



*Philosophical
and
Educational Perspectives in
Engineering and Technological
Literacy 3*

Technological and Engineering Literacy and Philosophy of Engineering Division of ASEE 2015 – 2016

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Philosophical and Educational Perspectives on Engineering and Technological Literacy handbooks are published by Members of the Technological and Engineering Literacy and Philosophy of Engineering Division of the American Society for Engineering Education.

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Handbook No 3 is edited by John Heywood, Trinity College- the University of Dublin, Dublin 2, Ireland.

This issue is printed by Reads, Main St. Bray, Co. Wicklow, Ireland

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Acknowledgement

We are grateful to the American Society for Engineering Education for permission to publish the paper Defining Engineering and Technological Literacy which was published in the 2012 Proceedings of the Annual Conference of the Society and is their copyright. It is catalogued as ISSN 2153-5965. Pages 25.381.1 – 25. 381.9. Permanent URL <https://peer.asee.org/21139>.

EDITORIAL

This is the third Handbook produced by members of The Technological and Engineering Literacy/ Philosophy Division (TELPHE) of The American Society for Engineering Education. The common theme is the curriculum (formal and hidden) and its discontents.

The publication of *Engineers of Jihad* by Diego Gambetta and Steffen Hertog (Princeton, 2016) caused much discussion in ASEE and in particular among members of TELPHE, and led to a panel discussion at the annual conference. Stephen Frezza a contributor to the previous Handbooks opens this issue with his response to the view that the engineering curriculum reinforces the mind-set that drives a person to commit terrorist acts. A key question is, “what response should those engaged in the teaching of technological and engineering literacy have to these criticisms of the curriculum?”

One of the reasons for embracing philosophy in the work of the Division was that apart from the fact that this growing field of interest had no home, any reform of the curriculum had to begin with a fundamental discussion of the philosophy(ies) on which the curriculum is grounded. This is illustrated by Mani Mina who shows that if the philosophy of John Dewey is followed it leads to an entirely different attitude to what the curriculum should achieve as well as to inquiry base student centred teaching. Cheville continues his efforts to demonstrate the value of John Macmurray’s philosophy to this debate in particular his analysis of personal relationships, a matter that is held to be of some importance by those investigate the causes of terrorism.

The philosophy of the curriculum depends of clarity of terms. For this reason, with the permission of ASEE, the divisions report on technological and engineering literacy which was given at the 2011 annual conference is reprinted. It is followed by a case study of an organization in the aircraft industry that attempts to link the understanding of technology with learning-how-to-learn now considered to be an important goal in higher education.

JOIN THE CONVERSATIONS

The Division hopes you will engage with the authors of these papers and those that have preceded them in the previous issues by writing comments which can be incorporated in the next issue of the Handbook. As a beginning we have attached comments to two of the contributions in this issue. Please join in.

If you wish to make a submission please contact John Heywood or any of the current officers of the TELPHE division whose names can be found on the ASEE website.

Considering the Engineering Mindset – A Response to *Does Engineering Education Breed Terrorists?*

Stephen T. Frezza

A recent *Chronicle Review* article raised the question *Does Engineering Education Breed Terrorists?* (Berrett 2016). The article centers on the recent book by Diego Gambetta and Steffen Hertog on this topic. The text focuses on a surprising fact: *engineers are overrepresented among violent Islamist extremists.* (Gambetta and Hertog 2016, viii) These researchers narrowed their list of identified Islamist terrorists to 207 people who pursued higher education and whose majors could be determined. A pattern emerged: 93 of them, nearly 45 percent, had studied engineering. This frequency far exceeded what would be predicted statistically; among male college students from the 19 countries represented in the sample, fewer than 12 percent studied engineering.

Seeking to bring nuance to what is known about the causes of terrorism, Gambetta and Hertog's then examines the extent of the relationship between engineering education and Islamist and other right-wing extremists groups. Raising the question about what makes engineering unique, they go on to explain the link between educational discipline and this type of radicalism by looking at two key factors: A sociological one dealing with the social mobility (or lack thereof) for engineers in the Muslim world, and a particular mindset seeking order and hierarchy that is found more frequently among engineers. (Gambetta and Hertog 2016).

Through the study of European engineering graduates responses, they observed that the engineers' mindset has elements they claim is consistent with

those of violent terrorists and other right-wing extremists:

- A need for cognitive closure, or a preference for order and distaste for ambiguity
- An acceptance of prevailing hierarchies
- The experience of high levels of disgust when confronted with the unfamiliar.

A significant issue that this research exposes is that there is, statistically speaking, an 'Engineering Mindset' that is in fact different from that of other mindsets for other majors. The particular challenge to engineering educators is that, independent of what that mindset might be currently, as observed across hundreds or thousands of graduates, what that mindset *should* be, and why.

Challenges of the Engineering Mindset:

While the article goes on to share typical (and also refuted) reasons for the unusually large participation of engineers (mostly western-trained) in Jihad, it also raises questions from the Engineering Education community concerning the engineering mindset. Donna M. Riley of Virginia Tech commented how traditional engineering programs not only attract certain kinds of minds but also reinforce positivist patterns of thinking. "As it is," she says, "engineers spend almost all their time with the same set of epistemological rules."

The *Chronicle Review* article expands these ideas further, looking at the response to the research, but also the findings of others that expose aspects of the

engineering mindset. Other terrorist researchers such as Arie Kruglanski suggest that engineers are particularly likely to act on their beliefs, and like terrorists, engineers are looking for closure, certainty, and reassurance from like-minded individuals. Consistent with positivist patterns of thinking, Jeffrey Victoroff, comments that the need for closure is an example of systematic thinking, or a preference for conducting analysis without the distraction of emotions.

Similarly, American engineering education researchers found related issues with engineers' commitment to ethical responsibilities. For example, research shows that between their freshman year and graduation, engineering student survey responses showed drops in measures of public-mindedness, including a commitment to professional and ethical responsibilities and a social consciousness. Similarly, that the discipline's culture and curricula emphasize "an ideology of depoliticization," which treats nontechnical factors as irrelevant to the work of "real" engineering (Cech, 2014).

In contrast with traditional science education emphasizing theory (Frezza, Nordquest and Moodey, 2013), effective engineering education emphasizes "practice applied with judgment" (Cheville, 2014). But like most science education, current engineering programs and accreditation schemes emphasize the cognitive. The claim these and other critics of current cognitive-oriented engineering education raise is that there is an assessable 'engineering mindset' – in its current form appears to make these graduates more likely to be candidates for involvement in terrorism and other right-wing extremism. The real challenge for engineering educators is realizing the 'flip-side' of Hertog and Gambetta's research:

that students' sense of their engineering program's emphasis directly effects their own beliefs. (Cech, 2014).

The point here is that there are values and beliefs that are communicated implicitly and explicitly through the engineering programs, and students pick up on these. Through classes, internships, design projects, and friendships, students are transformed from laypersons into engineers; they are expected to adopt the professions epistemologies, values, and norms; identify with particular symbols, and learn to project a confident, capable image of expertise (Cech, 2014). Significant research into students' identity *e.g.*, (Peters, 2014; Kinnunen et al 2016) into personal epistemologies, *e.g.*, (McDermott, et al. 2013), affective-domain outcomes (Fuller and Keim, 2008), or even the philosophical foundations of engineering (Frezza, Nordquest and Moodey, 2013). All suggest that there are values and beliefs about engineering that are common, communicated, affect student identity development, and shape students' mindset. That some perspectives on engineering education might help shape some students' mindsets toward terrorism should come as no surprise, even if many might agree that this is not the desired outcome.

The challenge of the Engineering Mindset, then is to shape engineering education in such a way that it recognizes and shapes these values and beliefs in ways consistent with the goals of the discipline as a whole. Particularly challenging is that these common disciplinary goals are both affective cognitive, oriented toward not just what the student knows about engineering, but rather how they think and what they value, and most engineering programs present and assess engineering through discipline specific cognitive

(knowledge) rather than cross-cultural affective (value) leases.

Cross-Disciplinary and Cross-Cultural Goals of Engineering

Any proposed 'Engineering Mindset' clearly needs to extend beyond the cognitive foundations current to engineering education. As a disciplinary goal such a mindset must be both cross-disciplinary, and cross-cultural, as both Engineering and Engineering Education are fundamentally rooted in particular cultures, and largely relegated to sub-disciplines that do not generally talk to one another on a cross-disciplinary basis. Consequently, identifying what the goals of engineering education are, or should be, is a social construction and not easily established. Inquiry into these questions certainly continues, but this author suggests that there are fundamental aspects of an Engineering Mindset that are both discipline- and culture-neutral. Yet the challenge for the modern academy is to develop disciplinary-neutral education when most engineering educators are hired for their research and disciplinary-specific expertise, not their ability to lead cross-disciplinary learning (Frezza 2014).

One such formulation of the Engineering Mindset offered by Samuel Florman suggested the following cross-discipline values as an 'Engineering View' (Florman 1987):

- *Belief in Scientific Truth*, in verifiable truth, and that scientific truth is insufficient. This including the values of independence and originality, dissent and freedom and tolerance, comfortable familiarity with the forces that prevail in the physical universe.
- *Pragmatic*: Application of truth to human objectives; the goal is not absolute truth, but rather to create a product that will perform and

function; a belief in hard work in the quest for knowledge and understanding in the pursuit of excellence; a willingness to forgo perfection to get real and useful products delivered.

- *Responsible*: Accepts responsibility in the face of risk and uncertainty; Dependable to achieve agreed goals in an effective manner, with appropriate logic and precision: A belief in hard work that values cooperation and established social structures
- *Creative*: A passion for creativity, that values tinkering, and change that serves the common good, and the good of the project

Given this and similar formulations (e.g., (Frezza 2014)), the question is not whether there is an "Engineering Mindset" that embodies disciplinary and cultural goals of engineering, but rather what engineering mindset a particular program, institution, or accreditation scheme targets for their students, and how such mindset/values are implemented in their program.

The research results from (Gambetta and Hertog 2016) suggest that among the engineers-turned-terrorist and others they studied, the engineering mindset they had evidence for showed a preference for order, but not necessarily the risk and uncertainty that go along with effective engineering. This mindset is one that values established social structures, but not understanding, or accepting the ambiguity involved with real human problems and objectives, or the humanity of the people served by technology. Perhaps the real lesson of "engineering education breeds terrorists" is that the programs and accreditation schemes sampled failed in consciously educating students in more value centered, socially appropriate Engineering Mindset. They might have

graduated from engineering programs, but had they really taken on the values of engineers?

References

Berrett, D (2016). Does Engineering Education Breed Terrorists? *The Chronicle of Higher Education*, March 23.

Cech, E. A (2014). A Culture of Disengagement in Engineering Education." *Science, Technology, & Human Values* (Sage) 39(1), 42-72.

Floorman, S. C (1987). *The Civilized Engineer*. New York, NY: St. Martins Press.

Frezza, S (2014). A Knowledge Basis for Engineering Design. *ASEE/IEEE Proceedings Frontiers in Education Conference*. 158-165.

Frezza, S. T., Nordquest, D and R. Moodey (2013). Knowledge-generation epistemology and the foundations of engineering. *ASEE/IEEE Proceedings Frontiers in Education Conference*, 818-824.

Fuller, U and B. Keim (2008). Assessing students' practice of professional values. *13th ACM annual conference on innovation and technology in computer science education*, Association of Computing Machinery (ACM), 88-92.

Gambetta, Diego, and Steffen Hertog (2016) *Engineers of Jihad: The Curious Connection Between Violent Extremism and Education*. Princeton, NJ. Princeton University Press.

Kinnunen, P., et al (2016). Understanding initial undergraduate expectations and identity in computing studies." *European Journal of Engineering Education*., February : DOI:10.1080/03043797,2016.1146233.

Marra, Roe, and Betsy Palmer(1999). Encouraging Intellectual Growth: Senior Engineering Student Profiles. *ASEE/IEEE Frontiers in Education Conference*. 12c1-6.

McDermott, R., Pirie, I., Cajander, Mats Daniels, M., and C. Laxer (2013). Contemplations on results from investigating the Personal Epistemology of computing students. *ASEE/IEEE Frontiers in Education Conference*. Oklahoma City, OK: IEEE-CS, 2013.

Peters, A-K (2014). Identity Development in Computing Education: Theoretical Perspectives and an Implementation in the Classroom. *9th Workshop in Primary and Secondary Computing Education*. Berlin, Germany.

Response from Alan Cheville.

For several years papers have been published which claim that as a percentage of participation in violent Jihadist groups those with some higher education in engineering are significantly over-represented. This research has recently been published in a book, *Engineers of Jihad: The Curious Connection between Violent Extremism and Education* by Gambetta and Hertog, published this year by Princeton University Press. The book claims that the over-representation is due to a combination of low social mobility and a mindset found more frequently among engineers. As one might expect, and as should be the case with any research that makes generalized claims, there has been much debate as well as a vigorous refutation.

Regardless of the eventual merit of Gambetta and Hertog's claims—and the actual truth is likely to be complex and nuanced—the publication of their book deserves a response from the engineering education community that is more than a mere denial. While it might be simpler to simply ignore their conclusions, the reality is that we are in a time when technology can spread rumor globally in a matter of seconds, social media thrives on the sensational, and the political process reminds one of the lines of Yeat's poem *The Second Coming*: "...The best lack all conviction, while the worst / Are full of passionate intensity." In such a time beliefs and myths are given new power, and words, no matter the weight of fact that lies behind them, are able to influence people's lives. But as engineers our professional obligation as engineers is to both search for and speak truth in any response we make.

Frezza's editorial, in which he explores the engineering mindset, how it is developed in students, and what such a mindset is or should be is one such response. Frezza raises questions about our educational process, and asks us if we can agree on what mindset our students leave their degree program with. Frezza, as well as others who seek to understand the construct of a mindset will speak at a panel discussion at the 2016 American Society of Engineering Education (ASEE) annual meeting in New Orleans sponsored by the Technological and Engineering Literacy / Philosophy of Engineering Division. Here a debate by experts on the merits of the arguments put forth by Gambetta and Hertog will lead to insights that can frame other responses.

Nowhere will be found neatly packaged answers to the questions raised by the preponderance of engineers in violent organizations. Truth is rarely simple even to the very wise, despite the fact that it profits media companies and politicians to make it seem so. The path to truth can only be followed through vigorous dialog and a willingness to come together in community with both an open mind and an open heart. Both philosophy and literacy are needed if one desires to walk this path. As difficult as it is to question our motives and practices, the engineering education community should take a long moment to reflect on whether the actions we take as educators have the potential to create harm, and if so what form such harm might take. We hope you will join us as we try to open new forums to debate issues that are not, and never shall be, fully quantifiable.

Response from John Heywood

The book review in the *The Chronicle of Higher Education* that began with the

question "Does Engineering Education Breed Terrorists?" seems to have caused a furore among engineering educators in the United States. Not so on this side of the Atlantic although one of the authors, Steffen Hertog based at the London School of Economics been interviewed twice on the BBC to my knowledge. Perhaps engineering educators in these islands happened to read an article in *The Times* (April 2nd 2016) by the distinguished historian Michael Burleigh because he summarily dismissed the book. Having done so his penultimate paragraph read "There is another serious flaw to the authors' approach. They do not even explore what engineers are taught-or acknowledge the differences between the various disciplines within the field."

Mani Mina had told us that it was not surprising that the proportion of engineers should be high, or be followed by medics because in the Middle East the status subjects were Engineering, Medicine, and Law from which many national leaders are drawn. In his second broadcast Hertog applied relative deprivation theory to the problem. It suggests that the failure of so many students to have their expectations met led to high levels of frustration with the consequences observed. Asked by Professor Laurie Taylor (a sociologist) what he would recommend, Hertog replied that governments in the Middle -East should concentrate on reforming primary and secondary (elementary and high school) education. What was perhaps more surprising he went on to say that the numbers studying engineering should be reduced (BBC Radio 4. "Thinking Aloud" 4 pm, June 8th 2016).

As a counterpoint to Hertog, Raffaello Pantucchi another researcher working in the field argued that it was important to understand the social dynamics that made a person become involved and committed

to terror. This process was a social activity, so understanding how terrorist cells socialise their reports of considerable significance. While we are familiar with Bucciarelli's (1994) concept of design as a social activity we tend to forget that higher education is experienced as a social activity as well. It is through the social organization that the students find the support they need not the classroom. Astin after his monumental longitudinal studies of students in American liberal arts colleges wrote "The student's peer group is the single most potent-source of influence on growth and development during the undergraduate years, and in so far as the affective development of students are concerned students' values, beliefs, and aspirations tend to change in the direction of the dominant values, beliefs and aspirations of the peer group." A hundred years previously Newman had written "when a multitude of young men, keen, open-hearted, sympathetic and observant as young men are, come together and freely mix with each other, they are sure to learn one from another, even if there be no one to teach them, the conversation of all is a series of lectures to each, and they gain for themselves new ideas and views..." What matters is that they should be students of all kinds and not simply from a subject specialism such as engineering. That this should be of concern to those responsible for engineering in their particular colleges.

A key question that Astin presents to engineering educators is the extent to which the affective development of the individual is catered for by the organization of the university, curriculum, and teaching. As Frezza points out students are very immature when they enter university. Developmental psychologists like William Perry and King and Kitchener have shown that the way instruction is given can impede

development leaving the student not much more mature than when they entered the institution. In this respect Gambetta and Hertog might be given leeway for not mentioning instruction in engineering for it is an issue that faces higher education generally. Nevertheless it surely time that engineering educators re-visited the developmental curriculum developed at the Colorado School of Mines Pavelich and Moore, (1996), and the investigations carried out by Marra, Palmer and Litzinger (2000) at Penn State university.

More specifically Gambetta and Hertog are open to the criticism that they should have looked at the research on personality that has been done among engineering students.

My starting point was a paper by Furneaux who in 1962 reported that the mechanical engineering students likely to perform best in the school of engineering of one of Britain's leading universities were likely to be neurotic introverts which might, just might support the theory given that extraverts are supposedly less susceptible to social conditioning than introverts. Other studies which were made of personality and performance do not help the case made by Gambetta and Hertog. Two distinguished British educators – Noel Entwistle and John Wilson (1970) concluded from a literature survey that Furneaux's students were atypical of university students as a whole. Lest you think that lends support to the argument consider that twenty years later Paul Kline (1993) an equally distinguished psychometrician concluded from a study of students at five British Universities that there were no differences between engineering students and other students in these universities in respect of extraversion and emotional stability (Kline and Lapham, 1992).

In the same period in the United States the Omnibus Personality Inventory was used to study engineering students by C. F. Elton and H. A. Rose (1966). They found a significant difference between engineering students on the dimension of “intellectual disposition.” Strangely, an absence of high intellectual interests was found among those who persisted. In another study the concluded that personality differences among students sharing accommodation could impede or enhance performance. There was also in the nineteen-seventies and eighties interest in the Myers-Briggs Indicator (MBTI) as expressed in articles in Engineering Education. They led Mary McCauley (1990) to argue that people skills were undervalued by engineering educators as measured by the “Feeling” dimension of the MBTI. As Frezza argues the affective domain continues to be undervalued by engineering educators continues to be made, a view that is supported by other writers (Heywood, 2016).

There would seem to be nothing in the available evidence on personality and performance in engineering education in western universities to confirm the personality dimension of the thesis put forward by Gambetta and Hertog. Neither do these studies have they anything to say about the curriculum and its impact, but then neither do Gambetta and Hertog.

Nevertheless, since we believe that what we do in engineering education changes

students, and since we don't appear to study the impact of the curriculum on development Gambetta and Hertog should make us begin to think about what it is we are doing, and with what effect.

References

- Bucciarelli, L. L (1994). *Designing Engineers*. Cambridge, MA. MIT Press.
- Elton, C. F and H. A. Rose (1966). Within university transfer. Its relation to personality characteristics. *Journal of Applied Psychology*. 50(6), 539.
- Entwistle, N. J. and J. D. Wilson (1970). Personality, study methods, and academic performance. *Universities Quarterly*, 24(2), 147-156.
- Furneaux, W. D (1962). The psychologist and the university. *Universities Quarterly*, 17(1), 33-47.
- Heywood, J (2016). *The Assessment of Learning in Engineering Education*. Policy and Practice .Hoboken, NJ. IEEE Press/Wiley,
- Kline, P (1993). *The Handbook of Psychological Testing*. London, Routledge.
- McCauley, M. M (1990). The MBTI and individual pathways in engineering design. *Engineering Education*. 66(7), 729-716.
- King, P. M and K. S. Kitchener (1994). *Developing reflective Judgment*. San Fransico. Jossey-Bass.
- Kline, P and S. Lapham (1992). Personality and faculty in British Universities. *Personality and Individual Differences*, 13, 855-857.
- Marra, R., Palmer, B and T. A. Litzinger (2000). The effects of first year design course on student intellectual development as measured by the Perry scheme. *Journal of Engineering Education*. 89(1), 39-45.
- Pavelich,, M. J and W. S. Moore (1996). Measuring the effect of experiential education using the Perry model. *Journal of Engineering Education*. 85, 287-292.
- Perry, W. G (1970). *Forms of Intellectual and Ethical Development in the College Years. A Scheme*. Troy, Mo. Holt, Rinehart and Winston.

Defining Engineering and Technological Literacy

*John Krupczak, John W. Blake, Kate A. Disney, Carl O. Hilgarth,
Randy Libros, Mani Mina, Steven R. Walk*

Many Americans lack even a rudimentary understanding of the principles underlying the technology essential for daily life. Engineering concepts are pervasive in decision making within industry, government, education, and health care, yet most people complete formal education with little exposure to the central ideas and principles underlying our technological society. The terms engineering literacy and technological literacy have been used to describe aspects of this understanding of human-developed process and products. This work addresses some of the differences and similarities between the concepts of engineering literacy and technological literacy. A clear well-defined understanding of each of these areas is an essential first step in developing a means to promote these understandings in the undergraduate general education program. Engineering literacy is viewed as having a focus directed more toward the process of creating or designing technological artifacts or systems. It is argued that technological literacy includes a broader view of the products or results of the engineering process as well as the relation between technology and society. Each literacy is seen as having a time-independent and a constantly evolving or changing component. The engineering processes can be viewed as independent of the specific nature of technology which changes over time as technology evolves. The specific artifacts, processes, and systems that define any technological era are transient. The hardware aspects of technological literacy will be an ever-changing subject. The interactions and relationships of society to technology are

viewed as constant and little-changed as different artifacts and systems move into and out of importance to daily life. This work will use the process of a comparison of engineering and technological literacy to help define and describe each area of knowledge.

The Need for Understanding Technology and Engineering

Technology affects nearly every aspect of our lives, and informed citizens need an understanding of what technology is, how it works, how it is created, how it shapes society, and how society influences technological development. The critical role of technology in creating and maintaining our modern standard of living has been emphasized by the National Academy of Engineering in *Technically Speaking: Why All Americans Need to Know More about Technology* (Pearson and Young, 2002). The NAE promotes technological literacy as means by which individuals can function more effectively in modern technological society. This is consistent with E.D. Hirsch's general definition of "literacy" as "information that is taken for granted in public discourse" (Hirsch and Trefil, 1987).

The importance of understanding engineering has also been advocated. The National Academy of Engineering (NAE) has published *Changing the Conversation: Messages for Improving the Public Understanding of Engineering* (NAE, 2008). The NAE document outlines the importance of clarifying the nature of engineering and the role engineers play in improving the quality of life. It has also

been argued that a person who has no perception of the contribution that engineering can make to our understandings of behavior and society is not liberally educated (Heywood, 2010).

The American Society for Engineering Education (ASEE) has an established Technological Literacy Division. A goal of the division is to advance “broad technological understanding” by all individuals. Based on topics addressed by papers in the divisional sessions at ASEE national conferences it is apparent that the subject matter of technological literacy encompasses a wide range of issues related to helping all types of students to understand engineering and technology.

Recently the authors, who are also members of the ASEE Technological Literacy Division, have noticed that the terms technological literacy and engineering literacy appear in discussions in similar contexts with differing meanings. In some discussions technological literacy and engineering literacy are treated as synonyms. In others the two are treated as separate concepts. There appears to be a need to clarify the ideas of engineering and technological literacy. This paper intends to begin a discussion about the differences and similarities that might exist between engineering and technological literacy.

There are a number of possible types of literacy relevant to engineering and technological literacy. These include such concepts as computer literacy, mathematics literacy, and financial literacy. A more thorough and wide-range review of literacies should include the similarities, differences, and nuanced distinctions between these concepts and technological literacy. The present analysis will be confined to engineering and technological literacy as a first step.

Definitions of Technological Literacy

Technology is all of the many products of the engineering disciplines not just personal computers and information technology. Technology, in a broad sense, is any modification of the natural world made to fulfil human needs and wants. This includes not only its tangible products, but also the knowledge and processes necessary to create and operate those products. The infrastructure used for the design, manufacture, operation, and repair of technological artifacts is also considered part of technology.

At the start, it is essential to distinguish technology and engineering from science (Pearson and Young, 2002; NAE, 2008). Science is the development of an understanding of the natural world, while engineering is the creation of new technologies to improve human welfare (NAE, 2008). The separate, but related goals, of engineering and science necessitate a differentiation between technological literacy, engineering literacy, and knowledge of science.

For a number of years groups seeking to define the content and curriculum of science and mathematics have included the human-built world, or technology, when developing content standards. Initially these efforts included technology as a peripheral aspect of science content (AAAS, 1993; NRC, 1996) In a recent K-12 effort, the International Technology and Engineering Educators Association (ITEEA, formerly the International Technology Education Association) developed Technology Literacy Standards (ITEA, 2000) explicitly addressing technology. While these efforts are directed at K-12 students, the general topics and organization of the technical world provide useful information for

efforts intended for the undergraduate level.

Project 2061: *Benchmarks for Science Literacy* (1993)

In 1993, the American Association for the Advancement of Science (AAAS) published, *Project 2061: Benchmarks for Science Literacy* (AAAS, 1993). The AAAS devoted one of the twelve chapters to the Designed World. The focus was on the products of engineering and their impact on daily life. Eight topics were considered: Agriculture, Materials and Manufacturing, Energy Sources and Use, Communications, Information Processing, and Health Technologies. The benchmark recommendations emphasized that technology is a human activity that shapes our environment and lives.

The National Science Education Standards (1996)

In 1996 the National Academies produced the *National Science Education Standards* (NRC, 1996). This document contained a section devoted to technology. A notable inclusion in these standards was a highlighting of the importance of the design process as a defining aspect of technological endeavors.

ITEEA Standards for Technological Literacy (2000)

In 2000 the then International Technology Education Association published *Standards for Technological Literacy: Content for the Study of Technology* (ITEA, 2000). The ITEEA standards project was a broadly based effort that included more than 150 reviewers from K-12 education, the sciences, and the engineering disciplines. An intent of this effort was to encourage educational

curricula that would provide technological literacy to K-12 students.

The ITEEA 2000 Standards are comprehensive in scope. They are divided into five main categories that sub-divide into 20 specific standards. The five main categories used to define technological understanding include:

1. Understanding the Nature of Technology,
2. Understanding of Technology and Society,
3. Understanding of Design,
4. Abilities for a Technological World, and
5. Understanding of the Designed World.

Important features of the scope of understanding technology are seen in the ITEEA standards. The standards consider the nature of technology or helping K-12 learners to be able to distinguish technology from other aspects of their environment. The standards also highlight the importance of specifically studying the complex interaction between technology and the society which creates it. The design process as the mechanism of technological development is a separate area of the standards. The standards then include specific abilities related to technology such as the ability to select technological products appropriate for a specific set of requirements, or to carry out basic problem-solving in the context of technological systems. The last main category attempts to identify certain broad areas of the human-built world such as communication, manufacturing, and energy technologies. The ITEEA standards represented a significant advance and elaboration of the parameters defining the technological world, and the recognition that, given the importance, all students should begin to develop an increasingly sophisticated understanding

of technology starting at the earliest years of school.

National Academy of Engineering:
Technically Speaking (2002)

During the same time period that ITEA was addressing technological understanding in the K-12 realm, the National Academy of Engineering began promoting the importance of public understanding of technology and engineering. This led to the publication of *Technically Speaking* (NAE, 2002). While the ITEA work was intended to influence the K-12 curriculum, *Technically Speaking* was intended to reach a broad audience and inform the general public.

Technically Speaking emphasized that technology consisted of the broad array of products and processes that are created by people to satisfy human needs and wants. This was an attempt to redirect the association of the word “technology” with personal computers and the internet to a broader definition encompassing all the technology of our human-built world. *Technically Speaking* also fostered the recognition that engineering and science are distinct but related activities. *Technically Speaking* advocated that knowledge in the technical realm might be categorized in a series of levels consisting of Knowledge, Capabilities, and Ways of Thinking and Acting.

The NAE makes an effort to distinguish technology and engineering from science (NAE, 2002; 2008). Science is the development of an understanding of the natural world, while engineering is the creation of new technologies to improve human welfare (NAE, 2008). The separate, but related goals, of engineering and science developed a differentiation

between technological literacy and knowledge of science.

Engineering Literacy

While technological literacy has been well-defined, comparable standards or definitions of engineering literacy have not been developed. The various existing standards for technological literacy include elements that can be recognized as aspects of engineering. For example the design process is included in nearly all of the standards. This process is normally considered to be a hallmark of engineering activity. However the term engineering is not treated systematically by any of the technological literacy standards.

There is a need to distinguish between the terms engineering literacy and technological literacy. The two are interconnected and the potential for confusion is understandable. Nevertheless some effort should be made to clarify engineering literacy.

Distinctions Between Engineering Literacy and Technological Literacy

In this section some means to help distinguish engineering and technological literacy are described. This is considered to be an initial effort and the starting point for a discussion. Refinement of the engineering literacy concept is anticipated as was the case for technological literacy. Some area of distinction between engineering and technological literacy are listed in Table 1.

| Engineering Literacy | Technological Literacy |
|----------------------|------------------------|
| Process | Product |
| Verb (Actions) | Noun (Objects) |
| Narrow focus | Broader focus |

Table 1: Some Areas of Distinction between Engineering and Technological Literacy.

Process versus Product

One means to distinguish engineering from technology is by considering the difference between process and product. Engineering can be viewed as a process. The process of creating physical artifacts and procedures that meet human needs and wants. Technology on the other hand might be seen as the product of the process. Technology is the created device, system, or component that is brought into existence by humans engaging in a creative problem-solving process.

For example a person who is technologically literate might have a knowledge of the major systems of an automobile such as the engine, power train, and brakes along with the basic principles underlying the functioning of these systems. This is knowledge of the product. Engineering literacy would include knowledge or ability to design, analyze or otherwise create the constituent components of the automobile.

Verb versus Noun

A more general way to emphasize the distinction between engineering and technology is to introduce the idea that the difference between the two is related to the fundamental difference between a verb and a noun. In this discussion, engineering can be considered to be a verb. Engineering is an action. Something is happening which is identified as engineering. Engineering activity results in a transformation of materials, energy, or information. Something is different before and after engineering activity takes place.

Technology can then be classified as a noun. Technology can be viewed as the identifiable things that result from engineering or related work. Technological literacy would then include some knowledge of these components, systems, and processes.

As an example, consider an integrated circuit chip. An integrated circuit is a technological device. A person who is technologically literate might be able to recognize an integrated circuit, describe what it is, and explain the general uses and importance of integrated circuits. An engineering literate individual would be more familiar with how an integrated circuit can be used as a means of converting an abstract schematic design into a working physical object.

Narrow versus Broader Focus

Another area to help distinguish engineering from technological literacy would be to consider one as having a broader or more diverse focus than the other. If engineering literacy is viewed as having a focus directed more toward understanding the process of creating or designing technological artifacts or systems, then technological literacy includes a broader view of the products or results of the engineering process as well as the relation between technology and society.

For example, while it is not necessarily the desired situation, it is true that individuals can engineer or create technological artifacts in a state of near isolation from other concerns or interests. The engineering design process can create its own isolated internal value system. A successful engineering effort can be defined as a design that works according to the specifications of those providing the resources to carry out the project. Incarcerated individuals might be compelled to create a particular technological device with no knowledge of the intended use of that device. If the device functioned as intended and met all specified design requirements it would be difficult to argue that the creators were not engineering literate. However without

knowledge about why the particular design requirements were chosen, and what use the device served, it could be said that the prisoner-engineers did not fully understand the technology and were therefore not technologically literate.

Evolution or Change Over Time

It may be helpful to consider how the understanding of engineering or technology may evolve or change over time. It can be seen that both engineering and technology have both a time-independent or permanent nature and also a constantly evolving or changing aspects. The engineering processes can be viewed as independent of the specific nature of technology which changes over time as technology evolves. The specific artifacts, processes, and systems that define any technological era are transient. The hardware aspects of technological literacy will be an ever-changing subject. The interactions and relationships of society to technology are viewed as constant and little-changed as different artifacts and systems move into and out of importance to daily life.

Role of Analysis

Since engineering literacy appears to be directed more toward the process creating or improving technological objects it may be that computation and analysis appear differently in engineering literacy than technological literacy. It may be that an individual who is technologically literate might acquire an ability to use technological tools and mathematical methods in a problem-solving context. It would seem that in engineering the purposes of analysis are more narrowly focused toward creating and improving technological products.

For example, a person who is technologically literate may sample a drop

of water from a pond and then count the number of single-celled organisms in one drop of pond water by correct use of an appropriate microscope. This person may then be able to use information obtained from maps and other published data to determine the volume of the pond. They may then be able to use a spreadsheet to determine an estimate of the total number of single-celled organisms in the pond. This process has involved technological systems and quantitative analysis but it would not appear that this activity would be classified as an engineering project.

Degree of Overlap and Open Questions

Once a distinction is made between engineering literacy and technological literacy, the question of the degree of overlap between the two concepts becomes an interesting potential area of discussion. What is the overlap or commonality between engineering literacy and technological literacy? Is one completely contained within the other? Is engineering literacy a subset of technological literacy or is the opposite the case?

One way to help frame the question of the relationship between engineering literacy and technological literacy is to ask: are engineers technological literate? If not why not? Is this because of a deficiency in current engineering education or is it due to a fundamental difference between the scope of engineering and technological literacy? Alternatively, in considering general education, what are the appropriate elements of engineering and technological literacy to be included?

Summary and Conclusions

An initial effort to distinguish between engineering and technological literacy has been made. A clear well-defined understanding of each of these areas is an

essential part of developing these literacies. Engineering literacy is directed more toward the process of creating or designing technological artifacts or systems. Technological literacy includes a wider ranging scope including the products or results of the engineering process as well as the relation between technology and society. The extent to which engineering and technological literacy form a subset of each other remains a topic for future discussion and investigation.

Acknowledgement

This work was supported by the National Science Foundation under awards: DUE-0633277 and DUE-0920164. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the authors and do not necessarily reflect the views of the National Science Foundation.

References

- AAAS (1993). *Project 2061: Benchmarks for Science Literacy*, American Association for the Advancement of Science, Oxford University Press, (1993).
- Heywood, J (2010). Engineering Literacy: A Component of Liberal Education” *Proceedings of the 2010 American Society for Engineering Education Annual Conference*.
- Hirsch, E. D and J. S. Trefil (1987) *Cultural Literacy: What Every American Needs to Know*, New York. Random House.
- Hirsch, E. D and J. S. Trefil (1987) *Cultural Literacy: What Every American Needs to Know*. New York. Random House.
- ITEA (2000). *Standards for Technological Literacy*, Reston, VA. International Technology Education Association. <http://www.iteaconnect.org/TAA/Publications/TAA_Publications.html> (accessed December 15, 2011).
- NAE (2008). *Changing the Conversation: Messages for Improving the Public Understanding of Engineering*, Committee on Public Understanding of Engineering Messages. National Academy of Engineering. Washington DC, National Academies Press
- NRC (1996). *National Science Education Standards*. National Research Council, National Academies Press, (1996).
- Pearson, G and A. Thomas Young,(editors) (2002). *Technically speaking: Why all Americans need to know more about technology*. National Academy of Engineering. Washington DC. National Academies Press.

The Idea of a Firm as a Learning Organization and its Implications for Learning-how-to Learn

John Heywood

Abstract

Recent attempts to define engineering and technological literacy show that the process of producing a product is complex and that different levels of engineering and technological literacy are required by non-engineers who engage in the management of technology and its products. The dimensions of engineering and technological literacy cover a broad range of activities from how to make things (artefacts, software) to studying the impact those things make on society. The public at large are likely to be more interested in the impact of technology than the nitty-gritty of making things that are rightly the interest of the manager. Common to both is the need to understand people. In society failures to understand the impact of technologies on individuals can have adverse consequences. Similarly failures to understand one's employees can lead to the withdrawal of labour or a loss of motivation. It is incumbent therefore, that those who would wish to manage engineers or those who design artefacts have a critical understanding of human behaviour.

One approach to understanding people and organizations is to understand how we learn; for learning is a necessary, if contingent, activity in which success and failure contribute to our future actions. All life is necessarily a learning activity that contributes to our behaviour. We all have theories or philosophies (explicitly or unconsciously held) of how people learn that contribute to our personal behaviour. In spite of this very little attention is paid to how we learn in the education system except for one or two courses on learning-how-to learn. Yet we do expect the products of education to be able to think critically and those who study critical thinking regard meta-cognition, the ability to reflect on our own learning, as a key skill in critical thinking. At the same time many students find thinking-about-thinking difficult.

One impediment to such understanding is the view that each person thinks differently to the other. Many people find that the idea that there are others with the same learning style as themselves disconcerting and reject the idea that there are instruments that can detect these learning styles, and that an instructor's knowledge of the learning styles can influence the way a lesson is structured and improve the effectiveness of learning. A possible way to interest students in their own learning is through case studies of learning organizations. Organizations that are successful continually learn. In any event organizations are at their simplest aggregates of learners. The factors that impede and enhance learning in classrooms also impede and enhance learning in organizations. The purpose of this paper is to

demonstrate this case by means of a case study of a manufacturing organization. It is shown that study of the organization leads to a number of questions that should enable the reader to reflect on their own thinking skills.

Introduction

The idea that organizations are learning systems has received much attention since Peter Senge published "The Fifth Discipline" in 1990 (Senge, 1990) although the concept can be traced back to at least to work by Argyris in the nineteen-fifties (Argyris and Schön, 1974). An alternative and/or complementary approach suggested by this writer [Heywood, 1989:2000] is to describe the learning curve of an organization in terms of models of learning, problem solving, decision making and critical thinking that are commonly discussed in the literature. Many of them are linear and have common elements. This writer demonstrated this point by reference to an organization in the aircraft industry in which he and several colleagues task analysed the work done by those persons classified as engineers (Youngman et al, 1978). As part of the investigation he carried out an illuminative evaluation (Heywood, 1976) that included a study of the firm's history. From this study he constructed learning curves using models of decision making similar to that proposed by McDonald to explain the work of teachers (exhibit 1 (McDonald, 1968) and that which he and other colleagues had developed for the assessment of project work in engineering science (Carter, Heywood, & Kelly, 1986). The history of the organization had been documented by Langrish et al (1972) and Gledhill (1966). It was analysed in terms

of problem solving/decision making by Heywood (1974). It began with the statement of the origins of the organization found in Langrish et al (1972).

The history of the organization showing its stages of learning

Langrish and his colleagues record of the Aircraft Equipment Division of the English Electric Co states that “During the 1940’s the English Electric Co., at Bradford were involved in manufacturing industrial motors and generators. Manufacture of aircraft actuators for English Electric at Preston and a separate section was formed to deal with this equipment. When the decision was taken in 1953 to extend the activities of this section into aircraft generating equipment, it was felt by some including Mr P. J. Dalglish, the Divisional Manager, that the requirements of the aircraft manufacturers not only for increased capacity (i.e electrical power output) but also for lighter weights and better reliability would not be resolved by an extension of the same concepts to higher voltages. They suggested that further developments could only be made using alternating current techniques; indeed this trend had already begun to emerge in the United States.”

The *problem as formulated* was to manufacture alternating, as opposed to direct current machines. It is evident from the statement that the Divisional Manager thought that this goal could be reached by the vertical transfer of learning. Examination of the organization’s historical development shows that the engineer’s *knowledge was structured* by the purchase of information in the form of a licence to manufacture a constant speed drive from the Sundstrand Corporation of Illinois. It should be noted that McDonald 1968 and others make a quite clear distinction between problem finding,

problem formulation, and problem solving, a distinction that is maintained by this writer as result of the assessment of performance in project work in engineering science (Carter, Heywood & Kelly, 1986)

A constant speed drive maintains the generator at a constant speed when driven directly from the main engines of the aircraft. Without this intervening mechanism the transmission speed of the generator would vary with that of the aircraft engine.

This arrangement enabled the firm to manufacture alternating current generator systems. Improving the system involved the engineers in *the restructuring of knowledge that was already well organized*. They learnt and this example is a good example of that definition of learning which says that it is that process by which experience develops new, and reorganizes old, concepts (Saupe,1961).

Even so, both ac and dc machines remained highly unreliable, particularly at high altitudes. By the mid-nineteen-fifties jets had emerged and plans for supersonic flight were under way. One reason for this unreliability was the fact that the commutator brushes were subject to excessive wear under conditions of low air pressure and humidity. So in 1956 English electric began to develop brushless rotating rectifier machines. They were given “additional impetus when a Valiant bomber in 1952 and a Vulcan 1 in 1958 crashed as a consequence of the failure of their 112 volt dc systems.” Both aircraft were part of the British Nuclear deterrent; the Vulcan was the first delta wing bomber built in the UK: (in the same period of the 1950’s the Convair F102-Delta Dagger was developed in the US).

By 1957 with the introduction of suitable semi-conductor diodes the Aircraft Equipment Division went wholly over to a new programme of engineering which had as its objectives the development of both ac and dc brushless generators and a further reduction in the weight of aircraft electrical generating systems.

In 1966 Gledhill explained that “its basic format is essentially the same as that developed from the initial design study undertaken in 1956. Over the intervening years the potential of this basically sound concept has been steadily exploited in a series of applied investigation programmes into five fundamentals: heat transfer, electromagnetic design, insulation selection, rectification and mechanical design” (Gledhill, 1966).

It will be seen that the solution of the problem caused the structuring of relatively disorganized knowledge. For example “...a more reliable and cheaper system is sometimes obtained by the addition of a third stage to the generator comprising a permanent magnet pilot exciter...the continuously available voltage-derived power source provided by the pilot exciter obviates the need for current-derived excitation power to cater for the condition of symmetrical short circuit. *This has made possible the development of extremely lightweight control gear packages...*”

The effects of this advance are that at 7.5 lbs it weighs some 10lbs less than the previous comparable unit. Gledhill illustrated the radical changes in size and weight which have been achieved first with printed circuits, then miniature printed circuits and finally modular packaging of the regulator and control panels.

If the data provided by Gledhill (figures 1 and 2) and Langrish in their articles is plotted in learning curves of the kind implicit in models of learning and decision making suggested by McDonald (1968) a pattern of the kind displayed in figure 4 emerges. Each development (curve) follows the pattern of the model shown in figure 3 which is related to the probable demand for the work force.

In addition to continually *reorganizing its knowledge* of existing products the firm was from time to time faced *with substantially new problems* arising from the demand for the delivery of much more electric power at higher altitudes and higher speeds of flight. These faced the engineers with a total reformulation of their thinking.

At the same time, advances in other firms such as the application of different material (e.g high cobalt iron alloys in the magnetic circuits of both rotor and stator), new technologies (e.g. printed circuits, semi-conductors) and new techniques (e.g. computer-aided design) - aided the acquisition of knowledge.

But it is equally important to remember the other side of the coin for adaptation to this new knowledge demanded *substantial relearning on the part of individuals in the division*. Moreover, this was stimulated by relatively quick changes in demand for improved equipment in output, reliability and weight culminating in a design study for Concorde in 1964.

The phrases and sentences that have been put in italics highlight problem formulation and identification, structuring and restructuring of knowledge. They show that these are continuously recurring phenomena and they account for the complexity of exhibit 4. But the individuals who contribute to these curves

are also using similar heuristics. Wales, Nardi and Stager (1976) go so far as to argue that their heuristic of guided design

is a general method used across the realms of knowledge for making decisions and solving problems and they

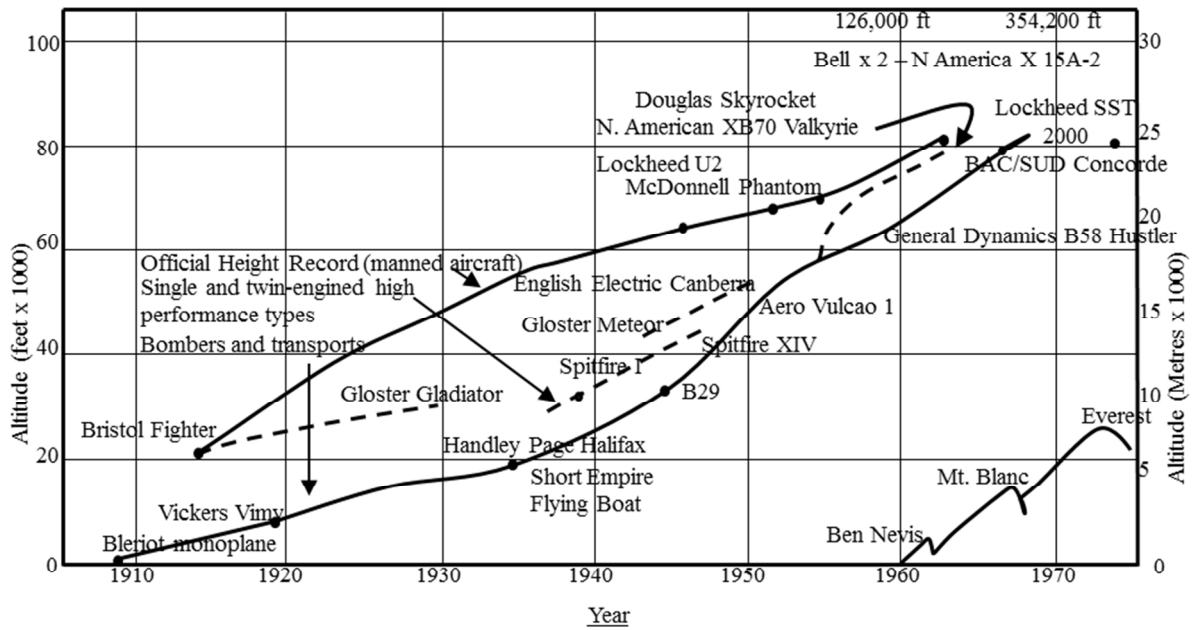


Figure 1. Progressive increases in aircraft operational altitudes from J. D. Gledhill (1966). Recent development in electric power generating equipment for aircraft. *The English Electric Journal*, 21(6),35.

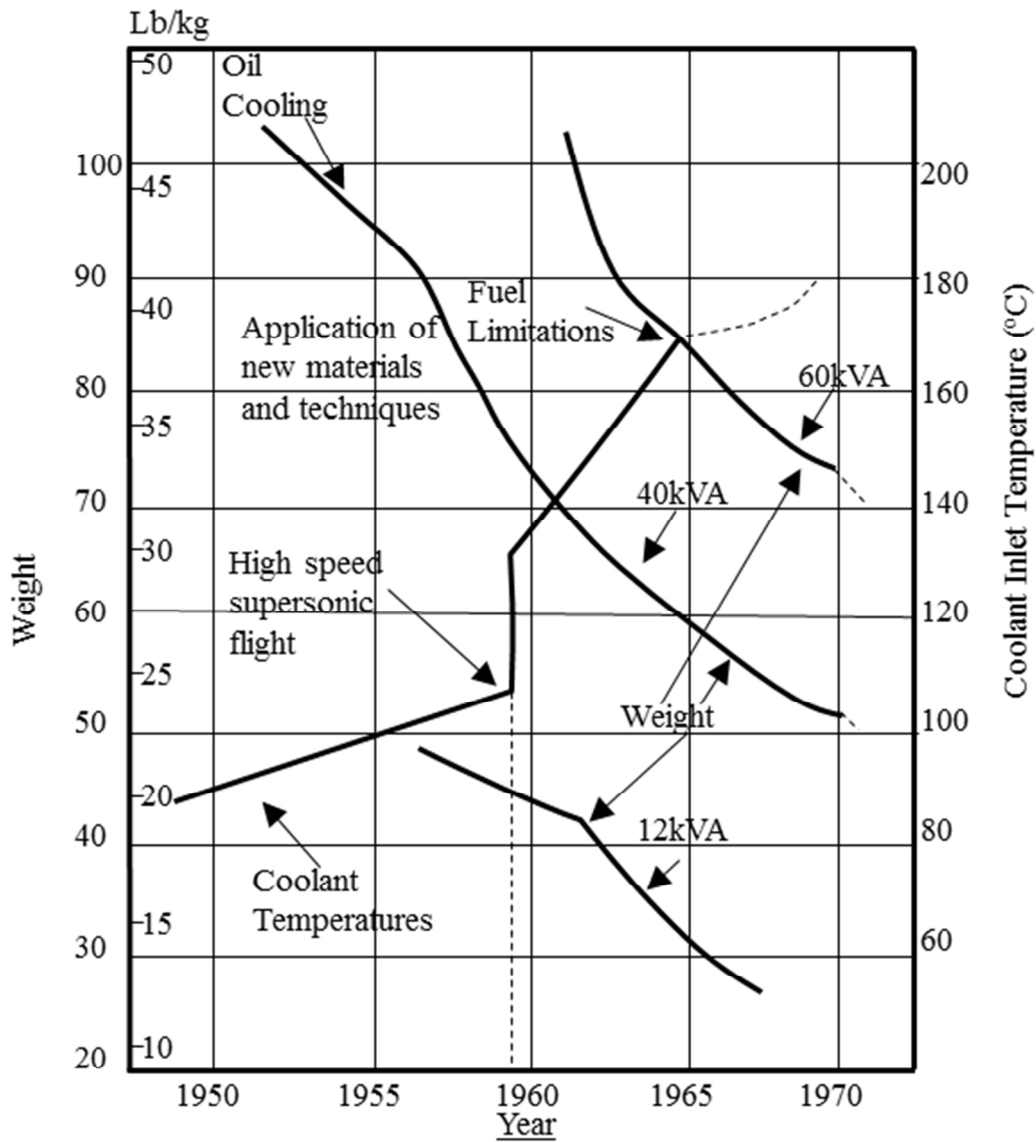


Figure 2. Trends in weight and coolant inlet temperatures of aircraft generators from J.D. Gledhill (1966). Recent development in electric power generating equipment for aircraft. *The English Electric Journal*, 21(6),36.

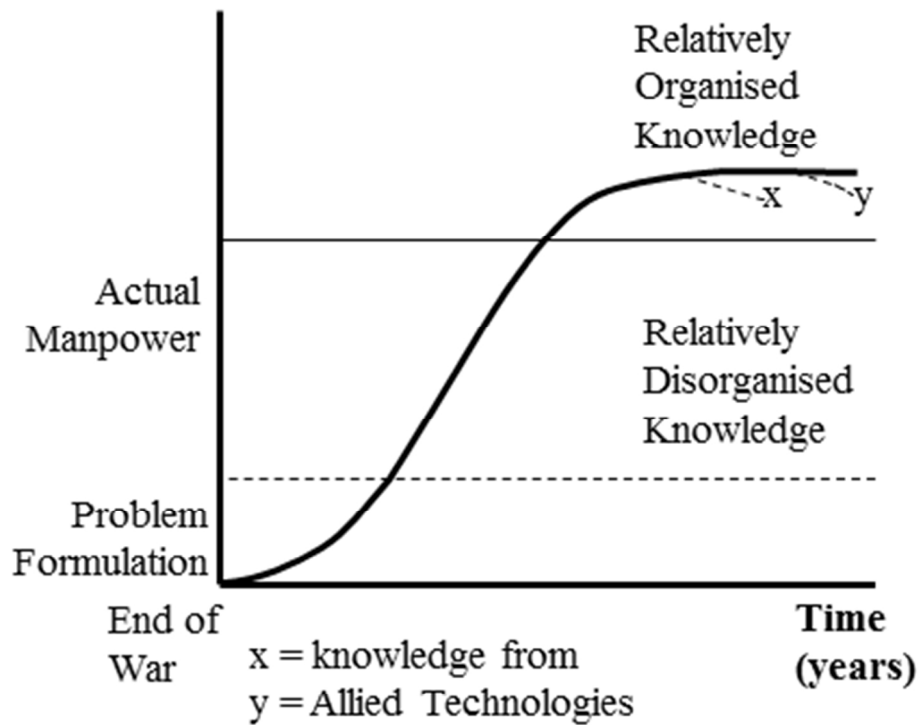


Figure 3. An organizational learning curve related to probable demand for manpower from J. Heywood (1972). A Note on the employment of qualified personnel in the sixties and seventies. Final report No 9 to the UK Employment Department of The Industrial Training Research Project, Department of Educational research, University of Lancaster.

The acquisition of knowledge in the development of a system represented by increasingly organised knowledge in the direction A-G, showing the response to new demands (I, II, III, IV), the influence of external learning by acquisition of licence to manufacture and develop (V), the effects of new materials and techniques (VI) and the influence of changes in electronic circuit design.

Key

- (i) Design & manufacture (ii) Work Begins (iii) First Production Contract
- (a) Application of techniques developed in sub-system 2 to previously organised technology.
- (b) Firm sponsored design study. (c) Award of design study contract
- (d) Inspiration (collected experience turned into application – creativity)

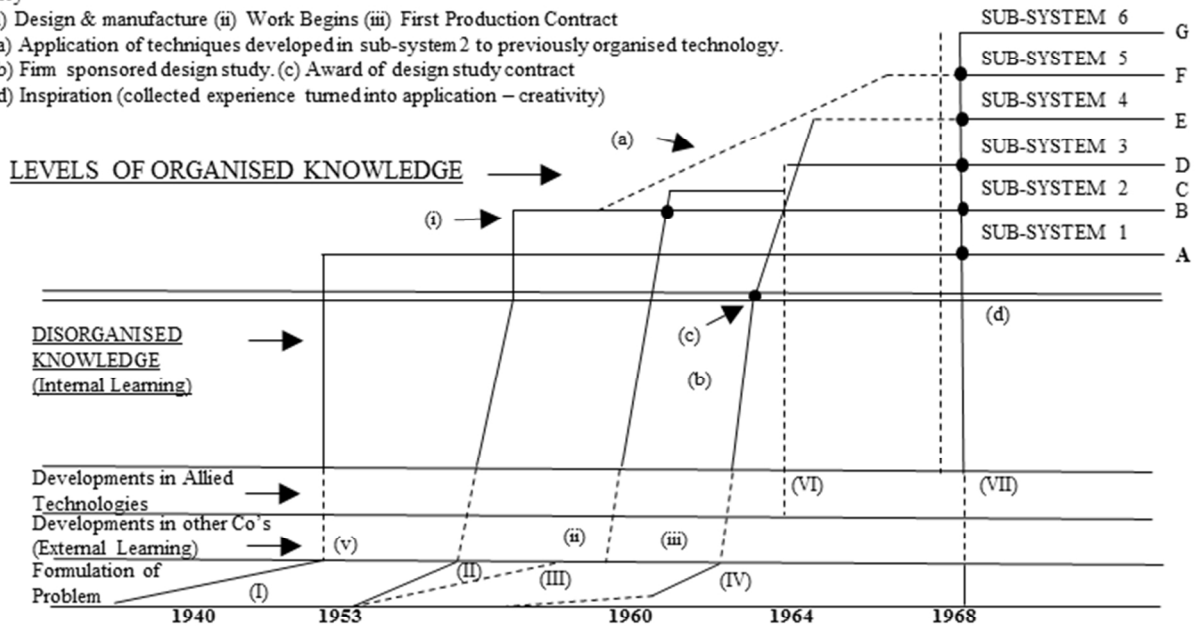


Figure 4. Learning curves of an organization making aircraft generating equipment from J. Heywood (1972). A Note on the employment of qualified personnel in the sixties and seventies. Final report No 9 to the UK Employment Department of The Industrial Training Research Project, Department of Educational research, University of Lancaster.

illustrate this point by numerous cases that Sherlock Holmes might have solved. The guided design heuristic is:

Define the situation.

State the goal

Generate ideas

Prepare a Plan

Take action

Eck and Wilhelm (1979) modified the Wales and Stager model thus

Identify the problem

Gather information

State objectives

Identify constraints and assumptions

Generate solutions

Analyze

Synthesize

Evaluate alternatives.

The engineering science model puts the evaluation of alternatives immediately after the finding of solutions. While evaluation, the final stage, requires reflection on what was achieved and whether it could have been improved.

Many students in second level education in Ireland (ie years 6 – 12) found that heuristics of this kind (mainly Wales and Stager's but some Polya (1957)) were useful in decision making and problem solving. One reason given for this was the structure it gave to their learning (Heywood, 1996). Data obtained from the assessment of engineering science projects suggested that some students have difficulty with problem finding. Others had difficulty in generating suitable

alternative solutions, and others with evaluation. Some students fail to understand the assumptions they make when undertaking projects and investigations.

A series of questions arise from the use of such heuristics that should help students reflect on their learning process(es). Some examples are expressed in the first person are.

1. Do I find problem solving a heuristic useful? If not, why not?
2. Am I able to define problems of my own making succinctly?
3. Do I find it easy/difficult to generate alternative solutions?
4. Do I find it easy/difficult to understand the assumptions I am making in completing any activity?
5. Do I find it easy/difficult to change strategy? To the extent of changing what it is I want to do?
6. Do I find it easy/difficult to reflect on what I have achieved?
7. How easy/difficult do I find learning?

Some students find learning difficult and it is easy to blame students when their difficulties may, quite possibly, have been due to the teacher. A classroom has many similarities with a learning organization. Given that this is the case it behoves us to consider the factors that impede learning in the classroom.

Impediments to learning in the classroom

Given that all organizations are learning organizations it follows that the factors that enhance or impede learning will be similar to those that enhance and impede learning in classrooms of which there are many. In the paragraphs that follow the focus will be on the role of experience in learning and group learning.

(1) Set mechanization (induction).

Many students when they learn a particular way of solving a problem will use the same technique again and again even when the technique is not particularly appropriate for the particular problem to be solved. This idea is due to Luchins who asked pupils to obtain specific quantities of water from three jars filled to different levels (capacity) (Luchins, 1942). First of all he showed them how to do two problems that involved all three jars. Then in another nine problems he found that students continued to use the three jar approach even when a two jar solution was possible. This 'set' interfered with their problem solving. Then Luchins divided another group into two sub-groups. The first sub-group worked through the problem in the usual way, using the three jar solution. The second group were told to think carefully about how to solve the problems, and given that instruction the second sub-group moved to the more simple solution of using two jars. We too easily rely on a 'set' with which we are familiar, and the 'set' becomes a controlling influence. Experience is a very powerful influence on thinking whether it be in classroom, organizational or other life settings. It prevents us thinking outside of the box.

(2) Innovation and experience

It is important to distinguish between experience and experiential learning such as that undertaken, in say, projects or role-playing exercises. The latter are specifically intended to help us reorganize previous experience so that something new is learnt and as the learning curves of this organization show it can continually reorganize its knowledge. "A crucial problem for human development is that we have to be aware of the discrepancy

between our perception and the incoming information from our environment, and of the impact of our own subjective experiences upon our perceptual world." So writes Peter Hesselting (1966) who goes on to write "Applied to our subject this means that special experience in the same organization provides an individual with such frames of reference. The very existence of these frames of reference or schemata determines the meaning of our perceptions. It shortens the time before reaching a percept and reduces the ambiguity of the situation. Specialism fosters autistic tendencies because one tends to define each situation as fitting our own schemata." It tends to condition the assumptions we make and the models we use.

In 1966 when Hesselting wrote these words autism was a term that was seldom used. The Oxford Dictionary of 1964 defined it as "morbid self-admiration or absorption in phantasy". A little more explanation would have been better but it is easy to see that innovation often challenges what we believe and cognitive dissonance arises when we defend our values against any reasoned argument [19]. That we tend to rely on experience rather than work from first principles, in the first instance seems to be self-evident and in the firm in the case study presented above we found that engineers when faced with a problem in the transfer of learning, in this case the ability to design a gear box several magnitudes greater than they had previously experienced, instead of starting from first principles searched in their past experience in vain for something that was like what they had to do. They had to go through a new learning exercise for which they were not adequately prepared. This is not to argue that they should not have looked at past practice but they should not

have become bogged down by it. The problem was, of course, solved.

In our investigation instruments we included items that would give us an insight into Hesseling's theory and, to some extent, it was validated. We found that as the engineers grew older the more they were likely to rely on past-experience and reject the notion that training was beneficial. Younger engineers tended to value training. We felt there was sufficient evidence to justify the view that excessive reliance on experience may, in the end, be destructive of innovation. In a work force that is relatively static the effects of age structure on performance cannot be ignored. Anecdotal evidence suggests that large firms in the IT industry take the view that it is young people who maintain an organization's creativity. As firms grow, there seems to be an in-built mechanism which leads from the organic and creative response to the environment to the closed response of schemata limited by experience. A change from a relatively open system to a relatively closed system. Firms in this situation sometimes may see the way forward to be by merger with another company. Either way this has implications for the workforce, the individual members of which need to be highly adaptable and that means being able to reorganize their knowledge which in turn means they will have to learn rapidly.

The reflective learner will add to question 5 above the questions:

To what extent do I rely on experience to solve a problem?

How do the ways in which the box interacts on me and my response influence my capacity for problem solving?

Are their times when experience has prevented me from standing outside the box?

What can I do to try and stand outside of the box?

To what extent do I think into the future?

And this brings us to the issue of creativity and the extent to which we believe we are creative.

Creativity in the organization

It is not unreasonable to suggest that the individuals in this organization who were responsible for the developments described above were very creative but in very many small ways. In his book *Management and Machievelli* Anthony Jay wrote that, "in a small way creative ideas are being produced all the time" (Jay, 1967). The need to adapt in simple situations forces us to be creative. The same kind of thinking is evident in the firm. In the final section of his article Gledhill writes of the future that "improvements to existing generations of equipment will continue to be made in the short term by the introduction of new materials and techniques. Among the most promising of these are electron beam welding, and the pure glass conductor insulation systems developed at the English Electric Nelson research Laboratories. Experimental machines built with this material have indicated that when the problems of construction are finally solved the weight saving may be as high as 15%."

"Slightly further ahead are changes in the design concept of machines, but retaining the generator, as a discrete unit. More direct forms of oil cooling, spraying, canning, drowning and phase-change systems are logical developments and are being evaluated in proto-type machines."

“Probably the ultimate development still using so-called conventional arrangements will be the integration of the generator within the engine or auxiliary power unit. Various proposals have been put forward for arrangements of this sort but none to date has met all the requirements of high speed and extreme environment.”

“Although these and other developments will continue to push higher operating limits of conventional machines, the time is fast approaching when this concept will no longer meet the requirements involved. Artificially contrived easier environments will then become necessary with the large weight penalties that these involve.”

Such thinking goes on in any firm of this kind commonly referred to in those days as a design and development organization for small batch manufacture of highly specialised artefacts and systems which are the subject of continuing modification. This firm was a highly innovative enterprise with a number of European ‘firsts’ and one world ‘first’ and depended for its future success on the extent to which its technology remained at the frontiers of knowledge. It worked at the frontiers of manufacturing technology not at the frontiers of pure knowledge where academia works. Our understanding of learning tells us that if the problems are wrongly formulated or there is a failure in creativity, or there is over reliance on experience or the market, the firm, any firm for that matter can fail. It also tells us that since organizational learning is an interactive activity among individuals in the organization that the way in which it is structured is important since the structure can either impede or enhance learning (Barnes,1960) demonstrated this point when he analysed two units doing almost identical jobs in the electronics industry. He found the one that was the most close

to an “open-system” was more productive than the one that most closely resembled a “closed-system.” The company of the case study stood somewhere in between.

People and organizations as socio-psychological systems

It was clear that the effectiveness of the organization was dependent on the interdependence of its workforce. Because roles were not defined with precision we found that even at the lower levels individuals needed to widen the scope of their initial brief through skills of communication and liaison in order to take some action. It appeared that communication was a complex skill, the nature of which varied with the activities undertaken. It seemed that persons were appointed to roles which they had to change in order to communicate. The organization was more a system of persons-in-relation than a strictly hierarchy structure. It is in such structures that feelings of responsibility are acquired.

We often allow ourselves to confuse status and responsibility: I am as guilty of that as anyone else. To put it in another way we often have to seek status in order to be responsible and that may be the reason why many persons seek to take on managerial roles. The feeling of responsibility accompanies or generates a feeling that the person is doing something worthwhile. In this organization almost everyone was directing and controlling, to a greater or lesser degree, and for some it was mainly a function of themselves. Job satisfaction is to some extent a measure of the degree to which an individual’s needs for direction and control are satisfied. In our study we showed that this was as much a function of personality as it was of history, ability and interest. What is an

acceptable goal to one person will not be to another: some wanted to be stretched others wanted a strict routine. No two persons in a section will be exactly alike. It may contain both aggressive people and timid people who can work together in a way that enhances or inhibits learning. Some who are taken outside their sphere of controlling may have to be supported.

A person is a psycho-social system. Within the boundaries of that system most individuals wish to be 'organic,' to modify a term used by Burns and Stalker (1961). They wish to be able to take actions and decisions as well as mature. The boundaries of these psycho-social systems arise as a function of the needs of the job and the needs of the person. When these are matched for each person in the organization a hierarchic system becomes structured by individuals who are organic within their own system, and grow in it in such a way that the organizations goals are achieved when it also becomes organic. Both systems have to be self-adjusting and when they are doing that the organization is learning.

The key question for reflection is:

Do I interact with others in ways that enhance or impede our learning?

We have, therefore to learn about ourselves. Reflective thinking (self-assessment) should yield observations that will help us cope with other people and groups.

Discussion

The purpose of this text has been to show that learning is at the heart of all human activity, and that one way of promoting the understanding learning is by means of case studies that pose questions about our own behaviour. A spin off should be an understanding of the observations we

should begin to make when we start work in an organization. Organizations do not run smoothly and often this can be put down to impediments to learning such as cognitive dissonance between various members. Thus learning about the factors that make teams functional or dysfunctional should be an important part of the curriculum. But learning about learning is much more than that. It is about our own maturation.

References

- Argyris, C and D, Schön (1974). *Theory in Practice. Increasing Professional Effectiveness*. San Fransisco, Jossey Bass.
- Barnes, L. B (1960). *Organizational Systems and Engineering Groups. A Comparative Study of Two Technical Groups in Industry*. Boston, Harvard University, Graduate School of Business Administration.
- Burns, T and G. Stalker (1961). *The Management of Innovation*. London, Tavistock.
- Carter, G., Heywood, J., and D. T. Kelly (1986). *A Case Study in Curriculum Assessment. GCE Engineering Science (Advanced)*. Manchester, Roundthorn Publishing.
- Eck, R. W and W. J. Wilhelm (1979) Guided design: an approach to education for practice in engineering. *Engineering Education*, November, 191-198.
- Festinger, L (1957). *A Theory of Cognitive Dissonance*. Stanford, CA. Stanford University Press.
- Gledhill, J (1966). Recent developments in electric power generating equipment for aircraft. *The English Electric Journal*, 21,(6), 35.
- Heywood, J (1974) *Assessment in History (Twelve to Fifteen)* Report No 1 of the Public Examinations Evaluation Project. Dublin, School of Education, the University of Dublin.
- Hesseling, P (1966). *A Strategy for Evaluation Research*. Assen, Netherlands. Van Gorcum.
- Heywood, J (1976). Engineers at work. An "illuminative" evaluation. *The Vocational Aspect of Education* 28, 25 – 38.
- Heywood, J (1989). *Learning, Adaptability and Change. The Challenge for Education and Industry*. London, Paul Chapman/Sage.

Heywood, J (1996). Teaching decision making in schools using an engineering heuristic. *Proceedings Frontiers in Education Conference (IEEE)* 67 – 74.

Heywood, J (2009). *Managing and Leading Schools as Learning Organizations*. Dublin, Original Writing for national Association of Principals and Deputies.

Jay, A (1967). *Management and Machiavelli: An enquiry into the politics of corporate life*. Harmondsworth, Penguin.

Langrish, J., Gibbons, M., Evans, W. G and F. R. Jevons (1972). *Wealth from Knowledge*. London, MacMillan.

Luchins, A. S (1942). Mechanisation in problem solving. The Effects of Einstellung. *Psychological Monographs* 248 cited in McDonald (1968)

McDonald, F. J (1968). *Educational Psychology*. Wadsworth, Belmont, CA.

Polya, G (1957). *How to Solve It*. 2nd edition. Garden City, Anchor Doubleday.

Saupe, J Chapter in Dressel, P (ed) (19610). *Evaluation in Higher Education*. Boston, Houghton Mifflin.

Senge, P (1990) *The Fifth Discipline. The Art and Practice of learning Organizations*. New York, Doubleday.

Wales, C, E., Nardi, A and R. A. Stager (1976). *Professional Decision Making*. Morgantown WV. Center for Guided Design, University of West Virginia.

Youngman, M. B., Oxtoby, R., Monk, J.D and J. Heywood (1978). *Analysing Jobs*. Aldershot, Gower Press.

Response by John Krupczak

In this article Heywood suggests that the study of learning in organizations may interest students in their own learning. The idea is advanced that the case studies of how organizations have been able to continually learn may provide a motivation for students to take an interest in their own need to continually learn.

I agree with Heywood's view and see many potential benefits in this approach. Learning in organizations can serve a catalytic role in prompting students to take both an interest in their own learning processes and responsibility for continued learning over the course of their careers. First it has proven difficult to interest

the majority of the US undergraduate engineering school students to make a connection between the ability to engage in life-long learning and the type of activities related to learning with which they engage as undergraduate students. This is despite the existence of the ABET accreditation criterion (i) "a recognition of the need for, and an ability to engage in life-long learning." Meeting this condition has been a part of ABET accreditation for nearly 15 years and most programs struggle to genuinely accomplish this goal. Typically the criterion may be met by having students teach themselves some small topic within the larger content of an engineering science course. This situation is in reality the faculty member carefully selecting and preparing the self-teaching experience so that the students have a reasonable probability of being successful. Further the students are typically required to engage in this self-teaching activity as part of a course requirement. This circumstance is not close to optimal in terms of actually instilling recognition of the need for, and an ability to engage in life-long learning. However exposing students to the need for continual learning in organizations may help to provide a convincing context for engaging students in their own learning.

Studies of the need for organizations to continually learn may also help engineering faculty to themselves allocate sufficient importance to the issue of students' ability to engage in life-long learning. Faculty priorities tend to focus on the specific engineering science topics viewed as comprising the essential core of the engineering curriculum in a particular sub-field. Some progress has been made in broadening faculty perspectives, and now professional skills such as communication ability, and teamwork are recognized by most faculty as critical elements in the competencies of students. The ability to learn-to-learn has languished on the periphery of the professional skill set of engineers. Drawing attention to the imperative that organization be learning organizations may help faculty to allocate attention to this professional skill.

The study of learning organizations as advocated by Heywood may help students become more adept at self-directed learning by making use of a natural teaching and learning technique currently under-utilized in higher education: that is the teaching power of stories. Stories have been a traditional method of education that appear to be highly effective in the ability to impact the attention, memory, and future behavior of learners. However, stories are little-used in higher education, especially in the technical disciplines. Stories or synonymously case studies of learning organizations have the potential to create memorable impressions on students.

Heywood's advocacy of case studies of learning organizations shares some features with ethics education. Ethics is an area of engineering education that achieved general recognition as critical to the professional development of engineers and the case study approach found to be effective in ethics instruction can be transferred to the issue of learning how to learn. The issue of learning how to learn shares features in common with learning to behave ethically as an engineer. In particular ethical judgment cannot be taught or learned in rote fashion. Ethical decisions are in large part issues of judgment. While it may be possible for students to memorize a list of ethical principles, the appropriate application of these principles to an unpredictable series of ethical challenges over the course of a career is not an ability that exists as a static competency. Similarly, an individual ability to engage in self-directed learning is an attribute that requires critical analysis and judgment of circumstances. It seems then that, like ethics, use of case studies which require application of critical evaluation, as advocated by Heywood, are likely to provide the kind of learning environment compatible with students developing competence in self-directed learning.

Heywood also suggests that the study of learning in organizations might include an appraisal of the type assessments or judgments that should be made by an individual that is a new member of an organization. These appraisals or analyses would be directed

toward the learning style and learning effectiveness of the organization. This suggestion could have significant impact on the learning effectiveness of organizations. In particular, organizations seek to attract new employees with the skills, abilities and other attributes deemed desirable by the organization. If these candidates for employment were equipped with the ability to critically inquire about the process by which the organization learns and how effective the organization is at learning, to the point of perhaps asking for specific examples and episodes, then the organizations themselves are likely to place a higher priority on being learning organizations and possibly attempt to be better and more effective learning organizations.

In a similar vein if new entrants to the labor force are trained and skilled in the topic of how organizations learn and prioritize this aspect of employment, then the baseline competence of organizations in this area will improve. The case study approach advocated by Heywood is an effective means to introduce critical thinking into this area of inquiry.

Response by Mani Mina

The idea that organizations are learning systems has received much attention since Peter Senge published "The Fifth Discipline" in 1990 although the concept can be traced back to at least work by Argyris in the nineteen-fifties. The view presented in this text is that organizations are aggregates of learners, more over the extent to which organizations are effective and efficient is a function of the way in which learning is impeded or enhanced by the way individuals interact with each other in the organization. As has been pointed out the factors that impede and enhance learning in the classroom are no different to those that impede learning in a classroom.

Linear models of critical thinking and in particular decision making and problem solving tend in whatever way presented to use similar skills. Problems have to be defined, knowledge has to be gathered and sorted,

alternative solutions have to be evaluated, a solution has to be chosen, whatever is required to be done is implemented, and the solution evaluated, and information is fed back to the originator. Similar models of the design process are found and are sometimes used to support the idea that design is a generic activity. Linear models of this kind are easily faulted for much human behaviour (learning) is not linear even when formalised in a classroom. Nevertheless they highlight important skills about which there is common consensus.

The purpose of this paper is to demonstrate that these models are useful in understanding how organizations function as learning systems by means of a historical case of a firm engaged in the design and production of aircraft systems. It is also argued that reflection on the case study should enable students to better understand how they learn.

Response by John Blake

In this paper, Heywood examines technological and engineering literacy (TEL) by looking at an engineering organization as a group of people who collect, organize, and use knowledge to create and improve products. This approach can be used to identify the needs of different individuals within the organization (engineers, managers, sales and marketing personnel, etc.) and others who interact with the organization (customers and clients, other affected parties). This can help people in the TEL community in education better understand and meet needs, and it can also be used to help engineering organizations build better teams. The paper examines the process of collection, organization, and use, as well as the critical elements of adding new knowledge and reorganizing knowledge to meet new needs and to incorporate new technology. As a result, this study can be used to develop ways to help individual engineers make their optimum contribution to an organization at every stage of their career. The paper notes that an engineer's ability, both

real and perceived, to contribute changes as they progress through their career. The young, new engineer lacks experience. The older engineer has experience and knows a great deal but may also allow themselves to be constrained by how their work has been done in the past. Examining how organizations collect, organize, and reorganize knowledge has the potential to help engineers improve their ability to contribute at the different stages of their careers. This will help them to be - and to be recognized as - valuable contributors in every stage of their careers.

Heywood presents a case study of an engineering organization that creates and then improves a type of product over a period of time. This example covers a period where an established company moved into a new area of products. With a need for improvement over existing products, the company had an opportunity to move into an area that was new for them but was related to their existing products. To do this, the company had to obtain new knowledge, some of it by buying the rights to use technology developed by another company, and had to build on knowledge from within their organization. This knowledge had to be selected and organized to develop the new product line. Their new product line was a success. Over time, the product was being used under more demanding circumstances, and new technologies became available that could be used to improve these products. To meet the new demands and incorporate the new technologies, the organization had to organize, add, and reorganize knowledge. The people brought together in the organization had to do this to create new products and to improve products, otherwise, this venture would fail.

The paper relates this example to Wales and Stagger's heuristic for guided design. It could also be related to Koen's discussion of heuristics for engineering (Koen, 1985; 2003)) and heuristics for problem solving used in Fogler, LeBlanc, and Rizzo (2014). An analysis of case studies such as the one presented in this paper help to validate and demonstrate the usefulness of these heuristics.

The example in this paper leads to a series of questions. Consideration of these questions can help someone reflect on the organizational learning process, *on how they can best contribute to an organization, and on how to improve their ability to contribute*. These questions are remarkably useful. The paper notes that these questions can be useful for self-assessment and reflection by individuals at all stages of their careers with both engineering and non-engineering backgrounds. They can be used by people who are managing project teams, people in other mentoring or coaching roles in the workplace, and by educators who are preparing people for work in areas related to engineering and technology.

For people ranging from students to senior, experienced members of project teams and for engineers and non-engineers alike, these questions can help people be strong contributors to the organization. The paper notes that a person's potential to contribute changes as they progress through their careers. While the needs of people entering the workforce will be of great interest to the TEL community, preparing these people to anticipate and cope with the needs of people later in their careers is also of great interest.

All too often, it seems that organizations do not value employees in general and engineers in particular who are beyond a certain age. Engineers are urged to take early retirement packages or are let go before they are ready to leave the workforce. Younger engineers are then hired to take their place. While the younger engineer with little or no experience may be less expensive, organizations lose valuable experience. Unless the more experienced engineer can find another employer willing to hire them, the careers and lifetime earnings of older engineers are cut short. A valuable resource in society, engineering knowledge and ability, is wasted.

There is a perception, at least in the United States, that there is a shortage of engineers. Engineering schools are pushed to do more to recruit and retain students. Some employers have pushed for changes in immigration policy that will allow them to hire more engineers

from overseas. It would be far better for all involved to find ways to help engineers continue to be valuable contributors as they age instead of pushing them to leave the engineering work force.

The paper addresses some of the concerns with older, more experienced engineers. While their experience is valuable, people in this group may be constrained by their experience in ways that cause them to miss opportunities to be creative. Worse yet, they may restrict others from being creative. This may be intentional behavior (as in we've always done it this way) or an unintentional response, perhaps resulting from bad experiences in the past. Understanding the problems is an important step towards finding ways to help people avoid these problems while keeping these people as productive assets to the organization. It can also help show ways that the younger and older engineers can help each other be more creative and productive. It can also help educators working with people preparing to enter the workforce help their students look beyond the start of their careers to see what they should be doing, as well as what they should avoid doing, as they progress through what one hopes will be a long and continually productive career.

This paper is based on one case study. Other cases can yield insight into other aspects of engineering and technology and can yield other useful questions. Similar studies of cases that go into different aspects and explore different groups, such as an example that would give more insight into customers or the public, would be useful and could be approached in a similar manner.

To function well, an organization must manage knowledge that is new to the organization as well as knowledge available within the organization to create and improve products. The organization's members and structure must enhance, and must not impede, learning and innovation. For the people in the organization, especially the managers, a greater degree of technological and engineering literacy can help them set up structures and direct efforts for self-

improvement and the improvement of others that will serve this goal. Case studies such as the one presented in this paper contribute to our understanding and our ability to help others develop this literacy.

References

Fogler, H. Scott and Steven E. LeBlanc with Benjamin Rizzo (2014), *Strategies for Creative Problem Solving*, 3rd Edition, Upper Saddle River, NJ. Prentice-Hall.

Koen, Billy Ray (1985). *Definition of the Engineering Method*. Washington, DC. American Society for Engineering Education.

Koen, Billy Ray (2003). *Discussion of the Method: Conducting the Engineer's Approach to Problem Solving*. New York. Oxford University Press.

Response by Alan Cheville

Heywood makes several interesting points in this article which uses a case study of an aerospace engineering firm in Great Britain. He introduces well known steps of design that were found to serve as heuristics for decision making in engineering firms and that also are used today to teach design. As Heywood points out these steps are not to provide a formula that once learned enables an engineer to undertake successful design, rather they serve as a framework to ask questions about one's own work. In other words to learn about one's self as one learns.

From this perspective the goal, whether one is at school or work or engaging with friends and family is to be a reflective learner. As Tennyson put it poetically from the mouth of Ulysses before Heywood, "...yet all experience is an arch where through gleams that untraveled world whose margin fades for ever and for ever when I move." It is through our experience that we remake the world for ourselves by developing schemas, schemata, that allow us to interpret new experiences and make difficult tasks

routine by organizing knowledge. Like Ulysses we are not only shaped by our experiences but they form the strong arch that shows us a gleaming new world. Heywood focuses on communication, mental agility, and learning about oneself as vital to graduates success post-college.

While seemingly a case study of engineering work half a century ago, one that has relevance for questions we still pose in engineering education today, this article poses some troubling questions. For me the one of the most challenging aspects of this work is the characterization of the relative values of knowledge gained through experience and the insight one brings to a problem when addressing it from first principles. Every time I have had to solve a principle from first principles it has been a gruelling undertaking but one that is richly rewarded by an ultimate sense of accomplishment. However changes to the world have made it much easier not only to draw on one's own experience but that of others to much more quickly tackle problems outside one's own experience. Is the value of younger engineers that they are less burdened by experience giving them a better ability to address problems from first principles, or is it that they draw on electronically encoded experiences via resources such as YouTube in a way older engineers have not mastered? Regardless, the questions implied by the article raise significant questions for engineering education as commonly practiced. The article raises even more significant concerns for the value of humans in a world when the routine, those aspects of work supported by experience, are increasingly prone to automation.

The second question this article raised for me has to do with Heywood's assertion of

the importance of metacognition to adapt to one's environment and to continue to learn. In this conceptualization of education students must ask themselves difficult questions about their abilities and use the answers to navigate their futures. Here Heywood seems to invoke a design methodology, but the design is not of an engineering artefact, but rather the design of ourselves. The article raised questions in my mind of what type of environment would enable students or employees to honestly confront the questions he poses about their ability to change, learn, and grow. There is a level of honesty that is required that seems difficult to muster, particularly if a society is in difficult economic times, or the media or an organization expresses values for what one is not. In a university the ability to ask such questions of oneself seems to be a

factor of the supportiveness of the learning environment. If students feel that they are potentially not welcome to continue with their education, if their answers to these questions are misaligned with the beliefs expressed by faculty, then there would be a tendency to develop one-dimensional engineers, perhaps with authoritarian characteristics.

In conclusion Heywood raises some interesting points for how engineers might need to be educated if they are to successfully navigate 21st century careers. While the case study draws from old data, it highlights that despite our desire to attach the label "New!", ultimately our success and happiness depends on relations, and in many respects these relationships are enduring.

Non Nova, Sed Nove Part II: John Macmurray and Engineering Education

Alan Cheville

Abstract

As engineering evolves with society to address new economic practices and more global issues there are significant challenges as to how students are prepared to enter the profession. This paper undertakes a critique of current educational practices by exploring the relevance of Scottish philosopher John Macmurray's Gifford Lectures to engineering education. The exploration of Macmurray's work is intended to start a conversation on reexamining the ends towards which engineering works and to inform potential new directions for engineering education. This paper, the second in a series, develops Macmurray's ideas on agency, personal relations, and the impact of personal philosophies on society with a focus on how they can inform engineering education. The paper explores his philosophy of the personal which focuses on human agency and how an agent develops notions of other persons. Macmurray's three modes of reflection on action—pragmatic, contemplative, and personal—are analyzed to develop an understanding of the personal mode of reflection in the framework of educating engineers. An argument is made that by focusing too much on pragmatic modes of reflection engineering educators are currently creating students who may be incapable of working towards moral good in society. A claim is made that if engineering programs could focus more explicitly on community and developing personal and contemplative rather than purely pragmatic modes of reflection engineers will be better prepared to work ethically in a highly interconnected world.

Introduction

We face a quiet crisis in engineering education. This crisis is not one of too few engineers, student unprepared for the profession, or our inability to change the education system, but rather one of meaning, of purpose. For over a century engineering has been the willing partner of business and government, the practical production side of real world industrialization, defense, and capitalism [1(Cheville, 2014)]. This relationship has brought great benefits to many as evidenced

by the unprecedented rise of standards of living in industrialized countries over the last century. It has also provided purpose

to engineering which seeks to advance technology, increase production, reduce cost, and utilize natural forces for human good. In the United States high level policy reports recognize the impact of engineering on the economy. But the societal benefit of engineering seems increasingly disconnected from its personal meaning to many students. As people become increasingly aware that the side effects of engineering are creating new challenges that must be addressed holistically it may be time to reexamine the ends towards which engineering education was proposed as a means at the start of the 20th century. One step is to rethink the relationship between engineering, with our tradition of science-based pragmatism and ethical canon of preventing harm, and that of business which is increasingly growth- and profit-focused and seeks to maximize the poorly defined notion of utility ((Sedlacek,2011). Exploring the ends toward which we prepare engineers for a profession is both a philosophical and engineering journey. This paper, the second in a series, continues an exploration of the relevance of Scottish philosopher John Macmurray for engineering education as possible first steps on this larger journey.

Macmurray's development as a philosopher was driven in part by his experiences in the First World War and his disillusionment with the societal institutions that let such a conflict occur. Macmurray's work explores what it means to be human, focusing on the importance of both personal agency and fellowship. As will be described in this paper his work claims that the pragmatic values of

engineering—i.e. increasing production, efficiency, or serving as the means to ever more sophisticated ends—lead invariably to loss of individual agency. In Macmurray’s time fascism and communism were the dehumanizing systems, today we see the same concerns being expressed about crony capitalism (Reich, 2016). To counter such trends Macmurray sought in his Gifford lectures to develop a “philosophy of the personal” that foregrounds the individual. Thus one goal of this paper is to critically view engineering education through the lens of Macmurray’s system, particularly focusing on the role reflection plays in learning and how under-developed modes of reflection can lead to engineers unable to work for moral good. Since technology increasingly impacts, and is impacted by, human relations a philosophy of personal relationships has implications for engineering education. It can also be argued that engineering has more need of understanding personal relations than other STEM disciplines since in mathematics and the physical sciences the existence of humans is often secondary to discoveries while in engineering work supports human ends. Since the individual focus of Macmurray’s philosophy may add insights to the predominately pragmatic values of engineering, a second goal of this paper is to highlight key elements of Macmurray’s “philosophy of the personal” that are relevant for engineering education. The path this paper navigates through Macmurray’s philosophy ends with some reflections on how this work can inform new directions in engineering education.

Macmurray’s Gifford Lectures

In the first of his two part Gifford lectures John Macmurray defined a philosophy based on action that circumvented a dualism between acting and thinking in

Western philosophy. He viewed the cause of this dualism as Descartes’ focus on an isolated, rational mind which has led to a Western philosophy and underlying societal narratives that are overly egotistical and theoretical. In *The Self as Agent* [(Macmurray, 1957). Macmurray’s overall conclusion was that being human is defined iteratively through action that is reflectively informed by knowledge gained through prior action. It is through our actions that we both come to know the world and through which the world is changed in some way. The philosophy of action was explored in part I. In the second half of the Gifford Lectures, published as *Persons in Relation* Macmurray (1961) seeks to understand both the reasons we act and how to act in ways that create moral good by exploring modes of reflection—how we generate knowledge from action—that can help an agent act in a way that supports a satisfactory end. The claim made throughout *Persons in Relation* is that the artistic and scientific ways of developing understanding that were explored in the *Self as Agent* cannot by themselves lead to a better society. Engineering aligns closely with Macmurray’s definition of the scientific, or pragmatic, mode and thus cannot by itself benefit society. Rather satisfactory ends can only be achieved through a more personal form of reflection informed by a comprehensive philosophy of the personal.

Compared to the logical flow of *The Self as Agent*, *Persons in Relation* is much more disjoint; there is considerable iterative repetition of a core set of ideas as Macmurray seeks to expand the development of the personal mode of reflection from mother-child relationships to society as a whole. For this reason the paper does not follow the flow of *Persons*

in Relation linearly, but rather explores major themes that are relevant to engineering education. The overall argument that Macmurray lays out builds from several assumptions:

- Due to the strong influence of other agents on our actions, the individual unit of humanity is not an isolated, rational mind but humans in relation.
- Descartes' view of an isolated rationality does not qualify as fully a human existence.
- Human relationships are not a means to an end or a skill, although they have elements of skill, rather relations with others exist as an end in themselves.
- Humans are defined by actions, and actions always occur in relation to others.

Persons in Relation builds upon *The Self as Agent* by framing ways to understand relationships through the cycle of withdrawal and return introduced in the first set of Gifford lectures and addresses how relationships affect our actions both as individuals and as societies. However because of the range he sought to cover Macmurray's philosophical system is left substantially incomplete.

The Development and Forms of Relationships

Persons in Relation begins where *The Self as Agent* leaves off, that human existence derives from action. While previously the agent was considered isolated, acting alone against the Other, being human means we all exist within a field of other agents who affect our actions. For Macmurray the fact that we act within a network of other agents, persons, is the central fact of human existence. We are born into a mother-child relationship that defines what it means to be human; both the Aristotelian notion of a child as an unformed adult as

well as organic and evolutionary views of human development fail to capture relational aspects of childhood. The mother-child relationship serves as an end in itself as well as, for the child, a means to the end of survival. Human beings survive not on instinct but by being helpless, and this helplessness builds the need for relationship into our core being. If an infant were to develop without human contact then his or her actions could be attributed to a core rational being in the Cartesian sense. However numerous case studies show that unfortunate children, and even monkeys, who develop without such relations have great difficulties throughout adult life (Davis, 1940; Suomi et al 1976). Our first relation is with a caregiver who is another agent; without this relationship a child does not survive. Our relations then expand to a web of personal relationships (family) and we learn to perceive that our actions against a non-animate Other should be different than those against other agents. Thus we as humans are born into a personal relationship and over time learn three different modes of action: treating the Other as personal (another agent), treating the Other as inanimate stuff (not agent), and a middle, indeterminate category that can apply to other forms of life; for example we may eat beef but have a relationship with a pet.

As we grow we develop different types of relations with other agents. Direct relationships are when we interact with the agent and indirect are those in which we do not know them but our actions affect them. Interactions between agents can similarly be classified into personal and impersonal relationships. An impersonal relationship is one in which we do not see the other person as a human being like ourselves, but rather view them through an instrumental or rational lens, for example

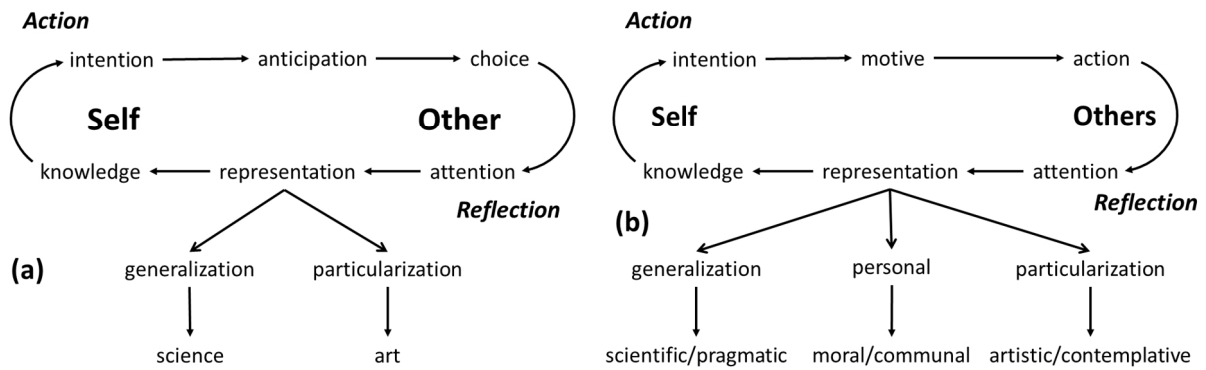


Figure 1: The cycle of withdrawal and return as outlined in (a) *The Self as Agent* for an isolated individual and (b) as modified in *Persons in Relation* for personal relations.

as a means to an end. Impersonal relationships do not form a separate class relationships can be done for human reasons (e.g. doctor-patient). Indirect relations are always impersonal.

Relationships are broadly based on either love for, or fear of, others. For Macmurray love refers to action taken for benefit of another agent and is always focused outward, or is heterocentric. Fear on the other hand is egocentric and can take the form of fear for oneself or the fear of another. The emotion which predominates in the relationship—love (positive) or fear (negative)—depends both on our prior relationships and how we reflect on those relationships. In other words relationships are iterative and developmental. Personal relations, like actions, can thus can be framed in the cycle of withdrawal and return that was first introduced in *The Self as Agent*, Figure 1(a), with the modifications shown in Figure 1(b). The upper portion of the cycle corresponds to action which in the realm of the personal is a relation building phase in which the agent seeks personal connection followed by a phase of withdrawal (the bottom, reflective part of the cycle) to reflect on the interaction.

but are a subset of the general case of personal relationships since impersonal In the action part of the cycle the agent's intention is modified by their motive. Intention is what we wish to accomplish while motive is the underlying emotion to which can be either fear or love. While our intention to act is conscious, we are generally not aware of our motive since we focus our attention outwardly on our goal rather than inwardly on our emotions. Discernment of motive is complicated by the fact that love and fear often occur simultaneously with the subordinate emotion acting as an inhibitor. We don't love fully since there is always some fear nor do we fully withdraw from another in fear. Note that motives are meaningless for an isolated, rational individual since they can only be satisfied or blocked by another's response. In relationships we rely on others' actions for our own well-being; i.e. others help to determine our emotional state. The combination of two interacting agents leads to four possible connections between action and reflection (knowledge) which depend on whether the motive is for love or fear and whether the action towards another succeeds or fails. The four combinations of action and motive serve to steer our attention to different aspects of the relationship we intended to establish as shown in Table 1.

| | Motive of Love (towards another) | Motive of Fear (of another, for oneself) |
|------------------------|---|---|
| Action Succeeds | 1) Develops stronger relationships. | 2) Develops animism where I-It replaces I-You therefore isolating the agent [8]. |
| Action Fails | 3) Develops intellectual or moral judgment depending on the form of representation. | 4) Develops relationships based on domination or obedience which can lead to mutual hatred. |

Table 1: Macmurray's outcomes of action and motive

These four possibilities affect our personal development as follows. 1) When the agent's action succeeds and they act from love the relationship strengthens and there is mutual growth in fellowship. 2) If the relationship succeeds but is based on a motive of fear, the agent learns they are able to manipulate others which develops a tendency for impersonal relationships. 3) If the agent is centered on another out of love but perceives their action fails it triggers withdrawal and reflection because the intended relationship is frustrated. If the reason their action failed was that they chose the correct action but either used the wrong means to achieve their intent or were unskilled, they develop intellectual judgment. If on the other hand the agent realizes that they misread the intent of the other person, and thus acted the wrong way towards the other agent they develop moral judgment. In either case they are better equipped to pursue relationships in the future. 4) In the case that the motive is fear for ourselves or fear of another and the relationship fails, reflection strengthens that fear. If our fear is of the other agent we may withdraw and become more obedient to the others will which drives the agent into an internal life of fantasy. On the other hand if we seek to oppose the other agent because we are afraid for ourselves, we seek to defend ourselves by accumulating power which drives us to dominate. If this framework is applied to teamwork in engineering education it highlights that teaching the methods of teamwork only addresses part of case three. Developing teamwork may require

other interventions such as teaching students to better recognize motives and skills in personal, rather than merely professional, relations.

The Role of Reflection in Becoming Human and Acting Morally

As with an agent's action against an inanimate Other that was outlined in *The Self as Agent*, the critical moment in developing personal relations occurs when we reflect following an action directed towards another agent. Where we focus our attention and the mode of reflection we adopt helps us develop various representations of human relationships, i.e. different forms of knowledge, which inform future actions. According to Macmurray the fact that we are constantly withdrawing from and reestablishing relationships is vital to our development as human beings since it is by withdrawal we are able to adapt our response to another and reforge the relationship in a new way. In other words, we are continually learning through our relationships how to be human and even antagonistic relationships develop agency and will. All the tensions that define human existence emerge through relationships in which we face either opposition or support from others. These representations become habitual if practiced long enough such that the action-reflection cycle happens without much conscious thought. In brief, the way we act towards others is determined by what we pay attention to following an action, and how we reflect eventually becomes unconscious, developing into a habit.

Macmurray terms our view of others which arises from reflection “mode of apperception” following Descartes and Kant. The mode of apperception we adopt at a given time determines what we pay attention to and thus which results of our action get integrated into our existing knowledge and schemas. The development of an agent’s apperception is determined by the entire cycle of Figure 1: what they intend to accomplish when they interact with others, their subconscious motive, the results of the action, which actions they pay attention to, how they develop representations of the interaction, and how this affects their store of knowledge or skill to base future interaction on. The agent’s apperception of others can be thought of as habits of attention that are developed over time and once established can be difficult to break out of. The four possible pathways for an agent’s interactions, Table 1, and what the agent chooses to pay attention to following the interaction, can lead to different apperceptions. The apperception developed depends on three interconnected factors: the intention and motive of the agent, the knowledge the agent possesses, and the skill that was brought to bear in the action. An action can be unsuccessful either due to a lack of skill or because the agent misunderstood the nature of other agents and acted (perhaps with great skill) in a way that could not achieve the desired end. Skill is ultimately technological and arises from viewing the world pragmatically. Understanding others’ nature comes from contemplating how satisfactory one’s actions are. Skill arises from generalization or scientific reflection while choosing the right action depends upon particularization or one’s aesthetic judgment, Figure 1(a), as discussed in *The Self as Agent*. It is the agent’s intention

and motive, however, that determine the ability to act morally; neither skill nor aesthetic judgment is inherently moral.

Since the world in which we act is the sum of the actions of all agents (Macmurray’s principle of the world as one action) when an agent acts these actions affect others whether the agent wills it or not. Reframed in engineering terms we are all part of a highly interconnected system, and our actions drive feedback loops that determine the state of the system, not only for ourselves but for others. Thus unless the education of engineers explicitly develops intention and motive it may well be engineers cannot act for systemic good. Since being human is based on relations as well as rationality, then my ability to act, my freedom, depends in part on how you behave. Macmurray defines a moral action as one that intends greater community for agents. If my intention is to support greater freedom and agency for others then my actions are moral. If I intend benefits for myself without regard for others my actions are immoral. To act morally one must be part of a community and intend to support or increase community among agents. For Macmurray moral behavior is a personal and social good as well as an end in itself. From this perspective the purpose, or ends, of an engineering education are to support human systems that build community.

One cannot act morally simply by having good intentions, however. Morality has its root in intention, but intention develops from the agent’s apperception. Apperception derives from attention and attention in turn leads to intention since we pay attention to what we intend. This is the circular and iterative feedback cycle shown in Figure 1(b) which eventually develops into habits. We must actively

work to develop our ability to act morally at all parts of the cycle of withdrawal and return by aligning action and intention. Thus teaching engineers to act ethically should be approached as developing habits which cannot be done through one or two courses on codes, but rather must be integrated throughout a student's education. If we were isolated Cartesian minds our actions would only be affected by our own apperceptions. We develop, however, within a community or society and the dynamics of personal relations that surround us both influence our indirect relationships and are mirrored onto society at large. The habitual apperceptions a society develops thus determine the accepted morality for its members. Macmurray claims communities often share modes of apperception—i.e. there are different forms of apperceptions in societies—and thus the community helps determine the accepted morality and thus the intention of agents. As William James (1912) also points out, what we believe matters and the way we view a society or community affects what that society is, which Macmurray defines as the principle of the world as one action.

Modes of Apperception

If agents are to act morally then ways to develop modes of apperception at the individual and societal level that support community are needed [1]. Macmurray frames three ways of perceiving the Other, one of which directly supports moral action (positive) and two others which do not (negative). The positive mode of apperception is a communal/personal mode that arises when one acts for the greater community and seeks to build bonds between agents. The negative modes are the scientific/pragmatic and artistic/contemplative modes introduced in *The Self as Agent*. The term “negative” in

Macmurray does not mean “bad” but rather “not personal”. All three modes of apperception need to be developed if an agent is to act effectively. In the case of engineering, a culture that values effective action, focusing education too strongly on the generalizable knowledge of the scientific mode may limit engineers' effectiveness unless they learn to develop other modes independently.

As discussed previously the two negative modes arise from misalignment between the agent's motive/intention and the results of action as discussed previously (see Table 1). When there is repeated misalignment between intention and action and the agent acts from a motive of fear rather than love they take a defensive posture and withdraw from others. Such distance makes us more egocentric and prone to conflict, thus supporting the perspective that the agent is separate from others, or the Cartesian duality Macmurray sought to critique. The contemplative mode of apperception arises when the agent seeks to defuse the intention-action conflict by distancing themselves and retreating into a more ideal mental or spiritual representation of the world. The pragmatic mode arises when the agent seeks to control their own response or the response of another; in this mode power matters and we tend to treat others as means [2]. If the agent's motive is love, however, these negative modes lead to growth in intellectual or emotional judgement, as discussed previously.

In Macmurray's philosophy modes of apperception and the knowledge they generate support action. Which mode is appropriate in a given situation depends upon the agent's intention in acting. If the agent's intentions is to seek truth—choosing the right means to achieve their

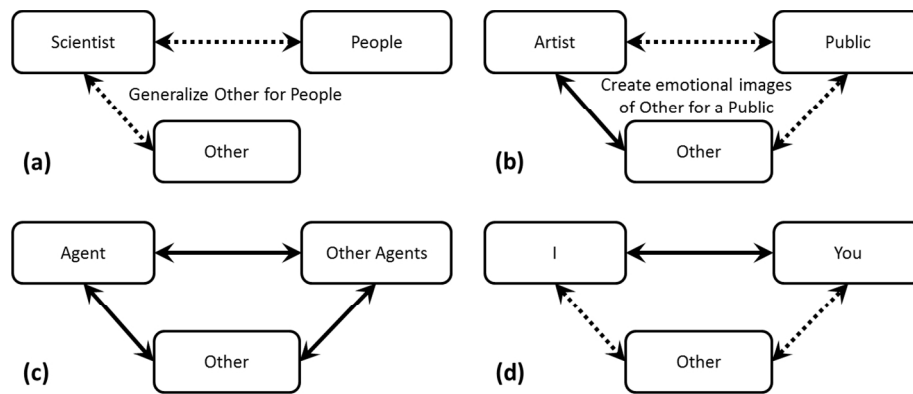


Figure 2: Representations of the (a) scientific, (b) artistic, and (c, d) personal modes of thought. Solid lines represent direct relations that have a personal engagement while dashed lines represent indirect or impersonal relations.

intention—then the pragmatic mode is appropriate and knowledge gained by acting serves as a means to future action. This mode addresses means only, and ultimately finds general rules that support action. Whether or not the end chosen is satisfactory or not to the agent requires the contemplative form of reflection. This mode seeks to expose form and refine sensibility in understanding the Other so that better ends can be chosen and in this sense is idealistic. In the pragmatic form of reflection rules serve as a means while in the contemplative mode form is an end to be enjoyed and thus both modes need to be employed if correct means are to be chosen to reach a satisfactory end. Macmurray also identifies these modes as scientific and artistic from the archetypes of scientist and artist. Engineering aligns predominately with the scientific/pragmatic mode of apperception, but draws on elements of the artistic/contemplative mode as it applies generalized processes to specific, contextualized needs. To maintain a needed objective distance the idealized scientist has indirect, or impersonal, relationships both with the Other they are investigating as well as the people who will use the generalized knowledge they create to further their own actions. The archetypical artist, on the other hand,

engages in a direct, personal relationship with the Other to capture its ideal form. The artist then represents this form to an impersonal audience or public who also view the artist's work to develop an indirect relationship with the artist's subject. The scientific and artistic modes of reflection can be represented as shown in (a) and (b) of Figure 2. Here dashed lines represent impersonal or indirect relations and solid lines represent direct or personal relations.

For Macmurray both the scientific/pragmatic and artistic/contemplative modes are reflective and abstract. Furthermore these modes are impersonal since they support an isolated agent and their future actions. Reality, however, is more complicated and Macmurray's conceptions are oversimplified. The scientist does not live in a vacuum and when they present results they are to an audience of peers, many of whom the scientist has personal relationships with (Kuhn, 1966). The effectiveness of the scientist's work in changing the views held by a community of scientists depends greatly upon these relationships. The same logic applies to engineering since if engineers are to have influence in societal decisions about infrastructures and systems then skills in

relationship building are required. Similarly the public image of the artistic genius toiling alone to capture beauty in a new way is similarly a myth, designed in part to sell art (Wolff, 1993).

Our actions always have consequences regardless of whether the end is satisfactory or not, or whether effective or ineffective means are used. This leads to a quadrant of action as shown in Table 2. If one works towards the wrong end, the result of actions are unsatisfactory emotionally and reflection on what the agent values is necessary. The role of education is then to develop the contemplative mode of apperception. If on the other hand one chooses the wrong action to achieve the desired end, the results are not what was intended and education needs to develop the pragmatic mode. It is only when we are working in the right way for the right end is our intention satisfied. However the basic unit of humanity is not “I” but “Us”, and all actions are performed on a field of other agents. It is the personal model of apperception that one uses to act morally and align ends and means.

The positive or personal mode of apperception developed by Macmurray supports community, or better relations between persons. Where the pragmatic mode of reflection generalizes rules for future action and the contemplative mode captures the satisfactoriness of an action, the personal mode is concerned with how our actions affect others. The personal mode is just as necessary to action as the

negative modes since our actions take place not solely against an impersonal Other but on a field of other agents. An action cannot be judged as satisfactory and effective without also being moral (compatible with community) since it takes all of us to fully determine the future. Thus while each of the three modes of apperception—pragmatic, contemplative, and personal—contribute to rational reflection Macmurray considers the personal mode as primary since it is the first mode we learn as humans and thus underlies all other forms of learned reflection. The personal mode of apperception seeks to integrate means to end and the scientific to the artistic modes in the service of right (moral) actions and hence is only defined through action. This is a key point, we cannot develop this mode of reflection without engaging in relationships. With respect to educating engineers it follows that without the ability to reflect on one’s own relation to a community and being able to act to strengthen those relations then it would be difficult to act for moral good within that community. Given engineering’s identity as a profession dedicated to public good and the need for self-regulation as an element of professional identity (Cheville & Heywood, 2015) it follows that without developing the personal mode of apperception it is difficult to be an engineer. In summary the personal mode of reflection seeks to develop a satisfactory representation of action as it relates to the community of other agents who live in the same world; Figure 2 (c).

| Means, pragmatic End, contemplative | Effective | Ineffective |
|--|------------------------|------------------------|
| Satisfactory | Right end, right means | Right end, wrong means |
| Unsatisfactory | Wrong end, right means | Wrong end, wrong means |

Table 2: Pragmatic and contemplative modes of apperception and relation to means and end.

The personal mode of apperception is developed, as are the other modes, through the cycle of withdrawal and return, Figure 1(b). Emphasizing the personal requires that we seek to develop a motive of love and an intention to act for others' benefit. It is this struggle, to see all others as persons, that for Macmurray defines what it is to be human. Developing personal relations is difficult, and can be defeated by modes of apperception which are based on fear. Additionally we tend to depersonalize others as we extend our relationships, but we should strive, as much as we are able, to retain the notion of persons. Our willingness to try to personalize all relationships is how we develop this mode of apperception. Elements of this mode include caring for others rather than oneself, the importance of individuality and agency, a recognition that each of us is realized through others, and treating relations with others as an end in themselves rather than as a means to an end. One critique of *Persons in Relation* is that as Macmurray lays out his philosophical system, clear definitions of the personal mode of apperception remain vague and scattered.

Since the development of fellowship has generally been considered a function of religion Macmurray also refers to the personal mode of reflection as a religious mode. Recall that both *The Self as Agent* and *Persons in Relation* were given as Gifford lectures, established to "promote and diffuse the study of Natural Theology in the widest sense of the term—in other words, the knowledge of God" (JTF, 2016). Macmurray frames religion as necessary for rational growth while rejecting its more supernatural aspects. Macmurray rejects both Freud's view of religion as regression as well as Marx's view of religion as an opiate of the masses

(Marx, 1971) [3]. From this rational perspective religion enables community and a Supreme Being serves as a universal Other, or the overarching member of the community that all other members relate to and draw their relations from. In the personal mode of apperception one's relation with their Deity serves as an ideal mental archetype from which they base other relationships. Since personal reflection seeks to universalize the problem of how I act towards others who are also agents, belief in a universal Other whom we all stand in relation to serves as an aid personal/religious reflection and enables us to better align our intentions with actions towards others. For Macmurray religion is not escapism or a way to abrogate responsibility but rather it serves as a means to emphasize intention towards community with religious ceremony and celebration serving to strengthen the community's will towards fellowship. From a philosophical perspective there are other reasons to look to religious thought in developing a personal mode of reflection. Since our knowledge of others come through our relationships, all personal knowledge comes at least partially through revelation since we cannot morally compel other agents to reveal information about themselves. Nor can others compel me. To build fellowship I must lay bare my own intentions and motive (the origin of "revelation" is from reveal). While revelation is not generally accepted as a source of claims in rational philosophical systems, it can be in religious ones (Baggini & Fosl, 2010). Thus it is through willingness to learn about myself by revealing myself to others that I develop a philosophy of the personal.

The personal mode of apperception addresses a tension Macmurray saw

between knowing and acting: that knowledge requires certainty but action requires freedom. In other words for knowledge to be complete the future must be determinate, but freedom—the ability to act to change the future with intention—requires an indeterminate future. The role of the personal mode of apperception in society is to identify a “middle path” that accepts uncertainty and integrates reflection with action, or one’s inner life with an external life in society. Knowledge and action are always in dynamic relationship with the outcome determined both by reflection and intention. Navigating this dualism is extremely difficult and it is never an easy task to act in the right way towards others. This mode cannot be developed without engaging in relationships or without risk to oneself. In the words of Macmurray:

“Action is the determination of the future. Freedom is the capacity to act, and so the capacity to determine the future. This freedom has two dimensions; the capacity to move, and the capacity to know; both of which have reference of the Other. To move is to modify the Other: to know is to apprehend the Other. To act, then, as the essential unity of these two freedoms is to modify the Other by intentions. To this we add that since the agent is part of the Other, he cannot modify the Other without modifying himself, or know the Other without knowing himself.”

The freedom to act always implies that actions affect both the agent and the community of which the agent is a part. Macmurray equates the ability to reflect with rationality since it is only through reflection we are able to obtain the knowledge needed to act in a way aligned with our intention.

To summarize, the pragmatic, contemplative, and personal modes of apperception determine our intentions by focusing our attention. An individual is not locked into one of these modes, rather they are reflected in various degrees in all of us. However through intention and attention the cycle of withdrawal and return shown in Figure 1 becomes habitual, and over time some of the modes tend to predominate and thus determine our capacity for moral action.

Apperceptions and Society

The mode of apperception developed by individuals in a society affect, and are affected by, society at large. This is because individuals develop in relation with others so personal apperceptions are developed through personal relationships which are in turn affected by society. Macmurray argues that an important role of society is to maintain personal relations, particularly indirect relations. The ideas previously developed for individuals apply to societies as well because a society’s perception of its own functioning is derived from its theories about relationships, which are themselves human activities and thus influenced by personal relationships (Giddens, 1987). In other words, Macmurray applies the logic of Figure 1 to societies through the principle of the world as one action. This is in contrast to dualistic, Cartesian model where an observer can stand apart from society and learn the truth without having to live by the truth.

Macmurray claims that Western cultures generally adopt a pragmatic mode of apperception and view society as a State since our political systems arose from Roman societies that used the law as a tool to unite heterogeneous populations.

Hobbes' *Leviathan* (1651/1982) is the archetype of the pragmatic mode that claims it is rational to form a state since the State can enforce cooperation between agents. The pragmatic mode of apperception that underlies this view of a State assumes that some general set of rules, in this case law, are required to bind together a society and through this process the community becomes more efficient. In such a society law serves both to regulate morality and to maintain equilibrium in relationships. Moral behavior arises through self-control as espoused by the Stoics and Kant (Sedlacek, 2011). A society based on this mode is technological and guided by efficiency. Macmurray's criticism of this mode is twofold. First, if driven by a motive of fear such societies can focus on domination through law. Second, the underlying assumption that law is required since people seek advantage does not adequately represent the better nature of people. Here Macmurray parallels more recent critiques of the rational actor models modern economic theories are based on (Sedlacek, 2011; Kahneman, 2011). Societies that evolve from the pragmatic mode undervalue personal modes of existence and are predominately "engineered" to be functional. Although not discussed by Macmurray, it would be expected that such societies value engineering. However if the motive for valuing engineering is fear of others or fear for one's own safety in society then the society will evolve to deemphasize personal modes of existence and may end in some form of authoritarianism or tyranny.

The contemplative mode of apperception at a societal level is represented by Rousseau's *The Social Contract* (1762/1968) that assumed man in his

natural state is inherently good. The goal of society is then to find the most satisfactory role for its members. In such a world we are able to give ourselves to the process of society and thus advance through society towards an ideal. In such societies most agents are spectators, and the actors are discouraged from deviating from their roles since this causes discord from the perceived ideal. As the contemplative mode of apperception focuses inwardly on the ideal, Rousseau's view of society mistakes what should be for what actually is. Macmurray points out that since such societies support an internal life of the mind they can be prone to tyranny from those who set ideals. A society in which the contemplative mode is dominant is based on forms and roles, e.g. Plato's *Republic* [20]. Compared with the more mechanistic pragmatic societies, the contemplative mode of apperception leads to a society that is more organic where members serve roles that support the societal functions.

The personal mode of apperception applied to society determines whether the actions of the society are moral, i.e. enhance the freedom of all members. Such a society seeks "realness" or authenticity in relationships. While the pragmatic mode seeks the right means to operate efficiently and the contemplative mode seeks satisfactory ends through ideals, the personal mode seeks to integrate correct means with satisfactory ends to maximize freedom for all agents. Recall that freedom is the ability of an agent to act to determine the future with intention, but such actions always affect the community so acting morally requires reflection on one's relations with other agents. While the State is central to the negative modes of apperception, religion historically has played the central role defining

standards of personal relationships. The role of religion in the personal mode is to help members of society arrive at truth about relations, in essence expressing the conscience of a community. Religion succeeds in this role when it supports relationships based on love and fails if it is egocentric, self-serving, or grounded in fear. If the community's mode of apperception is pragmatic then religion serves as a "spiritual technology" to control external forces that affect our lives such as suffering and loss. In contrast the contemplative mode of apperception uses religion to express utopian visions and thus allow the agent to look internally and withdraw from the world as it is.

Macmurray next turns his focus to how friendship and community, the outcomes of morality in action, can be maintained in large societies. While in a small community it is relatively easy to maintain personal relations, it becomes more difficult to support such relations as the community grows, Figure 2(d). In larger societies agents become increasingly connected indirectly through the work that they do and economic relations. The human systems which adjust indirect relationships are politics and economics, which in turn were derived to maintain justice or fair relationships (Reich, 2016). In Macmurray's philosophy justice serves as a virtue that safeguards and upholds other virtues. Since morality is defined here as the intention to uphold both freedom and community, justice serves as the impersonal aspect of morality since one cannot be moral (upholding community) without being just (fair and reciprocal in relations). Society sets up contracts and laws for the case people do not act morally in indirect relations and governments then act as the agencies that maintain social cooperation through law.

Thus law serves as a means to an end and necessarily adopts a pragmatic value system. Law itself is supported by the State as a pragmatic and practical morality for indirect relationships since we cannot fairly judge ourselves. Although Macmurray makes this point for law it is certainly appropriate to include engineering as a means to maintain society due to the role engineering increasingly has in upholding and maintaining social infrastructure.

Macmurray lived the destruction of the First World War and witnessed the rise of both communism and fascism, events he attributed to the state being idealized as an end in itself rather than as a means to community. In the philosophy of the personal all systems within the morality → justice → law → state hierarchy should serve to ensure that indirect relations maintain community and support friendship. If one posits a spectrum with morality, that is satisfactory relations between persons, on one side and the state on the other, the state pole represents pure means while morality represents ends. From this perspective law, politics, and the state serve increasingly as a means to an end and their value is determined by how well they substitute for morality in indirect relationships. Dysfunctional political and economic systems arise, in part, when pragmatic or contemplative modes of apperception dominate. The contemplative mode leads to romanticism when people assign religious functions to, or personalize, organizations. This error of personalizing an organization leads to tyranny from those who determine what the correct form of relations should be and then force others into idealized roles [4] Under the pragmatic mode of apperception organizations, which are intended to be a means to community, become ends in

themselves and efficiency is valued for its own sake. What is right becomes what is possible and the valuation of efficiency creates a positive feedback cycle where actions are done not for the sake of morality, but for the sake of more power. Law and commerce then become the definition of justice, not a means to justice, and moral actions are those which align with the interests of organizations. Both of these visions of the State are illusory, or in Macmurray's words:

If we track the State to its lair, what shall we find? Merely a collection of overworked and worried gentlemen, not at all unlike ourselves, doing their best to keep the machinery of government working as well as may be, and hard put to it to keep up appearances. They are, like ourselves, subject to the illusion of power. If we expect them to work miracles, we flatter them, and tempt them to think they are supermen. If we insist that it is their business to make peace on earth and hand us the millennium on a platter what will happen? Those of them who are wise enough to know their limitations, and to be immune to the gross adulation of their fellows, will resign; and government will be carried on only by megalomaniacs, who are capable of believing themselves possessed of superhuman attributes and whose lust for power is the measure of their weakness.

In a society based on personal apperceptions the purpose of justice and law, which sit between morality and state, are to moderate tendencies toward authoritarianism. Justice is the replacement for morality in indirect relations of persons and in this role serves to self-limit power since justice implies an

obligation to treat others fairly. Law reflects a society's will for justice. If all relations were just there would be no need for law, since law presupposes the existence of injustice (or the perception of injustice which is a *de facto* injustice). Law both reflects a society's beliefs about justice (and thus morality) but also serves to effectively adapt to changes in society to prevent or minimize the development of new injustices, e.g. those created by technology. To Macmurray, justice in a society is necessary but not sufficient for morality. Although without justice there cannot be voluntary cooperation and relationships become fear-based, justice does not presuppose friendship since it is simply fairness in indirect relations. Similarly in industrialized societies technology should serve to support individual agency, and engineering should reflect society's will towards community. Technology should support rather than replace friendship.

In concluding *Persons in Relation* Macmurray seeks to fulfill the obligation he assumed when he agreed to give the Gifford lectures, which, according to the bequest of Lord Gifford was to "...promote and diffuse the study of *Natural Theology in the widest sense of the term—in other words, the knowledge of God.*" Macmurray sought to address the validity of religion through a rational rather than a romantic (emotional) or revelatory lens. His claim is that the dualism of Western philosophy has intentionally dissociated thought and action, emphasizing the former, and only by reuniting them can we act morally. By giving primacy to action and claiming that only by acting are we certain we exist, he sought to unite the practical and theoretical world view since action must be informed by knowledge if it is to be effective.

Knowledge must address both means and ends since only when we are working in the right way for the right end is our intention satisfied. However the agent does not work alone, but rather with and through other agents. This is the personal or religious mode of apperception which is more than simply taking others into account when we act. From this perspective our reflections acknowledge that our actions are only worthwhile when done in concert with and for others. At the core of Macmurray's philosophy is that mutual dependence is the central fact of personal existence. We co-construct realities with others, and without them these realities collapse; "we need each other to be ourselves." Morality is determined by our intention and can only be realized when our motive is love, not fear. The moral end towards which we should strive is freedom, defined not as the ability to act independently of others but rather as the capacity to jointly determine the future through our actions. To act in a way that has meaning, for a satisfactory end, I must develop knowledge not just of an inanimate universe, but of other agents with whom I am engaged in action to create a better world.

Personal Relations and Engineering Education

How has this brief foray into Macmurray's philosophy of the personal addressed the questions defined at the start of the paper of: 1) starting a conversation on reexamining the ends towards which engineering works, and 2) informing potential new directions for engineering education by taking a critical view of today's practices? Macmurray's emphasis on the personal mode of apperception at first glance seems secondary to the dominant narrative of why society educates engineers. The root definition of

engineering [5] indicates that students need "...the acquisition of that species of knowledge...being the art of directing the great sources of power in Nature for the use and convenience of man..." (ICE, 1870). Such an education aligns closely with pragmatic modes of apperception which are supported in curricula by an emphasis on math and science in early years. From this perspective engineering devises technologies that let society operate more efficiently and the success of engineering programs is determined by how efficiently engineering graduates can develop new technologies that address society's needs. As society becomes more dependent upon technology to support an increasing population and growing economy the actions of engineers increasingly affect many others indirectly. This is the tone increasingly heard in reports on STEM education, at least in the United States; i.e. it is necessary to improve the education of engineers in order for society to continue advancing.

Macmurray's philosophy critiques this dominant STEM narrative by implying that if engineering education focuses on getting students to adopt a solely pragmatic view of the world, focusing on means, their education will be incomplete. By limiting its attentions to questions of truth, or creating generalizable knowledge, ultimately engineers will contribute to a society so focused on efficiency that has no place for human beings. In other words, if engineering educators train engineers to only reflect on their actions from a pragmatic apperception they are contributing to creating organizations and societies that undervalue being human. During Macmurray's life he saw the rise of modes of thinking that undervalued human freedom and led to the rise of communism and fascism (Costello, 2002). Although

one might claim such concerns are outdated today the issues Macmurray raises against tyranny are increasingly being made about the consequences of unfettered capitalism [3]. Through the lens of “the world as one action” if engineers are trained to see the world pragmatically, then our actions matter little and we necessarily exclude ourselves from the world we inhabit. The invisibility of engineering in society is well documented (NAE, 2008).

A question that was framed at the start of this paper is to what end should an engineering education serve, and who should determine this end? Macmurray’s principle of the world as one action implies that by acting in a field of other agents our students will act to change the future. The actions of engineers increasingly determine the state of the world we inhabit even if they don’t change the scientific truths we use to engineer new technologies. In this case our actions as engineering educators, no matter how small, matter both to ourselves, our students, and others in society; what we intend matters. What do we intend? If engineers are to serve as the element of society that best exemplifies the pragmatic mode of apperception—refining means to meet ends defined by others—then we should continue on our present path. Macmurray is clear, however, that such a path does not support the moral good of freedom since purely pragmatic modes of reflection support authoritarianism. Since their actions affect others engineers trained with only one mode of apperception are at best amoral. This is not to say that engineers don’t develop contemplative and personal modes of apperception, just that they are generally not intentionally developed in engineering education.

Heywood (2014) has made an analogy to a stool with three legs that are needed to support engineering practice. Following this analogy the key outcomes of an engineering education are to equally develop the scientific/pragmatic, artistic/contemplative and personal/religious modes of apperception. If one thinks about the goals of education from a student perspective these might address questions such as “What parts of the world in which I live might I want to improve if I could do so” (contemplative), “How can I gain the knowledge and skills to be effective in making these changes?” (pragmatic), and “How will these changes support both freedom and friendship for others?” (personal). In such a program developing the contemplative mode of reflection would let students judge if their education is helping them to articulate and achieve personally satisfactory goals. This definition of “satisfactoriness” is different than that used in engineering which is often characterized as meeting specifications and operating within externally imposed constraints. Building capability for this mode of reflection would require engineering students to visualize satisfactory ends by developing a capability to reflect on whether their actions satisfy their intentions. Here “intention” is not something mundane like getting a good grade or seeing that an experiment matches theory, although that is a part, but rather that the process of becoming an engineer is providing capabilities that support students intention to change the future. This perspective sheds new insights on the rationale for adding arts to convert programs from STEM to STEAM (Robelen, 2011). The reason given for such efforts is generally pragmatic, for students to gain creativity, but in this case the value is to develop the ability to reflect on the larger purpose of

one's actions and whether they are emotionally satisfying when related back to one's intention.

The third leg of the stool is to develop the personal mode of apperception, or understanding how our actions affect freedom for others. This mode is vital if engineers are to work for worthwhile ends since engineering codes of ethics emphasize public welfare (Cheville & Heywood, 2015) which can be interpreted as supporting freedom for others. If engineering programs are to support students in developing this mode then Macmurray's philosophy may lay out some guideposts for engineering education. Unfortunately Macmurray is mostly silent on how the personal mode of apperception is actually to be developed, and doesn't address engineering directly in his Gifford Lectures. However the framework Macmurray created aligns with some current trends in engineering education. One of these is human- or user-centered design that frames design around human needs. Another is the increasing focus on both teamwork and service learning within engineering education. It should be noted, however, that a strong pragmatic theme often emerges in the rationale for implementing these methods as highlighted by the proposed revision of ABET's outcome for teamwork: "*An ability to function effectively on teams that establish goals, plan tasks, meet deadlines, and analyze risk and uncertainty*" (ABET, 2015). The goal of such techniques and pedagogies should be to support fellowship rather than be a process for training more effective engineers. Another author who has proposed a specific technological direction from a philosophy of the personal is Ivan Illich (2001) who frames the effectiveness of technology as being directly related to

the level of control and agency they provide users.

Despite these positive changes within engineering education there is still a considerable distance to travel if future engineers are to be educated in a way that explicitly develops a responsibility to know others and communicate that the ends of engineering work are always ultimately personal. Too often the stated constraints of engineering—global, economic, environmental, or societal (ABET, 2015)—are inadequate proxies for supporting the freedom and welfare of other agents. One might imagine a degree program in which building a capacity for direct and personal relationships would be at the forefront rather relegated to the co-curriculum. Rather than spending a year immersed in math and science under the assumption students first need to understand natural forces in order to "engineer" them, such a program might foreground community, spending the first year to understand how to relate to others, what it means to be human. From a curriculum perspective designing such a program is a challenge, but might include humanities, psychology, art, and religion; in other words the classical liberal arts degree. In such a program engineering would not be seen as the discipline devoted to harnessing the forces of nature for the use of man since man has a history of misusing those forces (Vesilind, 2010), but rather as the discipline that masters all three modes of apperception, creating those who can imagine a more human future.

Notes

[1] Macmurray does not directly address education in his Gifford lectures, but the development and support of these modes which is ultimately the goal of both formal and informal education.

[2] It is an interesting mental exercise to imagine this iterative process being played out over many homework and examination cycles in an engineering degree program and what impact it might have on student development.

[3] Note that in the original (translated) form of Marx's oft-paraphrased statement is "Religion is the general theory of this world, its encyclopaedic compendium, its logic in popular form, its spiritual point d'honneur, its enthusiasm, its moral sanction, its solemn complement, and its universal basis of consolation and justification. It is the fantastic realization of the human essence since the human essence has not acquired any true reality. The struggle against religion is, therefore, indirectly the struggle against the world whose spiritual aroma is religion. Religious suffering is, at one and the same time, the expression of real suffering and a protest against real suffering. Religion is the sigh of the oppressed creature, the heart of a heartless world, and the soul of soulless conditions. It is the opium of the people."

[4] It is important to note that unlike today where issues of justice are beginning to emerge around corporate capitalism Macmurray uses the term "State" since fascism and communism were the issues of his time. Note that US law has granted personhood to corporations under the 14th amendment to the Constitution.

[5] This definition, dating from 1828, has determined today's discussions of engineering and is, in modified form, in use by ABET and many introductory engineering texts.

References

- ABET (2005). *Proposed Revisions to criteria for Accrediting Engineering Programs. Definitions, General criterion 3 Student outcomes and General criterion 5 Curriculum*. Accreditation Board for Engineering and Technology.
- Baggini, J and P. S. Fosl (2010). *The Philosophers Toolkit. A Compendium of Philosophical Concepts and Methods*. 2nd Ed. Chichester, UK. Wiley.
- Buber, M (2010). *I and Thou*. Eastford, CT: Martino.
- Cheville, R.A (2014) *Defining Engineering Education*, in Proceedings Annual Conference *American Society for Engineering Education*. Indianapolis, IN.
- Cheville, R. A and J. Heywood (2015). Drafting an code of ethics for engineering education. *ASEEE/IEEE Proceedings Frontiers in Education Conference*. El Paso, TX
- Costello, J. E (2002). *John Macmurray. A Biography*/ Edinburgh. Floris Press.
- Davis, K (1940). *Extreme Social Isolation of a Child*. *American Journal of Sociology*, 45: p. 554-565.
- Giddens, A (1987). *Social Theory and Modern Sociology*. Cambridge. Polity Press.
- Heywood, J (2014). Engineering at the Crossroads. Implications for Educational Policy in A. Johri and B. M. Olds (eds). *Cambridge Handbook of Educational Research*. New York. Cambridge University Press.
- Hobbes, T (1651/1982 ed). *Leviathan*. London, Penguin Classics.
- Illich, I (2001). *Tools for Conviviality*. London. Marion Boyer.
- James, W (1912). *The Will to Believe and other Essays in Popular Philosophy*. New York. Longmans Green.
- JTF (2016). The John Templeton Foundation. The Gifford lectures 2016 [cited 2016 May]. Available from <http://www.giordlectures.org/>.
- Kahneman, D (2011). *Thinking Fast and Slow*. New York: Farrar, Strauss and Giroux.
- Kuhn, T. S. (1996). *The Structure of Scientific Revolutions*. 3rd edition. Chicago. Chicago University Press
- MacMurray, J (1957). *The Self as Agent*. London: Faber & Faber.
- MacMurray, J (1961). *Persons in Relation*. London: Faber & Faber.
- Marx, K (1971) *Critique of Hegel's 'Philosophy of Right'*. Cambridge Studies in the History and Theory of Politics. Cambridge. Cambridge University Press.
- NAE (2008). Committee on Public Understanding of Engineering Messages. *Changing the Conversation. Messages for Improving the Understanding of Engineering*. Washington, DC. National Academies Press.
- Plato (2000). *The Republic*. Ed P. Negir. New York. Dover.
- Reich, R. B (2016). *Saving Capitalism for the Many, Not the Few*. New York, Alfred A. Knopf.
- Robelen, E. W (2011). Building STEAM. Blending the Arts with STEM Subjects in *Education Week*.
- Rousseau, J-J (1762/1968 ed). *The Social Contract*. London. Penguin Classics.
- Sedlacek, T (2011) *Economics of Good and Evil. The Quest for Economic Meaning from Gilgamesh to Wall Street*. New York. Oxford University Press.
- Suomi, S. J. et al (1976). Effects of maternal and peer separations on young monkeys. *Child Psychology and Psychiatry & Allied Disciplines*. 17(1), 101-112.

Vesilind, P. A (2010). *Engineering Peace and Justice. The Responsibility of Engineers to Society*. London, Springer.

Wolff, J (1993). *The Social Production of Art*. New York. NYU Press.

John Dewey's Philosophical Perspectives and Engineering Education

Mani Mina

Abstract

Recently several criticisms have been made about the engineering curriculum. Among them are that the demands being made on an already packed curriculum are crowding out the teaching of fundamentals. Another complaint that seems to relate to the 'packed' and 'inflexible' curriculum is that students do not retain knowledge that engineering educators regard as important. It is also said, that they do not demonstrate powers of critical thinking because they are so used to providing answers to questions that require single solution answers they find it difficult to tackle "wicked" problems that require for their solution the integration of knowledge from a variety of sources. These complaints are often made within the context of an instructor-centred curriculum. It is suggested here that students are more likely to retain knowledge and develop skill in critical thinking if they are given more responsibility for their own learning which implies a shift away from a transmission to a transformational approach to instruction.

Studies of change suggest that teachers resist change because of the dissonance created for their own belief systems. Whether or not they are conscious of it, they all have an epistemological view about how students learn, and change will only be brought about if they are willing to change their views. Since beliefs about the merits of the transmission model have persisted over hundreds of years and are part of the culture of education they are difficult to change. The first stage for those considering or participating in change is for the change agents to ask the participants to examine their own philosophies in the light of alternatives and justify their final choice. To be able to do this requires some understanding of alternative philosophies. The purpose of this paper is to present a student-centred view of learning that derives from the philosophy of John Dewey.

Dewey's philosophy of pragmatism is less important to this discussion than his epistemology of problem solving through a form of inquiry and his promotion of social democracy in education. The modern embodiment of Dewey's educational philosophy is problem based learning. Movement toward such a curriculum requires changes in the identity of the teacher from a controller, gate-keeper and transmitter of knowledge to one that is a facilitator of learning, and for many this is a large step too far. Change that works is always accomplished in small steps. This paper discusses how within the framework of a traditionally oriented curriculum Dewey's epistemology of inquiry based learning might be introduced.

Introduction

For decades there have been debates, discussions, and altering approaches regarding how to create effective engineering curricula. "Long before the post-war rise of 'engineering science' it was understood that engineers needed a grounding in these 'fundamentals' to have command of basic principles that could be applied to a variety of technical problems. It was also understood that many if not all engineers would eventually migrate into managerial roles, where human and organizational work would dominate. The typical professional track began in science and ended in bureaucracy." (Williams, 2002). Williams in her history of MIT explains how after the end of World War II engineering science became the dominant model. "Engineering education was based on a thorough grounding in scientific principles and engineering research was based on models of scientific research" (p 42). This focus on engineering science made it difficult for engineering design as the link between theory and practice to effectively become established in curricula. Williams argues that while engineering education never ceased to be an adjunct of industry, it became much more an adjunct of science. Moreover, until recently little notice has been made of attempts to establish what it is that engineers do when they work in industry in order to better understand the relationship between the curriculum and industry. Recent studies of this kind suggest serious weaknesses in the curriculum (Trevelyan, 2014). At the same time new technologies continue to be developed and make new demands on the

curriculum often splitting off into new ‘disciplines.’ Finally, as workplace and business practices change, they may create new demands and challenges for educational programs.

These developments have led to complaints about the engineering curriculum and its ability to prepare engineers adequately for subsequent professional performance. Among these complaints are that the demands being made on an already packed curriculum by advances in technology and the development of new technologies are crowding out the teaching of fundamentals. Some educators engaged in the provision of liberal studies for engineers see such criticisms as requiring a reduction in the time devoted to liberal studies. Others see the argument as supporting the demand for a lengthening of the curriculum (as from 4 to 5 years).

Another complaint that seems to relate to the ‘packed’ and ‘inflexible’ curriculum is that students do not retain knowledge that engineering educators regard as important. They argue that if students are to think critically they need to be given time for reflective learning outside of the curriculum. They also noted the negative impact that assessment can have on both the curriculum and instruction.

In recognition of this problem some engineers in the United States began in the 1970’s to experiment with different methodologies such as co-operative learning groups (Johnson, Johnson, Smith, 1991), and assessment and teaching practices that would foster creativity. In the United Kingdom projects were introduced in the 1950’s, and with the advent of ABET’s EC2000 criteria senior capstone projects became the norm in the US. These innovations moved the focus of learning away from the instructor to the

student who had to take much more responsibility for his/her own learning.

Since then there has been a continuing flow in small steps of developments that have as their purpose the revitalization of engineering education as Sheppard and her colleagues report (Sheppard et. al. 2008). Many schools and programs engage in problem-based and activity-based learning as alternative models to instructor-centered approaches.

However, traditional engineering lectures are engaged in disciplinary perspectives where knowledge defines the boundaries of the discipline. But at times it feels that there is an element of the “just-in-case” the students might need ‘this and that’ chunk of knowledge syndrome. Students will be helped if they commit this disciplinary knowledge to memory and testing will verify that students are able to recall that knowledge. Consequently, assessments remain of the traditional kind and students receive little training in solving ‘wicked’ problems (Buchanan, 1992: Schmidt 2006). Students have to respond to an ever increasing span (breadth) of knowledge and the efficiency of their education is a measure of their knowledge of that base.

Toward change

Logic dictates that if there is to be a solution to the problem of the overloaded curricula that many educators will have to make substantial changes in their views about learning. It is well understood that change is difficult and that for change to take place individuals may have to change their innermost beliefs. Change, therefore, invites the educator to examine the operational philosophies that guide their teaching. Consider for example, the question of whether their end goal is ‘efficiency’ or ‘effectiveness.’ A multiple choice test set at the end of course may

well test the efficiency with which the material delivered in the lectures is remembered but does it test understanding? To assess (measure) the latter is a measure of effectiveness (Jinks, 1996).

It is well understood that if changes are to be made much prior work has to be done by those requesting the change to prepare those who are being asked to change with information in advance. That preparation necessarily involves educators in the examination of their teaching philosophies for it is those philosophies that drive the method of teaching they adopt. Everyone, Sherren and Long (1972) wrote, teaches to one's own philosophy. In general there is no escape from examining the assumptions that teachers make about how students learn. A transmission model is founded on the view that the mind is *tabula rasa* on which the teacher's commentary is written. It is assumed that this is the best way to help students remember and learn. It also assumes that the student's perception of what the teacher says is the same as that which the teacher believes has been delivered.

Regardless of whether we are conscious of it or not, our activities, whether teaching or research, are driven by epistemological beliefs which we seldom examine. This paper argues that John Dewey's pragmatism reflects engineering practice and provides an alternative to traditional instructor-centered approaches that might better motivate the students to retain knowledge and think critically.

John Dewey and Pragmatism

John Dewey (1859-1952) (see exhibit 1) was one of the pioneers of what is known as American Pragmatism. As initiated and established by Peirce (1839-1914), Pragmatists believe that reality is

constantly changing and that we learn best through applying our experiences and thoughts to problems as they arise. The universe is dynamic and evolving, and pragmatism thus has a "becoming" view of the world. There is no absolute and unchanging truth, but rather, truth is what works based on our experience. Peirce believed that thought must produce action, rather than linger in the mind and lead to indecisiveness. From the perspective of this discussion it is not evidence based research that dictates if a teacher should change. What determines whether to change or not is whether the particular teaching method works for the teacher, the evidence being the teacher's evaluation of his/her experience (Heywood, 2008). The corresponding moral imperative is that a teacher who is asked to try out a different method should do their best when trying it out.

John Dewey applied pragmatic philosophy in his progressive approaches to education that he called 'instrumentalism.' By this he meant that knowing is a conceptual activity that anticipates and guides our future interactions with our environment (Delaney, 1995). Dewey stated:

"But in the proper interpretation of "pragmatic," namely the function of consequences as necessary tests of the validity of propositions, provided these consequences are operationally instituted and are such as to resolve the specific problem evoking the operations." (Dewey, 1938, p.iv)

"The purpose of knowing is to effect some alteration in the experiential situation" (Delaney, 1995, p 198). Formal learning takes place when students (people) interact with environments created specifically for learning that have the purpose of helping learners modify their cognitive structures. This also true of informal learning which

happens all the time. Thus the teacher's role is to create experiences that will help the learners create knowledge for themselves. "Knowledge is thus rarely spoken of in terms of 'to know' but often in terms of 'to experience.'" (Schiro, 2013, p 119). Dewey believed we all learn by doing. Students are 'active' creators of learning.

In summary Dewey believed that learners must adapt to each other and to their environment. Schools should emphasize the subject matter of social experience. All learning is dependent on the context of place, time, and circumstance. Through education different cultural and ethnic groups can learn to work cooperatively and contribute to a democratic society. The ultimate purpose of education is the creation of a new social order. Character development is based on making group decisions in light of consequences. For Dewey all learning and progress starts in problem solving, and inquiry. From a felt difficulty, to posing a question, and seeking solutions, Dewey (1933) argues that thinking, learning, knowledge, and all

human advances are the result of inquiry-based problems solving that defines the human development process. In consequence learner-centered educators have as their primary aim the fostering of growth (or development) and as such value the work of Piaget (1952). In engineering, learner-centered educators value the work of such persons as William Perry, and Patricia King and Karen Kitchener.

The epistemological basis for this argument is Dewey's view that all thinking is problem solving, and that there is much agreement among engineers and engineering educators that engineering education is problem solving. Dewey argues that the best and most natural way of thinking and problem solving for humans is by posing good questions and engaging in the process of inquiry that begins with a 'discomforting' problem. In his approach the inquiry process helps students to examine their learning, education, and formation of ideas and knowledge in a learner-centered environment, so how does it contrast with the instructor-centered approach.

About John Dewey and his life

To recognize Dewey's significance for engineering it is necessary to have some understanding of his life. The following is a quick summary

John Dewey was born in 1859 in Burlington Vermont. His father was a storekeeper with great interest in books, especially British literature who shared his interest with his family. He left his business to become a Union Army soldier in the Civil War. His mother, Lucina Artemisia Rich, was a decisive factor in encouraging him toward education and making him a universal thinker. He grew up in a community where duties and responsibilities were cherished. Even as kids they had to participate in performing their duties to make sure the welfare and well-being of all was taken care of. So, the sense of helping, participating and giving to the community was instilled in him from the early days.

After graduation in 1879 he worked as a high school teacher at a seminary in Oil City, Pennsylvania. He was laid off after two years and returned to Vermont and started teaching in a private school. During that time he studies philosophical treatises and discussed them with his former teacher, Torrey. As he got more and more interested in Philosophy, he decided to take a

break from teaching and went to The John Hopkins University where he enrolled in philosophy and psychology. During his work at The John Hopkins two professors George Sylvester Morris and G. Stanley Hall were among the most influential and transformative teachers for Dewey. G. Stanley Hall founded the child study movement, which encourage educators to study children as they actually are in order for the curriculum and teaching to be designed to meet the child's needs. To a greater or lesser degree all teachers do this in order for them to accurately assess their progress or lack of progress and understand why it should be. This raises the question for engineering educators as to how much they should know about their students? Dewey received his doctorate in 1894.

He then accepted a teaching position as assistant professor at University of Michigan where he worked for 10 years. At Michigan he met and married Harriet Alice Chipman (in 1886) and they had 6 children and adopted 1 child during their lives together.

He wrote his first two books *Psychology* (1887) and *Leibniz's New Essays Concerning the Human Understanding* (1888) during his tenure at university of Michigan. Dewey started to look more critically into sciences and investigated the relationship of philosophy and sciences.

In 1888 Dewey spent a year at professor of Philosophy at the University of Minnesota. In 1889 he returns back to University of Michigan and stays for 5 years. In 1894 he joined the newly founded University of Chicago, where he started his empirically based theory of knowledge and at the same period he developed American School of Pragmatism or 'experimentalism' as he preferred to call it. The first of the American Pragmatists was C. S. Peirce for whom knowledge is an activity (knowledge is doing). It was a theory of meaning whereas William James thought as a theory of truth. The Penguin Dictionary of Philosophy defines pragmatism as "the theory that a proposition is true if holding it to be so is practically successful or advantageous advantageous."(p485). Engineering problems often require engineers to make decisions on pragmatic grounds.

At Chicago he founded an experimental or 'Laboratory School' which was based on learner-centred (or child centered) education. It greatly influenced Dewey's thinking about education. It is associated with 'progressive education' which many politicians deride because they think it will lower standards. Many teachers in engineering are wedded to a scholar academic ideology in which the curriculum, or as some say, the fundamentals are all important and are to be conveyed from a rostrum (Schiro, 2013). Equally there are engineering educators who foster inquiry learning and problem solving which is at the heart of the learning by doing philosophy. The learner-centred ideology is associated with constructivist methodologies.

W. H. Schubert (1997) reports that in 1918 William Heard Kilpatrick published an article entitled "The Project Method" in Teachers College Record that was read round the world as a concrete embodiment of Deweyan curricular philosophy." (p 75). Projects have been used in engineering courses for at least seventy years. The two ideologies promote key quotations for the design of the engineering curriculum, how to teach critical thinking, and the ability to deal with wicked problems. Dewey believed that the function of education was to develop critical thinking and not the conveyance of information.

In 1904 Dewey joined the Department of Philosophy at Columbia University where he spent the rest of his educational/professional career.

His interest in educational theory deepened and was supported by his work in the Teacher College at Colombia. In *How We Think* (1910; revised in 1933) he applied his theory of knowledge to education. Finally in 1916 *Democracy and Education* was published which is another well received and impactful work.

Dewey retired in 1930, but his creative transformational worked continued. He continued to publish and be truly active. In this period, he worked on more than a few books, and took many important public stances. Some of his noteworthy efforts include his participation in the

Commission of Inquiry into the Charges Against Leon Trotsky at the Moscow Trial (against Stalin's policies), and his historically importance defence of fellow philosopher Bertrand Russell against a reactionary movement that tried to remove Russell from his Chair at the College of the City of New York (1940).

Dewey was one of the organizers of League for Independent Political Action (founded in 1929) with the goal of creating a new political party. He was also an editor of the *New Republic* magazine. He helped found the American Civil Liberties Union as well as the American Association of University Professors. After World War I (1914–18), Dewey travelled the world. He lectured in Japan (at the Imperial Institute) and spent two years teaching at universities in China. In 1924 he pursued to study schools in Turkey. After two year in Turkey, he visited the University of Mexico.

Over the course of his lifetime, Dewey published more than 1,000 works, including essays, articles and books. His writing covered a broad range of topics: psychology, philosophy, educational theory, culture, religion and politics. Through his articles in *The New Republic*, he established himself as one of the most highly regarded social commentators of his day. Dewey continued to write prolifically up until his death at the age of 92 in June 1952.

Dewey was a shy and quiet person. He was not the most excitable teacher. At times he would put his students to sleep. Those who loved his lectures and would pay full attention do report that during the lectures they would witness a professor who is fascinated with ideas and would challenge and create ideas in his classroom.

Dewey's approach to engineering education faces the educator with a choice between a learner-centred strategy, or an instructor-centred which requires that the instructor has a well versed philosophy (epistemology) on which to base his teaching for a profession that is necessarily pragmatic. Dewey has first to reconstruct the notion of philosophy Dewey came to believe that the only method of thinking that had proved fruitful in any subject was the method of science (Dewey, 1933).

Exhibit 1.

The inquiry based approach v traditional engineering problem solving

There are five major steps in Dewey's cycle of inquiry. These are:

A felt difficulty

Its location and definition

Suggestion of possible solutions

Development of solution by reasoning of the bearings of the suggestion

Further observation and experiment leading to its acceptance or rejection; that is, the conclusion of "belief or disbelief."

Inquiry is an activity (practice) that people engage in when they come out of balance

from their environment (then they have a felt discomfort about something.)

According to Dewey, all thinking begins with a problem. In the traditional engineering problem solving approach, the problem is provided to the student (inquirer). In addition, the problem and the understanding of the problem will initiate ongoing activities for the learner-inquiry. Consequently, the problem and the mental activities will have special meaning to the student-inquirer derived from the interests, identities, and the values adopted from the social world of the student/inquirer. Consequently, a learner whose thinking and cognitive engagement is triggered by a given problem, where ever the source is, will initiate the thinking and the felt

difficulty. That is why many engineering students like puzzles and not trivial questions to think about. Dewey considers step (iii), to be “the very heart of inference”; it involves going from what is present to something absent. Hence, it is more or less speculative, adventurous, and full of experimentation. Due to the inherent uncertainty this step will involve risk taking and require action by the inquirer to learn/experience new things. Step (iv) engages the learners reasoning. Reasoning is defined by Dewey as “The process of developing the bearings--or, as they are more technically termed, the implications--of any idea with respect to any problem” (Dewey, 1933). Dewey writes, “As an idea is inferred from given facts, so reasoning sets out from an idea” (Dewey, 1933). On steps (ii) and (v), he writes (Logic) that in “the more complex organisms, the activity of search [ii and v] involves modifications of the old environment [the environment in which the problem has been encountered], if only by a change in the connection of the organism with it.” (Dewey,1933). Consequently, steps (ii) and (v) require “the transformation of the situation [which] is existential and hence temporal.” In the search the inquirer changes as he/she interacts with the environment (Mina, Omidvar and Knott, 2003).The inquirer needs to continually think and ask questions, especially when the solution is done. In many cases these questions will be created as difficulties arise and have to be put aside in pursuit of the solution and addressed later. Clearly, one can see the level of engagement that students need to be involved in this process. Finally, students need to reflect on their process and questions.

Reflections are considered to be essential parts of the inquiry cycles by Dewey. Since the purpose of inquiry is to resolve

an unbalance or a felt difficulty, the more one can think, engage, and examine a problem from different perspectives and depths the better solution can be achieved. The role of reflections (as a personalized as well as social activity) become essential in the development of the idea and growth of the individual.

This model should be contrasted with what is typically used in engineering classes and textbooks. The problem solving model that is found in many traditional engineering texts generally advocate the approach described in the next section.

Steps for Problem solving often found in engineering texts

State the problem Clearly

Describe and understand what is given (input) and what is needed (output)

Identify some approaches and small part solutions, try them

Identify a strategy and make a systematic solution

Put the solution together

Test to solution with different data, iterate for validity, generalize, communicate.

These steps can have similar intentions to Dewey’s inquiry process. By stating the problem clearly and understanding the intention of the requirements of the problem the heart of the problem can be found. The purpose of steps 1 and 2 are very similar to the first two steps of the inquiry based cycle. However, these are more general steps. During the first two stages, the inquirer may go through many cycles of inquiry. As the problem is cyclically examined many felt difficulties may be illuminated.

Steps 3 is similar to the third stage of Dewey's inquiry cycle. The learner needs to think about the bearing of the solutions as he or she thinks about approaches and possible solutions. This connects with the 4th and 5th steps which identify a strategy and making systematic solution. When a solution is found and tested, the inquirer may or may not be aware of the belief and disbelief that was created. In the Inquiry based method the learner need to reflect on those. In reality many engineers do have open questions, doubts, and continuous thinking about the solutions they created. These could be the stage of understanding belief and disbelief. Dewey argued that by going through the steps of the cycle, repeating them and reflecting on them cycle the learner is enriched. He/she learns how to pose better questions, and examine the next problem in the light of previous experience.

Since the process of inquiry helps the student examine his or her belief, thinking, knowledge, and ideas, problems in the cycle become more contextual and meaningful to the student and the students' socio-technical reality. The contextual aspect of the problem will be lost if the problem solving steps are treated as a mechanical to-do list, and set mechanization where the same approach is used to solve every problem even though there may be a better alternative is avoided. (Heywood, 2008).

Those who create better questions, do deeper thinking and engage cognitively while going through the problem solving steps. If that is the case, those individuals are in a sense creating their own cycles of inquiry by asking better questions and examining all aspects of the problem with critical angle. Such students are those who continually create great questions, and keep generating meaningful challenges.

There are many situations where the engineering problem solving steps can be useful and can create complete solutions. This is true for problems that are known where there is a need to modify an already existing solution to create a solution for the new problem. In such cases the inquiry process can be viewed as inefficient since it makes the learner/problem solver think in cycles that would form new questions that need to be pursued. If the goal is finding a quick and implementable solution, the process of inquiry is not the right solution. This is the case in many engineering classes, since the nature of the problem is to emphasize some of the class teaching, and the students' time is limited.

There are numerous examples of the use of the problem solving model in engineering education. For example when students are asked to solve wave equations in Electromagnetics, Elasticity, vibrations, and other areas. They will use plane wave and uniform plane wave solutions following the process outlined above. The advance classes require students to discuss and evaluate their answers and the design classes will require students to provide multiple possible solutions. However, as previously indicated, this process too easily becomes a set of actions (that need to be checked) and not cognitive engagement and challenge, and losses its effectiveness. Students often experience this approach for solving problems in tiered lecture theatres in which they are the passive recipients of information. In most cases, they attempt to memorize the process for the purpose of passing tests (see above).

In contrast, activity (inquiry) oriented learning is much more concerned with learning and the assessment of student growth (development). While there have

been a few attempts to design curriculum that will foster student growth using the Perry Model or others with a similar purpose they have not engaged the minds and motivations of engineering educators (Pavelich and William, 1996). It is argued that such designs help students integrate and expand their knowledge while systemizing their experience. The construction of evaluation and assessment procedures is critical to the achievement of the systems goals and attention needs to be given to the type of problems that novice engineers will confront (Trevelyan, 2014).

Implications for the curriculum

The characteristics of a learner centered curriculum is derived from Dewey's principle of learning by doing. It is activity based, interdisciplinary, and the responsibility for what occurs is shared between the teacher and the student. The premise is that the students develop a responsibility for their own learning, which is also a major goal of higher education. Schiro writes that those who run activity schools "believe that students should confront the real world and all that it is directly and not through intermediaries such as text books and information giving lessons" (Schiro, 2013, p 106). In Deweyan type schools students are invited to solve problems using the method of inquiry outlined above. These cycles of inquiry necessarily cause students to interact with a variety of information from a variety of resources in order to solve the problems with which they are faced. The students are not necessarily encouraged to partition this integrated information into the traditional disciplines of knowledge. "It is assumed that it is the learner's job to integrate knowledge and that configuring what goes on inside the learner's mind is not the job of the teacher or the curriculum" (Schiro, 2013, p 113). This is

a challenging view for many engineering educators who claim to develop independent thinkers via the transmission method, for it would seem to be self-evident that transmission learning in which the students are passive recipients of information could not possibly achieve that goal.

The project method first advocated by W. H. Kilpatrick (1918) is widely considered by learner-centred educators to be the embodiment of Dewey's philosophy of curriculum (Schubert, 1997).

The project as envisaged by Kilpatrick is familiar to engineering educators and individual projects have been used in engineering since 1918). They meet the Dewey criteria when the student chooses the topic of the project but in engineering education the topic is often chosen by the instructor who can choose questions that will lead to inquiry (discovery) based learning. Different kinds of project have been used to achieve different kinds of goals, but in general they are associated with the development of cognitive and affective skills that will not be developed by traditional teaching and assessment. While these are important purposes they are not the purpose which this paper addresses. This is, that a learner-centered approach will resolve the problems of knowledge retention in preference to critical thinking perceived by many instructors among their students.

However, the challenge is to show that projects can be used and better motivate students to learn the key concepts and principles that are called fundamentals in a non-linear way. The knowledge base is developed by participating in a range of different projects. A model of such a curriculum in engineering was described as long ago as 1966 (Heywood et al 1966). Their model included some traditional

courses. So, the way forward from which developments in engineering were made came from medicine, in particular the work of H. S. Barrows at McMaster University. It is now widely used in medical schools across the world, and in particular the Netherlands. Donald Woods (1994) and his colleagues in chemical engineering at McMaster developed a problem solving program that incorporated some problem based learning, although the first major development in engineering was at Aalborg in Denmark which was one of several universities in Europe that introduced new degree structures in the late 1960's.

The language used to describe this kind of student-centered learning is rather mixed: the terms problem-based, problem-based project work, project oriented which have the same meaning in some writings and different meanings in others. Inquiry based learning and team based learning are terms that are also used in this context. Cowan calls the method used in the Basic Education Year at Aalborg project-oriented which is akin to problem-based learning when "students only study what they need to in order to cope with the problem at the heart of their project (Cowan, J (2006, p 19). This kind of project learning is based on Just-in-Time knowledge; it is different to the integrated project approach modelled by Heywood and his colleagues in that the matrix of projects are designed cover the key concepts (fundamentals) of the program (Heywood, 1966/2005). Their model also included traditional discipline based courses. In the basic education program a quarter of the program is devoted to study unit courses for "highly predictable parts of the course" (e.g. computing, physics).

Heywood (2005) in a later review concluded that the evidence, although from

comparative studies with other methods of learning although small, gave, "sufficient evidence" to challenge engineering educators. The reports lead to the suggestion that because the skills developed are required by graduates in engineering practice, project work and/or problem based learning should accompany more traditional approaches throughout the total curriculum and not just in another phase (semester) of the overall program. In this way the needs of the cognitive and the affective development will be taken into account.

It is understandable that a traditional curriculum cannot be changed to a problem based curriculum overnight. Apart from the planning that has to be done, effective change is highly dependent on the commitment of all those who are to be involved. Commitment depends on an understanding of what is required. Dewey's approach would be to engage teachers in the use of inquiry based learning in traditional classes modified for that purpose, and so move forward by a small step.

The author has experience in using student-centered and traditional lecture approaches in a course on introduction to electromagnetism. Using a student-centered approach, each lecture is broken in a lecture/discussion about the concepts and formulation and their application. This is followed by the second part of the lecture that will be working on problems in small groups, group discussions and, at times, group debates. Students in the class were introduced to the inquiry based procedure. At this stage they discussed the utilization of the process. By reflecting on their experience in the class, they were led to examine their belief and disbeliefs about their process and solution to the problem. For examples students would use a certain

equation to solve the problem. When asked why they used the equation, they would say that other equations never worked for them. This opened up a new discussion and examination of their beliefs and disbeliefs about what would work and would not work. The reason for not liking a particular equation was found in most cases to be the student's negative experience in previous attempts in solving problems with that equation. As indicated earlier this is known as "set-mechanization" or "set-induction" (Heywood, 2008).

In contrast a traditional lecture class is conducted by delivering the material in the form of lectures and handouts for class discussion which is directed and led by the faculty. The author found that as expected, the student-centered class could not cover as much material as traditional lecture classes can. However, the students do have better understanding of the basics, and show in-depth thinking regarding the subject compared to the instructor-centered class. The average grades (that include class activities, HW, quizzes, tests, final, and reflections) for the student-centered class were found to be in the range 80-85%. In contrast the average grade for the instructor-centered class (that include HW, quizzes, tests, final, and final project, and reflections) was found to be in the range 70-75% (see also Deslauriers, Schelew and Wieman 2011). In addition, students in the student-centered class showed more in-depth detail in their work and reflections. They always had better questions, and developed much richer approaches to new problems as individuals and as a group of learners. Finally, a great number of the students in the student centered class, decided to take more advanced EM courses after the introduction class. This shows the importance of defining educational outcomes required from a

course. Some of the courses that had had a hard time attracting students, were fully subscribed by the student-centered participants since it seemed they wanted to learn more and work together on more challenging problems.

Commentary

In an earlier study the author and two colleagues examined engineering education at the leading colleges in the light of John Dewey's model of education (Mina, Omidvar and Knott, 2003). We asked what would John Dewey surmise after visiting a typical engineering college? The paper reported that Dewey would agree with the intention of the engineering education which is educating students in understanding, advancing science and technology, and designing for a better world. To develop technological critical thinkers with sociotechnical capabilities and a willingness to take responsibility. However, he would show concerns about the lack of flexibility and the over-packed curricula that engineering programs were (and still are) facing. Dewey would propose more "play time" thinking time, and inquiry in the program. He would identify the condition as "lack of openness, lack of a democratic state of learning".

There are many interpretations of what Dewey means as a democratic state. For the purpose of engineering education he would advocate openness among faculty, student groups and administration. The goal of a democratic state for engineering education is openness in all aspects of education to empower students and their teachers with a sense of belonging, responsibility, citizenship, and socio-ethical awareness to make the world around them better for all. Dewey argues that students will face change that arises from more difficult problems than those experienced by the previous generation,

some of which are left for them by the previous generations, which fundamentally challenges both the purpose and claimed effectiveness' of engineering. Since each generation faces more difficult problems than the previous generation this must repeatedly challenge the present purpose and claimed effectiveness of engineering education as perceived at the time. In any case potential engineering students will always need to be tooled with critical thinking, open mindedness, and sociotechnical awareness, and a curriculum that has predictive validity.

“A society which is mobile, which is full of channels for the distribution of a change occurring anywhere, must see to it that its members are educated to personal initiative and adaptability. Otherwise, they will be overwhelmed by the changes in which they are caught and whose significance or connections they do not perceive. The result will be a confusion in which a few will appropriate to themselves the results of the blind and externally directed activities of others.” (Dewey, 1916, section 7)

Some of the teachers with whom we discussed our findings liked the idea that Dewey would agree with the intention of engineering education which is educating students in understanding, advancing science and technology, and designing for a “better world,” without questioning Dewey’s meaning of this concept. They also agreed that perhaps we need more openness. But in almost contradictory terms they said they did not know how to cut content from their programs. That led them to ask why do we need so many classes from outside of the engineering, math, and physics? As engineering educators we understand the issues but hesitate to make changes because

traditional teaching covered the curricula efficiently.

However, true understanding of Deweyan philosophical approach would reveal that once there is lack of openness and flexibility (for thoughts, ideas, examination), and a push for learning facts outside the context of students’ lives, students perceive emergent knowledge to be dogmatic and the principles laid down by the authority as incontrovertibly true, a state of affairs that is inimical to the development of critical thinking.

“Men still want the crutch of dogma, of beliefs fixed by authority, to relieve them of the trouble of thinking and the responsibility of directing their activity by thought. They tend to confine their own thinking to a consideration of which one among the rival systems of dogma they will accept. Hence the schools are better adapted, as John Stuart Mill said, to make disciples than inquirers.” (Dewey, 1916, P.394)

In an open and democratic educational environment, faculty and students are responsible for the creation of meaningful challenges that would advance their knowledge and capabilities and would help society. It all starts with small groups, faculty, and students, administrations that engage in open discussions, challenges, and development. Creating and supporting communities that work together, grow together and utilize diversity of thoughts.

If the challenge stops, if the inquiry cycle does not continue, all of the players and members will converge and get tasks done in the most efficient way but not necessarily the most effective way. The danger of a push for efficiency will be at the expense of effectiveness. Efficiency is the degree to which students are able to remember and memorize information. For

example when instructors use multiple choice tests and report for percentage of the students who did successfully, they are measuring/reporting of efficiently. Whereas, effectiveness refers to the ability of the students to apply their knowledge and solve new and unseen problems. For Dewey the role of education and the role of the thinkers in society is to face challenges, pose better questions, and create new ideas and visions to improve the status quo. The role of all of us is to be effective in the process of inquiry. Consequently, in his model universities are not to be efficient places but need to be effective learning institutions.

Finally, Dewey places responsibility on everyone engaged in education: students, faculty, and administrators. From an educational perspective Dewey would advocate that faculty also have a responsibility to grow, find better ways to educate students and conduct classes. Faculty need to keep updated with research and finding of educational pioneers, participate in the creative process of inquiry and seek better ideas and approaches to be more effective. These are the professional, social, and ethical responsibilities of the faculty.

A need to create communities of learners

At present because of the heavy emphasis on the syllabus and material coverage, we do not allow students to make arguments, debates, and build critical perspectives on what they read, learn, and design. Students are treated like children and in consequence consider what is taught to be the truth that will get through examination. Great stress is placed on memory and this is at the expense of reflective and critical thought. According to the Deweyan principles we need to encourage them to discuss, debate, and challenge each other's

ideas. They need to go through active examinations of their ideas, solutions, and designs. This is much more achievable in a community of learners. The community of learners will bring problem solving, discussion, examination, and cycles of inquiry in a social structure that is built to help students learn, learn together, and achieve active experimentations of ideas and their knowledge base.

Unresolved issues for engineering education to think about

There are a few important issues arising from Dewey's philosophy that remain to be addressed in the future.

For John Dewey the goal of education is not to get a degree but to become a life-long learner. But for many of our students that will be the main point of their focus. This perspective can hinder students' progress in inquiry based discovery and learning. Student will value the information to pass the examinations, more than the process of learning to continue their path of becoming life-long learners (Cheville, 2016).

Dewey would also like to have all students take charge of their learning, growth, and education. They need to be the leaders of their lifelong learning. How do we reach that? How do we encourage and enhance these responsibilities? However, for all practical approaches, creating and maintaining community of learners for students could be the first meaningful steps toward achieving better results regarding these questions. Experience shows that learning communities that create effective empathetic relationships amongst student members, educators, and external industrial sponsors show great level of success in projects and learning in the process (Pezeshki, 2014, Pezeshki et al 2014).

Finally, according to Dewey's learner-centered model, the curriculum is defined with major objectives, but the delivery, the syllabus, and class activities are created by students needs and instructors coaching, enabling, and guidance. He does not question if the students know all that they need to know. He addresses if students are capable of breaking problems down, pose meaningful questions, seek answers, examine results, participate in active experimentation of their ideas and possibilities, and providing a solution with reflections on the process and critique of the steps. This differs from the focus point of engineering education where many users of the active learning approach still believe in a body of knowledge that needs to be covered and syllabi that need to be delivered.

Conclusions

The main goals of this paper were to illustrate the importance of the educator's personal philosophy of learning to his/her practice and in so doing to present an alternative student-centred view of learning that derived from the philosophy of John Dewey. As engineering education is progressing toward new frontiers in the 21st century, the challenges of packed curriculum, finding more effective ways of training students, and debates on instructional techniques continue to engage many engineering educators. John Dewey's philosophical ideas are presented as an alternative approach to instruction that encourages students to take responsibility for their learning and to think critically through the cognitive engagement that a more student-centered approach to engineering education demands.

References

- Barrows, H. S and R. Tamblyn (1980) *Problem Based Learning. An Approach to Medical Education*. New York, Springer.
- Buchanan, R (1992). Wicked problems in design thinking. *Design issues* 8(2), 5-21.
- Cheville, R. Alan (2016). Linking capabilities to functionings: adapting narrative forms from role-playing games to education. *Higher Education* 1-14. High Educ (2016) 71:805-818 DOI 10.1007/s10734-015-9957-8
- Cowan, J (2006). *On Becoming an Innovative University Teacher. Reflection in Action*. 2nd edition. Maidenhead, Open University Press, p 19.
- Delaney, C. F (1995) Dewey, John. *The Cambridge Dictionary of Philosophy*, Cambridge UP p 198-200.
- Deslauriers,,L, Schelew, E, and C. Wieman (2011). "Improved learning in a large-enrollment physics class." *Science* 332.6031, 862-864.
- Dewey, J (1938). *Logic: The Theory of Inquiry*. New York. Holt, Rinehart, and Winston. p. iv.
- Dewey, J (1916). *Democracy and Education*. New York, Macmillan.
- Dewey, J (1933). *How We Think: A Restatement of the Relation of Reflective Thinking to the Educative Process*. DC Heath and Company.
- Heywood, J (2005). *Engineering Education. Research and Development in Curriculum and Instruction*. Hoboken, NJ. Wiley/IEEE Press. P 238.
- Heywood, J (2008). *Instructional and Curriculum Leadership. Towards Inquiry Oriented Schools*. Dublin. Original Writing for the National Association of Principals and Deputies. P 245.
- Heywood, J., Lee, L. S., Monk, J. D., Moon, J., Rowley, B. G. H., Turner, B. T., and J. Vogler (1966). The education of professional engineers for design and manufacture. *Lancaster Studies in Higher Education* No 1, p 5- 100.
- Jinks, R. F (1996). Knowledge, understanding (mind the gap). *Engineering Science and Education Journal* (October) 227-230.
- Johnson, D. W., Johnson, R. T and K. A. Smith. *Cooperative Learning*. Interaction Book Company, 1989.
- Kilpatrick, W (1918). The project method. *The Teachers College Record*. 19(4), 319-335.
- Mina,M., Omidvar, I., and K Knott (2003). Learning to think critically to solve engineering problems: Revisiting John Dewey's ideas for evaluating engineering education." *Proceedings Annual conference of the American Society for Engineering Education*.

- Pavelich, M. J., and W. S. Moore (1996). Measuring the effect of experiential education using the Perry model. *Journal of Engineering Education*
- Pezeshki, C (2014). Influencing performance development in student design groups through relational development”, *International Journal of Engineering Education*, 30,
- Pezeshki, C., and Kelley, R (2014). It’s All about Relationships – How Human Relational Development and Social Structures Dictate Product Design in the Sociosphere, Product Development in the Socio-sphere: Game Changing Paradigm for 21st Century Breakthrough Product Development and Innovation, Springer.
- Piaget, J (1952). *The Origins of Intelligence in Children*. New York: International Universities Press.
- Piaget, J (2013). *The Construction of Reality in the Child*. New York, Routledge.
- Schiro, M. S (2013). *Curriculum Theory. Conflicting Visions and Enduring Concerns...* Los Angeles; Sage.
- Sheppard, S. D., et al (2008). *Educating engineers: Designing for the Future of the Field*. San Fransisco, Jossey-Bass.
- Sherren, D.C and T. R. Long (1972). The Educator's Dilemma: What Makes Clyde Want to Learn?. *Engineering Education* 63(3),188-190.
- Schubert, W. H (1997). *Curriculum; Perspective, Paradigm, and Possibility*. Upper Saddle River NJ. Prentice Hall. P 75.
- Schmidt, Douglas C (2006). Model-driven engineering. *COMPUTER-IEEE COMPUTER SOCIETY*- 39(2), 25.
- Trevelyan, James (2014). *The Making of an Expert Engineer*. CRC Press, 2014.
- Williams, R (2002) *Retooling. Historian confronts Technological Change* MIT Press. P 40 and 42.
- Woods, D. R (1994). *Problem-Based Learning. How to Gain the most from PBL*. Hamilton, Ontario. McMaster University bookshop

PHILOSOPHICAL AND EDUCATIONAL PERSPECTIVES ON ENGINEERING AND TECHNOLOGICAL LITERACY 3

Prepared for the Technological and Engineering Literacy and Philosophy Division of the American Society for Engineering Education by Alan Cheville, Stephen Frezza, John Heywood and Mani Mina.

The Technological and Engineering Literacy and Philosophy Division of ASEE is a forum for those seeking to impose the broad understanding by all citizens of all aspects of technology and the role of engineering in the creation and management of technology. Here technology is “the entire system of people and organizations, knowledge processes and devices that go into creating and operating technological artifacts, as well as the artifacts themselves.”* Technology affects nearly every aspects of human life.

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**Technically Speaking*. National Academic Press, (2002) p 13.

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