Cui Bono. Engineering and Technological Literacy and Higher Education

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Abstract

During the last five years the TELPhE Division of ASEE been engaging in constructive dialogue with its members about its purposes and intents. In 2016 the author presented a paper at ASEE's annual conference that raised questions about the intent of technological literacy in society at the present time. To further encourage dialog the Division invited its membership to submit short responses to the issues raised in the paper with a view to publishing them in one of the Divisions handbooks. These were published in 2017. The publication of the responses serves no useful purpose unless they are scrutinised by the author who caused the responses for in this way ideas are sharpened and refined. The paper reflects the non-linear process of the rhetoric of dialog. It is presented as contribution to the dialogue the Division began when in 2018 it initiated proceedings to produce a White paper on the purpose and future of the Division.

It is evident that there are a number of audiences to be met. There is a public audience and an engineering audience particularly of students. The public is not a homogenous group but has several different needs. These needs will only be met by alternative approaches to technological literacy designed to meet different levels of understanding. Most of the courses offered in technological literacy (not to be confused with Science, Technology and Society STS) are electives, but the essay by Keilsen suggests an alternative curriculum for general education programmes.

The implications of this review are that the general aims or purposes of programmes in engineering and technological literacy are far from clear. The one that comes through in the essays is the ability to control or change technology. Since, whatever is looked at in this area shows different benefits for users and vendors, the question arises, *Cui Bono*? This implies that aims will have to be considered within the framework of the common good.

The essays show the need for clarification and amplification of the definitions of engineering and technological literacy, even if it means a revised unitary definition. In any event there is a need to take into account the different audiences and perspectives

Notwithstanding the issue of finance, or indicators of issues for research raised by this study, as for example, levels of required mathematical attainment, Krupczak shows there is plenty of research to be done in this area that is not being done and should be done

Introduction

The idea of technological literacy as a subject that should be taught belongs to the United States although discussion of the concept it is to be found in papers originating outside of the United States. Technological literacy is proposed in addition to science literacy which, as Krawitz points out, is well established in the United States. More recently discussions in the Technological Literacy Division of the American Society for Engineering Education have led to the complementary promotion of the idea of engineering literacy. Technology considered to be the product that results from the process of engineering. Unfortunately, there is little agreement on what concepts and practices should be taught, or to whom they should be taught, or indeed the definitions themselves. Hence the symposium that is the subject of this commentary [1]. *Cui Bono* engineering and technological literacy?

Krawitz's wrote in response to the anchoring article that part of " 'liberal education' beyond the student's major is delivered through the General Education portion of the curriculum, a series of elective courses with a wide range of subject areas: Social Science, Science, English, Humanities etc. Thus engineers must take Humanities/Social Science and humanists must take some Math and Science, but not Technology". But this presupposes that engineers are technologically literate, a proposition that Mani Mina challenges. Krawitz understands that what is proposed by the division is the "placing of technological literacy into the mix, not as a curriculum, not as a major, not as a department, but as a course, an elective course in most cases".

A major problem for many members of the Division is that Technological and Engineering Literacy have not taken off as subjects. Krupczak seeks to find out why this should be but ends up by listing questions that ought to be answered and research that might be done (see last section). Three of the contributions make it clear that the definitions while useful require modification or extension (Cheville, Drew and Trevelyan and Williams). However, one contribution enables consideration of the topic as a curriculum (Keilson).

Literacy and the common good

As long ago as 1963 Richmond in the UK devised a test to measure "academic culture" [2]. There was, he argued, a body of knowledge that resides among science and literary intellectuals with which educated people should be acquainted. Although its results were surprising, and perhaps worrying, it did not have the effect of Hirsch's *Cultural Literacy* which, published in 1987, is still cited [3].

The effect of Hirsch's comments on public policy is a matter of conjecture. But, some educational authorities in the western world began to take the view that there was a certain level of knowledge in the areas of language and number that every person should have attained by the time they had finished primary (elementary) school. In Britain and Ireland schools were required to devote a given period of time each week to literacy and numeracy. But, it cannot be said that the knowledge and skills required at the end of the programme were ever adequately debated as part of public discourse. Hot on these footsteps was the introduction of science literacy. If Hirsch's view that literacy is "information that is taken for granted in public discourse" then it can be applied to specific areas of knowledge such as engineering, technology and IT.

A cynic might take the view that the advocacy of science literacy arises from either a desire to increase the number of persons seeking employment in science, or the hope that such knowledge will cause individuals to support greater expenditure in these fields, and not, in the first instance for the personal good of an individual. It is by no means clear what "good" the advocates of engineering and technological literacy seek.

A more generous interpretation might be that in being good for the person it is also good for society (the common good) since the common good of society cannot be achieved without all members of that society being widely literate [4]. The promotion of any literacy, in the first place, has to focus on the good (or evil) that it brings to the person. Sheila Tobias a graduate in history and politics responded that she "had to discover for [herself] that politics and history were grounded in technological change. Even women's eventual emancipation was determined by technological […]. She went on to argue "technological literacy has to be grounded in the discipline of engineering. And until engineering educators let people like me "in" to how they think and what they think about…we will continue to vote wrong on issues that matter to the future of ourselves, our country and the planet." In this respect, Sychov of the ITMO University in St Petersburg, in the final contribution argues that one of the two purposes of liberal education is to provide "a possibility to make qualified political decisions (supportive or discouraging) that is necessary for society (liberal, democratic society and a state as a general idea) to be a well-functioning system". In this sense politicians who legislate should have a high level of technological literacy. This implies that technological literacy for the public has to function at different levels. He writes, "Technological literacy is one of the most fundamental competences in the modern world but if it is taken alone, without logical connections to the basic scientific concepts behind technology and without solid understanding of the ideas network in which this technology is embedded, it will suffer a shallow mental incorporation, weak psychological interiorisation and dysfunctioning practical implementation".

While it is self-evident that among any random group of individuals there will be different levels of understanding of engineering issues the literature hardly considers this to be problematic. There is one report of an examination that illustrates this point which is given in full in the appendix. Part of a trial in examination design, it tested for comprehension, engineering analysis, project design, and engineering reasoning. A difference in the knowledge required to comprehend and analyse the newspaper article that was provided is easily discerned in the questions asked.

Most of the commentaries however, do not focus on the fundamental purposes of engineering or technological literacy although Kielson focuses on second order learning aims. Siller is, however, quite specific. He argues that the purpose of promoting these literacies is "the development of a public that can influence more than the choice of competing technologies but also add purpose to them. This implies a closer partnership between technology and society". He argues that "most calls for technological literacy desire to have more people understand technology but not for the purpose of changing it".

The first task of a literacy

Tests of literacy seem to be tests of knowledge of recall. Apparently the wider the range of knowledge a person held, the better educated that person was supposed to be. Hirsch argued that without appropriate background knowledge people cannot adequately understand written or spoken language. If this is correct, then, the first task of any literacy is to extend that language. Clearly, how that is done is a major issue for curriculum design, and in so far as engineering and technological literacy are concerned, for many individuals, related to the use or not of mathematics. But beyond this first task Drew writes, "[..] shouldn't we want a students and others to acquire knowledge, not simply process information. This translates into being able to contextualise information". He then says, controversially, "they must go beyond understanding how a devise works to considering the implications for its use for society". What population is he considering? Is it engineering students who Mani Mina thinks are technologically illiterate, and is that what Mani means when he suggests they are technologically illiterate? There is after all no good reason why a person needs to know how things work if their impact on society is the issue.

Extending the definition of technological literacy 1.

This conversation suggests that if the term literacy is to be used there is a need to distinguish between levels of literacy as well as approaches to its teaching. This is illustrated by Drew who points out that the contextualisation of information requires critical thinking. Indeed Siller's goal requires critical thinking but is critical thinking a function of level? It is not intended to discuss this issue here, but the reader may be helped to consider this problem by the example in the Appendix in which part of a trial examination tests for different levels of understanding in relation to the comprehension of a newspaper article on a piece of technology.

But Drew goes on to suggest that a new term is required. Building on Krupczak's distinctions "we might differentiate consideration of the product (technological literacy), consideration of the process (engineering literacy), and 'contextual knowledge' or perhaps "technological judgement"." An alternative definition is offered by Trevelyan and Williams.

Extending the definition of technological literacy 2.

Perhaps writes Krupczak "support for engineering as part of general education would be more enthusiastic if engineering educators could better define the specific utility of everyone knowing something about engineering and technology". He does not state what this might be. Trevelyan and Williams in their paper do.

They suggest that entrepreneurship should be considered as a component of both technological and engineering literacy. This is to place these literacies rather more in the business frame than in the research frame which governs the curriculum of most engineering courses. Nevertheless they point to a growth in the number of engineering courses that incorporate some form of study of entrepreneurship. They argue that focus on the entrepreneurial business aspect of engineering necessarily causes questions about the value of engineering to be asked. They note that research on engineering practice shows that few engineers working for private firms can clearly explain the economic value arising from their work. It follows that if the elements of value in an engineer's task can be identified that the value of engineering literacy can begin to be described.

Trevelyan and Williams propose that value is added to and protected by engineers in the 10 ways shown in exhibit 1.

A third extension has been proposed by Cheville but this be more usefully considered in the light of Kielson's alternative curriculum.

Keilson's schema for STEM literacies: the case for STEAM

Suzanne Kielson proposes that looking at engineering and technological literacies from the perspective of learning aims eliminates the need to decide whether an item of knowledge belongs in the domain of engineering, science, or technology. What matters is the learning outcome (aim).

She identifies three learning aims for technological literacy that should be offered throughout undergraduate education. They are; Teaching for Citizenship; Teaching for Living Skills and Competencies: Teaching for Employment Competencies.

Teaching for citizenship "would involve ethics, politics and philosophy and ways in which technological developments can impinge upon and challenge our understanding of moral reasoning". For example, advances in medicine are an ever present reminder of this effect. Among other matters they raise important questions about the right to die. Kielsen argues that these decisions are not to be left to technocrats alone but for the average person to participate a knowledge of the parameters and technical constraints is required. For example, what is "on people's minds with the advent of self-driving cars is how to embed ethical and moral reasoning into the product. This challenging question requires understanding the limits of what is currently technically possible, as well as entering into conversation about the legal understandings of product and personal liability". These are different ways of thinking. Hence, the goal of liberal education that students should be exposed to different ways of thinking, and the idea in subject specialist systems of education such as that of the UK that university students studying science should do some kind of science and vice versa,

"1. Efficiencies
Engineers create value by seeking efficiencies, reducing the materials, energy, time and human effort needed to achieve a given result, reducing costs.
By providing accurate performance predictions, engineers can reduce the allowances to cover knowledge gaps and uncertainties known as design and safety factors. Reducing design and safety factors can lead to further significant savings in material, assembly and transport costs".
"2. Product differentiation
By designing products that improve buyer and end-user experience (product differentiation) engineers increase the use-value of products and services".
"3. Innovation
Engineers create value for enterprises by innovating: finding new ways to achieve a given result that is better in some way than other known ways".
"4. Performance prediction
Engineers provide sufficiently accurate technical and commercial enterprise performance predictions creating enough confidence for investors to provide the resources needed to make new products or provide new services".
"5. Due diligence
By systematically checking designs and plans beforehand, and monitoring technical work for compliance with standards and specifications, engineers reduce both the real and apparent risks for investors, increasing the perceived value of an enterprise".
"6. Community value creation
Engineers help enterprises co-create value in their communities through ethical behaviour, improved safety, community capacity building, identifying and conserving resources, reducing or eliminating detrimental environmental and social impacts, and remediating environmental damage. Developing the community that hosts an enterprise rewards both the enterprise and the community".
"7. Reliable coordination
Reliable coordination within an enterprise improves the likelihood that the predicted product or service performance and quality will be delivered on time, safely, within the predicted budget and with acceptable environmental and social impacts. By doing so, engineers increase the value of the enterprise by aligning intentions with actions sufficiently well for investors to earn reasonable returns".
Ways in which engineers protect existing value
"8 Maintenance
Often referred to as engineering asset management or sustainment, maintenance engineering is critical to protecting existing value embodied in engineering products, systems and business".
"9. Environmental protection
Engineers naturally endow value by conserving both the renewable and non-renewable resources of our planet, our home".
"10. Defence and security
Engineers provide many products and services that limit or prevent destructive behaviour by other people, thus protecting accumulated value represented by our society and its various cultures and civilizations

Exhibit 1. 10 Ways in which engineers add value and protect it suggested by Trevelyan and Williams.

Inherent in Keilson's vehicle problem and the many other examples that can be brought to mind is the level of understanding required for a judgement to be made. It may be helpful to illustrate this point by reference to the domain of comprehension in the Bloom taxonomy [5]. To make judgements about any issue a knowledge is required of the issue which may require some problems solving and, therefore, some basic knowledge. Clearly there are different levels of comprehension that indicate different levels of understanding, and therefore, different skills and knowledge (see Appendix). One of the problems designers of courses in engineering and technological literacy face is the level at which they have to function, the knowledge required for this, and most significantly in transdisciplinary courses how that knowledge is obtained.

Kielsen suggests that the achievement of her second aim would "include technological skills as basic manual life skills and conceptual understanding. She argues that with the exception of incursions by the "maker movement" teaching for living skills and competencies is "practically non-existent" in spite of the empowerment they can give to thinking and creativity. It has long been understood that a high level of spatial ability contributes to the development of mathematical ability, and its development can be fostered through what have been called in the United States the industrial arts. A truly transdisciplinary course would attempt to link these two aims through carefully chosen project work.

Related to the development of spatial ability and perceptual skills is the teaching of the skills of visual composition which links Keilson's learning aims two and three. They also bring IT into the picture for "visual composition well known by the arts, adapted for presentation and charting software. Reasoning from graphs, constructing and presenting relevant displays are all primary learning aims for the developed 21st- century workforce. Our students will be judged as much on the way they insert a picture into a document, as much as they are judged on basic punctuation". Kielson considers that under the employment umbrella that general topics of usability and design can be introduced to all students to make them more aware of the current limits of human-machine interaction, whether in the home at work".

The weakness of her discussion as presented, is that no fundamental statements of intention accompany the three learning outcomes. For example, it could be argued that the development of "technological judgement" as defined by Drew is the intention of learning aim 1. Similarly, the competencies thought to be important for work need to be stated.

At first sight the scope of these three learning aims seems to be representative of a curriculum for STEAM rather than an elective. It would be fairly easy to fit the SCANS [6] competencies to a curriculum of this kind, even though they were described for high schools. Keilson's proposal also has some similarities with the transdisciplinary curriculum for higher education suggested by Heywood. Together they open up an avenue for discussion of alternative higher education curricula more suited to the needs of the 21st Century [7]

Suzanne Keilson follows the procedures for defining the curriculum often employed by curriculum designers. These challenge the traditional approach of thinking what content should be in a course and finding it difficult to know what to leave out. If Heywood's model engineering/technological activity were interpreted in syllabus terms that would be the case.

Hence, the argument for a transdisciplinary approach to the topic based and project and problem based activities. Such activities necessarily involve the student either in the acquisition of new skills or the development of skills already possessed.

Keilson in line with this approach argues that by stating the things that a student should need or be able to know and do eliminates discussion of whether a particular topic falls "under the umbrella of science, or engineering or technology". But this is also consistent with Trevelyan's view that the engineering curriculum should be derived from what it is engineers actually do. Thus, if one thinks in terms of a taxonomy, the key domain skills in an engineering curriculum would include communication and technical liaison, and these require an understanding of people as well as products, hard and soft, and that relates to Keilson's third learning aim.

While suggesting that her approach nulls the difficulties created by allocating topics to one of engineering, science, or technology Keilson's learning aims see a clear link between theory and practice; perhaps a better picture is given by "design and make" a phrase commonly used to describe project work in schools. Her approach is necessarily transdisciplinary by which is meant a problem for which "different solutions all of which are necessarily incomplete, depending on the viewpoint of each discipline" [8]. A feature of transdisciplinarity is that it may bring subjects that are relatively non-cognate when considered as disciplines on their own together. A major problem for transdisciplinary curricula is how does the problem solver obtain the disciplinary knowledge required without antagonising the integrity of the discipline especially disciplines that are semi-linear in their development. Some disciplines are necessarily transdisciplinary, education and management to name but two. From the perspective of the problems discussed here technological literacy is transdisciplinary. Unfortunately it does not resolve the problem of different audiences, neither does it necessarily resolve the problem of how to manage technology to our benefit for transdisciplinarity cannot resolve the problem of how to teach the continuing proliferation of technologies and the interconnections between them.

If it is accepted that we are all affected by technology and need to be able to control it, how as a community we can achieve this has to be a goal of liberal education. It is evident that the structure of general education as it is currently understood is in no way oriented to this mission. Therefore, there is a need to discover how best the curriculum might be changed, to better meet this goal. Given Mina's criticism of engineering students that they are not technologically literate, higher education might begin with a general programme of liberal education as suggested by Heywood. That model through problem based/project learning provides a range of contexts that, should in principle, deal with the problem of control in different contexts. But, as Cheville recognises this is becoming increasingly difficult because of the tension between the increasing gap between technological and educational capability. He suggests that we should all master some (rather than many) aspect(s) of *episteme* and *techne,* and we should learn to teach that aspect within "communities in which these knowledges can be shared".

Extending the definition of technological literacy 3

Cheville extends the concept of technological literacy and eliminates the need for engineering literacy. He may be interpreted as arguing that the act of making a decision in respect of the control (management) of technology is an act of wisdom. He contends that the issues raised in Heywood's paper can only be resolved if attention is paid to the relative value ascribed to the different forms of knowledge prevailing in a society that is dependent on a given level of technology for survival. He argues that the view of technological literacy that appears to be suggested in Heywood's paper in which technological literacy is equated "with knowledge of technology specifically, and knowledge itself more generally" limits the definition technology.

He writes that the term technology originates in the Greek *techne* which is one of Aristotle's five virtues, "the others being *nous* (intellect), *Sophia* (wisdom), *phronesis* (practical judgement), and *epistme* (knowledge of things that are unchanging). *Techne* was a fundamentally different virtue to *epistme* since it was a virtue developed by the act of making and thus related to artifacts that were made (came into being) rather than what existed naturally".

Cheville clarifies the distinction between *epistme* and t*echne* "by moving beyond the Cartesian domain of thinking to including the domain of acting. In this case the phrase "technological literacy" should be expanded to "technological literacy and proficiency" since the root of "proficient" means to make progress or be useful. From this perspective it is not enough to be literate in a technology, rather those who wish to be proficient in technology must also develop the skill to create, for as Aristotle says *techne* is concerned with those things "whose origin is in the maker and not in the thing made". In the case of engineering literacy or Keilsen's second learning aim it is not made clear. It certainly justifies as does Drew's argument the development of, or change in the existing definitions of engineering and technological literacy. Cheville would argue that "proficiency" removes the need for engineering literacy**,** and clarifies the relationship between designer and user which appears to be missing from Keilsen's second learning aim.

In this respect there is clearly a need to need to clarify who the user is, and thus for whom the designer is designing for as Zuboff showsa technology is something that it is used by a small set of users to control a much larger market of users [9]. *Cui Bono*? It is because this is the case that we need to be able to control technology that Siller's intention becomes the primary intention of technological literacy.

Distinguishing between the public and the engineering audiences.

Is the problem that the person in the market is a respondent and not a perpetrator of technology and is not in a position to control the design? There is no provision for that person to ask *ante-hoc* questions of the designer. In the case of the emission failures of automobile firms all the respondent can do is to seek answers from which to determine new regulations and or justice. The "proficiency" lies in the ability to ask the 'right' *post hoc* questions which may require "proficiency" in the technical sense described by Cheville. It may be argued that to resolve the data issues created by the information technology giants, knowledge of the technology *per se* is not required. However, in order for the victims of a fire disaster such as the Grenfell Tower tragedy to get at the truth of what happened "proficiency" at the technological level is desirable if not necessary if the 'right' questions are to be asked [10]. Cheville seems to argue that in general everyone should possess some "technological proficiency" that shared in a community, in this case the victims of the fire, would enable the 'right' questions to be framed. That is one audience. It is this audience, it seems, that Tobias would wish to join. It is this audience that Keilsen's curriculum, given that it gives insights into the engineer's way of thinking and where they are heading, is directed.

The other audience identified by both Cheville and Mina is the engineer. Cheville writes, "The increasing gap between the capabilities of technology and the capability of users of technology was captured by Ivan Illich in *Tools of Conviviality* which recognized that a technology that does not enable proficiency creates a "modernized poverty" [11]. It is for this reason that technological literacy and proficiency is an important issue for engineering since an inability to manage technology impoverishes us all". A designer may easily be conflicted between the requirements of the "owners" hidden use and the respondent user's independence.

Comment

It is not possible to draw conclusions from the nine commentaries discussed here. However, it is possible to indicate lines of discussion that the ASEE's Technological Literacy, Engineering Literacy/Philosophy Division should pursue. First, irrespective of these papers it is evident that there are a number of audiences to be met. At its simplest there is a public audience and an engineering audience particularly of students. It is clear that the public is not a homogenous group but has several different needs. It is also clear that these needs will only be met by alternative approaches designed to meet different levels of understanding. Most of the courses offered in technological literacy (not to be confused with Science, Technology and Society STS) are electives, but the paper by Keilsen suggests an alternative curriculum for general education programmes.

Fundamental to the design of any curriculum is a clear understanding of its general aims. The implications of this review are the general aims or purposes of programmes in engineering and technological literacy are far from clear The one that comes through in the essays is the ability to control or change technology. However, as is evident from Zuboff's recently published study of "*Surveillance Capitalism*" while technology use should be controlled the more important change that is required is in attitudes and values. Since, whatever is looked at in this area shows different benefits for users and vendor, hence the question, *Cui Bono*? This implies that aims will have to be considered within the framework of the common good.

The attention to the impact of IT carries with it the danger that other major aspects of engineering and technological literacy become neglected.

The essays show the need for clarification and amplification of the definitions of engineering and technological literacy, even if it means a revised unitary definition. In any event there is a need to take into account the different audiences and their perspectives.

Notwithstanding the issue of finance, or indicators of issues for research raised by this study, as for example, levels of required mathematical attainment, Krupczak shows there is plenty of research to be done in this area that is not being done and should be done. He writes,

"one suggestion for research might be to inquire of those engineers whose career paths have led them out of engineering into positions in which they are making contributions in other spheres of activity. Engineering is well known for the fact that many formally trained as engineers are now fulfilling other responsibilities that may also be occupied by individuals with other types of formal training. All types of business and management are obvious examples but individuals formally trained as engineers can be found in law, health care, the arts, education, and government. Can these individual shed any light on what specific aspects of engineering they have found particularly helpful as they have successfully navigated the responsibilities of jobs frequently held by other liberally educated non-engineers? Perhaps the experience of erstwhile engineers can help to clarify the how, what and why of engineering as an element of liberal education".

Finally, Carl Hilgarth who has chaired the Division meetings that have discussed these issues makes the point that it is very difficult to find anything in the literature that attempts to assess the long term understanding that students took away with them. That, he considers, is the point of the example in the Appendix. Fifty years old though it may be, it provides a template for assessment design for it could just as easily be set against newspaper articles on the Grenfell Tower and Boeing 737 tragedies.

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Contents

Heywood, J. Why technological literacy and for whom? 2 – 9.

Keilson, Suzzane A new scheme for STEM literacies. 10 – 11.

Krawitz, Aaron. Scientific vs technological literacy. 12.

Tobias, Sheila Comment on John Heywood's paper: Technological literacy and for whom? 13.

Trevelyan, James and Bill Williams. Literacies of entrepreneurship and value creation. 14 – 16.

Cheville, Alan. Technological literacy without proficiency is not possible. 17 – 18.

Krupczak, John. Unfinished business for the ASEE TelPhe Division and other engineering educators 19.

Siller, Tom. The purpose of technological and engineering literacy. 20 – 21.

Mina, Mani. Why and for whom as historical reflection. 22 – 23.

Drew, David. E. Moving the needle from literacy to knowledge. 24 – 25.

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APPENDIX

An experimental examination designed for the Advanced Level Examination of the General Certificate in Education in Engineering Science offered by the Joint Matriculation Board. It was set in 1968 during the period in which the examination was being designed. Its results contributed to the design of the public examination that was set in 1969. They are discussed in G. Carter, J. Heywood and D. T. Kelly. *A Case Study in Curriculum Assessment. GCE Engineering Science Advanced*. Manchester: Roundthorn Press, 1986. This study includes details of the examination but does not include the multiple choice questions which have been taken from the archive of Engineering Science papers held by J. Heywood for the Institution of Engineering and Technology. In this context it is intended to illustrate different levels of understanding. Candidates were asked to read an article and answer questions about it that were designed to test different levels of knowledge. The influence of the Bloom *Taxonomy of Educational Objectives. Cognitive Domain* which had been released in the UK in 1964 should be apparent.

The examination was given to students aged approximately 17 years at the end of the first of a two year high school course for the purpose of gaining entry to university. Students would also take mathematics to an equivalent level.

Concorde may be six years ahead of US rival

John Fielding

(Extract from The Sunday Times, 17th March 1968)

1. As the Concorde's option holders await an official commitment on possible delay in delivery, airlines holding options on the Boeing 2707 are likely to have to wait up to six years after Concorde, instead of the officially quoted four, before they can begin operating it.
2. For behind the recent statement by General Jewell Maxwell, the Federal Aviation Administration's supersonic transport direction, that prototype construction will be delayed for a year is a series of major reverses for the US aircraft that even Boeing's massive resources could not quickly cope with. It will not be late in 1962 before the Boeing gets into the air. By then the Concorde is due to enter airline service.
3. Options on the Concorde have cost the 74 holders £20, 000 compared with £900,000 paid for 122 options on the Boeing.
4. Almost a year ago Boeing began to realise that prototype design after their proposals won the US SST competition late in 1966 would take longer than expected.
5. By last July the 2,000 man design teams had decided to lengthen the fuselage to 312 ft., add canards (wing-like projections) on the nose to improve control stability at cruising speed, and modify several other features. It was not until December that final prototype design was reached, but by this time the most serious problem, that of weight, was becoming embarrassing.
6. Weight affects everything- range, capacity, performance, airline acceptance, economics. By January Boeing had to tell the FAA that construction of the prototype (which would not necessarily bear identical resemblance to the production aircraft) should be held up.
7. The effect of the excess weight has been reported as cutting the range from 4,000 miles to 2,300 and the cruising speed from 1,800 to 1,500 mph and increasing the operational empty weight to 330,000 lb. – 20 per cent over the limit originally envisaged.
8. Yesterday Boeing were due to report to the FAA what they were going to do about it.
9. One of the immediate suggestions has been to lighten the alloy used in certain parts of the aircraft. The Titanium alloy specified by Boeing could be replaced with a lighter alloy – ironically enough specified by Lockheed in their losing design. But this is more liable to crack and corrode, and even if it were used there would still be something like ten tons of surplus to dispose of.
10. One of the best ways of doing this to reduce drag. Boeing are already looking at several methods, including lengthening the wing and adding wing area where the leading edge joins the fuselage.
11. Another source of weight-compensation in the SST's four jet engines, which still have the capacity of being increased in thrust from their present rating of more than 60.000 lb.
12. Both these exercises are time-consuming and to achieve a 7 per cent reduction in drag over what is already the most efficient shape Boeing could devise is asking for miracles. There are also other problems.
13. Just how much work is still to be done was illustrated by General Maxwell's rueful comment last week that, "We'll look at things as broad as a whole new wing", though he won't throw overboard the variable sweep design.
14. With at least another year to go before the prototype starts building, and a lot of arguing over the SST budget between now and then, there is some way to go even before the Boeing 2707 reaches the starting line.
15. By contrast the Concorde teams have been able to concentrate on lesser problems associated with flying at 1,350 miles an hour. Delays have been in component supply and testing rather than design, and weight has been kept within acceptable limits consistent with seat-mile costs of 14 cents and New York – Paris range.
16. Airlines counting on the Boeing to bring them into SST market within three or four years of the Concorde have already begun looking twice at the Concorde in view of the 2707's delay. Among those lines is Canadian Pacific.

The article was accompanied by line sketches of the two aircraft

The following conversion table was also supplied

1000 miles	=	1613 km
1000 mph	=	48 m^{-1}

1000 lb	=	455 km	
G = 32.2. f s^{-2}	=	9.81 ms^{-2}	

This section of the paper is in four sections. There are 14 questions in all.

Answer Sections A, C and D by writing the appropriate single letter in the space provided on the answer-sheet.

One hour is allowed for the completion of this section.

Section A. Comprehension of the Article.

1. The 7% saving in drag (para 12) may be achieved by
   A. Saving in weight by use of alternative alloys
   B. Increasing the wing area
   C. Equivalent reduction by increasing thrust
   D. Lengthening the fuselage
   E. No clear indication given

2. The major problem now facing the designers of the Boeing 2707 is
   A. Reduction of dead
   B. Increase of thrust
   C. Improving the control stability at cruising speed
   D. Reduction of weight
   E. Range and cruising speed

3. The designers of Concorde have been faced with a simpler design problem in that Concorde will have
   A. A shorter range
   B. A lower cruising speed
   C. Greater financial backing
   D. Better prospects of airline acceptability
   E. A lower weight

4. The development of the Boeing 2702 has been further delayed in relation to that of the Concorde by a period of
   A. One year
   B. Two years
   C. Three years
   D. Four years
   E. Six years

5 The reason for the further delay referred to in question 4 is given as

A The greater number of contract options

B The size of the design team

C Modifications to the original design

D The design of the engines to be used

E The variable sweep wing design.

Section B. Knowledge of definitions

6. Explain what is meant by

A Engine thrush

B Aircraft drag

C Aircraft control stability

D Contract options

Section C Engineering understanding (projective)

7. The article refers to the speed of the aircraft in miles per hour (para 7) but aircraft of

This type are usually described by their Mach No. which is defined as the speed of the aircraft relative to

A. The ground
B. The wind speed
C. The earth's rotational speed at the equator
D. The speed of sound
E. None of these

8. The dimensions of Mach No. are

A. Miles per hour

B. None

C. Feet per second

D. Knots

E. Metres

9. Which of the five diagrams given on data sheet III (I, II, III, IV, and V) best describes

The flow pattern over the wing of a low-speed light aeroplane. (See diagram from archive at the end of

Test.

10. Figure IV of data sheet III shows the flow pattern appropriate to the movement of

A. "Concorde" aerofoil at supersonic speed

B. "Boeing SST" aerofoil at subsonic speed

C. A shark

D. A torpedo

E. A ship's rudder

Section D. Engineering analysis

11. Use the information in paragraph 7 to calculate the ratio of the kinetic energy at

Cruising speed of the (empty) aircraft of the earlier design to that of the aircraft now

envisaged

A 1.7

B. 0.578

C. 0.833

D. 1.20

E. 1.00

12. What acceleration (expressed as a multiple of g) can the four engines, each of 60, 000 lbf thrust, produce on the aircraft of the modified design in horizontal flight? (neglect drag)

    A. 1.38
    B. 0.727
    C. 0.182
    D. 7.3
    E. 0.873

13. If the drag were negligible how far would an empty aircraft of the newer design travel along a horizontal path before reaching its cruising speed? Use the acceleration calculated in question 11.

    A. 3. 18 km
    B. 31.8 km
    C. 12.7 km
    D. 127 km
    E. None of these

14. What was the expected drag on the aircraft of the earlier design if the engine thrust given in paragraph 11 would just maintain the cruising speed at 1800 mph?

    A. 1.07×10^{6} N
    B. 2.67×10^{5} N
    C. 1.07×10^{6} kgf
    D. 2.67×10^{5} kgf
    E. 0.62×10^{5} N

Section 2. Design – Problem formulation and reasoning

Time allowed 1Hr 30 mins**.**

You are required to set up an investigation to determine as fully as possible the properties and behaviour of springs having the dimensions given in the diagram below and a stiffness factor of 10^{3}N m^{+1}.

Such springs are supplied as part of a construction kit and may be used in tension or compression under steady intermittent or oscillating loads. You are to assume that the springs are freely available, that normal laboratory and workshop facilities are at your disposal and that any extra equipment you may need can be purchase or made to your design. Assume that you will be given a total of 50 hours excluding the writing of the final report and any time required for the construction of the apparatus of your design.

(a) List five mechanical properties of the spring that your experiment should determine.
(b) Sketch the arrangement of the apparatus that you would use for these experiments. Where such apparatus is not normally readily available produce a preliminary design indicating approximate dimensions and an estimate of the cost.

(c) Outline the experiments you would carry out, with the apparatus you have indicated, to determine the mechanical properties listed in (a) above, indicating clearly the procedures you would adopt and the method of handling results.
(d) Draw up a time-table of operations for the whole investigation.

It is very important that where possible and relevant you should explain the reasons for your choice of design, apparatus or procedure.

Section 3. Engineering Reasoning

Time allowed 30 minutes

Sketch an electric kettle, labelling clearly any feature of engineering significance. List the energy exchange processes which occur up to and following the moment at which the kettle boils.

Comment on the choice of the rating of the element and the possible incorporation of a boiling point cut-out from the point of view of:

(a) The user
(b) The manufacturer
(c) The electricity supplier

Inset 6

DATA SHEET - SECTION III