involves an array of competencies, each best thought of as a vector, that includes: functional skills, and critical thinking, constructive work habits, a set of generalized procedures for working with technology, actual technological capability, key interpersonal and teamwork skills, and the ability to learn independently" [18].

One reading of this statement might give rise to the view that a technologically literate person would be the holder of some kind of engineering degree that embraces computing. In any case this definition, written in 1991 does not respond to what has become a major worry, namely how do members of the public, who do not have engineering degrees, control technology at a time when it (the public) is becoming increasingly controlled by a particular form of technology-IT/AI. Moreover, how does it judge the technology assessments that policy makers make?

Technological literacy and liberal studies equate when they are viewed from a knowledge perspective that categorizes knowledge into different subjects. An alternative view based on competence/proficiency may well lead to a different understanding of the structure of technological literacy. To use Matts Daniels distinctions, the former is Content-focussed where the focus is on *episteme* within the context of fragmented of knowledge while the latter is Capability-focused on *techne* where knowledge is used as a tool (personal communication). It may be argued that the problems of technological literacy have arisen from a focus on content. If this is not the problem, is the function of technological literacy simply to provide a range of traditional studies, (e.g. philosophy, psychology, economics, sociology) that will help us to control the impact of IT/AI on our lives, the competency of control being acquired by osmosis? But if the function is to enable individuals to engage with technology then the curriculum has to take that into account or in Matts Daniels terms to be Identity-focused.

Technological literacy and liberal education do not equate when it comes to the philosophical assumptions that drive them. Liberal studies derive from a very long tradition that began with the ancient Greeks. Lawrence Davies opined that the liberal studies of the 1960’s could hardly be evaluated without reference to that tradition. His summary provides insights that may be of value to the debate about technological literacy.

The Liberal education tradition.

The bridge between (1) and (2) in Davies three dimensions of liberal education can be traced back to Aristotle who wrote in the *Politics* that,

“There is a distinction between liberal and illiberal subjects, and it is clear that only such knowledge as does not make the learner mechanical should enter into education. By Mechanical subjects we must understand all arts and studies that make the body, soul, or intellect of freemen unserviceable for the use and exercise of goodness. That is why we call such pursuits as produce an inferior condition of body mechanical, and all wage earning occupations. They allow the mind no leisure and they drag it down to a lower level. There are even some liberal arts, the acquisition of which up to a certain point is not unworthy of freemen, but which, if studied with excessive attention or minuteness, are open to the charge of being injurious” (as cited by Davies [19]).

Thus a liberal education is focused on gentlemen with the purpose of serving their needs. . More than that since the renaissance it has followed the doctrine that classical scholarship is the *sine qua non* of liberal education. The divide between liberal and vocational education was cemented. As perceived by its proponents liberal education “viewed in itself, is simply cultivation of the intellect”. By the nineteenth century it was an education for gentlemen.

That a liberal education is of much higher value than technique persists to this day in the UK where distinctions continue to be made between the academic and vocational (or practical), and theory and practice. They are clearly divided by social-class so attempts to persuade some students to attend technical colleges for a vocational education rather than pursue degrees that some perceive to be of little value are doomed to fail for the meritocracy says that you need a degree if you are to climb the social ladder. Such is the power and simultaneous failure of the utilitarian philosophy that governs education.

Davies does not follow the conflict between an Oxford education and the useful education provided in Scottish universities that began in an article in the *Edinburgh Review* in 1808-

1809. Consequently he does not mention the replies of Edward Copleston or John Davison against useful education which Newman cites copiously in the 7th discourse on the "*Idea of a University*" [20]. Rather he focuses first, on the debate about whether scientific education should be a component of liberal education, as it was comprehensively argued by T. H. Huxley (1894). He attacked the neo-classical humanism of the ancient universities. His second focus is on Matthew Arnold who strongly supported the classics against materialism which he thought would overrun society. Interestingly, although he was an Inspector of Schools he did not rest his argument on educational grounds except to argue that the classics would preserve the cultural heritage if a person was to "acquaint himself with the best that has been thought and said in the world; of this best the classics of Greece and Rome form a very chief portion and the portion most entirely satisfactory" (cited by Davies).

Put in another way, and loosely interpreted, in the twentieth and twenty first centuries it became a battle between specialism and generalism. Specialism is held to "narrow" the mind therefore, there was a need for those who specialised in technique to have their minds broadened (freed up) which would be achieved by the inclusion of liberal studies in the curriculum. Thus Davies writes, "A modern liberal education, it is fairly generally agreed, seeks to confer on its recipients a freedom of mind which those who do not possess this advantage will not exhibit". Given the assumption by government that technological students in Technical Colleges did not possess that freedom of mind, it was incumbent on them to provide for their liberal education, and this was undertaken through a variety of different subjects primarily by lecture or discussion (see Appendix A). Clearly it broadened the students' knowledge and some student's minds were undoubtedly enlarged in the way Newman envisaged (see Appendix B), but Davies did not discuss Newman's work in that light.

Differences and similarities

Although there has been substantial progress in the development of philosophies of engineering that have some common ground [21] nothing has been written that is the equivalent of the philosophies that underpin the liberal education which give liberal studies teachers their credence. The nine articles in Handbook 4 and others presented to the Division may be taken as the beginning of a search for such a philosophy. Technological literacy will not survive without such a philosophy. But that may not turn out to be possible for whereas the disciplines that serve liberal studies derive their *raison d'être* from the philosophy of liberal knowledge, each of the disciplines that serve technological and engineering literacy help create those literacies has its own philosophy or *raison d'être*. Neither, technological or engineering literacy is a discipline in its own right. Taken as a whole the nine articles are testimony to this fact. At the moment technological literacy has different meanings as a function of the audience to whom it is addressed.

It may be objected that technological literacy is similar to liberal education, that is, a goal to be achieved. But unlike liberal education the subjects that claim to be liberal can do so by virtue of their contribution to breadth given the modern goal of liberal education, that is, to offset specialization.

Whereas relatively little is known about teachers of technological literacy in the United States somewhat more is known about those who taught liberal studies in the CATs. The most significant fact reported by Davies is that something like 80% of those teaching liberal studies in one enquiry had a teacher education qualification which was much more than among teachers of technological subjects [22]. Recent work in the US suggests that teachers of technological literacy may benefit from such training.

Of a very small sample of staff in CATs [23], and a large sample in one CAT [24] the majority of the teachers thought that liberal studies were necessary. But only half of the sample in the first survey thought they should be compulsory. There was no comparable information about teachers in universities where courses of this kind were offered in the US. Perhaps the most significant finding of the second study, in this writer's opinion, was that "the desire for a link between technological and liberal sides was firmly expressed, and most teachers wished to further liberal education by adopting newer methods. Few welcomed the addition of cultural subjects to the curriculum, but most were willing to find a place for subjects of a more serviceable kind. No attempt was made in either study to establish whether or not the teachers had a philosophy of education. Similarly little is known about the philosophical dispositions of teachers of technological literacy. These philosophies are of considerable importance because they contribute to the culture of the department. Hostility toward any subject that is made known to students by their teachers can have a negative influence on the attitudes students bring with them to such studies. Nothing is known about the situation of teachers of technological literacy in this respect. The evidence suggests that the culture of the CATs was positive toward liberal studies.

Main subject teachers are unlikely to support subjects they regard as unnecessary particularly in circumstances where they feel they will take time away from mainstream work. Given that it is, and was well understood, that the engineering curriculum is overcrowded to the point of being overloaded the level of satisfaction reported above might be perceived to be remarkable.

Peers and Madgwick obtained information about the problems faced by and attitudes of students in two CATs [25]. They found that there "was an overwhelming expression of approval from students for the inclusion of general studies in their courses" but, "a great majority considered that syllabuses were too overcrowded, that there were far too many lectures, and that methods of teaching left much to be desired". It seems reasonable to surmise that technological literacy courses would run into this difficulty. In these circumstances it is difficult to imagine that the sandwich system was conducive to reflective thinking. But the idea of reflective practice was not then part of the dialogue.

Of equal interest is the fact that by and large the students preferred Social Studies as their first choice. It was followed closely by Management Studies with special reference to human relations in industry. Whether or not these studies belong to what traditionalists call liberal knowledge is a moot point. But they certainly broadened their studies. Moreover, industrialists tended to support this approach to liberal studies and in both the US and UK have continually complained to this day that graduates are inadequately prepared for industry. Korte has shown that graduates themselves wish they had been better prepared for their initial experience of industry [26].

Back in 1963 Andrews and Mares were led, as a result of their investigation, to distinguish between tool/fringe and cultural subjects. While cultural subjects would seem to be the most likely to induce the sensibilities that Arnold and other 19th Century academics thought flowed from liberal knowledge, in their sample 39% of the students preferred tool/fringe subjects.

Finally, both students and their teachers spent much time arguing about the merits of examining liberal studies. Davies found that attitude and examination success might be related in liberal studies. This might be equally true of students taking courses in technological literacy.

There was considerable discussion as to whether these courses should be examined or not. At the time examinations in the UK were very different to those in the US. At the level of technique, for example, few British students would have heard of multiple choice tests. They would expect a substantial 3 hour examination at the end of the academic year requiring lengthy essay answers. In these circumstances some students thought that examinations were necessary otherwise they would not have bothered with these studies. (There was a corresponding debate as to whether liberal studies should be compulsory or not). There were also concerns that low grades might influence their overall classification in the honours system. An interesting suggestion was that the marks for the major and the liberal studies should appear separately on the certificate. The logic of a competency based programme is a profile rather than a single mark. The single most important point is that any form of assessment other than by a written paper was desirable and many courses were assessed by dissertation. Some of those involved in technological literacy have begun to examine the way it is assessed [27].

Structure and innovation.

The introduction of liberal studies cannot be regarded as a major innovation in that they were subjects taught to degree level in their own right. In this respect they were disciplines. Whether or not they were influenced by the faculty psychology of the late nineteenth century is unknown but it has persisted in some quarters even to this day. It was the belief that some subjects, notably Latin, had greater "transfer" value than others in facilitating learning. For example, Latin would help people think more rigorously, thus a student wishing to enter Oxbridge should demonstrate proficiency in Latin in the entrance examination. John Henry Newman wrote to his sister Jemima in 1845, predating faculty psychology- "The great point is to open men's minds – to educate them-and make them logical it does not matter what the subject is, which you use for this purpose. If you will make them think in politics you will make them think in religion". In the twenty first century Brad J. Kallenburg showed how reasoning in design is analogous with reasoning in ethics, and how the design paradigm can be a means of bringing engineering ethics into conversation with Christian theology [28].

Later, in 1918, E. L. Thordndike was to show that there was little or no transfer between subjects unless the learner is aware of common elements between them. It becomes more difficult when the cognate distance between the subjects is great. It is one reason why having to undertake studies in a range of subjects is desirable since it provides the base for seeking out common elements where they exist.

Liberal studies became an umbrella for many different subjects probably as a function of those wanting to contribute to the area. The essence was to broaden the mind. The popularity recorded by Davies of such subjects as the History and Philosophy of Science and the Fundamentals of Science has to be seen in this light. The mind is necessarily broadened, when it detects the common elements, even though the cognitive distance is necessarily small.

It may be argued that technological literacy is simply an umbrella for a wide range of subjects that will help different audiences deal with problems posed by technology and its role in society. It is clear that many technological problems are highly complex requiring the engineer to be acquainted with several areas of knowledge. Technological literacy provides a space for explorations in how these combinations may be made effective among persons in different audiences. A fundamental question that can be answered under this umbrella is "What structures of higher education do we need to help us live in a technologically dominated society? Recent work suggests that the fulltime courses in specialist disciplines or liberal arts without technology are not up to the challenges being posed by technological advance.

Whither TELPhE?

This analogy between liberal studies in CATs and developments in technological technology was undertaken in the light of a previous commentary on nine short papers in TELPhE's fourth Handbook. That showed just how difficult it would be to get agreement on a definition of technological literacy. For this reason it is impossible to determine what competency in technological literacy is. Perhaps attempting to answer this question would lead to a definition.

At the same time, this study highlights the fact that technological literacy does not have an adequate philosophical base. Such a base may well place limits on a subject to be called technological literacy. In these circumstances technological literacy may well be thought of as an umbrella concept that allows for content and method to be developed for the audiences to be served. In this respect TELPhE has significantly failed to consider the needs of the general public. It may feel that the K – 12 system provides for that need, but that has yet to be determined. It is evident that within the public there are different audiences with diverse needs, as for example, parents, journalists and teachers, the logic of which would seem to be that a technologically literate layperson is likely to have different competencies to those required by journalists and teachers, as for example in mathematics. Clearly there is a need to investigate the level of mathematical competency required by the different groups.

For example, in the 1960's the University of Lancaster required its arts students to take a course (approximately 60 contact hours) in a science subject during their second year. Hubert Montagu Pollock who taught the physics course found it difficult to teach in the first year it was delivered because of the lack of mathematical skill among the students in the class. He reasoned that someone who spent a very few hours mastering some of the essentials would be able to follow scientific arguments put in a much simpler form than would be possible in words alone. With this in mind he developed a programme in the language of physics.

The manual was given to the next group of students immediately after an introductory talk and its completion was their first task. He assumed that the numerical ability of the students would be similar to that of the students in the first course. It was designed for programmed instruction- the precursor of computer assisted learning. TELPhE could usefully attempt to answer the same problem for technological literacy. Is there a single language that suffices the multi-dimensions of technological literacy, or do the different audiences require different treatments? Alternatively do the numeracy requirements arise from the key concepts that are said to define technological literacy? For example, there is probably general agreement that

"Risk" is a key concept in technological literacy. Understanding risk requires an understanding of probability but, at what level?

At the same time TELPhE has sponsored a number of innovations, notably the attempts to develop a philosophy of engineering education. Recent work in this area suggests that alternative curriculum may better meet the needs of a general education that is responsive to the changes in society being wrought by technology. However, the models that have been developed required different higher education structures. This serves to reinforce the point made at the end of the previous section that TELPhE might consider initiating a substantive inquiry that answers the question - "What structures of higher education do we need to help us live in a technologically dominated society? A question that is unlikely to be answered by attention to a single curriculum focus.

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Appendix A

Lawrence Davies model for a programme of liberal education.

Components.

(1) The foundation year – to be pursued by all students and aimed at conveying some basic knowledge of the human and social sciences.

(2) The elective programme – divided into units and extending over the remaining three years of the course. It is proposed that each student should select one optional subject which he will study for two years only, and a further option to be studied for the full three years.

(3) The art of communication- a course in the writing and speaking of English, and in the principles of industrial administration, to be pursued by all students for the full four years.

Subjects

(a) Human Nature and Society – foundation study.

(b) Electives

History and philosophy of science and technology

Contemporary literature

The Fine arts

History and Appreciation of Music.

Social and Political Theory

Anthropology.

Archaeology

Psychology

Comparative Religion

A Foreign Language

Education.

(c) Compulsory Subject

Communication Skills

Appendix B.

Extract from J. Heywood Engineering at the Crossroads. Implications for Educational Policy Makers. Distinguished Lecture. American Society for Engineering Education, Annual Conference 2012.

The requirement that we should become more adaptable makes its own case for a broad education. However, it does not dictate what that breadth should be or how it should be structured. It does mean that however the curriculum is structured it should focus on what John Henry Newman called "*enlargement or expansion of mind*" (a). For Newman enlargement like knowledge was a process through which a person obtained a philosophical disposition or wisdom. Therefore, one of the aims of higher education is to help students acquire the knowledge and skills necessary to enlarge their minds. Often when he is writing about what today are called the outcomes of university education Newman uses terms and phrases from which we can only conclude that he embraced all those domains of the person that are non- cognitional. For example "*such an intellect* […] *cannot be impetuous, cannot be at a loss, cannot but be patient, collected, and majestically calm*" (b). It is to be found in his idea of a university tutor and the value placed on residence. For us, it is a reminder that the skills of the affective domain are as important as those in the cognitive domain which is the point that industrialists are making when they demand personal transferable skills.

Newman argued that "*knowledge itself, though a condition of the mind's enlargement, yet whatever be its range, is not the very thing that enlarges it*"(c). Rather it is the ability to perceive the relationships between subjects. "*Enlargement consists in the comparisons of the subjects of knowledge one with another. We feel ourselves to be ranging freely when we not only learn something but when we also refer it to what we know before* (d)." This would seem to be consistent with that present-day view of learning that it is the process by which experience develops new and reorganizes old responses [e]. This is clearly what happens or should happen within courses. Without it there could be no development or movement within a course. But demonstrating that knowledge has been acquired is no guarantee that there has been enlargement.

Adaptability arises from a person's ability to think and reason. It is these abilities applied across a range of subjects that enlarge the mind. The one thing in which we are all engaged is reasoning. We are all engaged in "*deducing well or ill, conclusions from premises, each concerning the subject of his own particular business*"- "*The man who has learnt to think, and to reason and to compare, and to discriminate and analyse …will not at once be a lawyer […], or a physician, or a good landlord, or a man of business, or soldier, or engineer, or chemist […] but he will be placed in that state of intellect in which he can take up any one of the sciences, or callings I have referred to, or any other for which he has a taste or special talent […]"* [f]. That is the essence of an educated person.

But in today's understanding "transfer" will not take place if these subjects are taught independently of each other [g]. Since transfer will only occur to the extent we expect it to occur, the curriculum has to show how it can occur in what might be best described as interdisciplinary or trans-disciplinary situations. The failure to approach study in this way is the reason why a general education that comprises the study of a number of independently organized subjects is not liberal. It is the reason why in subject specialisms like engineering so many students are unable to combine knowledge from the sub-disciplines to solve complex problems. Taught in a way that overcomes this problem, that is, in a spirit of universality, engineering is as much a liberal study as any other [h]. Any detailed analysis of the activity (process) of engineering will demonstrate that this is so.

(a) Newman, J. H (1852/1858). *The Idea of a University Defined and Illustrated*. 1923 impression. London. Longmans Green. Pp 124 – 150

(b) *ibid* p 138.

(c) Newman, J. H (1890). *Fifteen Sermons Preached before the University of Oxford.* 3rd ed. London. Rivingtons. P287.

(d) *ibid.*

(e) Saupe, J. L. (1961) in P. Dressel (ed). *Evaluation in Higher Education*. Boston. Houghton Mifflin.

(f) *loc, cit*. ref (a) p 166.

(g) Transfer is related to critical/reflective thinking. See Heywood, J. (2000) *Assessment in Higher education. Student Learning, Teaching, Programmes and Institutions.* London. Jessica Kingsley. Section on critical thinking movement in higher education pp 177- 181 and 187 – 191.

(h) The argument was set out differently and in a little more detail in Heywood, J (2010) Engineering Literacy. A component of liberal education. Proceedings Annual Conference of the American Society for Engineering Education. Paper 1505.

Appendix C.

The programme instruction in the language of physics developed for a physics for arts students course by H. Monatagu Pollock.

"The first programmed manual followed the traditional pattern for programmed manuals in that (a) the items were relatively short, (b) they were presented on one side of the book form only, and (c) the page size was A5. The programme itself was of the branching type. The number of topics included in it was rather more than was customary for programmes of similar length. Included in the programme were single examples (for the solution of the items in the list below.

Algebraic symbols	Proportionality
Observations and unknowns	Formulae
Constants and variables	Re-arranging an equation
	Graphs: plotting and interpretation. Purpose of graphs.
Suffixes	
Plus or minus	
Multiplication, Division	Interpolation and extrapolation
Indices	Asymptotes
Zero and Infinity	Slope of a graph
Approximation	Straight line graphs.

The programme was completed in 85 pages. As a result of the first trial it was modified both in content and presentation and used in this modified form in the two following years. It was presented on A4 size paper and the items were generally longer than those included in typical linear programmes".

A Codicil to Whither engineering and technological Literacy? *Cui Bono* 2.

A new perspective of technological and engineering literacy is needed

– Prof. Carl O. Hilgarth

As this paper was in preparation, the author offered us the opportunity for a codicil to give some added perspectives on "Cui bono," i.e.: to whose benefit is engineering and technological literacy? The process leading to this appendix began in 2017 at the ASEE Annual Meeting and Exposition with intense discussion that continued through continued through the 2019 ASEE Annual Meeting and Exposition on clarifying and amplifying the definition of engineering and technological literacy and how it can be extended to the common good.

From the many papers published in ASEE conference proceedings the expressed need has been to create among others, a knowledgeable and informed student, parent, public, policy maker, politician, investor, elected official, and corporate leader; an initiative driven by focusing on the importance of individuals facing daily technological and engineering literacy problems, and needing to make knowledgeable decisions. The general approach to achieve this goal was to develop technology components for K-12 education and incorporating technological and engineering literacy. The success of these initiatives was supported by statistics and data reported in studies conducted by academia, government agencies, and professional societies.

However during the 2019 ASEE Annual Meeting and Exposition, several sessions, panels, and special presentations put forward that there are other components to technological and engineering literacy. Having now moved a period of time away from the discussion to gain a perspective, in retrospect, it turns out, that technological and engineering literacy is being conducted in a traditional academic context and administered much in the manner of a general education course; that is to have broad appeal, to be non-threatening to students (especially with respect to grade point average outcome), and be a function of the faculty's area of expertise and a function of the audience to whom the course or program is directed. As these discussions added several unto fore unconsidered (and seemingly unrelated) dimensions to the discussion suggesting a necessity for a broader understanding of this topic than previously thought, and that perhaps historical industrial, cultural, educational, and political perspectives have constrained our thinking, definitions, and philosophies of technological and engineering literacy.

Thus, a reevaluation of what technological and engineering literacy is, and a rethinking of curriculum focus to better suit a society and generation that is now more than ever dependent on technology and engineering, but who on the other hand, exhibit a narrower knowledge and understanding of technology and engineering, is in order.

New structure(s) of higher education to help us live in a technologically dominated society

– Dr. John Krupczak

The structure of higher education to help us live in a technologically dominated society now demands a complete inversion of the philosophy of engineering education from the current emphasis on training engineers as specialists to the priority of educating everyone to have a broad and sophisticated understanding of technology. Engineering and technology have reached the point that everyone must have an understanding of these activities that determine the circumstances of our everyday lives.

This required change in higher education is historically rare and profound. It is not an overstatement to say the change needed is comparable to the change that accompanied the development of printing. With printing, the need for the ability to read and write became important for all educated people not just specialists trained in calligraphy. Similarly, at some point in history, knowledge of arithmetic became an imperative for all educated individuals not just an esoteric subset of society known as mathematicians. In the Middle Ages mathematics became one of the liberal arts taught in universities. We have reached a similar juncture with engineering and technology.

Current thinking about engineering education must be turned on its head. Or perhaps it is more accurate to say it is currently upside down and needs to be properly righted. Engineering education now has the goal of winnowing and funnelling a subset of society to become practitioners. The priority now is on developing the skills believed to be essential for engineers trained to enact the wishes of those who control the resources paying their salaries. This view of engineering education is not much different than the training used to produce the scribes that recorded information on clay tablets. It is an educational philosophy directed toward reproducing skilled cogs in the existing socioeconomic machine.

In these circumstances, K12 engineering, technological and engineering literacy are constrained to be mere projections and simplifications of the knowledge and skills of career engineering practitioners. These diluted exposures are not likely to be successful and several decades of technological literacy efforts point to similar conclusions.

What is needed is a flipping of the script in the philosophy of engineering education. The first question should be what should everyone know about engineering and the human-created world and how should this knowledge be acquired? The education of specialist technology producers should follow from this first priority rather than the current reversed perspective. This is comparable to saying the educational system should be structured so that a priority is for everyone to learn how to read and then the system attends to the production of specialist literary scholars. Both are needed. Everyone should have basic competence in reading and some skilled specialists in 19th century English literature are important as well. However our current approach in engineering and technology is on only producing the specialists.

It is not difficult to see how the current efforts at K-12 engineering and many views of engineering and technological literacy are simply spin-offs from the curriculum for specialists. K-12 engineering emphasizes design methodology, simplified engineering science, communication of results, and teaming. While all of these are useful these skills hardly begin to address the background and competencies needed to think critically about the state of affairs and directional trends in a technologically dominated world. The curriculum is really a type of down-skilled version of the current training for practitioners.

What would be the structure of higher education if the priorities were reversed? Understanding the technologically dominated world would be a priority for everyone and specialist practitioner training would follow after that goal. We currently can only envision fragments of what this might be because it is so foreign to what has been the habit of higher education for so long. Rather than unending homage to the design process and engineering science the curriculum might examine the critical analysis of the creation of the requirements and constraints that largely drive the outcome of the engineering design process. Who determines the requirements? What is the nature of design constraints? From where do the means of embodying these designs arise? What assumptions are embedded in the processes of manufacturing regarding resources of energy and materials? At the same time it is difficult to argue that specialist practitioners would not be well served in having this type of understanding of our human-created environment in addition to knowledge of Ohm’s law or how to run a finite element analysis in SolidWorks.

It has been said that the period from 2010 to 2020 was the decade that tech turned dystopian. Thanks to ubiquitous smartphones we are all tracked every moment of our lives, every click we make is stored and owned, and the patterns of lives available to anyone interested enough to pay. It has also been largely recognized that this is a self-inflicted circumstance. The dystopia evolved of our own free will through purchase decisions and voluntary actions, not unlike how many animals are trapped by willingly taking the bait. Ironically it is easier to see than ever before that our technologically dominated world is a joint creation of actions of all participants. So this leads to the recognition that everyone is an engineer. Everyone is a contributor, a creator of technology. Consequently our system of higher education should recognize this truth and engineering education has a responsibility to properly address this reality.

<u>The perspectives of a new technological literacy</u>

– Dr. Mani Mina

In this note I would like to address few issues that can be considered important items for the developments of technological literacy.

The ASEE Division and developments from the early days.

The development of Technological Literacy and the Technological Literacy division at ASEE was aligned with the developments that were led by National Academy of Engineers (NAE) with two iconic publications Technically Speaking and Tech Tally.

- Technically speaking: Why all Americans need to know more about technology (National Research Council. *Technically speaking: Why all Americans need to know more about technology*. National Academies Press, 2002.)
- Tech Tally: Approaches to Assessing Technological Literacy (Gamire E., Pearson G., editors. Tech tally: Approaches to assessing technological literacy. Island Press; 2006.)

This was followed by series of other publications that would engage with different aspects of technological literacy. While the idea for the division was more or less clear, the division attracted different faculty and educational groups that included the technology educators, a special group of engineering and science faculty who offered classes for non-engineer, and other patrons of technology and technological literacy who are in various fields such as history, philosophy etc.

During the early 2000's the group started to grow, and the diversity of the group began increasing. Eventually, the group focused on better understanding of what is technological literacy, engineering literacy and different philosophical dispositions that our members as educators had. After a long set of meetings, discussion, paper sessions, and intellectual discussion, the group decided to change the name to Technological and Engineering Literacy and Philosophy of Engineering (TELPhE).

The most important question was "Should we, as the group members, define a curriculum for university, college, high schools, and others?" We found out that there are several groups who are already doing this. In particular NAE had a series addressing what is technological literacy and what areas of interest could be used for this effort. One can find a set of publications from NAE on this subject.

During 2010-2018 the group focused on ways to define, expand, and identify possible connections and areas of growth for the division. Our publications and papers that were presented in national and international conferences are good examples of our efforts.

On several occasions due to the fact that we, as a group, identified with the philosophical engagements, we were ask to lead discussions and sessions for ASEE national conferences on controversial issues facing engineering education.

Current perspectives, where to go.

It is interesting that one of the most popular discussions in the last half of a decade "the 21st century skills" includes technological literacy as one of the skills. In addition, some of the items that are part of the technological literacy such as critical thinking is also one of the skills. This opens another avenue for the growth of technological and engineering literacy which engaged our effort with a newly developing and expanding platform.

The 21st Century Skills:

1. Critical thinking
2. Creativity
3. Collaboration
4. Communication
5. Information literacy
6. Media literacy
7. Technology literacy
8. Flexibility
9. Leadership
10. Initiative
11. Productivity
12. Social skills

Looking at the two items that this discussion is based on, one can see that there is a need for developments of possible curricula that can address the important items at different levels from K-12, to university, to professional development. The question is who should take the lead, and how they should identify partners and meaningful engagements with different perspectives. This is the most important challenge. The TELPhE division should lead this. However, this needs effective engagement with national and international partners. This is the challenge of 2020's.