Engineering Educators Bringing the World Together
2025 ASEE Annual Conference & Exposition
Palais des congrès de Montréal, Montréal, QC • June 22–25, 2025
Paper ID #45493

The Role of TELPhE in the Education of Citizens and Engineers considered from an Historical Perspective within ASEE

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Abstract

The absence of any major report on engineering education in recent years coupled with the fragmentation of the society into divisions has covered up the possibility that there may have been significant developments that impinge on the findings of the major reports that began with the Mann Report of 1918. Using the 2021 Whitepaper of the Technological and Engineering Literacy/Philosophy Division (hereinafter referred to as TELPhE) as its anchor it is argued that the whitepaper is in a tradition of humanistic studies begun in the Mann report and followed through in subsequent reports, in particular the Hammond, and Walker reports. It is argued that If among its future activities TELPhE seeks to develop a programme for "technological citizenship" it will necessarily provide an alternative programme of general education that embraces engineering and technology. In so doing it will fulfil Walker's vision, although somewhat differently, that given the importance of technology to modern society, this change would allow engineering to become the 'liberal arts degree' of the twenty-first century"*.

The starting point of the paper is Bruce Seely's characterization of the history of engineering education as "reinventing the wheel", a view that is supported by British studies. Seely lists a number of questions that seem to be timeless including questions about the educational needs of citizens for the future.

The origins of TELPhE in workshops of the National Academy of Engineering and its' subsequent activities are summarised in the Whitepaper of 2021. It showed that while the Division has had success in developing courses for non-STEM undergraduates, and in developing a research base to support efforts to improve technological literacy in the United States, it has also been faced with several difficulties. First among them, is the question of what technological literacy is. The pace of technological change since the division was founded has been tremendous, bringing with it all sorts of new but relevant issues which are reflected in the contributions received and published. Second, in the range of knowledge contained in those contributions. Third, are the conflicts that such diversity creates. Of particular importance is the criticism that engineering students are technologically illiterate, a view that has not permeated ASEE more generally, which might be put down to the fractionalization of ASEE.

While it is suggested that the Division should focus on education for technological citizenship it is not suggested that any of its other activities should be discouraged.

*cited from Bruce Seely

Introduction

Recent studies in the UK [1] and US [2] show that some problems of engineering education re-appear as if they have never been considered before. Although the circumstances may have changed, they are sufficiently similar for Bruce Seely to have characterized the history of engineering education as "reinventing the wheel" [3]]. Alan Cheville thought the periodicity was of the order of a decade. He cited a statement in the 2018 National Academy of Engineering report *on Understanding the Educational and Career Pathways of Engineers* that was more or less identical with the conclusion of the 1918 Mann study of engineering education for the Society for the Promotion of Engineering Education (later ASEE) and its' associate institutions [4]. A British historian P. L. Robertson writing of the shipbuilding and engineering industries in the nineteenth century repeated complaints that the quality of apprenticeships was poor and should be supported by technical education [5]. "For over fifty years each new generation found the same conditions proposed the same broad remedies and cited much the same reasons for failure; and each time their remarks were greeted as original and salutary". Similar criticisms of apprenticeships of all levels were being made in 2023 [6]. They were similar in many respects to criticisms made in 1965 of the functioning of an act of 1964 that made training compulsory [7]. David Edgerton noted that British historians concerned with the decline of Britain as an industrial power seemed not to be aware of continuity in their arguments and used Robertson's example to make his point [8]. There had, he said, been a "disinvention of tradition" by these historians.

Seely lists some of the topics that appear to be timeless -Questions of what to include in tight curricula; how long should engineering education last? How much specialisation should there be at the undergraduate level? How should students be prepared for careers that include both technical and managerial tracks? How should students be selected? How should the needs of, and expectations of society be met? [9]. To which we might add How should students be assessed?

In both Britain and the United States, the view taken of the curriculum is of a list of content that has to presented to the student. Given the developments in engineering, it should not be surprising that there are long running debates about what to leave in and what to leave out. Disputes about the broader dimensions of engineering such as management persist, as they do in the US [10]. The term 'professional studies' is sometimes used to describe this group of teaching activities.

The 1918 Mann Report offered answers to many of these questions: Mann had triggered psychometric research in the areas of selection and assessment. In particular the report challenged the notion of the curriculum as a set of syllabuses pointing out that across the engineering schools in America there are substantial variations within the syllabuses of a particular topic, as for example, mechanics. It proposed the use an 'outcomes' approach to assess abilities rather than knowledge.

Perhaps the most significant part of the report is its attempt to reconcile theory with practice, to state the positive value of practice and to see a partial solution in cooperative education. It was not until 1944 in the UK that a debate began about the value of cooperative education (called sandwich courses) leading to substantial research and development.

Similar discussions relating to its recommendation for a general curriculum to be followed by specialization arose with the 1968 ASEE Goals of Engineering Education report. The theory-practice debate continues.

Questions about the needs and expectations of society come within the domain of general education (sometimes called liberal studies). While there is a long tradition in the US of compulsory general education for engineers, there is no such tradition in the UK. For a period of about seven years in the 1950's and 1960's so-called liberal studies (general education) were compulsory for all students pursuing degree equivalent diplomas in technology in

Colleges of Advanced Technology. This note is included because liberal studies were the subject of much evaluative research and philosophical discussion that remains relevant [11]. Like the engineering education in the US liberal studies in the US has been the subject of several debates, major reports and changes. The creation of the Technological Literacy Division may be regarded as a development within the frame of general education, or humanistic education as it came to be known in SPEE/ ASEE.

The purpose of this discussion is to argue that as technological literacy has developed it has shown that it can perform a basic societal need for the development of citizens who are personally fulfilled, and technologically and socially literate, the parameters of technological citizenship. At the same time, it has created a number of issues that have yet to be resolved relating to the numerous avenues it pursues and could pursue.

To begin at the beginning is to begin with the 1918 Mann Report on Engineering Education which was the first in a series of reports initiated by SPEE

The Mann Report

The Committee of Engineering Institutions convened by SPEE began its work in 1907 and received a grant from the Carnegie Foundation in 1908 to support Professor Mann in the wholetime study of the effectiveness of engineering education as it had developed in the previous fifty years [12].

In its introduction to the report which was published 1918 the Committee wrote "The history of the origin and development of the (engineering) schools is concisely told, and the connection between curriculum and changing demands of industrial activities is clearly narrated". The Committee would have been satisfied with that as a result but Mann went much further causing the Committee to write that a **"**significant characteristic of the report is the general failure to recognise such factors as 'values and cost' the importance of teaching technical subjects so as to develop character, the necessity for laboratory and industrial training throughout the courses, and the use of good English"

The Committee were very concerned about the large drop-out rates, congestion of the curricula, broader training in the fundamentals of science "as an equipment for all engineers and forming a sort of 'common core' to every curriculum" all of which were addressed in the report and supported by research.

Historically the report is of great importance first, because it showed the value of educational research and different techniques for its accomplishment that were then available. Second it showed the need for teacher training (exhibit 1). Third, it showed that alternative curriculum could be devised, and in its examples showed the possibility of what is now called curriculum development, and the need for the curriculum to have a philosophical basis. It also indicated the possibility of problem and project-based learning [exhibit 2] Fourth, that there are alternative techniques of teaching that in some circumstances are preferable. His illustration of an alternative approach to the teaching of English for the purpose of developing what is now called critical thinking will be described in the next section.

"Mann wrote that a series of questions about educational aims, methods and practices which he personally presented to faculties at seven schools he visited "proved highly unpopular". 88 per cent of the professors spent no time in increasing their understanding of educational methods. He argued that if serious progress was to be made then the study of education required much more attention, and while taking into account the many factors that militated against this, he also argued that "the inability of teachers to carry conviction as to the merits of teaching and the meaning of experiments in education is one of the chief reasons why teaching fails to receive the recognition accorded to research". In 1918 performance was beginning to be measured by the published results of research. "The line of progress in education does not lie in making arbitrary distinctions between research and teaching, but rather in the direction of removing the limitations placed upon the spirit of enquiry so as to encourage its expansion to education and human relations generally", (which, it might be argued, anticipated the thesis of K. Patricia Cross put 68 years later that teaching will only become respectable in higher education when teachers treat their schoolrooms as laboratories for research*). Even if it did not have this in mind the Mann Report contains a powerful case for research and development in engineering education especially in assessment and test construction, curriculum and pedagogy, and training for teaching. To achieving these goals schools of engineering might "consider seriously cooperation with departments of education in the professional training of teachers of applied science and in the scientific study of their teaching problems".

Exhibit 1. On teaching and educational research in the Mann Report. * Cross, K. P (1986). A proposal to improve teaching or 'what taking teaching seriously should mean. *AAHE Bulletin* 9 -14. (American Association for Higher Education)

Mann describes a freshman course at the University of Cincinnati organized by Professor H. M. Goettech. For sixteen weeks students follow a course of training similar to that ordinarily given in courses in elementary chemistry then during the next ten weeks they spend all day (8 am to 4.30 pm) for ten weeks "solving problems of industrial chemistry. Projects such as 'Make baking powder and determine whether it is better and cheaper than you can buy' are assigned without any instructions or references, and the student is required to work out his own salvation in the library and the laboratory. In the period of ten-weeks he completes a number of these projects covering a wide range of of topics, but little effort is made to present the topics in logical or any other sort of orderly sequence. Much emphasis is placed on synthetic work on the cost of a given product by different processes; while chemical analysis and ionic theories of matter, which usually occupy the centre of the stage in chemistry courses, here take a subordinate place. The course in mechanics devised by Professor C. C. More at the University of Washington is another example of this type or reorganization of content in which the logical sequence of topics is subordinated to project work, and theory evolved from rather than illustrated by problems and experiments" […]

[…] "although the suggestion that an effective course can be constructed as a series of apparently disconnected projects comes as a shock to those who have grown up with logically rigorous courses, the value of the enthusiasm engendered by well-chosen projects must not be overlooked. Our most valuable information and training come from working out projects that are really worthwhile; and if this method works in life, why not in school? Especially since in educational institutions it is always possible to organize significant projects into connected series that leaves a well-developed conception of the whole subject in the student's mind. This has been accomplished in the courses just mentioned, where the summing up is done after sufficient facts to warrant summaries have been secured" […]

Exhibit 2 Mann's illustrations of courses based on projects. The term 'project' evidently relates to short investigations of a few hours and not to large projects. Forty year later such short projects were described the UK's Joint Matriculation Board (JMB) as Experimental Investigation. (*Notes for the Guidance of Schools on Engineering Science at the Advanced Level (1973*). Manchester, JMB)

Mann's fundamental proposition was that the curriculum approach that put theory first and practice second was the wrong way round. Practice should lead to theory. Whether or not he was aware that in this reversal of traditional assumptions he was making a philosophical statement is unclear. It was not until the 1950's that a Scottish philosopher John Macmurray contended that all "theoretical activities have their origins, at least, in his (man's) practical requirements" [13]. More than half a century later Alan Cheville was to show how Macmurray's philosophy of the personal leads to a philosophy of engineering and engineering education [14]. But, throughout the hundred years between Mann and Cheville engineering educators have followed the western tradition and given primacy to theory. The theory-practice debate goes on.

Mann's reasoning derived in part from his understanding that among the most common complaints of employers was the view that "college graduates have serious difficulty in applying theory to practice" which would be overcome by emphasising the "interrelation between the concrete and the abstract throughout the courses" (p88). It is clear that this kind of thinking contributed to his advocacy of cooperative courses.

His analysis of the curriculum into discrete and isolated courses that allowed of no interconnection led him to the same view (exhibit 3). A generation later Richard Culver in several papers at ASEE conferences was pointing out that the same defect could be remedied by a course design based on Perry's model of intellectual development [15].

Mann understood that a curriculum that met his various requirements would be difficult to design but he considered that four types of work would be included in such a curriculum. These were 1. An integrated industrial experience which he thought should begin at the beginning of the freshmen year (a finding supported by research in the UK forty years later). 2. Engineering laboratory work, including drawing and descriptive geometry. 3. Mathematics and science, which should be developed systematically in logical order so as to furnish the backbone of the course. He envisaged that the sequence of laboratory projects would be arranged with the same logic in mind. Fourth Humanistic studies which he felt was the field "that offered the greatest opportunity for effective changes in current practice, because lack of good English, of business sense, and of understanding men are most frequently cited by practising engineers as points of weakness in the graduates of the schools"

This view was supported by a substantial research project conducted in collaboration with a distinguished psychologist Professor Thorndike.

> "The real purpose for which engineering schools were established is to increase industrial production, because the ultimate aim of engineering is more intelligent production. But every production project requires the coordination and adjustment of three factors, namely scientific theory, mechanical practice, and cost. A theoretically perfect machine that cannot be built is no more useless than one that costs so much that no one is willing to buy it. Success in engineering comes to him who most often judges soundly concerning the best adjustment of these three complex factors" (p91) […],
>
> "It is customary in designing curricula to keep these three essential phases of engineering distinct from one another and to teach them as independent units, leaving their synthesis into well-organized mental processes to the student's own efforts. This practice is so widespread that its validity is naively accepted as a matter of course, and few seem to suspect that it may be connected in any way with the year or two of floundering thru which most graduates pass after leaving college and before finding themselves. Universal experience, on the other hand, seems to indicate that the most effective way of learning is by doing; so that if engineering depends ultimately on power to interrelate theory and practice and costs, a training that requires the student frequently to interrelate these three fundamental factors is likely to yield a better product than is secured from a training that largely ignores their interdependence" (p91).

Exhibit 3. Extracts from the Mann report relating to education and the relationship between theory and practice.

1500 engineers were asked to respond in writing to the question, "What are the most important factors in determining probable success or failure in engineering?"

The respondents mentioned personal qualities (subsequently called 'character') seven times as frequently as engineering science and the technique of practice. A six-point list of qualities was drawn up and in a second investigation over 7, 000 engineers ranked them in order. They were Character, Judgment, Efficiency, Understanding of Men, Knowledge and Technique. Character came top of the leaderboard "by a majority of 94.5%, while Technique was voted to the bottom by an equally decisive majority".

Mann wrote, "Schools that intend to train engineers cannot afford to neglect wholly the personalities of students. While it is obvious that personal traits like integrity, initiative, and common sense cannot be taught didactically like the rule of three, it is no less obvious that the growth of these essential characteristics in students may be either fostered and encouraged or inhibited and discouraged by the manner in which the school is organised and the subject matter presented". In hindsight he anticipated the findings of organisational research made in the early 1960's, and research in higher education that continues to demonstrate a positive relationship between outcomes and the interrelationships between academics and students and between themselves which depend greatly on organizational structure [16].

Patterns in the general education for engineers.

The following is a brief summary of some the comments relating to the general education of engineers in Bruce Seely's paper {17] that accompanied *Educating the Engineer of 2020* [18]. Seely's first point is that in the last quarter of the nineteenth century engineers did not feel they were respected. They were conscious of "their lack of social position". During this period engineering was one of several professions that believed that the improvement of the nation depended on scientific knowledge and that those who possessed it "should be given political and moral authority, as well as social status that comes with authority". University education would provide that expertise.

In the UK the first engineering society had restricted entry and subsequently the building of the Institution of Civil Engineers had the aura of a gentlemen's club [19]. But there was a continuing debate in Britain between those who fostered the notion of liberal education and those who promoted education as a utilitarian activity, in particular the Scots. Liberal education was associated with the Oxbridge Colleges and seen as an education for gentlemen. Whether or not that idea crossed the Atlantic is not a problem with which this study can engage but Seely makes it clear that in the US around 1900, "a professional was expected, almost by definition, to be a 'gentleman' a term that assumed a well-rounded education". Required studies in the liberal arts would achieve this goal. This notion came to be built into the curriculum. Those supporting the idea arguing on the one hand that it would "smooth the rough edges of engineering students" and on the other hand that certain courses would be valuable for careers". Arguments for the "special value of everything from foreign languages to literature, political science to philosophy" were given. Thus, some form of general education (liberal study) came to be built into the engineering program and compete for syllabus space. In contrast, in England it was believed that attendance at a university knocked the edges off a person and the idea that engineering students in universities should receive a component of liberal education was not a matter for discussion until the mid-1960's when the Council of Engineering Institutions incorporated a compulsory examination in the "Engineer and Society" which could be achieved by a single course [20]. But in the United States although it remained a major component of the curriculum it changed its emphases at times during the 150 years that followed.

Seely writes that these early discussions focused on three areas. 1. Technical writing, with some institutions requiring compulsory courses in this topic. 2. Economics in order for the products to be better designers and to understand the "calculus of profit and loss". 3. History – especially the history of science and engineering for which two reasons were advanced (i) it would provide role models and (ii) knowledge of the accomplishments of technology would show the public why engineers should be leaders in society (see last paragraph of this section). In England in the 1960's such subjects were called tool/fringe subjects since they were closely related to engineering [21]. As Seely writes, they were the "non-technical side of engineering", and throughout the twentieth century arguments were made for the broadening of engineering education, and he cites the 1927 Wickenden report in this respect.

But before then the Mann had warned that there was a "serious danger of actually becoming to materialistic, thereby sacrificing powers of abstract thought and humanistic ideal on which real progress ultimately depends. Efficiency in the mastery of materials without humane intelligence to guide and control it is now recognized in all civilised countries as a curse" […] "every effort must be made to enforce the truth that mechanical efficiency, while essential to success, is servant not master" [22]. Mann thought that this offered opportunities to history and English by changing the content of their courses and the report illustrates this by reference to the program in English developed at MIT by Professor Frank Aydelotte, the second year of which, is described in detail in exhibits 4 and 5.

Questions about the functions of engineers (are still relevant and related to the question what is engineering (exhibit 4). They bear upon the controversies over what should be taught and the continuing debate about the relative merits of theory and practice. Indeed, a very substantial development in the philosophy of engineering that has implications for engineering education has taken place since 2007.

The conclusion of exhibit 5 is that skill in critical thinking and reflection cannot be developed in traditional courses and different approaches have to be taken, and that remains the case. Today, 100 plus years later complaints are still heard that university students *per se* do not receive adequate training in critical thinking and reflective practice. Unlike the engineering students in exhibits 4 and 5 there is no great enthusiasm among today's engineering students for such courses, and neither is there among their teachers. Mani Mina, a past Chairman of TELPhE who has developed courses in technological literacy reports that students are primarily concerned with exam grades and will do little other than concentrate on getting good grades. They do not see the relevance of programmes that do not conform to the norm [23].

“The work of the second term of the freshman year begins with class discussion of such questions as: What is the difference between a trade and a profession? What is the meaning of the professional spirit? What should be the position of the engineer in society in this new era of the manufacture of power – that of hired expert or that of leader and adviser? Is the function of the engineer to direct only the material forces of nature, or also human forces? Such questions readily arouse the interest of engineering students and bring on thoughtful discussion, in which different points of view are expressed by the students and debated with spirit. Essays by engineers are then assigned for reading, and after further discussion each student is asked to write out a statement of his own position on the mooted question. These themes are criticised in personal conferences in which faults are corrected by asking the writer first what he intended to say; and, second whether the sentence or phrase in question really says it, rather than by reference to formal rules of grammar and rhetoric. Those who have had experience with this work claim that once the habit of self-criticism from the point of view of the idea is established, the student makes astonishing progress in the ability to express himself clearly and independently; he gathers hints from all sources; and, in ways to complex for pedagogical analysis he is more likely to acquire such power over language as he is naturally fitted to possess, than by current formal methods. For the achievement of this complex end, the conventional instruction in technique is too crude and clumsy to be of more than incidental use”

Exhibit 4. First paragraph of a description of the second term of a freshman year course in English for engineers at MIT designed and delivered by Professor Frank Aydelotte (circa 1916) given in the Mann report p 64.

“Having discussed the question: What is engineering? The class proceeds in the same manner to wrestle with such problems as: What is the aim of engineering education? What is the relation between power of memory and power of thought? Is there any relationship between a liberal point of view and capacity for leadership? What qualities do practical engineers value most highly in technical graduates? What is the relation between pure science and applied? What is the relation of science to literature. The authors read in connection with the discussion generally change from engineers to scientists like Huxley and Tyndall and then to literary men like Arnold, Newman, Carlyle and Ruskin. The student seems to read this material with no less keen interest than was shown for the writings of engineers; so that thru his own written and oral discussion of masterly essays each comes to work out for himself some rational connection between engineering, with which he began, and literature, with which he ends. No orthodox point of view is prescribed; his own reason is the final authority. The aim is to raise questions which it may take half a lifetime to answer, but the thoughtful consideration of which will give a saner outlook on life and on his profession”

Exhibit 5. The second paragraph of a description of the second term of a freshman year course in English for engineers at MIT designed and delivered by Professor Frank Aydelotte (circa 1916) given in the Mann report p 64.

The idea that engineers should study the liberal arts comes again into the conversation with the publication of the Hammond Report on “*The Aims and Scope of Engineering Education”* (ASEE) in 1940 [24]. It was argued that because engineers engaged in work outside of technical decision-making study in the liberal arts was necessary. Seely notes that “Hammond coined the term ‘humanistic stem’ to characterize this aspect of engineering education, defining it as a parallel to a ’scientific stem of undergraduate coursework’ “.

Subsequently ASEE put in place a review of the humanistic strand and a curriculum was developed at Case Institute for Technology to produce the “best most broadly educated engineers in the country” [25]. In 1968 the Final report of the Committee on the Goals of Engineering endorsed the emphasis on liberal studies but as Seely comments the major endorsement came with the ABET Ec2000 requirements for course recognition [26]. At least half of the twelve competencies could be met through courses in the social sciences and humanities. However, Seely concludes “The discussions today, in fact deal with the same topics that were current more than a century ago” [27].

More generally Seely notes that a major impact on the humanistic curriculum has been the effect of social forces outside of academia. He wrote, “Attitudes and outlooks in American society were never static, however, and as expectations changed the efforts of engineering educators also changed. Adjustments appeared almost every decade most often in the humanistic stem. For example, during the 1920's the wave of technical changes symbolized by Henry Ford's assembly line had prompted a significant social interest in efficiency, as well as social acceptance of big business. Engineering schools therefore placed slightly less emphasis on cultural improvement for gentlemen and slightly more on preparing students for a business environment with accounting and management courses. The economic catastrophe of the Great depression and talk of technological unemployment, however, undermined some of the enthusiasm for technology and big corporations. As a defence measure of sorts, engineering curricula placed additional emphasis on economics and other courses that might help explain the depression" [28].

Seely gives other examples among them the effects of World War II and the cold war which "encouraged engineering schools to direct students' attention to the nature of government, above all the differences between democracy and totalitarianism against the siren song of communism, the humanist stem was significantly strengthened" [29].

This latter example is included for two reasons. First, its self-evident relevance to the world as it is being experienced today, and second because of pervasive intrusion into these debates by technology as it is used as a propaganda machine: and, as a consequence the need to produce citizens who are technologically literate. Whether or not ASEE understands this is an open question even though in response to discussions in the National Academy of Engineering it established a Division for Technological Literacy in 2007 [30].

Since then, there have been major developments in the technologies that support information delivery and communication between organisations as well as between individuals that have brought with them major problems for society and academia in relation to the conveyance of information that may be false or propaganda, and therefore, its control. They face the Technological Literacy Division, which had in 2014 taken the philosophy of engineering under its wing, with major problems, not least, the question of what it is. The debate which followed has revealed a substantial body of knowledge that follows different tracks. It is argued here that it leads to an alternative construct of a liberal arts curriculum.

Because of the structure of ASEE into Divisions the work of the Technological and Engineering Literacy and Philosophy of Engineering division (TELPhE) is largely unknown, and yet the social press suggests that it is where the next debate about humanistic studies in engineering should be. Since it has much to say about the curriculum and pedagogy it provides a natural follow up to the controversial 1968 Goals of Engineering Education Report [31]. It would necessarily involve a discussion of the role of engineering in liberal arts education rather than the role of the liberal arts in engineering education as E. A. Walker who chaired the 1968 Committee later envisaged

It is important, therefore, to understand how TELPhE came about and what it has achieved.

From Technological Literacy to TELPhE

The Whitepaper written by John Krupczak, Alan Cheville and the author [32] records that "in 2002 the National Academy of Engineering Committee on Technological Literacy published in association with the National Research Council "*Technically Speaking. Why all Americans Need to know More About Technology*" [33]. Its major recommendations were:

- “Strengthen the presence of technology in formal and informal education including K – 12 and the undergraduate education of non-STEM students.
- Develop the research base to support efforts to improve technological literacy in the United States.
- Increase informed decision making on technological issues.
- Reward teaching excellence and educational innovation”.

Underlying these recommendations was the view that “technological literacy is concerned with sophisticated and heterogeneous combination of “knowledge, ways of thinking and capabilities”.

This was followed up by a National Academy sponsored workshop on “*The Technological Literacy of Undergraduates. Identifying the Research Issues”* organized by John Krupczak and David Ollis [34]. It identified the need for an organization to serve as a focal point for technological literacy. To meet this need ASEE fostered a Constituent Committee for this purpose, and given its initial success ASEE formed a Division for Technological Literacy in 2008. Prior to the foundation of the Division Kathryn Neeley had argued in 2006 against the use of the term technological literacy “because ‘literacy’ implied remediation rather than the aspiration to create something that had never existed before: a well-informed citizenry with knowledge, motivation, and confidence to engage in purposeful deliberation about technology” [35]. As recently as 2023 Carl Hilgarth has suggested the name ‘Technological Literacy’ is problematic and should be reviewed [36].

In parallel with this development ASEE also founded a K -12 division which took care of the National Academy’s desire for the development of the topic in K -12. It has focused on “career opportunity awareness, the engineering design process, and engineering applications of science and mathematics”.

During this period TELPhE concerned itself with the second objective, that is to develop a research base to support efforts to improve technological literacy in the United States. Had both sides been aware of the Bruner’s model of the spiral curriculum a fruitful collaboration might have arisen between the two divisions [37]. Unfortunately work in the English system of public examinations which showed that concepts were open to different levels of understanding, in this case the concept of ‘system’, was not widely publicised in England [38].

In 2011 a significant paper by D. B. Moore who was in the College of Education at Ohio University went by unnoticed, not that he made any reference to the work of either of the ASEE divisions! In it he proposed that “technology literacy had three distinct levels, including, (1) identify technologies relevant to the task. (2) understanding how to use the technology and how to navigate its interface, and (3) understanding the inner-working or structure of technology”. He went on to argue “that one or more of these three ways of knowing are involved in almost every learning task” [..] therefore “technological literacy should not be thought of as an isolated set of skills but as an essential strategy for most learning objectives” [39]. An argument that would seem to support the view put forward several years later that technological literacy was not a subject but a competency (see below).

However, in the division matters became confused because “the term “engineering literacy” began to be used in various places as distinct from “technological literacy “that complicated the work of the Division since the term “technological literacy” was also used to refer to similar concepts”.

At the 2010 annual conference a paper from Ireland which was called “*Engineering literacy. A Component of Liberal Education*” the author (this writer) presented the model of technology shown in exhibit 6 with accompanying script [40]. To make matters worse the author used the terms technology and engineering interchangeably. Had he known of E. A. Walker’s views he might have written a different paper, but presented it to the Liberal Education Division since it provided a rationale for Walker’s view.

The net result was that a working group led by John Krupczak was asked to resolve the confusion. It suggested “that engineering literacy could be viewed as having a focus directed more toward the process (verb-action) of creating or designing technological artifacts or systems Technological literacy includes a broader view of the products (noun – object) or the various results of the engineering process as well as the relationship between technology and society”.The Whitepaper went on to say that “in light of later work, these definitions while helpful, are now recognized as incomplete” [41].

But in the media and publishing the terms engineering literacy and technological literacy were used synonymously and a change in the divisions name was deemed necessary. About the same time this writer had been promoting the philosophy of engineering education and given the success of two meetings on the topic at FIE (Frontiers in Education) conferences had obtained support from the ERM (Educational Research and Methods) division and the IEEE Education Society for a one-day workshop on ‘Exploring the Philosophies of Engineering and Engineering Education”. The first attempt failed but the National Science Foundation (NSF) intervened and enabled a one-day meeting prior to FIE 2011 [42]. It was also successful, and NSF’s Ms Kemnitzer considered that all engineers should develop or have a developed philosophy of engineering. Since ASEE did not cater for philosophy *per se* (it had an Ethics Division) it was thought that the Technological Literacy Division would be a suitable home. Accordingly in 2014, a proposal to the division that it should become involved in philosophy was accepted. At the same time the name was changed to the ‘Technological and Engineering literacy/Philosophy of Engineering Division’ or TELPhE.

An in-depth analysis of the papers presented at the 2016 annual conference of ASEE by Neeley showed that the philosophical dimension of the divisions remit had made a considerable impact [43]. She found that notwithstanding the differences between the papers that four consistent themes emerged from the papers which showed how the philosophical turn had manifested itself in technological literacy. She claimed that the first two were evident in the divisions discourse in 2006. These were:

1. The complementary goals of STS (Science, Technology and Society) and technological literacy.

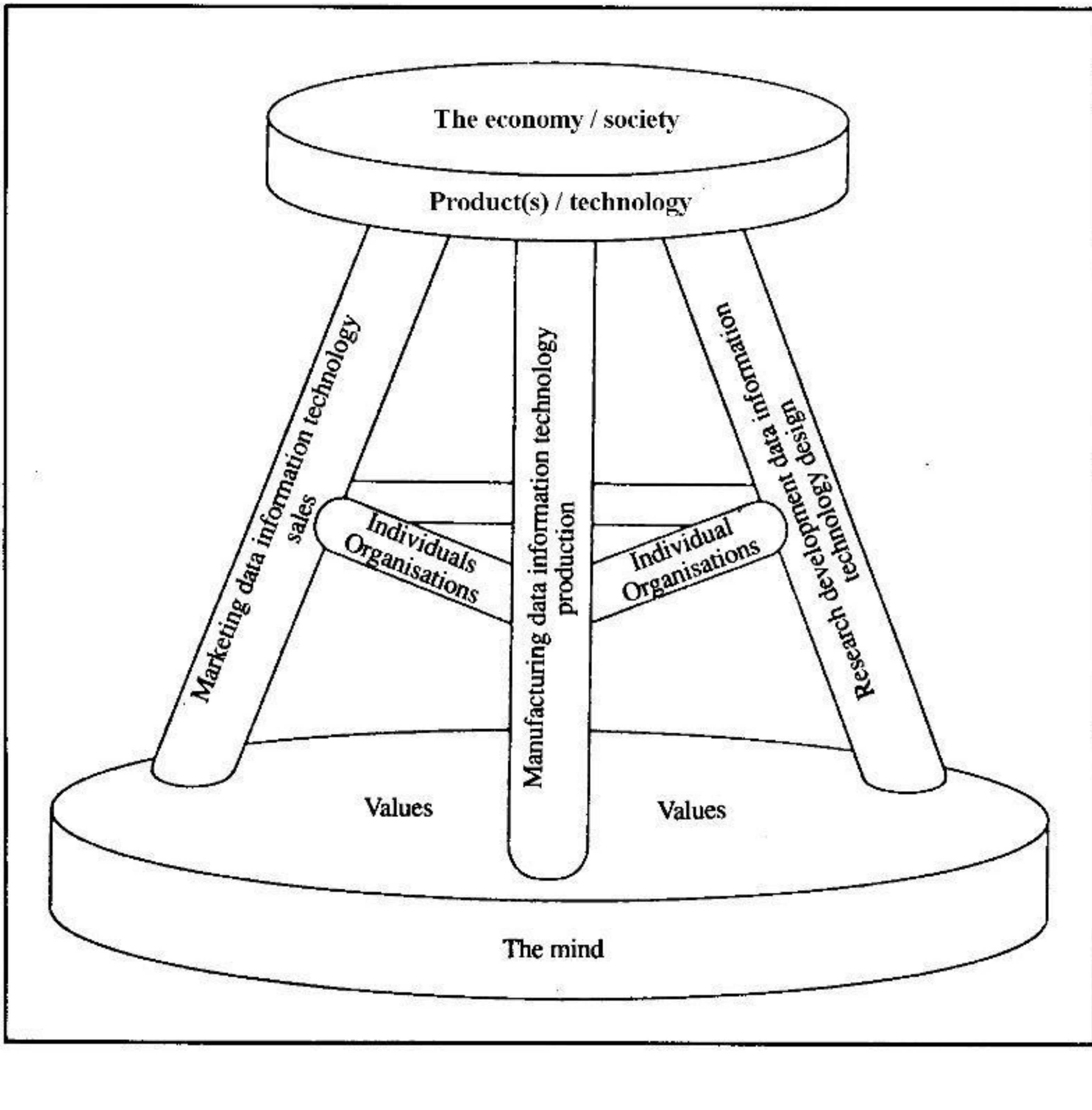
2. The connections among Technological Literacy, democratic deliberation, and communication about technology and engineering.

Neeley was of the opinion that the other two themes had emerged more recently.

3. The relevance of research in technological Literacy to engineering education research more generally.

Exhibit 6. A model of the way in which the various aspects of technology support the economy and Society as developed by John Heywood, Michael Murray and Glyn Price in 1985

Script that accompanied the diagram "The base represents the power of the human beings as represented by their minds. It is the mind which is the source of ideas and decisions. Information is passed from and to the mind along the legs and for convenience this flow is shown at the centre of each leg. The legs contain the technologies of action which support the economy and embrace society. The horizontal support which is attached to the technologies of action represents the binding forces brought about by the interaction between individuals and their organizations



4. The relevance of technological literacy for engineers as well as non-engineers.

The third was no doubt a reflection of the direction that ASEE was taking. The fourth, despite its significance, it seems not to have spread throughout the engineering divisions of ASEE which illustrates the general weakness of the division referred to more recently to get its work discussed outside itself; this is a reflection of the division of labour in ASEE which reflects the division of labour in engineering education *per se* [44].

It is this writer's opinion that the blitz of papers on philosophical issues during this period was problematic in that the other engineering and technological activities seemed to take a backward place for a time.

The 2021 White Paper contained an overview of TELPhE's activities.

Overview of the areas of TELPhE Effort

Before commenting on the main areas of activity the White Paper noted that the few studies that promoted a broader understanding of technology were characterised by a varied terminology and a cross over between engineering/technological literacy and science literacy. Indeed, the paper on radio astronomy was drawn from a course on Physics for Arts Students [45].

The areas of activity discussed in the White paper directed at the development of a research base and pedagogical approaches to improve the broad understanding of technology in the United States are listed in exhibit 7. It is also evident they reflect the complexity envisaged in the National Academies report which said that "technological literacy is concerned with (the) sophisticated and heterogeneous combination of "knowledge, ways of thinking and capabilities".

1. Personal empowerment with respect to hardware.
2. Responsible citizenship.
3 Engineering literacy for engineers.
4 Engineering as a missing element of General Education
5 Engineering Minor
6 Course Development
   Survey courses
   Technology focus courses
   Engineering design for everyone
   Technological impacts. Assessment and history course.

Exhibit 7. Areas of activity directed at establishing a research base and pedagogies

Despite this activity the Whitepaper suggests that of all the work anticipated by the National Academy's paper the "broad understanding of technology" remains a challenge. The Whitepaper made a number of recommendations the headings of which are given in exhibit 8.

In retrospect, the surprising thing about the Whitepaper is that while it was strongly influenced by Goldman's paper "*Why we need a philosophy of engineering. A work in progress*" [46] it makes no reference to Billy Vaughan Koen's study of the engineering method [47] both having an important bearing on items 1 and 3. But the really surprising omission was any discussion of Neeley's 2017 paper which apart from anything else showed the importance of philosophy in engineering education. However, it is this writer's opinion that her championing of Frankenfield's idea of "Technological Citizenship" which if adopted might solve many of the difficulties currently involved in understanding what technological literacy is. Moreover, it shows why engineers do not necessarily meet the requirements for technological citizenship and justifies the work of Krupczak and Mina [48].

1. Emphasize informed decision making on technological issues.
2. Address "technological misunderstandings"
3. Advance understanding of necessary versus contingent.
4. Create case studies.
5. Develop new dissemination approaches.
6. Study models of technological decision making.
7. Develop collaborations and partnerships.

Exhibit 8. Headings covering proposals for future work by TELPhE.

Frankenfeld defined technological citizenship "as an ideal and emerging reality [that] covers environmental policy, technology assessment, risk ethics, democratic theory, informed consent, trust, technocracy, citizenship, integrational ethics and risk communication" [49].

It is not clear if this means a single course that integrates all these dimensions, or derivatives from already existing courses. Like Andrews in *Practicing Technological Citizenship* [50] there is no indication that the course would be other than knowledge/information based.

The Whitepaper takes a different approach. While acknowledging that many dimensions of knowledge are involved, to a large extent this complexity is resolved if technological literacy is considered to be a "framework for decision making", that is, a competency. "This competency encompasses technological and engineering literacy at some level. Technological competence is the skill that provides a technological way of viewing the world that enables individuals and groups to respond to and control the technological contingencies encountered in everyday life. The idea of technological judgement has also been suggested, and it can be linked to technological competence".

"The concepts of technological and engineering literacy are not a specific course or even a series of course. There is no coherent subject that should be called technological literacy because it relies on knowledge from a wide range of areas. Technological literacy requires bringing that knowledge together. Technological literacy can be thought of as a competency in dealing with technological problems at various levels. Solutions to technological problems are necessarily contingent. Technological literacy is necessarily dealing with contingency".

That engineering literacy should be treated similarly is made clear. Thus, the Whitepaper continues, following the constructs used by Goldman to distinguish between science and engineering.

"A central issue concerning technological literacy is the distinction between the necessary and the contingent. This distinction should be made clear. Engineering involves contingency and the ability to make contingent decisions, while science is reductionist and truth seeking, concerned primarily with defining what is necessarily true. An educational structure that is organized around reductionism and identification of what is true is not well aligned with developing abilities to make contingent decisions. Developing an ability to conduct contingent decision making is not well supported by the traditional western system of education. Some aspects of contingent decision making involving a technological component only minimally involve engineering but are essentially the management of technology and the scale of the technology systems".

Curriculum requirements for technological citizenship

From the foregoing it may be deduced that technological citizenship requires individuals to be both engineering and technologically literate at some level. It also requires them to be both problem solvers and decision makers, and in such activities, they have to engage in critical thinking, or reflective practice as it is sometimes known. Since they can be learnt an understanding of the factors that contribute to our learning, then learning-how-to-learn should be included in the base of the stool in exhibit 6. This argument has been developed previously in more detail in respect of the need to understand how we learn in order to control technology[51]. Also missing from that diagram is "design" for conversion of a design into an artefact or an operational idea that can be used is the function of engineering. Design and learning are intimately related as are their epistemologies as Harvard psychologist has shown in his book *Knowledge as Design* [52]. Commonly 'Design and Technology' Courses are included in K – 12 programmes across the world.

Likewise, Frankenfield's ideal of technological citizenship is not covered adequately by the diagram. Key concepts like those he listed should be placed on the seat of the stool. Among them will be citizenship and control. Several of his key concepts relate to the application of ethics, (represented by values in the base of the model), he also includes 'risk' but there are other key concepts that relate to the evaluation of technology in terms of exercising control over it, as for example learning, prejudice, cognitive dissonance, deception and perception [53].

The publications accepted by the division over the years refer to many of these constructs. Revision of the stool diagram shows that the development of critical thinking required for technological citizenship requires an understanding of many areas of knowledge and modes of thinking. The fundamental question for curriculum developers is, how can all that be achieved? If the items are attached to the traditional subjects with which they are associated and these are expected to be learnt the student will be considerably over burdened. At the same time that student would have received a general education, but being information based that student would have received nothing that would help him with contingent thinking in a complex situation from which a variety of knowledges were required for the solution of a problem

Mann was apparently aware of this (but not the terminology) in 1918. It was observed above that Mann believed that courses that were given independently from each other did not help develop what might be called an engineering mind set. He believed that theory should be derived from practice: therefore, courses should begin with the practical. The basis of practice would be a project: moreover, a curriculum could be designed from a number of carefully conceived projects/problems. Such projects/problems would be interdisciplinary or transdisciplinary. Given the quantity of information available it would be necessary to design inter or transdisciplinary background courses, some blended for group delivery [54], and others arranged for self- study. The ability to work out one's learning needs and to provide a course for self-study is likely to become more important as job changes and changes within jobs require shifts from cognate (with one's prior learning) to non-cognate in a different area of knowledge and experience. Working in the contingent will necessitate an ability to think in different modes, and therefore understand how people with different backgrounds and thinking, as for example an engineer's way of thinking about a failure compared with a lawyer's.

While this approach is based on an alternative conceptualisation of general education it is not quite as Walker envisaged it: but its goal is similar, and one of the project/problem-based areas would be in engineering design and technology. Bringing a design to reality requires an understanding of one's own philosophical position, how design is a social activity, how human behaviour influences decision making and interpersonal relationship {55]. Such understanding is of the essence of a liberal education, and as such it represents another step in ASEE's development of humanistic studies that is closely allied to the needs of citizens.

And TELPhE

The Whitepaper indicates but does not list the vast number of contributions that have been made during the last twenty years. Inspection of some them reveals a data base of theory and practice that could be used in the curriculum development of programmes for technological citizenship. But much more is required.

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