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Biography

John Heywood. Professorial Fellow Emeritus of Trinity College Dublin and Formerly Professor of Teacher Education in the University of Dublin. Began life in the Merchant Navy and the Radio Industry. Subsequently taught radio at a London Technical College and undertook research in radio astronomy as Director of the British Astronomical Association's radio-electronics section. In 1961 he became senior research fellow in technological education at Birmingham College of Advanced Technology, and in 1964 was appointed to the first of two lectureships in higher education in the UK at the University of Lancaster. His research focused on assessment of student learning- especially as it related to engineering in universities and K-12. In 1970 he went to Liverpool University to lecture in industrial studies and develop methods of analysing the work that engineers do. He joined the University of Dublin in 1973. His research broadened to include the training of teachers including higher education. Since his retirement he has focused on engineering education and his book "Engineering Education: Research and Development in Curriculum and Instruction" (IEEE/Wiley) received an award from the American Educational research Association. He has over 100 publications including 11 books. He is a Senior Member of IEEE and a Fellow of ASEE.

Philosophy, Engineering Education and the Curriculum.

Abstract

Recently some leading senior engineering societies have encouraged discussions about the philosophy of engineering that even extend to metaphysics. Authors acting independently have also published substantial papers on the topic. However, little has been written about philosophy and engineering education. The purpose of this discussion is to extend the debate that is emerging in this respect. From the examples given it is argued that just as intending teachers in training are exposed to the philosophy of education so teachers in higher education, in this case engineering, should also be exposed to its study. In short it is argued that engineering educators should have a defensible philosophy of education. The primary focus of the paper is the contribution that philosophy can make to decisions about the curriculum and instruction. The paper begins with a short review of recent developments in the philosophy of engineering. A distinction is made between operational or working philosophy, philosophy and philosophical disposition. Arguments for exposing teachers to the philosophy of education are briefly presented. In considering the curriculum and the aims of engineering it is important to be quite clear about the terms that are used. This point is illustrated with reference to the design of instruction and assessment. In publicly financed higher education it is of importance to maintain an on-going critique of the aims that drive that finance as well as the "one-sided criticisms of others." Lists of aims are often contradictory and require in the first instance to be screened by philosophy. The recent study of engineering by Williams points to the need for profound debate about the aims of engineering education.

The potential for such a debate is illustrated by Whitehead's aims of education together with his rythmic theory of learning and development. The implications of his philosophy for the structure of education and instruction are considered. His arguments require a response from those responsible for engineering programmes. The proposition that engineering educators who have a philosophy of education will be in a better position to help schools design engineering programmes is illustrated by the application of Whitehead's model to a specific case. It is for educators to arrive at their own defensible philosophies of education.

Recent developments in philosophy and engineering

There has been a recent interest in philosophy and engineering. Apart from a major philosophical treatise[1]and some substantial contributions on the nature of engineering and how it is differentiated with science.[2] Professional organizations in China, the United Kingdom and the United States have discussed the matter[3]. This may not be surprising for in the last century a substantive study in the philosophy science allied with its history emerged. Early in that century distinguished scholars were writing about the philosophy of physics[4]and by the nineteen-fifties organizations for the study history and philosophy of science had emerged. There seems to have been a long-standing interest in the history of technology but not in the possibility of it having a philosophy. This was to change with the growth of technology in schools and a considerable literature on the nature of technology[5] that irrespective of particularised uses of the term, extends into higher education and the province of engineering.[6] In the UK this was in part forced on those concerned to develop technology and/or engineering in schools by scientists who argued that science teaching[7] obtained all the goals that technology transpired to achieve. In the late nineteen-sixties some argued that the pursuits of science and engineering required different modes of thinking. For this reason engineering should be taught in schools.[8] The proposition that ' modes of thinking' differ between subjects (e.g. subjects in the humanities versus subjects in the sciences) has re-surfaced. For example, IBM holds that if it is to help the service industries better it needs to know how the different kinds of people that make up that sector think.[9] Thus debates about the philosophies of science and engineering/technology necessarily have implications for the educational programmes offered in these areas and ways of thinking in them. In the second half of the twentieth century substantial contributions were made not only to the history of science but to its philosophy as it related to education. It has been argued for example that had some attention been given to the history and philosophy of the pendulum in the National Science Education Standards of 1996[10] that science teaching could have been transformed "*resulting in a much richer and more meaningful science education for American students*."[11] It is for the reader to judge whether or not Matthews succeeds in proving his point. It raises the question as to what it is in engineering that makes the subject most meaningful to students. The question for this discussion is whether philosophy more particularly the philosophy of education can contribute to the practice of engineering education. It is argued that every engineering educator should have a defensible philosophy of education. Beyond that Grimson has argued that a module in the philosophy of engineering could usefully[12] be included in the undergraduate curriculum but discussion of this topic is beyond the scope of this paper. First it is necessary to make a practical distinction.

Operational or working philosophy, disposition and philosophy

By operational or working philosophy is meant the value system that drives a particular curriculum (programme), syllabus, course or teaching session. It is the personal motivation of individuals that sustains them. Many articles about new courses, irrespective of where in the world they were introduced, described the philosophy behind the programme or course.[13] Sometimes the statement that emerges is so brief as to be meaningless: at other times it is substantive. The need to define a philosophy seems to be felt when new courses are proposed and the new course needs to be justified. Morant who wrote about electronics as an academic subject in the United Kingdom said that- "*a clear course philosophy is also a good basis for determining strategic priorities. Higher education is responsible to students, industry and society in general to provide for the best possible education with limited time and resources available. A logical basis is required for determining how to use resources for maximum efficiency*."[14] Of course such thinking could lead to a more substantive philosophical debate, and one outcome of such a debate might be the philosophy of the professions that two Canadian writers called for.[15] A common topic for discussion is the nature of design philosophy.[16]

Related to such discussions have been considerations of the attitudes and dispositions that students should bring to the study of these subjects. There are examples where curriculum authorities state the attitudes and dispositions that should be promoted by study in a particular engineering course.[17] More recently discussion has focused on the moral purpose of the outcomes of studies in particular areas of engineering, as for example the impact of design on the environment or genetic engineering.[18] There is not however much debate about the more general effect of beliefs and attitudes on a student's general philosophical disposition or habit of mind.[19]

Finally in this context Grimson showed how a philosophical viewpoint derived from formal philosophy and philosophies could contribute to design. He used the example of the design of one of Britains most famous nineteenth century buildings – The Crystal Palace[20]. He characterised engineering on the basis of the direct use of activities that correspond to the five classical branches of philosophy – aesthetics, epistemology, ethics, logic and metaphysics. He demonstrates the relevance of philosophies such as empiricism, idealism, existentialism, logical positivism, and rationalism. It is unfortunate that he omitted realism from his list since the contrasting positions of constructivism and realism have been the subject of a major debate in education especially in the sciences and school education[21] and more generally in respect of ethics.[22]

Education and philosophy

Many schools of teacher education require their students to take a course in philosophy as it may be applied to education. There are different ways of approaching such courses. Some approach it from the perspective of history and begin with the Greeks. Someone has said that philosophy is simply a series of footnotes to Aristotle and Plato. Even if the focus is on epistemology it is difficult to escape the classicists. As Shulman points out, when learning theorists adopt a particular theory they take a particular epistemological stance. They have a theory regarding how things are known. Generally speaking these positions will either be in a tradition that can be traced back to Aristotle or in a tradition that can be traced back to Plato. Gagné is representative of the Aristotelian tradition and Bruner of the Platonic.[23] Generally speaking Philosophy has possibly a more significant role in helping us to understand/unravel what it is we think education is or what the purpose of the experience of education is.

Smith in the *Journal of Engineering Education* gives one answer to why we should read educational philosophy. "*Perhaps*", he writes, "*in part to get a better understanding of where we are and where we came from (sort of the Darwin of education). With all the talk about curriculum reform and technology changing the role of the university, as well as what engineering will be like in the 21st century it is important to go back to basic questions. Reading educational philosophy helps answer questions such as: who should be educated? What should be the purposes of education? How should students be educated? Educational philosophy also helps shed light on standardized testing, core curriculum versus distribution requirements, the Carnegie unit (credits and contact hours), and many other issues*."[24] It is reflection on such issues and the more profound questions of existence that helps develop the reflective capacity that has come to be valued in higher education or more generally a philosophical habit of mind. The distinguished mathematician and philosopher A. N. Whitehead did not think of philosophy as a body of expert knowledge, but a mode of thought.

This position seems to have been that of Newman before him in his classic treatise on *The Idea of a University*.[25] Notwithstanding the importance of this dimension the position taken here is that a philosophy of education can also help us make better educational decisions than we currently make.

Few would dissent from the view that many poor decisions are made about education. At the one extreme administrators who control the purse strings, and at the other extreme, teachers who control learning in the classroom often make decisions that are irrational or found to be wanting when implemented. Often they result from ideologies that while implemented for the 'good' of students have unintended consequences that outweigh their merits. But as Fitzgibbons has shown educational decision-making can be raised above the "*level of mere guesswork only by increasing our knowledge and understanding of how to make these decisions rationally*." As he put it educators have to give up "*flying by the seat of one's pants*."[26] The discussion that follows will focus on issues related to the curriculum and instruction.

The curriculum and the aims of education

One of the reasons that the curriculum is slow to change or reverts to what it was quickly after changes have been implemented is that it is the result of tradition and beliefs which for one reason or another we don't want to change. Nevertheless the curriculum does change, if but slowly, and in technological subjects change is caused by changes in the technologies themselves. For example, in engineering curricular in the United States there was in the nineteen eighties a reported decline in the in the importance attached to the role of mechanics as evidenced by the number of mechanics departments.[27] Another example is the increasing status ascribed to design relative to engineering science.[28] But by far and away the most radical changes in the US have been caused by the introduction of the ABET requirements for EC2000. These changes depend on beliefs and values as much as anything else. This is not to say that beliefs and values do not have a rational basis but, particularly if they emerge from committees, they are often contradictory and ambiguous. This is not surprising since they result from compromises that attempt to be all things to all people. If modern philosophy has had an impact on we plebeians it is that we must be very careful with meanings for if we aren't we leave ourselves open to substantial criticism. Unfortunately educators never want to stay with terms for very long and this creates its own havoc and there is no better example of this than the so-called objectives movement. EC 2000 has been criticised by Yokomoto and Bostwick for its lack of clarity. *"Dissimilar words are used as synonyms, such as "outcomes," "attributes," and competencies to describe what students must demonstrate. Sometimes the term "performance outcome is used*."[30] Lack of clarity and confusion also applies in the field of assessment and evaluation.[31]

For example, it matters that we should be clear about what we mean by "knowledge." It is used in a variety of ways in education. Knowledge as used in *The Taxonomy of Educational Objectives* is a low order concept. It is seen as a domain that categorises the information a learner has to consider. Undoubtedly these categories have their uses. But *The Taxonomy* per se is conceived by many educators to be in the scientific and managerial idioms and uncongenial to their perceptions and feelings about the aims of education. It is writers like Bruner[32] and Lonergan[33] who strike a responsive chord.

Lonergan jumping from knowledge to knowing wrote that- "*I conceive knowing to be, not just experiencing but a compounding of experiencing, understanding and judging. Hence, if there is historical knowledge there must be historical experience, historical understanding and historical judgement*."[34] Human knowing for Lonergan "*is a compounding of experiencing understanding and judging.* Or alternatively Bruner who wrote of a body of knowledge that is *"enshrined in a university faculty and embodied in a series of authoritative volumes, is the result of much prior intellectual activity. To instruct some one in these disciplines is not a matter of getting him to commit results to mind. Rather it is to teach him to participate in the process that makes possible the establishment of knowledge. We teach a subject not to produce little living libraries on that subject, but rather to get a student to think mathematically for himself, to consider matters as the historian does, to take part in the process of knowledge-getting. Knowing is a process not a product*."[35] It implies that there are other ways of knowing, a consequence of which is that there might be differences in "method" as between the subjects.[36]

In both Bruner and Lonergan "how we know" rather than "how we acquire knowledge" is the central aim of learning. It also implies that we make meaning of the knowledge we obtain and this brings us back to the nature of knowledge itself. It is a process as opposed to a product view of education. It relates to one of the central debates in science education has been about the nature of knowledge as perceived by realism on the one hand and constructivism on the other hand.[37]

Bucciarelli in "Engineering Philosophy" distinguishes between information, knowledge and knowing. He "tries" to use the term "knowing" rather than "knowledge." Information is "*any representation, any human production which has been endowed by its authors with a disposition to provoke knowing*."[38] (Some of us would call information 'data'). Bucciarelli uses these distinctions and argues that if we want to distinguish between engineering knowledge and scientific knowledge we have to find out what engineers and do before we can find out what engineers know and what scientists know. There would seem to be some similarity between Bucciarelli's views and those of A. N. Whitehead whose views and terminology are recorded in a later section.

Plato's view of knowledge would seem to differ from Bucciarelli's usage although when applied to the curriculum they would seem to lead to similar conclusions. In the Platonic scheme of things objects in the 'sensible' world are manifestations of 'ideal' or 'prototypes' held in the mind. The sensible world is a world of the 'particular and they belong to the world of becoming whereas the ideas or forms belong to the intellect, which resides in the world of being. These forms are organized in a system the top of which is the form of the good. Knowledge is of the absolute and permanent order of ideas. For each true universal concept there corresponds an objective reality.[39] True knowledge is therefore of the universal. Knowledge of the universal (e.g. goodness) is the highest kind of knowledge and knowledge of the particular is of the lowest kind of knowledge. Today, for example, we judge the knowledge required of professional engineers to be more universal and abstract than that required by technicians. Thus the degrees of knowledge are distinguished according to objects and the human mind develops from opinion to knowledge. Much of what we do in engineering education is based on tradition and opinion about how students learn. Not on knowledge. It seems to me that Bucciarelli would agree with this position. Hence the importance of philosophy in the determination of the curriculum. It also relates to questions about the nature of a discipline. It has been asked recently is engineering education a discipline? In this respect the nineteen sixties debate between Phenix (an American) and Hirst (an Englishman) are of particular interest.[40] One thing they are both agreed about is the importance of concepts and it is for this reason that key concept maps are important in determining the curriculum provided they take into account what engineers do.[41]

Thus, what we think about knowledge and knowing clearly influences the aims of education we have and in turn the curriculum, the mode(s) of instruction, and assessment. We have to be clear about what we mean when we talk about knowledge and knowing.

In another analysis of important terms Wringe insists that aims are not objectives even though the terms may be more or less synonymous.[42] There has been a substantive debate about these differences more especially about the merits and demerits of objectives.[43] Whereas objectives are concerned with the immediate that is with the achievement of specified learning outcomes aims belong to a different category in that they are open-ended and on-going. They are concerned with such matters as the development of the full potential of students, the creation of a better world, and the pursuit of truth. There is no doubt that our beliefs and the value judgements we make are important drivers of what we do and for this reason it is clear that discussion of aims is as important as the determination of objectives for the conduct of particular and series of classes. Moreover, in publicly financed higher education it is of importance to maintain an on-going critique of the aims that drive that finance as well as *the "one-sided criticisms of others."* [44]

Screening aims

Any committee asked to produce aims is likely to produce more than a system could possibly handle. It is even worse with objectives for the problem with long lists is that they can be self-defeating and almost a syllabus of content. Whether it is aims or objectives (outcomes) they need to be strictly limited not least because of the overload that a long list imposes on teachers. Furst, one of the authors of *The Taxonomy of Educational Objectives* used the term goal instead of aim and wrote "*some of these goals will be more important than others; and some will be inconsistent in the sense that they call for contradictory patterns of behaviour. The school [institution] must choose a small number of important and consistent goals that can be attained in the time available*." [45] With respect to engineering programmes it has been argued that the number of domain objectives should be limited to only those that are significant, and that within them the sub-abilities to be tested should also be limited.[46]

But to return to aims the lists that are developed have to be screened for consistency and significance. Furst argued that the educational and social philosophy to which the school (department or institution) is committed should provide the first screen. His examples of such questions are similar to those suggested by Smith above. They are put in italics and their relevance to engineering is shown in brackets in normal type. His questions included – "*Should* *the school prepare young people to accept the present social order?*" (Should engineering students be prepared to accept the current mores of the engineering profession or should they be enabled to review and challenge them?). Another question was - *Should different social groups or classes receive different kinds of education?* (Should minorities receive different kinds of engineering education? Should engineering education be designed to cater for different personalities?)

"Should the school (engineering department) *try to make people alike or should it cultivate idiosyncrasy?"* (Should an engineering department encourage creative and innovative behaviour among students? Should an engineering department allow students to plan part of their curriculum?)

Should the school emphasize general education or should it aim at specific general education? (What is the role of general/liberal education in the engineering curriculum? Related to this issue is the academic versus vocational issue and the extent to which engineering education should be influenced by the views of industrialists?)

There is much in the engineering literature that deals with these issues. Furst's point was that the education that will be provided derives from the stance taken on such issues. The curricular that result can be radically different even in engineering. One of the problems of higher education is that irrespective of subject there has been very little debate about the aims of education. Such discussion is taken to be unnecessary. Rosalind Williams' recent study of developments in engineering shows that that position will not do.[47] There is a much needed debate about the aims of engineering education in the 21st century.

Whitehead's aims of education and their relevance to the curriculum

Although it was written in the first half of the twentieth century there is no better starting point for a discussion of aims than Whitehead's *Aims of Education and Other Essays*. Not surprisingly the essay was addressed to mathematicians about the teaching of mathematics. However, the essay is understood by many educators to apply to education in general. As Lowe points out Whitehead makes no acknowledgement to any *ism.* He opens his lecture with the sentence "*Culture is activity of thought and receptiveness to beauty and humane feeling. Scraps of information have nothing to do with it*."[48] Presented in London he felt that the school curriculum that was dominated by public examinations for matriculation at universities led to a piecemeal approach to education in which information, scraps of information at that were acquired without understanding." "*The result of teaching small parts of a large number of subjects is passive reception of disconnected ideas, not illuminated with any spark of vitality. Let the main ideas which are introduced into a student's education be few and important, and let them grow in every combination possible*." Lowe comments on the essay thus "*Many of the recommendations in this essay can be thought of in terms of the contrast between understanding and information. We today do best to leave information to computers; they are designed to retrieve it. Understanding must be living. It is approached as the student relates one idea to another and to more general ideas, and explores an idea's applications. The applications are what make an intellectual education worth having*."[49] In these words Lowe conveys the essence of Whitehead's thinking. In the British Isles the essential argument against the introduction of modular courses and extensive choice is that it leads to fragmentation and the provision of scraps of information. Whitehead's thesis clearly requires a response from those responsible for engineering programmes. And this should go beyond opinion and belief to research into student possession of coherence.

It should not go without notice that Whitehead understood the importance of "principle learning" in the design of courses and there would seem to be little doubt that he would have approved of curricular designed around key concepts.

There is a more general essay that follows the essay on the aims of education that serves to illustrate the fact that aims should not only be screened by philosophy but by psychology as well. Beginning with the principle "*that different subjects and modes of study should be undertaken by pupils at fitting times when they have reached the proper stage of mental development*"[50] Whitehead develops a theory of mental development that is expressed in stages. It is based on the argument that the idea around which school [college] curricular are structured, that is the concept of a uniform steady advance undifferentiated by change is based on a false psychology. This *has "gravely hindered the effectiveness of our methods."* [51] Life he argues is essentially periodic and he chose the term "rythmic" *"as meaning essentially the conveyance of difference within a framework of repetition."* [52] Hence the title of the essay "*The Rhythm of Education.*" He distinguishes between three stages of mental growth – romance, precision and generalization. "*Education should consist in a continual repetition of such cycles.*"[53] They may be of a long duration or of a short duration. Thus in the long term the stages shown in exhibit 1 can be related to primary, post-primary and higher education. But Whitehead would argue that we approach problems however simple or complex in this way. So understanding the stages leads to particular types of curriculum and instruction. There is an immediate lesson for those promoting the teaching of engineering in elementary and post-elementary schooling: that is, that the emphasis should be on the stage of romance. This is not to say that in elementary education there should be no attempt to help precision or generalisation. Those who inspired the philosophy for young children movement have shown young children are quite capable of precision and generalisation[54] but in their own terms a view that is supported by the work of Bruner. Furthermore as Crynes argued at an FIE conference engineering educators have as much to learn from elementary education as engineering educators have to give to it.[55]

Applied to Whitehead's theory the project method that has long been employed in primary schools is relevant to the stage of generalisation in university education just as it is to first year university courses where in some programmes design rather than engineering science is their chief feature. Project work has for many years been a feature of engineering courses. Whitehead argues that the curriculum should be designed to follow the rhythm of these stages

It may be argued that those engineering educators who have a philosophy of education such as Whitehead's are better position to help schools develop engineering studies than those who rely on experience alone. For example, because of an unusual feature of the Irish Post-Elementary system students have the possibility of taking a transition year between the end of the Junior cycle of post-elementary education at 15 and the beginning of the two year senior cycle at 16. Broadly speaking the programme is designed by the teachers to meet certain objectives that relate to the kills required for life. About a quarter of the time is devoted to the study of traditional subjects in the standard curriculum. But they may be taught in a variety ways. Otherwise students are encouraged to have short periods of work and community experience. Some schools have experimented with learning-how-to learn courses, and basic programmes in management.[56]

Stage 1: Romance: The stage of first apprehension (a stage of ferment). Education must essentially be a setting in order of a ferment already stirring in the mind: you cannot educate the mind in vacuo. In our conception of education we tend to confine it to the second stage of the cycle, namely precision [ ] In this stage knowledge is not dominated by systematic procedure [ ] Romantic emotion is essentially the excitement consequent on the transition from bare facts to first realisations of the import of their unexplored relationships. Stage 2: Precision: The stage of romance-width of relationship is subordinated to exactness of formulation. It is the stage of grammar, the grammar of language and the grammar of science. It proceeds by forcing on the students' acceptance a given way of analysing the facts, bit by bit. New facts are added but they are the facts which fit into the analysis. Stage 3: Generalisation: Hegel's stage of synthesis. A return to romanticism with the added advantage of classified ideas and relevant technique

Exhibit 1. Whitehead's theory of rhythm in the educational process. The stages of mental growth and the nature of education. A summary of pp 27 – 30 of the essay on The Rhythm of Education.

Exhibit 2 shows a model of a curriculum that was developed for the teaching of technology in the transition year that was based on Whitehead's theory.[57] The romance stage was to be achieved by concentrated courses. Evaluations of concentrated experimental courses in manufacturing technology and technical investigations each of two weeks duration have been reported.[58]

Although it can be argued that Whitehead's view of education is comprehensive it is at the level of first principles. The rythmic principle serves to illustrate the importance of psychology in screening aims for much of it could be considered to be a theory of motivation. Neither is the more general theory the only model that can help with screening. It is for educators to arrive at their own defensible philosophies of education.

Introduction	General programme	Mini-company
Manufacturing technology	P1 Applications of science	
	P2 Information technology/electronics. Systems engineering/control technology	Market research and marketing
Materials and processes	P3 Management 1/organization & individual. Technology of organization. People and machines	Product innovation and implementation
Problem based problem solving techniques	P4 management 2. Marketing/Product innovation. Quality control	Technique and organization
	P5 Technology and Society	
	P6 continuation of man and technology	
Stage A Romance (3 – 4 weeks)	Stage B Grammar/Precision (8 to 22 weeks depending on programme)	Stage C Synthesis/Generalization (3 to 4 weeks)

Exhibit 2. A model for transition year technology based on Whitehead's rythmic model of learning. The programmes vary in length as a function of objectives. The times shown are equivalents since there can be overlap between the stages.

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4. See for example Bright, L (1958). *Whitehead's Philosophy of Physics*. Newman Philosophy of Science Series. Sheed and Ward, London for a resumé. For a popular work see Whitehead, A. N (1925). *Science and the Modern World*. Cambridge University Press, Cambridge

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6. In the United States the term technology when used of degrees implies what in other parts of the world imply technician when applied to an activity. Technological in the UK when applied to degree level study would in every day talk apply as much to engineering degrees as to other programmes set up to apply science. See also note 5.

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19. Sometimes described by J. H. Newman as enlargement of mind. For a commentary on his views see Culler, A. D (1955) *The Imperial Intellect. A Study of Cardinal Newman's Educational Ideal.* Yale University Press. See P 190 in particular. Culler cites Newman's oft quoted discussion on the

enlargement of the mind thus “*which is the power of viewing things at once as a whole, of referring them severally to their true place in the universal system of understanding their respective values and determining their mutual dependence…Possessed of this real illumination, the mind never views any part of the extended subject-matter of Knowledge without recollecting that it is but a part, or without the associations which spring from this recollection. It makes everything some sort of lead to everything else; it would communicate the image of the whole to every separate portion, till that whole becomes in imagination like a spirit, every where pervading and penetrating its component parts, and giving them meaning…To have even a portion of this illuminative reason and true philosophy is the highest state to which nature can aspire, in the way of intellect...*”

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35. *loc.cit* ref 32.

36. In this respect it is interesting to compare Lonergan's *Method in Theology* (1973-2nd edition, Darton, Longman and Todd, London) with B. V. Koen's *Discussion of the Method. Conducting the*

Engineer's Approach to Problem Solving (Oxford UP-2003) which he believes to be universal i.e the method

37. Note that constructivism as described here is not mentioned in either the Cambridge Dictionary or the Oxford Companion to Philosophy under the heading of this name. But it is in the Penguin Dictionary of Philosophy. "Theory that knowledge is not something we acquire but something we produce;that the objects in an area of inquiry are not there to be discovered but are invented or constructed.

38. Bucciarelli, Louis, L (2003) Engineering Philosophy. Delft University Press, Delft, Netherlands.

39. This account of Plato is greatly simplified. See Copleston, F (1946). *A History of Philosophy*. Burnes Oates & Washbourne, London. Paperback edition 1993, Doubleday, New York. See also Scott-Kakures, D et al (eds) (1993). *History of Philosophy*. Harper Collins, New York.
On the particular issue [i] Copleston writes: "*if a man is asked what justice is, and he points to imperfect embodiements of justice, particular instances which fall short of the universal ideal e.g. the action of a particular man, a particular constitution or set of laws, having no inkling that there exists a principle of absolute justice, a norm and standard, than that mans mind is a state of opinion […]He sees the images or copies and mistakes them for originals. But if a man has an apprehension of justice itself , if he can rise above the images to the form, to the idea, to the universal, whereby all particular instances must be judged, then his state of mind is a state of knowledge.[..] Moreover, it is possible to progress from one state of mind to the other, to be "converted" as it were, and when man comes to realise that what he formerly took to be originals are in reality images or copies i.e. imperfect embodiments of the ideal…when he comes to apprehend in some way the original itself…then he has been converted to knowledge."*

40 Hirst, P (1975). *Knowledge and the Curriculum*. Routledge and Kegan Paul, London.
Phenix, P. H. (1964) *Realms of Meaning*. McGraw Hill, New York.

41. This note is included to give some idea of the flavour of the debate and to indicate the importance attached to concepts. In order to distinguish between the objects of knowledge Phenix classifies propositions by two dimensions. These are quantity (singular, general comprehensive) and quality (fact, form, norm). Apart from criticising the terms within the quality dimension Hirst asks why these two features should have been selected when there are other possibilities. For example propositions may be classified by tense (past, present, future). "*Manifestly one can classify propositions in a great variety of ways but if we are to classify them as true propositions and nothing else, we must do this by virtue of their logically necessary features and not by any other characteristics that they may happen to have*." This is how we happen to classify concepts. We become confused about concepts if we take into account properties that do not define them. Therefore, argues Hirst the criteria that distinguish the objects of knowledge are (1) concepts appropriately related in a logical structure so that propositions can be formed and (2) criteria for judging propositions to be true. This point illustrates the importance of concepts in learning and validates all the work that is being done in assessment in engineering to ensure that concepts are understood. It is on this basis that Hirst proposes his own classification of the forms of knowledge

42. Wringe, C (1988). *Undertsanding Educational Aims*. Unwin Hyman, London

43. *loc.cit* ref 30

44. See for example Furst, E. J. (1994) Bloom's taxonomy: philosophical and educational issues. In Anderson, L. W. and L.A. Sosniak (eds). *Bloom's Taxonomy. A Forty Year Retrospective*. Yearbook of the National Society for the Study of Education. University of Chicago Press, Chicago. Major criticisms of the Taxonomy were made by P. L. Dressel (1971). Values, Cognitive and Affective. *Journal of Higher Education* 42, (5) 400, and E. W. Eisner (1979). *The Educational Imagination. On the Design and Evaluation of School Programmes*. Macmillan, New York. For a review focused on engineering education see ch's 1 and 2 of ref 29.

45. Furst, E. J (1958). *The Construction of Evaluation Instruments*. David McKay, New York.

46. That argument related to objectives and outcomes. For example problem Solving would be a domain as would creativity. Heywood, J (1989). Problems in the evaluation of focussing objectives and their implications for the design of systems models of the curriculum with special reference to comprehensive examinations. *Proceedings Frontiers in Education Conference* pp 235 – 241

47. Williams. R (2003). *Retooling. A Historian confronts Technological Change*. MIT Press, Cambridge, MA

48. Whitehead, A.N (1932) *The Aims of Education and Other Essays*. 1950 edition. Benn London. Ch 1. Given in 1916. P12

49. *loc.cit* ref 25 p 48.

50. *loc.cit* ref 48 p 24

51. *ibid* p 27

52. *ibid*

53. *ibid* p30

54. See for example, Matthews, G. B (1980). *Philosophy and the Young Child*. Harvard University Press, Cambridge, MA

55. Crynes, B. L and D. A. Crynes (1997). They already do it: common practices in primary education that engineering education should use. *Proceedings Frontiers in Education Conference* 3, 12 – 19.

56. For a description of the Transition year and details of the development of these courses See Heywood, J and M. Murray (2005). Curriculum-led Staff development. Towards Curriculum and Instructional Leadership in Ireland. *Bulletins of the European Forum on Educational Administration* N0 4 Pages 7 to 97.

57. Heywood, J (1991) Theory and practice of technology education-implications for the senior cycle of secondary education. In Kussman, M and H. Steffen *Current Topics of Technology Education in Europe.* EGTB Report No 1. Pp 66 – 77.Europäische Gessellschaft für Technische Bildung EGTB, Dusseldorf.

58. On manufacturing technology with girls and boys see Owen, S and J. Heywood (1990) Transition Technology in Ireland. An Experimental Course in Manufacturing Technology. *International Journal of Technology and Design Education* 1, (1), 21 – 32. And Kelly, D. T and J. Heywood (1996) *Proceedings Frontiers in Education Conference.* 388 - 393