Designing a stage of ”romance” for programs in technological literacy

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Abstract

In previous paper in these proceedings* it was argued (a) that a liberal education that takes no account of engineering and technological literacy cannot be by definition liberal, and (b) that programs of engineering and technological literacy can be designed to bridge the academic-vocational divide inherent in reports such as that undertaken for the National Governors Association. In support of this argument a model curriculum based on the epistemologies of Macmurray and Newman was presented. It was necessarily integrated and trans-disciplinary, and it was argued that it could be realised in practice by following the three stage philosophy of learning described by Whitehead. This model was based on experimental work in the teaching of engineering and technology that had been completed in the post-primary system of education (high school) in Ireland. While the content and method applicable to each of the three stages of the Whitehead cycle was illustrated there was no in-depth discussion of the components of each of these stages.

The purpose of this paper is to consider in detail problems in the design of the first stage of the cycle called – "Romance". The paper begins with a short introduction to Whitehead's philosophy of rhythm in education.

As conceived here the stage of romance for a program in engineering and technological literacy is a short all embracing intensive program of activities that enable a student to discover the properties of engineering and technological literacy that are derived from key concepts representative of the different knowledge dimensions that comprise these literacies. Five goals are outlined for the stage of "romance." Their attainment has implications for the organization of the courses, its content, and the approaches to learning adopted.   A distinction is made between "bridging" and "over-arching" –concepts in curriculum design. Historical examples of attempts to achieve some of these goals are presented for the purpose of stimulating further discussion.

*Heywood,J. Defining engineering and technological literacies within the framework of liberal education: implications for the curriculum.

Introduction

In a previous papers it has been argued (a) that a liberal education that takes no account of engineering and technological literacy cannot, by definition, be liberal [1], and (b) that programs of engineering and technological literacy can be designed to bridge the academic –vocational divide that is inherent in reports such as that undertaken for the National Governors Association (NGA) by Sparks and Waits [2-3]. One of the trans-disciplinary frameworks that was briefly discussed was Whitehead's three stage theory of rhythm in learning. The purpose of this paper is to consider the design of the first stage, the stage of romance.

Whiteheads theory of learning, and transdisciplinarity.

Although Whitehead discussed the aims of education prior to the development of his rhythmic theory of learning [4] it is not a necessary consequence of the curriculum design process that it should begin with aims other than to provide an envelope that shapes the discussion. Curriculum design results from a conversation that draws on many dimensions of knowledge. In this case it was argued in the previous paper that curriculum structure should be shaped by Whitehead's stage theory of learning which he regarded as cyclic (or rhythmic) [2] which is in keeping with his process theory of reality [5]. The reason for that argument is that definitions of engineering and technological literacy put forward by Krupczak et al, or the way in which the dimensions of engineering and technology impact on society demand an understanding of many areas of knowledge [6]. Many problems faced by engineers cannot be solved without a seamless flow of information from different areas of knowledge. The process that produces a product (engineering) requires a technology of organization for its production (taken to include 'ideas'). Engineering and Technological Literacy are necessarily transdisciplinary [7], but to use Whitehead's term each has its own "style" or "way of thinking". The question that is faced by any course, and it is not answered here is, how much thinking in each of the specialisms is necessary for a person to undertake a transdisciplinary activity? The question might also be put this way – are there alternative ways of organizing knowledge that will achieve the same end? Or/ what is the necessary content and skills in the disciplinary areas that a person requires to be engineering and technologically literate?

Whitehead's stage theory is summarised in exhibit 1. The first stage of romance is necessarily one of transdisciplinarity because it is a stage of exploration, a stage of discovery. So too is the final stage of generalization (synthesis). But between them is precision. It is here that the language, which is the "style" of a particular subject, is learnt; and the interest found in the stage of romance turned into a search for expertise. But Whitehead does not expect the stage of romance to be one that is simply a collection of "scraps of information". In his lecture on the aims of education to mathematics teachers he said, "*Culture is activity of thought, and receptiveness to beauty and humane feeling. Scraps of information have nothing to do with it. A merely well informed man is the most useless bore on God's earth. What we should aim at producing* are [*is*] persons [*men*] *who possess both culture and expert knowledge in some special direction. Their expert knowledge will give them ground to start from, and their culture will lead them as deep as philosophy and as high as art* [4 p 1). Education is then, "*the acquisition of the art of utilisation of knowledge*" [4 p 6]. Looked at from the perspective of Whitehead's formal philosophy engineering and technology are creative activities. The stage of "romance" is not only one of discovery but of creative exploration [8] It is a view that fits well with what an engineer seeks to do.

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.**

The goals of a stage of "romance" in a program for engineering and technological literacy

The first goal is motivation. Motivation is seldom spelt out as an aim of education yet it is not an un-trivial aim especially where unusual courses, that is, those that step outside the plausibility of the perceivers, are concerned [9]. Currently programs of engineering and technological literacy (long or short) seem to fit this category. For them to be successful they have to send a message back to the student body that they are interesting, entertaining and worth learning. The key questions for the tutor and curriculum designer are "how do I motivate students through my teaching?" (i.e., "what instructional strategies are most likely to motivate the students?"); "what do I know about the students that will help me motivate them"? and "am I likely to motivate them with curriculum structures as they are presently organised?" (By structure is meant the linear organization of the timetable into subjects). Motivation, instruction and learning are intimately linked.

The second goal is the exploration of different ways of knowing and learning. It is not at all obvious that entering students will see that it is necessary for them to bridge the gap between the "liberal" and the "vocational." They will have been schooled in educational systems that are classified by subjects and where the distinctions between them are emphasised and therefore, between liberal and professional (vocational) knowledge rather than the seamless pattern to which they belong. For this reason students should be invited to explore different ways of conceiving knowledge including their own, and how it may be re- structured in order that they may use it in specialist study. Related to this is the need to understand how we learn and how we develop the reflective capacity that is indicative of higher order thinking. One of the major advantages of incorporating the fine arts into liberal education is that it forces on the learner an appreciation that there are many ways of thinking about objects in the real world such as connoisseurship [10].

Apart from the value of understanding how our learning styles influence the way we learn and our responses to different kinds of instruction our perceptions also influence our learning. Perception is an over-arching concept that plays an important part in the way we relate to each other in the workplace, social settings, and the classrooms [11, Ch 2]. As Bucciarelli has pointed out very often the problems teachers have in seeing the way their students understand a particular problem is because they have not learnt to speak the same language [12, p 92]. Engineers who are used as expert witnesses have to learn how lawyers use evidence, and what their role is in giving evidence [13, p 46]. Each of the dimensions of engineering and technology is a different "style" or way of thinking - a different "language".

In science and engineering there have been many studies that show students often have misconceptions of the principles that are to be understood. They have led to new epistemologies such as constructivism in attempts to show why this happens and how the problem can be averted through different approaches to instruction [7a, p 57 ff). Examination of the arguments for (realism) and against constructivism may provide a basis for students to examine their own epistemologies, and values.

The third goal is the exploration of one's personal value system. The base of all engineering and technological activity is the value system that we hold. Our beliefs and attitudes drive our personal and working behaviours. The person who is engineering and technologically literate will be grounded in a well thought out ethic. One way of arriving at an ethical position might be to examine the constructivist/realist philosophies in their response to the fundamental issues of ethics [14]. Another way might be to examine theories of moral development such as Kohlberg's [15] and how they might inform self-development the fourth goal of the stage of "romance" on the one hand, and to the concept of moral autonomy in engineering on the other hand [16].

The fourth goal is to provide for personal development. Whitehead's stage theory is clearly related to his view that "*the valuable intellectual development is self-development* [5, p1]. The teaching strategies we choose can enhance or impede development. Most education systems and teaching emphasise cognitive development at the expense of the affective even though it is well understood that in life individuals are expected to work in teams and that the effectiveness with which teams function is dependent on the emotional intelligences of their participants.The argument here is, however, that it (development) goes on throughout the whole of life, and that each transition, primarily a change in work and/or personal (family) circumstances is a stage that is accompanied by new insights and as such is a stage in development. The idea that intellectual development is self-development commands some assent but it needs to be unravelled further. Clearly there are two quite different dimensions at issue. There is personal development and there is development in engineering and technological literacy. Are they separate or do they live together? In either case the peak of development is the reflective capacity with which it endows an individual. As Macmurray points out this must embrace by the intellectual and the emotional: both are activities of knowing [17, p 196 ff]. A criticism of engineering education, and indeed other subjects within higher education is that they concentrate on the intellectual at the expense of the emotional although within recent years there has been recognition by industry that it needs individuals who have a balanced emotional intelligence, that is, it has assigned significance to the affective dimension of human behaviour. Students might be asked to discuss the question, "Given that our actions so often hurt the feelings of others should our understanding of "reason" embrace feeling and action?" Asking this or similar questions invites the students (us) to consider whether thinking and acting, emotion and reason, and freedom and responsibility are opposites? [18, p 17].

The fifth goal is to provide practical experience in the art and science of engineering, that is the experience of designing and making things. Engineering is an inherently practical activity. It embraces design, investigation and the making of things. They add skills without which any program of liberal education is incomplete. For example, a traditional academic curriculum mostly neglects the spatial abilities that are important in design and scientific thinking.

It is clear that a stage of romance that is directed toward the attainment of these goals will necessarily draw students through the cycles requiring some precision and some generalisation appropriate to the student's knowledge at the time as they search understanding. In Bruner's terms it is the first stage of the spiral in a student's personal curriculum [19]. It follows that the provision for learning in a stage of romance has to include activities that will help develop a student's reflective capacity both with respect to himself or herself as a person or a person engaged in the activities of engineering and technological literacy. And that is the foundation for bridging the gap between the "liberal" and the "vocational".

The stage of romance and content

Whitehead has much to say about the organization of the stage of" romance" but has little to say about content except that a person must be able to explore or better still venture into all the areas of knowledge that contribute, in this case, to engineering and technological literacy. While the teacher should determine what should be learnt the traditional methods of the stage of "precision" will not achieve "romance". Methods more akin to those used in primary (elementary) schools are better tuned for its accomplishment e.g., projects and case studies. Whitehead attributed the success of the Montessori system to the dominance of romance in the programme [8, p 62) but as has been shown project work and case studies and methods like debating also require the completion of the other stages of the cycle. It is to quote Edmund Holmes "*the path to realisation*" [cited in 8, p 66]. It provides the initial basis for insight into the field of human inquiry and human opinion that is engineering and technological literacy [20. p x]. The concern is with the engineer's act of understanding *per se* on the one hand and on the other hand with society's understanding of the products of the processes of engineering-technology. Good engineering occurs when these two understandings merge (Alan Cheville, personal communication). Whatever teaching method is selected, will also be in the service of that end. As conceived here the stage of romance for a program in engineering and technological literacy is a short all embracing intensive program of activities that enable a student to discover the properties of engineering and technological literacy that are derived from key concepts representative of the different knowledge dimensions, and the concepts that provide bridging between them.

Examples of "bridging" key concepts

There are a number of concepts (bridging) that enable an individual to better understand the differences and similarities between different areas of knowledge. For example, in a previous section the role of the key concept "perception" in learning was discussed. For example as between the humane subjects, social sciences and science and technology the concepts, "cause", "evidence" "mistake", "discrepancy", "probability", "random error/systematic error", "risk", "uncertainty", have some level of meaning that is strong or weak. Examining how they are used (not used) in each subject gives some idea of the differences between subjects. Thus in a test in a physics for arts students courses, the students were asked to "Compare the usefulness of the concept of error as used in physics with that of the errors occurring in the study of your major subject"[9, p 85]. (Any of the concepts listed can be substituted for "error" in the question). To be a little more particular, students might be asked to consider the differences between engineering and science and the roles of "risk" and "failure" in the engineering activity. Engineering texts tend to look at these two concepts within the context of how they improve engineering. Thus Vincenti argues that for as many successes there are in engineering there are likely to be just as many failures [21, p 46]. Davis considers that engineers and managers differ in the way they approach "risk". Engineers" reduce risk to "permissible levels" whereas managers "balance risk against benefit" [22, p 67]. In either case they do not seem to face up to the everyday problems posed by the consumer. Should we worry about an ophthalmic surgeon's capability when he gives a wrong scientific explanation for laser surgery, or should we go on his/her proven record of success with such surgery? [23, p 212]. This raises the question of how knowledge can be packaged in a set of enduring principles. But that is not the immediate problem.

The "over-arching" key concept of engineering design and learning method.

While these key concepts also act as bridges (bridging concepts) they are fragments of the engineering process and some overarching concept that brings them together. is required. In this case since the focus is on engineering, "engineering design" has to be the over-arching concept through which concepts such as these can be explored. Thus one of the components of the stage of romance might be a project to design and make an artefact. But Bucciarelli's argument that design is a social process should not be forgotten for to debate this proposition is at the heart of the technology and society debate [12, p 9].

A further integration may be made if students work together in a team project in which they are involved in the appraisal. One of the complaints that industrialists have made of new graduates is that many of them have no experience of working in teams. By participating in appraisals of themselves and their peers they should obtain some insights into human behaviour. Greater insight into human behaviour, particularly in organizations would come from exercises that focus on learning and perception.

Method

Clearly there has to be some closed instruction in a stage of romance, this may be taken to include formal reading. But the spirit of the stage is that of open-ended inquiry as a prelude to precision. In today's jargon the principal strategies induce active learning. It is not confined to anyone method although it is clear that if romance is to be achieved projects (mini and major) and problem based learning will have a major role to play. Some activities will necessarily be structured by some form of cooperative learning, and the philosophical and legal dimensions might be enhanced by debates. It is a matter of curriculum design to choose the most appropriate strategy for the attainment of the required objective.

The core activity of this transdisciplinary approach is engineering for it is engineering that produces the technology. A *sine qua non* of this curriculum is that students should experience the process of engineering which is to experience the process of design and manufacture. It was suggested in the earlier paper that students need to know about manufacturing processes and materials and how to use measuring equipment. It was also suggested that this might be achieved through participation in two short but intensive courses in manufacturing technology and technical investigations of the kind that had been reported elsewhere [24; 25].

The former was structured around nine mini projects. It was intended that most of the projects would focus on the processes associated with a material. Two projects were included in order to introduce the students to and its applications in the area of mechanics (structures) and electronics. The final project was intended to allow the students to integrate what they had learnt on the course. In ordered to foster ability in design a section on graphical communication was included early in the course (second exercise). The exercises are shown in the exhibit 2 for the purpose of clarification. Clearly there have been many developments since it was designed that would have to be incorporated in a revised course, as for example - 3D printing. The course did not include practice and experience with electronic circuitry as for example "breadboards".

Mini Project	Purpose(s) – Materials and processes. **To introduce the students to:-**	Method **The student is to design and manufacture (except in No 1)**
1	(a) Each other (b) Develop teamwork (c) Problem solving methodology	Working in (N) groups in competition to to build the tallest tower.
2	Computer-assisted machining	A component from a billet
3	Problems in the design and manufacture of acrylic plastic	A simple cassette rack
4	Simple vacuum processes and their potential	A tray insert (e/g. Cookery tray)
5	Turning and brazing mild steel	A trophy depicting a sporting activity
6	The principles of aluminium casting	A relief plaque
7	Techniques of cutting and bending sheet metal	A small jewellery box.
8. **Major project**	To enable the students to use their experiences in the mini projects in a more substantial creative activity in which all the skills acquired could be utilised.	A small clock (escapement provided)

Exhibit 2. The projects in order of their completion. 9 & 10 as planned are not included because they were not completed. Reproduced from Owen, S and J. Heywood (1990) Transition technology in Ireland. *International Journal of Technology and Design Education*, 1 (1), 21 – 32. The evaluation includes a daily account of what happened on the course. 12 males and 12 females in the age range 16 – 18 completed the three week program which was completed in a custom built laboratory financed by the Irish Christian Brothers.

The course in technical investigations was also delivered over a three week period with 12 males and 12 females in the age range 16 – 18. Its objectives were

1. To develop investigational skills in selecting and isolating parameters to be investigated, selecting and /or devising measurement techniques and equipment, selecting and/or devising procedures, obtaining reliable observations, processing those observations, drawing inferences and estimating the reliability of the inferences, reporting the investigation, recognising and applying optimisation criteria.
2. To develop an appreciation of the ways in which external forces can distort a structure, the ways commonly used structural materials behave under stress; common mechanisms and simple motors and their performance characteristics; the use of pneumatic devises to activate control.
3. To give experience in the use of science to help solve practical problems and to develop an appreciation of the importance of other factors in determining the optimum solution of a given practical problem.
4. To introduce students to some industrial practices relating to design and quality control.

These objectives were achieved with the aid of 10 mainly structured exercises (e.g. making a crank for turning axles; measurements with wheels and axles; making a reversing switch), and more open ended investigations into gears, and structures. The final week of the course was devoted to the completion of two projects. The evaluation showed that the fourth objective was not achieved. It was thought that it might have been better achieved if students could have had some work experience. It was found that the students were sufficiently motivated by the "practical" connotations of the program to work well for extended periods. The evaluation led the authors to conclude that the term "technical investigations" needed to be redefined and in consequence their aims which become: The development of:

(a) Practical investigative skills
(b) Understand useful technical devices and commonly used materials.
(c) Ability to apply mathematical skills in a useful context.
(d) Understand the uses of science as an aid to living and doing.
(e) Appreciate design and quality control as aspects of industrial activity.

These aims show the origins of the program in engineering science at the advanced level in England [26]. These were developed at a time when design was not taught in degree programmes which the advanced level program reflected. It assumed that design skills would be acquired by participation in a large scale design and make project. Little instruction was expected.
Even if the two courses were programmed together there would have been no over arching concept of design, and without that several key aspects of engineering and technological literacy would be missed, as for example, the differences in epistemologies used in engineering and science. Nevertheless, they do highlight the values of such approaches in the achievement of "romance".

Comment

The intention of this paper is to contribute ideas as to how programmes in engineering and technological literacy might be developed as a component of liberal education that has as its intention the elimination of the divide between the liberal and the vocational. It is argued that any such programme needs to begin with a stage of "romance" as defined by Whitehead. As conceived here the stage of romance for a program in engineering and technological literacy is a short all embracing intensive program of activities that enable a student to discover the properties of engineering and technological literacy that are derived from key concepts representative of the different knowledge dimensions required, and the concepts that provide bridging between them. Five goals were stated for the stage. "Romance" is essentially a stage of discovery which is most likely to be achieved by active learning methods in which projects (mini and major) and problem-based techniques have a large role to play. Historical examples of attempts to achieve some of these goals are presented for the purpose of stimulating further discussion.

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[5] This may oversimplify Whitehead's general philosophy which is stated in *Process and Reality* (1929, New York, Macmillan). For different perceptions of that work see Honderich, T (ed) (2005). The Oxford Companion tp Philosophy..p 957, Oxford UP. And Scruton, R (1994*). Modern Philosophy. A Survey*. Pp 372 - 374 London, Sinclair-Davidson.

[6] Krupczak, J., Blake, J. W., Disney, K. A., Hilgarth, C. O. Libros, R., Mina, M., and S. R. Walk (2012)DefiningTechnological Literacy. *Proceedings Annual Conference American Society for Engineering Education*, Paper AC 2012- 5100. In one of their ways of distinguishing between the two,literacies they argued that "*engineering literacy is viewed as having a focus directed more toward the process of creating technological artefacts or systems*" and that "*technological literacy includes a broader view of products or results of the engineering process as well as the relation between technology and society*". Krupzcak et al acknowledge that the "*extent to which engineering and technological literacy form a subset of each other remains a topic for future discussion and investigation*". On the basis of a process/product view of the matter Krupczak et al argue that a person who is technologically literate would have a "*knowledge or ability to design, analyze or otherwise create the constituent parts of the….*", and they give the example of the motor car. In respect of the broader view they say "*technological literacy includes a broader view of the products or results of the engineering process as well as the relation between technology and society*." Since "*technology can be viewed as identifiable things that result from engineering or related work*" it should therefore "*include some knowledge of these concepts, systems and processes.*"

[7] Transdisciplinary derives from the need to respond to a single complex, concrete problem that requires the assistance of several disciplines that give a variety of viewpoints to the solution of the problem which is not resolvable by a single discipline but requires the synthesis of a number of solutions. This definition has its origins in a 1973 OECD document which is summarised in (a) Heywood, J (2005*). Engineering Education. A Review of Research and Development in Curriculum and Instruction*. Hoboken, NJ. Wiley/IEEEE. For a discussion of various models of interdisciplinarity see (b) Fogarty, R (1993). *Integrating the Curriculum*. Pallatine Ill. IRI/Sky Publ.

[8] I have translated Whitehead's major concept of creativity to fit this argument but I think he would have agreed.. For Whitehead every concrete entity an individualization of the universal creative force that is his ultimate. See p 268 of Lowe, V (1990) *Alfred North Whitehead. The Man and his Work* Vol II. Baltimore, The Johns Hopkins University Press.

[9] Heywood, J and H. Montagu Pollock (1977). *Science for Arts Students. A Case Study in Curriculum Development*. Guildford, Society for Research into Higher Education. Shows how a course was redesigned to enhance the motivation of students.

[10] The term educational connoisseurship comes from Elliot Eisner who suggests that the teacher has to acquire the skills of an art critic when judging his or her own performance. Engineers require the same skill as part of their tool kit. Eisner writes: "the consequence of using educational criticism to perceive educational objects and events is the development of educational connoisseurship. As one learns how to look at educational phenomena, as one sees using stock responses to educational situations and develops habits of perceptual exploration, the ability to experience qualities and their relationships increase. This phenomenon occurs in virtually every arena in which connoisseurship has developed. The orchid grower learns to look at orchids in a way that expands his or her perception of their qualities. The makers of cabinets pay special attention to finish, to types of wood and grains, to forms of joining, to the treatment of edges. The football fan learns how to look at plays, defence patterns and games strategies. Once one develops a perceptual foothold in an arena of activity-orchid growing, cabinet making, or football watching – the skills used in that arena, one does not need the continual expertise of the critic to negotiate new works, or games or situations. One generalizes the skills developed earlier and expands them through further applications" (from E. W. Eisner, 1979). *The Educational Imagination; On the Design and Evaluation of School Programs.* New Yiork, Collier MacMillan.

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