A Select and Annotated Bibliography of Philosophy in Engineering Education

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Abstract – **The discussion of a philosophy of engineering and/or engineering education has encouraged the community to try and bring some coherence to the field. This select and annotated bibliography is one resource intended to enhance and continue the conversation. In conjunction with a preparatory review, this bibliography introduces the 2011 FIE special workshop on the subject of exploring the philosophies of engineering and engineering education. This work extends what has been done during the 2007, 2008, and 2009 FIE conferences. Focus is brought to bare on research and theoretical readings that discuss a philosophy of engineering education; the engineering identity crisis; differentiating engineering, science, and technology; engineering science verse engineering design, engineering epistemology, philosophy and practice of the engineering curriculum; philosophy in the engineering curriculum; engineering ethics; and engineering culture. Each of the focus areas is introduced with a list of annotated references that present current ideas, beliefs and findings related to these areas.**

Index Terms – Philosophy, Engineering Education, Bibliography

INTRODUCTION

Before a philosophy of engineering education can be developed a philosophy of engineering would have to be established. One attempt has been made to do this (Bucciarelli) and other attempts have been made to explore philosophy in engineering and engineering in context (Christensen). Those concerned with the promotion of a philosophy of engineering have to face three hurdles at the root of the current identity crisis in engineering education. First, they have to establish that engineering is not just the application of science, and therefore, a branch of the philosophy of science. A subordinate question is whether or not engineering is in addition an art and/or a craft. Second, they have to establish that engineering is something different to technology and, is not, therefore a branch of the philosophy of technology. Much has been written on this topic and, as in everyday life, may find the switches in terminology – from technology to engineering and back again – quite confusing. There is no escape from this debate because the public tends to use and respond to the terms technology and technologists rather than engineering and engineers. The Institution of Electrical Engineers has changed its name to the Institute of Engineering and Technology for just this reason. Third, especially in respect to a philosophy of engineering education, the conflict between engineering science and engineering design where, in education, science has higher status than design, must be resolved. Illumination of these issues will be found in answers to questions about what engineers know and have to know and who they are. There is an ever-growing literature on these topics, which we present in this annotated bibliography.

Disclaimer: Our exhaustive literature search included references to books, journals, and conference proceedings up to 2010. We recognize that this document has likely omitted some appropriate references and apologize to any authors whose literature we may have neglected.

BACKGROUND

This annotated bibliography was created as a resource for the 2011 Frontiers in Education Workshop on 'Philosophy and Engineering Education' sponsored by the Educational Research Methods (ERM) Division of the American Society for Engineering Education (ASEE), the Institute of Electrical and Electronics Engineers (IEEE) Education Society, and the National Science Foundation (NSF). The goal of the workshop and this resource is to begin a formal conversation about the philosophical meaning of engineering and engineering education that culminates in the creation of a community based on these topics and the work of those from years past.

After the Frontiers in Education Conference (FIE) in 2006, three of us (John Heywood, Roy McGrann, and Karl Smith) who regularly contributed to the conference and who were members of ERM came to the conclusion that philosophy was a neglected sphere of interest in the thinking of engineering educators. We came to this view from different perspectives and recognized that our differences would stimulate a healthy debate. Each of us had had some formal exposure to the philosophy of education and although we each had different perspectives, we thought that the philosophy of education had important contributions to make to educational policy making and student learning. Accordingly we proposed that a special session should be run at FIE 2007 that would seek to answer such questions as:

- Is a philosophy of engineering education distinct from a philosophy of education?

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- What are the "questions" of a philosophy of engineering education?
- How would a philosophy of engineering education differ from the philosophy of science education?
- Is a philosophy of liberal education necessary in a philosophy of engineering education or are they antithetical?
- To what extent is a philosophy of education necessary for the design of the curriculum?

This proposal was accepted and the result revealed substantial interest in this topic. Similar proposals were subsequently made for 2008 (six papers also submitted for a common session) and 2009 with major contributions from William Grimson, Trevor Harding, and Russell Korte. Additionally a set of six papers was submitted in 2008 for a common session and two sequential special sessions in 2009 (the second of these sessions facilitated by Russell Korte and Karl Smith won the Helen Plants Award). Numerous people attended these sessions. They were a heterogeneous group of engineering educators comprising persons from the engineering, humanities, and social sciences.

While there was a small core that showed considerable interest in the topic and who might have been interested in founding a group, the FIE Conference was not organized to respond to such needs. To maintain a "philosophical activity" at FIE would require more *ad hoc* effort to run special discussions and paper sessions. The group was determined to work toward an activity that would lead to publications, so that the work that it had done could be more widely disseminated. It, therefore, made successful applications to ERM and the IEEE Educational Society to sponsor an invitation workshop at FIE 2010. The proposal was modeled after the successful Forum on Engineering Education Leadership (FEEL) seminar that had been sponsored by ERM immediately prior to the 2002 ASEE Annual Conference. However, while the societies agreed to sponsor the event it was not possible to launch within the given timeframe. It was also suggested that a request be made to the NSF to join the list of sponsors. The award of a grant from NSF has caused the group to re-think the organization of the workshop to be held at the 2011 FIE Conference and to develop the philosophical framework on which original application was based. It is accepted that a key outcome of the workshop should be the development of a community that will continue this philosophical discussion of engineering education.

Coincidentally, a workshop on philosophy and engineering was held shortly after FIE 2007 at the University of Delft in the Netherlands. The workshop titled "Engineering meets Philosophy", grew out of a discussion between engineers and philosophers at MIT in 2006 and was triggered by workshops and seminars stimulated by the National Academy for Engineering in the US and the Royal Academy for Engineering in the UK. In parallel with that development a group of engineers and philosophers in Europe produced a textbook in the philosophy of science for engineers that they called *Philosophy in Engineering*. The workshop was organized around three parallel themes. The organizers called them *demes* and included philosophy, ethics, and engineering reflection. Although there was no specific *deme* for engineering education some of the papers were directly related to the problems experienced by students in learning engineering. The aim of the workshop was to examine the possibility of developing a philosophy of engineering. The organizers held a second workshop at the Royal Academy of Engineering in 2008, and an additional one-day meeting in Golden, Colorado in 2010. There is an intention to hold another meeting in 2012.

In contrast to those who attended the sessions at FIE, the group that were convened at these workshops were philosophers and engineers with considerable reputations. However, it is not clear that their work which finds its organizing structure elsewhere is well known among engineering educators apart from those who are members of the ASEE divisions for Ethics, Liberal Education, Technological Literacy, and ERM. The organizers noted that the "philosophy of technology" is a new discipline that is still maturing. But that it had its own society – Society for Philosophy and Technology – and its own journal – *Techné*.

Taken together these activities and associations promote several questions:

- Given that this "group" exists, if it were possible for it to include the theme of philosophy and engineering education in its future workshops, would that meet the need for continuing the work started by the members of our group?
- If not, does the Society for Philosophy and Technology meet the needs of those who are interested?
- Perhaps the more pressing question is whether or not a philosophy of technology is the same thing as a philosophy of engineering or embraces a philosophy of engineering as some authorities would suggest?

Answers to these questions cannot be resolved without some consideration of the target "audience". The groups have never had a comprehensive discussion as to who it was they wanted the participants to be, but they certainly discussed this matter from time to time. It is clear from their contributions that their focus was engineering educators in the broadest sense of the term. That is persons involved in policy making, educators at the front line of teaching both engineering subjects, and those responsible for the liberal arts dimension of engineering education. Their papers showed a desire to show how philosophy can contribute to policy making at both the national and local levels of designing and evaluating curriculum; how can the skills of philosophical reasoning be acquired by engineering students to enhance their learning; and how can the study of philosophy contribute to personal development as well as development as an engineer. These are the questions it is hoped this workshop will answer.

BIBLIOGRAPHY

Our previous exploratory studies of engineering students suggest that by the time students reach their senior year, they have not fully developed an overall understanding of modeling capabilities and uses. We believe that their conceptions are based on more than just semantic issues that arise with the term modeling. Students appear to be developing specific notions of engineering modeling in large part based on their course experiences. This suggestion reflects not just what is present in the curriculum but rather, what is absent or tacit.

I. Philosophy of Engineering Education

Whether or not we are consciously aware of it or not, we all have personal philosophies that drive our actions. The personal philosophies of engineering educators influence the approaches they take in teaching courses and assessing learning. The importance of philosophy to the design of the engineering curriculum as well as teaching and learning has lead to efforts to show the relevance of the philosophy of education to engineering education and to produce what might be called a philosophy of engineering education.

1. Bucciarelli, L. L. (2003). *Engineering Philosophy*. Delft University Press, The Netherlands.
   (a) Design is a social process. The social and technical/scientific domains are disconnected.
   (b) It will be possible to distinguish engineers from scientists when we gain a better understanding of what engineers do. "*We need to look at how and why and when it (science) is applied (but not like paint* […]" Illustrations are given to support this argument.
   (c) Ryle's distinction of *knowing that* and *knowing how* is pursued to establish what is fundamental in engineering thought and practice.
      - Ryle, G. (1948). *The Concept of Mind*. Hutchinson, London.
   (d) In a final chapter he provides a case study of an open-ended exercise that addresses the fundamentals of engineering and engineering education.
2. Christensen, S. H., Meganck, M., and B. Delahousse (2007). *Philosophy in Engineering*. Academica Press, Aarhus, Denmark.
   The book includes discussions on the philosophy of epistemology of engineering practice and engineering, engineering as an inherently philosophical enterprise (Grimson), the knowledge of engineers (Christensen & Erno-Kjolhede), methodology of engineering science as a combination of epistemic, ethical and aesthetic aspects (Mutanen), engineering science as opposed to applied science and natural science (Colyle, Murphy, and Grimson), some aspects of contemporary Anglo-Saxon philosophy (Buch), the philosophies of pragmatism and the relations between theory, practice, and technology (Lavalle) and other sections on ethics and the global knowledge of society.
3. Grimson, W. (2007). The philosophical nature of engineering. A characterisation of engineering using the language and activities of philosophy. *Proceedings of the American Society for Engineering Education Annual Conference & Exposition.* AC 2007 – 1611, 14 pgs.
   (a) Draws attention to the parallels between engineering and philosophy given Wittgenstein's view that "philosophy is not a theory, but an activity."
   (b) Argues the case for a module on the philosophy of engineering in the undergraduate curriculum in order to help engineering self-understanding through which a greater understanding of the community will be obtained..
   (c) Engineering activities are described that correspond to the five classical branches of philosophy (Epistemology, Metaphysics, Ethics, Logic, and Aesthetics).
   (d) The paper moves between a philosophy of engineering and a philosophy of engineering education.
4. Grimson, W., Murphy, M., Christensen, S. H. and E. Erno-Kjolhede. (2008). Philosophy matters in engineering studies. *Proceedings of the Frontiers in Education Conference*, S4H, 19 – 24.
   (a) However well argued the case, the inclusion of liberal studies in engineering programs is problematic, especially in Europe. This paper briefly explores the rationale for including in an integrated five-year Masters Engineering program liberal arts subjects, in particular Philosophy and the History of Science and Technology.
   (b) The arguments presented include embracing a neutral language of discourse with society and that the 'tools' of philosophy and history can provide additional insight into how engineering was and is 'performed' leading to greater self-awareness within the engineering profession.
   (c) Some results of an empirical case study carried out in Denmark are presented: the purpose of

the case study was to examine a sample of engineering teachers´ attitudes towards the relevance and scope of liberal arts subjects for engineering students.

(d) The general conclusion that can be drawn is that stronger arguments need to be put forward if liberal arts subjects such as philosophy and the history of science and technology are to have a regular place in the engineering curriculum. Hence the need for the general discussion to continue.

5. Saarinen, E., Hamalainen, R. P., Martela, M. and J. Luoma (2008). Systems intelligence thinking as engineering philosophy. *Workshop on Philosophy in Engineering.* Abstracts. Royal Academy of Engineering, London, 7 – 9.
   (a) Systems intelligence derives from (i) the contextuality of the human engagement, (ii) the complexity of any context, and (iii) the necessity to act. "*It is an ability to connect with the complex interconnected feedback mechanisms and pattern structures of the environment from the point of view of what works*".
   (b) Of particular interest is a lengthy discussion of the differences between philosophy of engineering and engineering philosophy and their relation to Herbert Simon's thinking.
      - Simon, H. A. (1956). Rational choice and the structure of the environment. *Psychological Review,* 63, 129 – 138.
   (c) They consider that philosophy of engineering is the philosopher's perspective on engineering whereas engineering philosophy refers to "*mindset and general orientation of an agent that seeks out an improvement in some identified part of her environment with a conviction that an improvement-generating solution to a problem at hand does exist* […]".
6. Christensen, S. H., Delahouse, B. and M. Meganck (eds.) (2009). *Engineering in Context*. Academica Press, Denmark.
   (a) The chapters relate to the philosophy of engineering education directly and indirectly.
   (b) The sections of the book are contextualism in engineering; engineering education in context; engineering design; engineers workplaces and institutions; engineers in civil society.
7. van de Poel, I. and D. E. Goldberg (eds.) (2010). *Philosophy and Engineering. An Emerging Agenda*. Springer, Dordrecht, The Netherlands.
   This book comprises the collected papers of the 2007 Workshop on Philosophy and Engineering at the University of Delft.
8. Durbin, P. T. (2010). Multiple facets of philosophy and engineering, in I. van de Poel and D. E. Goldberg (eds.) *Philosophy and Engineering An Emerging Approach*, 41 – 48.
   (a) There is not one philosophy of engineering (singular). What emerges is something that has many facets like a diamond.
   (b) For example, "*it is a guild with its own professional associations, educational system, and place within the larger society in which thrives* […]*."*
   (c) Like others the significance of pragmatism and the work of John Dewey for engineering are considered.
   (d) If engineers want to be philosophical they should take note of their critics.
9. Mitcham, C. and R. Mackey (2010). Comparing approaches to the philosophy of engineering: Including the linguistic philosophical approach. I van de Poel and D. E. Goldberg. *Philosophy and Engineering. An Emerging Approach,* 49 – 69.
   (a) Useful introduction for someone coming to the field afresh.
   (b) Argues for a pluralistic approach.
   (c) Distinguishes between 6 approaches - phenomenological; post-modernism; analytical philosophy; pragmatism, Thomism
   (d) Also provides an extended comment on linguistic philosophy (In this respect see Moses, 2008 and Yokomoto and Bostwick, 1999).
10. Vermass, P.E. (2010). Focussing philosophy of engineering: analyses of technical functions and beyond, in I. van de Poel and D. E. Goldberg (eds.) *Philosophy and Engineering An Emerging Approach*, 61 – 74.
   (a) Comments on the existing state of affairs between philosophers and engineers.
   (b) Discusses the steps needed for the analysis of technical functions.
   (c) Discusses the role of ICE theory namely the metaphysical activity of defining artifact kinds by their technical functions.

(d) Concludes that profitable collaboration is difficult and that the way forward may be to make it relevant to existing research in the philosophy of technology.

Arguments for a Philosophy of Engineering Education:

11. Furst, E. J. (1958). *The Construction of Evaluation Instruments*. David McKay, New York, NY.
    (a) Argues that every educator should have a defensible philosophy and theory of learning.
    (b) Illustrates the role of philosophy in screening aims and objectives.
12. Sherren, D. C. and T. R. Long (1972). The educator's dilemma: What makes Clyde want to learn? *Engineering Education,* 63(30), 188 – 190.
    (a) In order to know which "engineering characteristics he would like to teach, he must first examine his philosophy of engineering education to understand his goals and attitudes."
    (b) Illustrated by reference to realism, pragmatism, idealism, and naturalism.
13. Smith, K. A. (2003). The academic bookshelf: Educational philosophy. *Journal of Engineering Education*, 92(3), 203 – 205.
    (a) Lists a number of questions that educational philosophy can help engineering educator's to answer.
    (b) Suggests referencing the literature on a philosophy of education.
        - Noddings, N. (2007). *Philosophy of Education*. 2nd edition. Westview Press, Cambridge, MA.
14. Heywood, J. (2005). *Engineering Education. Research and Development in Curriculum and Instruction*. IEEE/Wiley, Hoboken, NJ.
    (a) Ch 3 illustrates the function of philosophy in screening aims and objectives. Cites arguments to the effect that the goals of engineering education are not achieved because they lack a philosophical base.
        - Sinclair, G. and W. Tilston (1979). Improved goals for engineering education. *Proceedings of the Frontiers in Education Conference*, 252 – 258.
    (b) Makes a distinction between 'philosophy' and 'operational' or 'working philosophy'. The latter refers to the everyday usage of the term by teachers and departments to explain their approach on curriculum.
        - Example: Morant, M. J. (1993). Electronics as an academic subject. *International Journal of Electrical Engineering Education,* 110-123.
    (c) It is noted that at the time little work had been done to understand what engineers actually do. Developments in philosophy are dependent on such understanding. This is illustrated by Koen's discussion of the engineering method which is thoroughly underpinned by a strong philosophical base.
        - Koen, W. (2003). *Discussion of the Method. Conducting the Engineer's Approach to Problem Solving*. Oxford University Press, New York, NY.
    (d) Discusses constructivism versus realism (see The History and Philosophy of Science Education section).
    (e) Ethics in engineering education are codes of conduct/professional responsibility; moral development (see Ethics & Engineering section).
15. Heywood, J., Smith, K. A. and R. McGrann (2007). Can philosophy of engineering education improve the practice of engineering education? *Proceedings of the Frontiers in Education Conference*. (Special Session), T1F, 1 – 2.
    Answers were sought to the following questions: Is a philosophy of engineering education distinct from a philosophy of education? What are the "questions" of a philosophy of engineering education? How would a philosophy of education differ from the philosophy of science education and a philosophy of medical education? Is a philosophy of liberal education necessary for the design of the curriculum?
        - Brubacher, J. (1977). *On the Philosophy of Higher Education*. Jossey Bass, San Francisco, CA.
        - Wringe, C. (1988). *Understanding Educational Aims*. Unwin Hyman, London.
16. Smith, K. A and R. F. Korte (2008). What do we know and how do we know it? An idiosyncratic readers' guide to philosophies of engineering education. *Proceedings of the Frontiers in Education Conference*, S4H, 25 – 28.
    (a) An update of Smith, 2003. Focus is on ontology (truth claim) and epistemology (method). Presented in a group of six papers devoted to engineering education and philosophy.
    (b) Argues that it is better to choose a philosophy of engineering and engineering education than to inherit one by default.
    (c) Introduces the idea of a Philosophy of Design.
    (d) Argues for a closer relationship between thinking and doing (engaged scholarship).

- Van de Ven, A. H. (2007). *Engaged Scholarship. A Guide for Organizational and Social Research*. Oxford University Press, London.
- Toulmin, S. E. (2003). *The Uses of Argument*. Cambridge University Press, London.

17. Heywood, J. (2008). Philosophy and engineering education: A review of certain developments in the field. *Proceedings of the Frontiers in Education Conference*, S4H, 7 – 12.
    (a) References some of the papers presented at the 2007 workshop on 'Engineering meets Philosophy' at Delft University. Much of the paper is clearly related to the engineering curriculum raising questions about why there is specifically a need for a philosophy of engineering education.
    (b) Considers the relationship between a philosophy of engineering and a philosophy of engineering education, and the relationship between engineering and the philosophy of science.
    (c) The problem of defining technology is considered, and a discussion of school technology and public policy is included together with a section on developments in ethics.
18. Simons, P. (2008). Relevance of metaphysics/ontology to engineering. *Presentation at the Workshop on Philosophy and Engineering*. Royal Academy of Engineering, London, 71 – 73.
    Engineering and philosophy share breadth, abstractness and a reflexive attitude. The uses of philosophy for engineering are most obvious in ethical issues, but ontological analysis is a potential source of mutual help and insight. Ontology is the maximally abstract, go-anywhere theory of everything. It aims at a categorical framework for any subject matter. Though philosophers trade in its internal disputes, away from the specialist journals ontology can provide relatively neutral analyses of concepts and objects fundamental to engineering: part/whole, structure, function, life-cycle, emergence, process and product, needs and requirements, success and failure, design and planning. Negatively, this can prevent conceptual foul-ups, whether informal or as enshrined in IT models. Positively, it can enhance conceptual transparency and inform tools for managing complexity.
19. Broome, T. H. (2010). The Metaphysics of Engineering. Springer, in I. van de Poel and D. E. Goldberg (eds.) *Philosophy and Engineering An Emerging Approach*, 295 – 304.
    (a) The central questions are: What is the setting of a learned work of engineering? Is that setting unique to engineering?
    (b) Argues that there are at least two settings: one, the real world in which engineering employs methods that seem to simulate the methods of mathematics and science; the other, the hyper-real world known as the assigned world in which engineering employs no simulations. While the question of uniqueness invites a more exhaustive inquiry into many learned disciplines than ventured herein, it can be said that when engineering is done in the real world it is done differently in some ways from mathematics and science, and that neither mathematics nor science is done in a hyper-real world whose natural laws are made from authoritative imperatives.
20. McCarthy, N. (2010). A world of things not facts, in I. van de Poel and D. E. Goldberg (eds.) *Philosophy and Engineering. An Emerging Approach*, 265 – 273.
    A study of Wittgenstein and argues that there is resonance with his later philosophy and both engineering itself and the philosophy of engineering.

Additional Readings of Interest:

21. Clement, J. (1981). Solving problems with formulas: Some limitations. *Engineering Education.* 25, 150 – 162.
22. Clement, J. (1982). Student preconceptions of introductory physics. *American Journal of Physics.* 50(1), 66 – 67.
23. Johnston, F. S., Fourkis, R. E. and H. Dietrich (1984). In search of a philosophy of engineering. *Proceedings of the World Conference on Engineering Education for Advancing Technology,* 227 -231.
24. Petroski, H. (1985). *To engineer is human*. Alfred A. Knopf, New York, NY.
25. Jinks, R. F. (1996). Knowledge-Understanding (Mind the Gap). *Engineering Science and Education Journal*, 227 – 230.
26. Self, J. (1997). From constructionism to deconstructionism. Anticipating trends in

educational styles. *European Journal of Engineering Education,* 22 (3), 295 – 306.

27. Jesiek, B., Newswander, L, K and M. Borrego. (2009). Engineering education research: discipline, community or field? *Journal of Engineering Education,* 98 (1), 39 – 52.

II. Engineering Identity Crisis

As stated in the Introduction, engineering is in the midst of an identity crisis and must clear three hurdles: 1) establish that engineering is not just the application of science; 2) establish that engineering and technology are different; and 3) resolve the unequal status between engineering science and engineering design.

1. Dias, P. (2008). The engineer's identity crisis: Homo Faber vs Homo Sapiens. *Workshop on Philosophy and Engineering*. Abstracts. Royal Academy of Engineering, London, 23 – 24.
   (a) There are three crises. One relates to the engineer's influence. It is related to the study of ethics. A second, relates to the engineering role. Is an engineer a scientist or a manager? This is related to ontology because engineers need to know who they are. The third relates to engineering knowledge. Is it theoretical or practical? These are questions of epistemology.
   (b) He suggests that Heidegger would be a good patron philosopher for engineers.
   (c) Many commentators have discussed the issue of identity.

III. Engineering and Science

The relationship between engineering and science is one of the sources of engineering's identity crisis. Is engineering simply applied science? If it is, is its philosophy the philosophy of science? If it is not, is there a substantial case to be made for a philosophy of engineering? Given that most of the engineering curriculum is devoted to teaching the applied or engineering sciences, it is more than appropriate to take cognizance of studies in the history and philosophy of science education. These 'new' studies have developed since the end of World War II along with developments in science education in the training of teachers.

1. Goldman, S. L. (2004). Why we need a philosophy of engineering. A work in progress. *Interdisciplinary Science Reviews*, 29(2), 163 – 176.
   (a) Argues that engineering is undervalued in the high culture of western society because it is a contingent activity.
   (b) The model of rationality that underlies modern science is that of necessity. It is cognate with 'certainty', 'universality', 'abstractedness' and 'theory' concepts of Platonic philosophy.
   (c) In a discussion of contingency in western philosophy he suggests that there are two clusters of cognate concepts that distinguish two "modes of reasoning […] of what it means to give reasons and to be reasonable, and of what will constitute knowledge and truth. They derive from the Principle of Sufficient Reason (PSR) on which science is based on the one hand, and what he calls the Principle of Insufficient Reason (PIR) on the other hand on which engineering reasoning is based. For example, intellect, reality, knowledge, truth, certainty, objectivity belong to the PSR cluster. Will, experience, belief opinion, probability, subjectivity belong to the PIR cluster
   (d) The author suggests a theory of action that leads him from the pre-Socratic philosophers to pragmatism.
   (e) Because engineering couples values and knowledge to 'the world' engineering practice should enable the exploration of experience "as itself a source of values."
   (f) "Engineering is now, and has for centuries been, ignored as a source of insight into the physical, social and cultural problems associated with technological innovation."
   (g) There are other important studies that take the view action takes primacy over theory
      - See Macmurray, J. (1954). *The Self as Agent*. Faber and Faber, London.
   (h) "Engineering problem solving employs a contingency based form of reasoning that stands in sharp contrast to the necessity based model of rationality that has dominated Western philosophy since Plato and that underlies modern science. The concept 'necessity' is cognate with concepts of 'certainty', 'universality', abstractness', and 'theory'. Engineering by contrast is characterized by wilfulness, particularity, probability, concreteness, and practice. The identification of rationality with necessity has impoverished our ability to apply reason effectively to action. [I…locate] the contingency based reasoning of engineering in a philosophical tradition extending from pre-Socratic philosophers to American

pragmatism, and suggest how a contingency based philosophy of engineering might enable more effective technological action."
(i) For a British philosophical study that starts with a similar criticism of western philosophy leading to a philosophy of action.

2. Schiaffonati, V. (2008). From philosophy of science to philosophy of engineering. The case of AI. *Workshop on Philosophy and Engineering*. Abstracts. Royal Academy of Engineering, London, 46 – 47.
   (a) Commonsense suggests that the philosophy of engineering is an area of the philosophy of science., but the differences between the two philosophies arise from the types of problems solved and the methods used to solve them.
   (b) The argument is illustrated by AI which is both a science concerned with the general study of intelligence and engineering concerned with the design of intelligent systems.
3. Blockley, D. (2008). Integrating hard and soft systems. *Workshop on Philosophy in Engineering*. Abstracts. Royal Academy of Engineering, London, 10 – 11.
   (a) Argues that engineering is both an art and a science.
   (b) Considers the nature of truth for engineers needs dependable information
   (c) Argues that truth is to knowledge as risk is to action. There is a need to understand risk better.
   (d) Engineering projects are team projects.
   (e) Highly integrated systems are vulnerable to small damage. This needs to be understood better.
4. Bocong, L. (2010). The rise of philosophy of engineering in the east and west, in I. van de Poel and D. E. Goldberg (eds.) *Philosophy and Engineering An Emerging Approach*, 31 – 40.
   (a) Begins with a brief comparison of developments in the philosophy of technology/engineering in the east (particularly China) and west.
   (b) "*The essence of scientific activity is discovery, the essence of technological activity is invention, and the essence of engineering activity is creativity or the making of artefacts*".
   (c) Places considerable emphasis on the concept of community and distinguishes between the scientific community and the engineering community.
5. Petroski, H. (2010). The *Essential Engineer. Why Science Alone will not Solve our Global Problems*. Alfred A. Knopf, New York, NY.
   (a) Engineer and historian. Prolific author of generalist books on engineering that contain many examples of engineering and comparisons with science that have a bearing on present debates.
   (b) In one chapter in this book he argues that not only do C.P. Snow's two cultures exist, but that there is a two culture problem between science and engineering.
   (c) Writes on failure versus falsification that helps sort out the divide between science and engineering. Considers that "*without faults or accidents, actual of imagined, there might be little driving change in large technological systems*."
   (d) Often the work of scientists and engineers overlap. How they handle risk, uncertainty and the unexpected are discussed.
   (e) Attaches considerable importance to the human dimension.
6. Moses, J. (2010). Architecting engineering systems, in I. van de Poel and D. E. Goldberg (eds.) *Philosophy and Engineering An Emerging Approach*, 275 – 284.
   (a) The overall purpose of the paper is to discuss design methodologies in large scale engineering systems.
   (b) The different methodologies relate to different cultural attitudes.
   (c) Points out that the craft of engineering is seldom mentioned. Engineering is a mix of craft, technology and science.
   (d) Positive views of the craft dimension are held in Germany and Japan, but not in the UK. The position in the US is mid-way.
   (e) These approaches are related to those adopted by Aristotle for the organization of city states, Plato for the just society and Darwin's use of evolution. They provide an approach to design.
7. Goldberg, D. E. (2010). Why philosophy? Why now? Engineering responds to the crisis of a creative era, in I. van de Poel and D. E. Goldberg (eds.) *Philosophy and Engineering An Emerging Approach*, 255 – 263.

(a) Times have changed since WWII when the education and research agendas for engineering were set. That paradigm is no longer suitable.
(b) The revolutions that have taken place since (quality, entrepreneurial, IT) have had minimal impact on the teaching of engineering.
(c) There is a need to develop better sociotechnology to push engineers to reflect on their education, training, and occupation. This will require qualitative thinking.
(d) He then illustrates how philosophy can help engineering students with references to Socrates, Aristotle, and Searle

Additional Readings on the History and Philosophy of Science:

8. Berger, P. L and T. Luckmann (1966). *The Social Construction of Reality*. Doubleday, New York, NY.
   Connects a sociological strand to science education traced back to Durkheim.
9. Driver, R. (1983). *The pupil as scientist*. Open University Press, Milton Keynes.
   (a) Studies of children's learning using Piagetian psychology
   (b) Well known to science teachers as it suggests different methods of teaching.
10. Driver, R. and V. Oldham (1986). A constructivist approach to curriculum development in science. *Studies in Science Education,* 13, 105 – 122.
11. von Glasersfeld, E. (1987). *The Construction of Knowledge*. Inter Systems Publications, Salins, CA.
    The nature of knowledge and learning in science discussed using Piagetian psychology.
12. Boomer, G., Lester, N., Onore, C. and J. Cook (eds) (1992). *Negotiating the Curriculum. Educating for the 21st Century*. Falmer Press, London.
13. Matthews, M. R. (1994). *Science Teaching. The Role of History and Philosophy of Science*. Routledge, New York, NY.
    Provides a summary of the two traditions while taking a realist position on the nature of knowledge.
14. Searle, J. R. (1995). *The Construction of Social Reality*. Free Press, New York, NY.
15. Matthews, P. S. C. (1997). Problems with Piagetian constructivism. *Science and Education*, 6 (1), 105 – 119.
    Challenged the two basic premises of Piagetian theory.
16. Matthews, M. R. (2000). *Time for Science Education. How Teaching the History and Philosophy of Pendulum Motion can Contribute to Science Literacy*. Kluwer, New York, NY.
17. McKenzie, J. (2008). Conceptual learning in higher education; some philosophical points. *Oxford Review of Education*, 34 (1), 75 – 87.
18. Cunliffe, A. L. (2008). Orientation to social constructionism; relationally responsive social constructionism and its implications for knowledge and learning. *Management Learning,* 39 (2), 123 – 139.

For associated reading in the history of sociology to the present see for example:

19. Ritzer, G. (1996). *Sociological Theory*. 4th edition. McGraw Hill, New York.

IV. Engineering and Technology

How the philosophy of technology and the philosophy of engineering differ is an important issue that bears on the identity of the philosophy of engineering. The issue is surrounded by a lot of confusion.

1. Mitcham, C. (1994). *Thinking through technology. The path between engineering and philosophy*. The University of Chicago Press, Chicago, IL.
   (a) Seminal work. Gives a historical understanding of the development of the philosophy of technology.
   (b) Distinguishes between two traditions: (i) the engineering approach with its focus on the importance of technology in life which he calls engineering philosophy or technology, and (ii) the humanities philosophy of technology which is concerned with morals and culture.
   (c) The text is in two parts the first of which is historical. The second considers analytical issues relating to technology. The final chapter is on the analysis of ethical issues.
2. McCormick, R. (2004). Issues of learning and knowledge in technology education. *International Journal of Technology and Design Education*, 14, 21 – 44.
   (a) The problem discussed is relevant to the science versus technology debate and the problem of how scientific knowledge is applied in technology.
   (b) The discussion is based on the view that "learning is situated" (context driven). That there is an intimate connection between learning and doing.
   (c) The role of procedural knowledge is discussed, and student problem solving is discussed, and student problem solving strategies are shown

not to resemble the "neat" algorithms that are taught.

(d) Examples of qualitative thinking are advanced and arguments made for its teaching.

(e) Difficulties with the teaching of systems are illustrated.

(f) A list of researches that might be done is given.

(g) For an epistemology that begins in the practical

- See Macmurray, J. (1954). *The Self as Agent*. Faber and Faber, London.
- For a text on qualitative thinking in higher education by an engineer see Cowan, J. (2006). *On Becoming an Innovative University Teacher. Reflection in Action*. SRHE/ Open University Press, Maidenhead, UK.

3. Pavlova, M. (2005). Knowledge and values in technology education. *International Journal of Technology and Design Education.* 15, 127 – 147.

(a) Begins with an analysis of the nature of knowledge in technology education. Distinguishes between major approaches to theorizing knowledge in technology education.

(b) It shows clearly how the philosophy of technology has arisen as an area of study and the controversies within it.

- See for example: Ferré, F. (1995). Philosophy and technology after twenty years *Techné: Journal of the Philosophy and Technology Society* 1, (1-2), 1-4.
- Durbin, P. T. (2000). SPT At the end of a quarter century. What have we accomplished? *Techné,* 5 (2).

(c) The arguments for technology knowledge not being an applied science are presented, but where engineering fits into this framework is not discussed. Neither is it discussed in a section on levels of generalization of technological knowledge. In Mitcham's view, technological theories are at the highest level of technological knowledge.

(d) The author presents a model of knowledge in order to discuss the place of values in the model. She identifies two types of knowledge – knowledge about technology and knowledge within technology. Intrinsic and non-intrinsic values relate closely to the two types of knowledge.

(e) From the engineering perspective this paper poses the question, 'Is a philosophy of technology in which there are many different perspectives the same as a philosophy of engineering?' To put it in another way 'Is there a need for a philosophy of engineering?'

4. de Vries, M. J. (2005). The nature of technological knowledge: philosophical reflections and educational consequences. *International Journal of Technology and Design Education* 15, 149 – 154.

(a) Identifies the differences between science and technology.

(b) Starting point is the proposition "that technological knowledge has normative component that science does not […]."

(c) The author has aim of getting a picture of what technology is through the philosophy of technology, which can provide a conceptual base for technology education. It may also be helped by reflections from analytical psychology.

(d) Difficulties with traditional conceptions of knowledge are considered. It is noted that not all knowledge of technology is propositional.

(e) A distinction is made between the four types of propositional knowledge: functional nature knowledge, physical nature knowledge, knowledge of the relationship between physical and functional nature, and process knowledge. The third is akin to knowledge in the natural sciences. The other three have a normative component that science has not.

(f) It is concluded that teaching technology should include the normative components of that knowledge.

(g) Students must be taught to make judgements with respect to function and functioning of technological artifacts.

(h) Students should learn norms, standards, and rules of thumb.

(i) Ethical norms make students aware of the ethical aspects of technology.

- See also de Vries, M.J. (2010). Engineering science as a "discipline of the particular"? Types of Generalization in Engineering Sciences, in I. van de Poel and D. E. Goldberg (eds.) *Philosophy and*

Engineering. An Emerging Agenda. Springer, Dordrecht.

5. McGrann, R. T. (2008). Philosophy of technology in engineering education. *Proceedings of the Frontiers in Education Conference*, S4H, 29 – 34.
   (a) Contains a useful short selected bibliography.
      - Achterhuis, H. (ed) and R.P. Crease (Trans.) (2001). *American Philosophy of Technology: The Empirical Turn.* Indiana University Press, Bloomington, IN.
      - Durbin, P.T. (1984). *A Guide to the Culture of Science, Technology, and Medicine.* Free Press, New York, NY.
      - Hickman, L. (1992). *Philosophical Tools for Technological Change: Putting Pragmatism to Work.* Indiana University Press, Bloomington, IN.
      - Ferre, F. (1988). *Philosophy of Technology*. University of Georgia Press, Athens, GA.
      - Kaplan, D. M. (ed.) (2004). *Readings in the Philosophy of Technology*. Rowman & Littlefield Publishers, Inc., Lanham, MD.
      - Koen, B. V. (2003). *Discussion of the Method. Conducting the Engineers Approach to Problem Solving*. Oxford University Press, London.
      - Mitcham, C. and R. Mackey (eds.) (1972). *Philosophy and Technology. Readings in the Philosophical Problems of Technology.* The Free Press, New York, NY.
      - Pitt, J. C (1999) *Thinking about Technology. Foundations of the Philosophy of Technology*. Seven Bridges Press, New York, NY.
      - Verbeek, P-P. (2005). *What Things Do: Philosophical Reflections on Technology, Agency, and Design.* Penn State Press, University Park, PA.
   (b) He argues that the issues for a philosophy of engineering are centered on what is engineering, investigations of engineering language and basic concepts, analysis of structure and the dynamics of engineering theories, development of a meta-theory and methodology of engineering judgment and engineering decision making, and problems in the philosophy of mind in engineering.
   (c) "As a comparison in "philosophy of medicine" H. Tristram Engelhardt analyzes the field in three areas of traditional philosophy of mind and ethics. The parallels between engineering and medicine, when both viewed as examples of professional practice, can be useful in framing questions that might be seen as relevant to the philosophies of education for each."
      - Engelhardt, H. T. (1980). Philosophy of medicine, in P.T. Durbin (ed.) *A Guide to the Culture of Science*, Technology and Medicine. Free Press, New York, NY. 364 – 461.

Additional Papers on the History & Philosophy of Technology:

6. Hansen, R. and M. Froelich (1994). Defining technology and technological education: A crisis, or a cause for celebration? *International Journal of Technology and Design Education*, 4, 179 – 207.
7. Gardener, P. L. (1994). The relationship between technology and science. Some historical and philosophical reflections. Part 1. *International Journal of Technology and Design Education*, 4, 123 – 153.
8. Gardener, P. L. (1995). The relationship between technology and science. Some historical and philosophical reflections. Part II. *International Journal of Technology and Design Education*, 5, 1 – 33.
9. Hansen, K-H. (1997). Science and technology as social relations. Towards a philosophy of technology for liberal education. *International Journal of Technology and Design Education*, 7, 49 – 63.
10. Ropohl, G. (1997). Knowledge and types of technology. *International Journal of Technology and Design Education*, 7, 65 – 72.
11. Ihde, D. (1997). The structure of technology knowledge. *International Journal of Technology and Design Education*, 7, 73 – 79.
12. Lienhard, J. (2000). *The engines of our ingenuity. An engineer looks at technology and culture*. Oxford University Press, London.
13. Stevenson, J. (2004). Developing technological knowledge. *International Journal of Technology and Design Education,* 14 (1), 5 – 19.
14. de Vries (2005). *Teaching about Technology: An introduction to the philosophy of technology for non-philosophers*. Springer, Dordrect, The Netherlands.
15. Ankiewcz, P., de Swart, E and M. J. de Vries. (2006). Some implications of the philosophy of technology for science. *Technology and Society (STS) Studies*. 16 (2), 117 – 141.
16. Childress, V. (2006). Review of the book - Teaching about technology: An introduction to the

philosophy of technology for non-philosophers. *Journal of Technology Education,* 17 (2), 76 – 77.

V. Engineering Design

Engineering design is at the heart of engineering. How a designer thinks, the values they have, and the values they create have considerable significance for society and social behavior. Philosophy has shown that it can make important contributions to understanding design and teaching and learning for design.

1. Perkins, D. N. (1986). *Knowledge as Design*. Lawrence Erlbaum, Hillsdale, NJ.
   (a) In this theory knowledge is created as a result of design.
   (b) A distinction is made between knowledge as information and knowledge as design. In many engineering courses knowledge is being conveyed as information. That knowledge is adapted so as to be applied to other situations. Therefore it is important that designers can break away from experience.
   (c) A theory of understanding is required that reflects the theme of design and the questions that have to be asked to obtain this understanding are those used by engineering designers.
2. Coles, R. and E. Norman. (2005). An explanation of the role values play in design decision making. *International Journal of Technology and Design Education*, 15, 155 – 171.
   (a) Design is to be understood as it is used in the British Design and Technology school curriculum (e.g. as it might be taught at the Royal College of Art). Nevertheless, the general thesis is applicable to engineering within the particular constraints that it operates.
   (b) The paper asks "What is the role of skills and values in the design decision making process?"
   (c) Beginning with Ryle's distinction between "knowing that" and "knowing how" it is argued that "knowing that" in design decision making is not easily distinguishable from other forms of knowledge and information.
   (d) While "knowing that" may be insufficient because one does not know the product only of it. "Knowing how" is derived from personal experience and "skill". However, the distinction between "skill" and "know how" is unresolved.
      - Polyani, M (1962). Tacit knowing: its bearing on problems of philosophy. *Review of Modern Physics*, 34 (4), 601 – 616.
   (e) The pursuit of design and technology is rarely free from the exercise of value judgements.
   (f) Because of the ill-defined nature of design problems they have to employ decision making strategies that are other than those used in scientific decision making (*satisficing*) and values necessarily play a part in this process. Five areas in which values might be assessed are technical, economic, aesthetic, moral, and hedonic. These are personal (internal) and societal (external).
   (g) The significance of values is seen in the debate about the extent too which technology determines our values.
   (h) The paper discusses how values in products may be measured.
   (i) A pilot study is reported that carries out a retrospective analysis of designers at work. Examples are given of "knowing that", "knowing how", personal values, social values influencing design, and use of existing products in the process of design.
   (j) A classification of external and internal values in the design process is proposed.
      - Cagan, J. and C. M. Vogel (2002). *Creating Breakthrough Products: Innovation from Product Planning to Program Approval.* Prentice Hall, Upper Saddle River, NJ.
      - Goontilalke, S. (1984). *Aborted Discovery. Science and technology in the third world.* Zed Books, London.
3. van de Poel, I. (2008). Conflicting values in engineering design and satisficing. *Workshop on Philosophy in Engineering*. Abstracts. Royal Academy of Engineering, London, 16 – 17.
   (a) Trade-offs between design criteria and their associated values have to be made. Engineers seek the 'best' option.
   (b) It is suggested that engineers could use satisficing strategies. Satisficing is a concept proffered by H. Simon (see Simon, 1956).
   (c) Satisficing involves the setting of an aspiration level that is "good enough" and selects an option that at least meets this level.

(d) For moral values to be met at a level should be set so that all moral values are met.
(e) Designers are considered to be satisficers.
(f) It is possible for satisficing to be rationally justified.

4. Haupt, G. and S. Blignaut (2008). Uncovering learning outcomes: Explicating obscurity in learning of aesthetics in design and technology. *International Journal of Technology and Design Education,* 18, 361 – 374.
   (a) There is little in the literature about reasoning in aesthetics in engineering.
   (b) The purpose of the study was to assess the extent to which Kirkpatrick's four level model of evaluation could evaluate learning about aesthetics in a design and technology course. A brief explanation of aesthetic design is given.
   (c) Kirkpatrick's model is summarized.
      - Level 1: Reaction. Learner satisfaction with the learning material. Positive reaction may not generate learning but a negative reaction would reduce the possibility.
      - Level 2: Learning. To what degree learners acquired the intended knowledge, skills, attitudes, confidence, and commitment based on their participation in a training event.
      - Level 3: Behavior. Transfer of knowledge and strategies learned to another context. Learners should be allowed to demonstrate changed behavior.
      - Level 4: Results. Achieved goals of training in terms of organizational performance (reduced costs, improved quality, increased production, etc.).
   (d) In this study the first three levels were used in an augmented version due to Alliger
      - Alliger, G. M., Tannenbaum, S.I., Bennett, Jr., W., Traver, H. and A. Shotland (1997). A meta analysis of the relations among training criteria. *Personnel Psychology,* 50 (1), 341 – 358.
   (e) The model did not reveal a causal link between the interventions and the participants learning. It shows the possibilities of the use of Kirkpatrick's model.

Additional Readings of Interest:

5. Dym, C. L., Agogino, A. M., Eris, O., Frey, D. D., and L. J. Leifer (2005). Engineering design thinking, teaching and learning. *Journal of Engineering Education,* 94 (1), 103 – 120.
6. Jonassen, D. Strobel, J., and C. B. Lee (2006). Everyday problem solving in engineering: lessons for engineering educators. *Journal of Engineering Education,* 95 (2), 139 – 152.
7. Vinck, D. (ed.) (2003). *Everyday engineering. An ethnography of design and innovation*. The MIT Press, Cambridge, MA.

VI. Engineering Epistemology

Engineering cannot be defined, neither can a curriculum be adequately designed unless there is some understanding of what engineers know and how they know it; as well as what engineers do and how they do it. That is the task of epistemology.

1. Langton, N. H. (1962). *The Teaching of Theoretical Subjects to Students of High Polymer Technology*. Two reports to the Nuffield Foundation, UK.
   Regrettably it was never published. It was a series of case studies in which polymer technologists described the work they were doing and gave details of the maths and science used.
2. Shulman, L. S. (1970). Psychology and mathematics, in E. Begle (ed.) *Mathematics in education*. 69th Yearbook of the National Society for the Study of Education, University of Chicago Press, Chicago, IL.
   (a) Remains a powerful introduction to the relationship between epistemology (traced back to Aristotle and Plato) and pedagogy.
   (b) The instructional theories of Ausubel, Bruner and Gagné are compared
   (c) For school based evaluations of the review of inquiry based learning and the problems associated with it see Ch 7 of Heywood, J. (2008). *Instructional and curriculum leadership towards inquiry oriented schools*. NAPD/Original Writing, Dublin.
3. Vincenti, W. G. (1990). *What Engineers Know and How they Know it. Analytical Studies from Aeronautical History.* The Johns Hopkins University Press, Baltimore.

(a) One of a series of books in the Johns Hopkins series in the History of Technology. Much quoted in the current debate about what an engineer is. Focuses on "*the character of engineering knowledge as an epistemological species"*.

(b) *"In the historical cases, I have inferred the nature of engineering knowledge more by examining knowledge production and the motives for it than by looking directly at its use in design*" Citing Karl Popper "*The central problem of epistemology has always been and still is the problem of the growth of knowledge.*"

(c) He argues that his historical case studies support the variation selection model for the growth of knowledge put forward by Campbell, and asks whether the process that he derives is the "engineering method". He acknowledges the different approach to method taken by Koen.

4. Davis, M. (1998). *Thinking Like an Engineer. Studies in the Ethics of a Profession.* Oxford University Press, London.

(a) It is as much concerned with engineering as with ethics and Davis considers it to be a contribution to the philosophy of engineering.

(b) He poses four questions for the social scientists. What is engineering? Vicenti's work is a start but more work is needed. What do engineers do? Up to 2005 very little work had been done but since then several studies have been initiated (see below). Empirical studies should help resolve this question? How do engineering decisions get made? His sense of the question "what do engineers know" is quite different to that of Vincenti. The implications for ethics of engineering decision making are considered (see below). "What can engineers do?" is the final question. He takes a different view to those who say that because engineers are employees there is no room for engineering ethics.

(c) Both Vincenti and Davis express the importance of knowing what it is that engineers do. During the last fifty years there have been a few attempts to do this but none have produced a holistic picture.

(d) Like others, Davis calls for studies of what engineers do. But this is not the same as studying the processes of doing and knowing. Langton perhaps came nearer to doing this than any other study. The sophisticated study of engineers at work by Youngman et al. found in broad terms what abilities engineers used in their jobs but it was not personalized. Within the last few years there has been renewed interest in what engineers do in relation to the construction of the curriculum.

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

5. Turns, J., Atman, C. J, Adams, R. S and T. (2005). Research on engineering student knowing: trends and opportunities. *Journal of Engineering Education,* 94 (1), 27 – 40.

(a) In spite of the considerable advances that have been made in engineering education research this paper is of value as the 12 case studies reviewed show different approaches to the study of how engineering students know.

(b) The case for studying how students know is made and suggestions for future research given.

6. Davis, M. (2008). Some problems Defining Engineering –from Chicago to Shantou. *Workshop on Philosophy and Engineering*. Abstracts. Royal Academy of Engineering, London, 66 – 70.

(a) Paper is built around a case study of American engineers dealing with a problem in Shantou. The question is asked "what would the engineer do in the same situation in Chicago? What does the American engineer do in Shantou when what he may be asked to do clashes with his codes of conduct as for example in issues of safety?

(b) The codes of ethics that are relevant to the situation are considered.

(c) In an aside, argues that engineering education ought to include cases like these within the normal technical classes because this education seems to hardwire much of engineering ethics.

7. De Figueiredo, A. D. (2008). Toward an Epistemology of Engineering. *Workshop on Philosophy and Engineering*. Abstracts. Royal Academy of Engineering, London, 94 – 95.

(a) Considers there are four dimensions of engineering knowledge inspired by science in which research is preferred modus operandi; a social dimension which is about the creation of social and economic value; a design dimension in which engineering is the art of design; a view of engineering as the art of getting things done.

(b) Inspection of these dimensions suggests a transdisciplinary approach to education.
(c) An epistemology of design is presented that argues that there are 'designerly ways' of knowing thinking and acting.
- Cross, N. (2001). Designerly ways of knowing: Discipline versus design science *Design Issues,* 17 (3). MIT Press, Cambridge, MA.

(d) In engineering "*the ontological question inquires about what reality can engineering know, the epistemological question looks into what is engineering knowledge, the methodological question asks how can engineering knowledge be built, and the axiological question asks about the worth and value of engineering knowledge*".

8. Pawley, A. L. (2009). Universalized narratives; patterns in how faculty members define "engineering". *Journal of Engineering Education*. 98, (4), 309 – 320.
(a) A 2008 report from the National Academy of Engineering (and others) argue that engineers and engineering educators "*should change the message of engineering away from the difficult and élite character of the profession towards one of social relevance and 'making a difference'*".
(b) A key question, therefore, is do engineering faculty members value these conclusions? How does the daily work of engineering educators enable these ideas to be put into practice?
(c) A qualitative study on interviews with 10 faculty members at one university is reported.
(d) Definitions of engineering were reported and categorized within three narratives – engineering as applied science and math: engineering as problem solving, and engineering as making things.
(e) These narratives are important because they are passed on to undergraduates. Therefore, in the future researchers need to establish how students interpret these narratives.
(f) They need to be tested in other institutions because they put "*engineering at odds with recommendations from the NAE report*".

9. Davis, M. (2010). Distinguishing architects from engineers: a pilot study in differences between engineers and other technologists, in I. van de Poel and D. E. Goldberg (eds.) *Philosophy and Engineering An Emerging Approach*, 15 – 30.
(a) Begins with a discussion of "names" and problems associated with their use.
(b) Outlines some differences between architecture and engineering and considers the historical contribution to these differences.
(c) Concludes that the differences lie in the history of the two disciplines.

10. Carberry, A., Ohland, M., and C. Swan (2010). A pilot validation study of the Epistemological Belief's Assessment for Engineering (EBAE): First year engineering students' beliefs. *American Society for Engineering Education Conference & Exposition*, AC 2010 – 91, 9 pgs.
(a) Describes a quantitative instrument to measure engineering epistemological beliefs – certainty of knowledge, simplicity of knowing, source of knowing and justification for knowing.
(b) Has its origins in Piaget's and Perry's theories of intellectual development but is primarily based on work by Schommer who developed an epistemological questionnaire to measure epistemological beliefs. A meta-analysis by Hofer and Pintrich led to the development described here.
- Schommer, M (1990) The effects of beliefs about the nature of knowledge in comprehension. *Journal of Educational Psychology*, 82 (3), 498 – 504.
- Hofer, B. K and P. R. Pintrich (1997). The development of epistemological theories: Beliefs about knowledge and knowing and their relation to learning. *Review of Educational Research*, 67 (1), 88 – 140.

(c) On this measure a survey of the four dimensions (see (a) above) among first year students found slightly sophisticated beliefs in the dimensions except for simplicity which was moderately sophisticated.

Additional Readings of Interest:

11. McGourty, J., Besterfield-Sacre, M., Shulman, L. J and H. Wolfe (1999). Improving academic programmes by capitalizing on Alumni's perceptions and experiences. *Proceedings of the Frontiers in Education Conference*, 13A5, 5 – 8.
12. Markes, I. (2006). A review of the literature on employability skill needs in engineering. *European Journal of Engineering Education,* 31 (6), 637 – 650.
13. Heywood, J. (2007). "Think…about how others think". Liberal education and Engineering.

Proceedings of the Frontiers in Education Conference, T3C, 20 – 24.

14. Anderson, K. J. B. and S. Courter (2008). Aligning educational experiences with ways of knowing engineering. Understanding the engineering profession. *Proceedings of the Frontiers in Education Conference,* T2G, 1 – 6.
15. Christensen, S. H and E. Ernø-Kjølhede (2008). Epistemology, ontology and ethics: galaxies away from the engineering world. *European Journal of Engineering Education,* 33 (5), 561 – 571.
16. Douglas, E. P., Koro-Ljungberg, M., and M. Borrego (2010). Challenges and promises of overcoming epistemological and methodological partiality: Advancing engineering education through acceptance of diverse ways of knowing. *European Journal of Engineering Education,* 35 (3), 247 – 257.
17. Trevelyan, J. (2010). Reconstructing engineering from practice. *Engineering Studies*, 2 (93), 175 – 195.
18. Gainsburg, J., Rodriguez-Lluesma, C. and D. E. Bailey (2010). A "knowledge profile" of an engineering occupation: temporal patterns in the use of engineering knowledge. *Engineering Studies,* 2 (3), 197 – 219.

VII. Engineering Curriculum: Philosophy & Practice

All curriculum proposals are based on the operational (working) philosophies of their authors. Sometimes these philosophies are made explicit while at other times they are implicit the first section lists some key reports, official and semi-official that have had an impact on the education of engineers and its curriculum. They set out the goals and aims of the curriculum not its details. Also listed are some reports and academic studies that have had a seminal effect on education and in the second part the role of philosophy in screening aims and objectives for consistency and clarity. Nowadays it is widely understood that a curriculum cannot be designed without the application of psychology and sociology to ensure that its philosophy is obtained. Key to student learning is their understanding of the key concepts of engineering.

Official and Semi-Official Reports:

1. Percy, E. (chairman) (1945). *Higher Technological Education. Report of a Special Committee appointed by the Minister for Education.* Her Majesty's Stationary Office (HMSO), London. (Commonly known as the *Percy Report*)
   (a) Considered there to be two types of higher education for technologists. One was for research to be provided by the universities. The other was for industry to be provided by technical colleges specifically authorized to carry out higher level work.
   (b) Debates based on the kind of philosophy engendered in this report continue to this day, although in a slightly different language.
      - See the White Paper on Technical Education (1956).
2. Grinter, L. E. (chairman) (1955). Report of the committee on evaluation of engineering education. *Journal of Engineering Education.* (Commonly known as the *Grinter Report*)
   The final report of the Committee on Evaluation of Engineering Education of the American Society of Engineering Education.
      - See: Harris, J.G. (moderator) (1994). Round table: Reflections on the Grinter Report. *Journal of Engineering Education*. 83 (1), 69 – 94.
3. Hutton, S. P. and J. E. Gerstl. (1964). Engineering education and careers. *Proceedings of a Symposium on Education and Careers sponsored by the Institution of Mechanical Engineers*.
   (a) An early example, if not the first in the UK, of a research study carried about by a British professor of engineering and an American sociologist that informed policy. They derived a curriculum that is compared with the model proposed by the Grinter Report.
   (b) Subsequently published as a book. Gerstl, J.E. and S.P. Hutton (1966). *Engineers: The Anatomy of a Profession, a study of mechanical engineers in Britain*. Tavistock, London.
4. Finniston, M. (chairman) (1980). *Engineering Our Future. Report of a Committee of Enquiry into the Engineering Profession.* HMSO, London. (Commonly known as the *Finniston Report*)
5. Clough, W. (2004). *The Engineer of 2020: Visions of Engineering in the New Century*. Report for the National Academy of Engineering. National Academies Press, Washington, DC.
6. Sheppard, S. D., Macatangay, K., Colby, A. and W. M. Sullivan (2009). *Educating Engineers. Designing for the Future of the Field*. A Report of the Carnegie Foundation for the Advancement of Teaching. Jossey-Bass: San Francisco, CA.
   A research based study material from which was made available to the 2020 committee.

Discussions about Engineering and Higher Education:

7. Snow, C. P. (1950). The two cultures and the scientific revolution. *Rede Lecture*, Cambridge University.
   Later published as a book: Snow, C.P. (1959). *The Two Cultures and the Scientific Revolution*. Cambridge University Press, London.

8. Bloom, B. (1956). *The taxonomy of educational objectives. Volume 1 Cognitive Domain*. David Mckay, New York. (Commonly referred to as *Bloom's Taxonomy*)
   (a) The original version inspired much criticism from philosophers.
      - Heywood, J. (2005). *Engineering Education. Research and Development in Curriculum and Instruction*. IEEE/Wiley, Hoboken, NJ.
      - Furst, E. J. (1981). Bloom's taxonomy of educational objectives for the cognitive domain: Philosophical and educational issues. *Review of Educational Research*. 51(4), 441-453.
      - Anderson, L. W. and L. A. Sosniak (1994). *Bloom's Taxonomy. A Forty-Year Retrospective.* University of Chicago Press. Chicago, IL.
   (b) Many engineering educators continue to use it without reference to the criticism.
   (c) Revised in 2000. See: Anderson, L. W., Krathwohl, D., Airasian, P., Cruikshank, K., Mayer, R.E., Pintrich, P., Raths, J. and M. Wittrock (2000) (eds). *A Taxonomy of Learning for Teaching and Assessing. A Revision of Bloom's Taxonomy of Educational Objectives*. Longman, New York, NY.
9. Krathwohl, D. R., Bloom, B. S. and B. B. Masia (1964). *The Taxonomy of Educational Objectives. Handbook II: The Affective Domain*. David McKay, New York, NY.
   (a) The authors were criticized for dividing the three domains - cognitive, affective, and psychomotor - into three volumes because it isolates aspects of the same objective. Nearly every cognitive objective has an affective component.
   (b) Heywood demonstrated this with respect to history
      - Heywood, J. (1974). *Assessment in History. Twelve to Fifteen. First Report of the Public Examinations Evaluation Project.* School of Education, The University of Dublin, Ireland.
   (c) Dressel powerfully criticised it because it did not take into account values.
      - Dressel, P.L. (1971). Values, cognitive and affective. *Journal of Higher Education* 42(5), 400.
      - See also: Luegenbiehl, H. C. and D. L. Dekker (1987). The role of values in teaching engineering design. *Engineering Education,* 77 (4), 243 – 246.
   (d) A substantive criticism of engineering education is that it pays too much attention to the cognitive and not enough attention to values. The authors of the revised edition acknowledge that they have not taken this criticism into account.
10. Kuhn, T. (1962/1970). *The Structure of Scientific Revolutions*. University of Chicago Press, Chicago, IL.
11. Eisner, E. W. (1979). *The Educational Imagination. On the Design and Evaluation of school Programs*. Macmillan, New York, NY.
   (a) A substantial criticism of behavioural objectives and the formulation of goals. We don't always pre-formulate goals, and there are times when goals should not be formulated. Expressive activities precede rather than follow expressive outcomes. He advocates that teachers should approach the evaluation of their work in the same way that art connoisseurs approach the evaluation of a picture.
   (b) Recent developments in engineering education suggest that future taxonomies of engineering education should be three dimensional.
   (c) Attempts to derive taxonomies for technology and engineering have been made.
      - Youngman, M., Oxtoby, R., Monk, J. D. and J. Heywood (1978). *Analysing Jobs*. Gower Press, Aldershot, UK.
      - Carter, R. G. (1984). Engineering curriculum design. *Institution of Electrical Engineers Proceedings*.
      - Carter, R. G. (1985). Taxonomy of objectives for professional education. *Studies in Higher Education,* 10 (2), 135 –149.

Works and Other Treatises Relating to the Aims of Higher Education:

12. Whitehead, A. N. (1932). *The Aims of Education and Other Essays*. Ernest Benn, London.
13. McGrath, F. (1962). *The Consecration of Learning*. Gill, Dublin, Ireland.
    One of many treatises that have been written on John Henry Newman's *Idea of a University.*
      - For a discussion of the relevance of Newman's Idea to technological education see Heywood, J. (2010). Engineering literacy: A component of liberal education. *Proceedings of the American Society for Engineering*

Education Annual Conference & Exposition, AC 2010 – 1505, 13 pgs.

14. Wringe, C. (1988). *Understanding Educational Aims*. Unwin Hyman, London.
15. Boyer, E. (1990). *Scholarship Reconsidered. Priorities of the Professoriate*. Jossey-Bass, San Francisco, CA.
16. Sullivan, W. M. and M. S. Rosin (2008). *A New Agenda for Higher Education: Shaping a Life of the Mind for Practice.* Jossey-Bass, San Francisco, CA.

The Curriculum:

17. Tyler, R. W. (1949). *Principles of Curriculum and Instruction*. University of Chicago press, Chicago.
    Has had a lasting influence on curriculum design and is the origin of objectivist approaches to the design of the curriculum.
18. Mager, R. F. (1961). *Preparing Objectives for Programmed Instruction*. Fearon, San Francisco, CA.
19. Heywood, J. (2005). *Engineering Education. Research and Development in Curriculum and Instruction*. IEEE/Wiley, Hoboken, NJ.
    Ch 1: discusses the relation of models in the curriculum process.
20. Heywood, J. (2008). Philosophy, engineering education and the curriculum. *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*, AC 2008 – 944, 20 pgs.
    (a) All engineering educators should have a defensible philosophy of engineering education.
    (b) Operational philosophy is defined.
    (c) Knowledge versus knowing.
    (d) Illustration of the screening process using Whitehead's philosophy of education.

Screening Aims and Objectives for Consistency and Clarity:

21. Furst, E. J. (1958). *The Construction of Evaluation Instruments*. David Mckay, New York, NY.
    (a) It should be noted that Furst does not include sociology or history as having a role in screening, although manpower studies have political implications and the organization of teaching has a bearing on the achievement of aims. It is not always possible, or even desirable to disentangle philosophy from psychology and sociology. Whereas the focus of Furst's illustration are on values. Linguistic analysis has a role to play in clarifying the meaning of aims and objectives.
    (b) A detailed summary of Furst's position is given in Heywood, 2005.
22. Yokomoto, C. F. and W. D. Bostwick (1999). Modeling the process of writing measurable outcomes for EC 2000. *Proceedings of the Frontiers in Education Conference*, 11b1, 18 – 22.
    Short but incisive paper showing inconsistencies in the use of terminology in EC 2000.
23. Heywood, J. (2008). Screening curriculum aims and objectives using the philosophy of education. *Proceedings of the Frontiers in Education Conference*, S4H, 1 – 6.
    (a) This paper has a different content to the first by the same author and examines the constructivist-realist debate for the purpose of deriving aims.
    (b) It might be argued that screening is a minor but necessary activity in the process of curriculum design, which should in any case depend on a defensible philosophy and theory of learning.
24. Moses, J. (2008). Toward an ontology for systems related terms in engineering and computer. *Workshop on Philosophy and Engineering*. Abstracts. Royal Academy of Engineering, London, 74 – 75.
    (a) Focuses on systems' related terms and other generic architectures that are used in the engineering disciplines and how their meanings differ between the disciplines.
    (b) The terms discussed are form, function, performance, properties, uncertainty, complexity, dealing with change (flexibility), robustness, and resilience.
    (c) Computer scientists and engineers in traditional fields have much to learn from each other.
25. Heywood, J. (2010). Engineering literacy: A component of liberal education. *Proceedings of the American Society for Engineering Education Annual Conference & Exposition,* AC 2010 – 1505, 13 pgs.
    (a) A definition of liberal education is taken from Newman's idea of a university.
    (b) A model curriculum for engineering literacy is described and it is shown to fit with Newman's epistemology.
26. Sangam, D. and B. Jesiek (2010). Circuits concepts inventories: A comparative analysis. *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*, AC 2010 – 876, 11 pgs.
    (a) Evaluation of four concept inventories (CI's) for their ability to assess conceptual knowledge.
    (b) In conclusions, propose that CI design methodology incorporate an understanding of how students pre-existing conceptions are

changed when exposed to instruction (Other work in science suggests it is necessary to follow up to see how permanent such changes are).

(c) How effective are CI's in evaluating instruction that is motivated by conceptual change theory? (knowledge-as-theory or knowledge-as-pieces).

- Streveler, R. A., Litzinger, T. A., Miller, R. L. and P. S. Steif (2008). Learning conceptual knowledge in the engineering sciences: Overview and future research directions. *Journal of Engineering Education*, 97 (3), 279 – 294.

Additional Readings of Interest:

27. Heywood, J. (1981). The academic versus practical debate. A case study in screening. *The Institution of Electrical Engineers Proceedings*, Part A, 128 (7), 511 – 519.
28. Staiger, E. H. (1983). Managing engineering education. *Engineering Education*, 152 – 156.
29. Prince, M. J and R. M. Felder. (2006). Inductive teaching and learning methods: definitions, comparisons and research bases. *Journal of Engineering Education,* 95 (2), 123 – 138.

VII. Philosophy in the Curriculum

There are various views about the purposes of teaching philosophy in the curriculum, but all are agreed that there should be some kind of mandatory module. Related to this are issues of depth. Proposed integration of philosophy include the following approaches: 1) teaching within engineering subjects such as design, 2) teaching as a separate module, 3) using a separate program to teach students how to use the skills of philosophy in pursuit of engineering, and 4) the focus should simply be about the pursuit of philosophy per se.

Examples: The teaching of the philosophy of technology is mandatory in Denmark.
A course in philosophy is taught in the Purdue Department of Engineering Education Doctoral Program (ENE 502 – History and Philosophy of Engineering Education; Instructors: Robin Adams & Alice Pawley).

1. Heywood, J., McGrann, R. and K. A. Smith (2008). Continuing the FIE 2007 conversation on: Can philosophy of engineering education improve the practice of engineering education. *Proceedings of the Frontiers in Engineering Education Conference*, T1A, 1 – 2.
   (a) Draws attention to other developments, especially the 2007 workshop on 'Engineering Meets Philosophy' at Delft University where among the questions asked was "Can a Philosophy of engineering contribute to public policy in respect of engineering?
   (b) Big question: Is there one philosophy of engineering education or are there many?
2. Christensen, S. H. and E. Ernø-Kjølhede (2009). Implementing liberal education in engineering studies in Denmark, in S. H. Christensen, B. Delahousse and M. Maganck *Engineering in Context*. Academica, Aarhus, Denmark.
   Ch. 6: Compulsory courses in the Philosophy of Technology.
3. Heywood, J., Grimson, W. and R. Korte. (2009). Teaching philosophy to engineering students. *Proceedings in the Frontiers in Education Conference*, M4A, 1 – 6.
   (a) This paper accompanied the two special discussions that were held at the 2009 conference.
   (b) The first special session teaching philosophy in engineering courses.
4. Korte, R and K. Smith (2009). Developing engineering student's philosophical inquiry skills. *Proceedings of the Frontiers in Engineering Conference*, T4B, 1 – 2.

- Rescher, N. (2001). *Philosophical Reasoning. A Study in the methodology of Philosophizing*. Blackwell, Malden, MA.
- Fitzgibbons, R. E. (1981). *Making Educational Decisions*. *An Introduction to the Philosophy of Education*. Harcourt Brace Jovanovich, New York, NY.

Useful Books for Students:

5. Matthews, G. B. (1980). *Philosophy and the Young Child*. Harvard Up. Cambridge, MA.
6. Scruton, R. (1996). *An Intelligent Persons Guide to Philosophy*. Penguin Books, New York, NY.
7. Johnston, D. (2006). *A Brief History of Philosophy. From Socrates to Derrida*. Continuum, London.
8. Noddings, N. (2007). *Philosophy of Education*. 2nd edition. Westview Press, Cambridge, MA.
9. O'Grady, P. (ed.) (2011). *Consolations of philosophy: Reflections in an economic Downturn.* Columbia University Press, New York, NY.

Engineering Examples:

10. Taraban, R., Anderson, E. E., DeFinis, A., Brown, A. G., Weigold, A. and M. P. Sharma (2006). First steps in understanding engineering students growth of conceptual and procedural knowledge in an

interactive learning context. *Journal of Engineering Education,* 96 (1), 57 – 68.

11. Moreno, L., Gonzalez, C., Castilla, I., Gonzalez, E. J. and J. Signut (2007). Use of constructivism and collaborative teaching in ILP processors course. *IEEE Transactions on Education*, 50 (2), 101 – 111.
12. Vejarano, G. and G. Guerrero (2008). A Constructivist simulation-based methodology for teaching mobile communications. *IEEE Transactions on Education*, 51 (4), 468 – 475.
13. *Prieto*-Blázquez, J., García-Torà, I., Herrera-Joancomartí, J. and A-E. Guerrero-Roldán (2008). Virtual laboratory ontology for engineering education *Proceedings Frontiers in Education Conference*, T1A, 1 – 6.
14. Donohue, S., Schnittka, C., and L. G. Richards (2010). The constructivist based workshop: An effective model for professional development training activities. *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*, AC 2010 – 1016, 11 pgs.
    (a) Workshop modelled on the Engineering Teaching Kit designed for middle schools to facilitate the integration of humanities and social science into the exploration of math, science and engineering concepts.
    (b) Theoretical basis of the kit is constructivism as understood by the authors.
    (c) Inquiry and inductive learning strategies are used.
        - See Donohue, S. K. and L. G. Richards (2008). Engineering teaching kits for K – 5 students. *Proceedings of the Frontiers in Education Conference*, W3B, 1 – 2.
15. Colace, F and M. de Santo (2010). Ontology for E-Learning: A Bayesian approach. *IEEE Transactions on Education*, 53 (2), 223 – 233.
    Ontology is defined "a set of concepts and their relationships". Ontology building is defined as a craft rather than an engineering activity.
16. Anderson, K. J. B., Courter, S. S., McGlamery, T., Nathans-Kelly, T. M. and C. G. Nicometo (2010). Understanding engineering work identity: a cross-case analysis of engineers within six firms. *Engineering Studies*, 2 (3), 153 – 174.
17. Rojter, J. (2010). Emphasising professional engineering elements in the teaching of materials technology. *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*, AC 2010 – 682, 24 pgs.
    (a) Makes a distinction between academic and professional discourse and epistemologies.
    (b) The course was developed to encourage professional ways of thinking.
18. Huser, K., Mina, M., Kelly, T., Ballou, S. and J. Crispin (2010). Venues to introduce and teach impact of engineering in history, society, and human development. *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*, AC 2010 – 1138, 9 pgs.
    (a) Course designed to teach the impact of engineering to non-engineering students.
    (b) Combines conventional approaches to history and philosophy to address the whole picture of technology.
    (c) The why and how of the impact of engineering on society is addressed through philosophical discussion.
    (d) Focuses on the personal relevance approach to learning.
19. Burian, S. and E. Barbanell (2010). Hydrotopia: Integrating civil, engineering and humanities to teach water resources engineering and management. *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*, AC 2010 – 1452, 12 pgs.
    (a) Course open to students from the technologies and humanities.
    (b) "Water in the West, is anticipated to become a defining challenge requiring a combination of scientific, social, philosophical, ecological, political, economical, and other expertise and knowledge".
    (c) Provides case for the integration of humanities into civil engineering education.
    (d) An integrated course that combines concepts from water resources engineering and philosophy is described.
    (e) Taught by an engineer and a philosopher.
        - See Taylor, M. C (2009). The end of the university as we know it. *The New York Times*, April 27.

IX. Engineering Ethics

When the special sessions in the philosophy of education were held at the Frontiers in Education Conferences of 2007, 2008, and 2009, the organizers made a conscious

decision to omit ethics from their discussions because engineering ethics was widely discussed and many papers had been published on the subject. Much interest has focused on Codes of Conduct. Some believe ethics to be irrelevant in this discussion because most engineers are employees who must do as their employers wish. This position has been strongly challenged.

Worldwide, engineers are increasingly undertaking technological work that creates ethical issues for the public (e.g. biomedical engineering). It is not surprising, therefore, that during the last decade there have been considerable changes in the teaching of engineering ethics where, in the United States it is a compulsory subject in the engineering curriculum. It is only recently in Europe that ethics has received the same kind of attention. A handbook on engineering ethics has been prepared at the Ethics Centre of the Catholic University of Lille as part of the EU's Socrates program. At the time the position seemed to be the same in Australia. Questions have also been raised about what engineering ethics should comprise. There have been demands that it embraces macroethics, while others demand that it should include science and technology studies. Whereas there has been little interest in theory this situation is now being rectified. In striking contrast are studies that claim that ethics is firmly based in cognitive psychology.

1. Moon, J. (1970). Professional ethics and education. A study of mechanical engineers. *The Vocational Aspect of Education,* 22, 1-13.
   Survey of the attitudes of mechanical engineers to ethics. Found that most of them were employees (see Delahouse below). The implications of the study for education were considered. This was further developed in a doctoral thesis. This work is important because the author, a mechanical engineer, was equivalent to the CEO of the Engineering Industries Training Board at the time.
   - Moon, J. (1992). The evolution of an ethical code for professional mechanical engineers. Unpublished Doctoral Thesis. University of Brighton.
2. Luegenbiehl, H. C. (1990). Moving beyond disasters. Ethical issues for engineering students. *Proceedings of the Frontiers in Education Conference,* 6 – 8.
   Questioned the value of continuously using the big disaster in case studies.
3. Heriard-Dubreuil, B. and P. Goujon (eds.) (2001). *Technology and ethics. A European quest for socially responsible engin*eering. Peeters, Leuven.
   There is a suggestion that role plays might enhance student learning in ethics.
   - See Coles, R. and E. Norman. (2004). An exploration of the role values play in design decision making. *International Journal of Science and Technology Education*. 15, (2), 155-171.
   - Didier C. (2007). Questioning whistle blowing as a response to the engineer's dilemma of loyalty, in S. H. Christensen, M. Meganck, and B. Delahousse (eds.) Philosophy in engineering. Academica, Aarhus, Denmark, 263 – 276.
4. Haws, E. D. (2001). Ethics instruction in engineering education: a (mini) meta-analysis. *Journal of Engineering Education* 90, (2), 223-231.
   (a) 42 papers were analyzed from papers given at ASEE annual conferences between 1996 and 1999.
   (b) Most of the papers he reviewed made no mention of the need for an ethical theory. Whereas Davis was very much on his own in the nineties this no longer seems to be the case.
   (c) 23 out of the 42 courses used case studies.
5. Catalano, G. (2004). Integrating ethics into the freshman year experience. *Proceedings of the Frontiers in Education Conference*, S3E, 8 – 11.
   (a) The danger of teaching codes of conduct and using case studies is that it produces a very narrow view of ethics.
   (b) Students should be forced to study in depth.
   (c) 4 levels of meaning are distinguished.
6. Herkert, J. R. (2004). Microethics, macroethics and professional engineering societies. *Emerging Technologies and Ethical Issues in Engineering. Papers from a Workshop Oct 14 – 15, 2003*. National Academies Press, Washington, DC.
   (a) Microethics = individual decision making of the engineering professional. Macroethics = the ethics of broader collective and social decision making about technology. See Herkert (2009).
   (b) Plea for macroethics to be part of a complete engineering education.
7. Harris, C. E., Pritchard, M. S and M. J. Robins (2005). *Engineering Ethics: Concepts and Cases*. Wordsworth, Stamford, CT.
   Analogy of ethics problems solving with the engineering design process.
8. Vesilind, P. A. (ed.) (2005). *Peace engineering. When Personal Values and Engineering Careers Converge*. Lakeshore Press, Woodsville, NH
   One paper notes that the education of engineers at West Point is increasingly directed toward understandings of social science and leadership that are used in maintaining peace.

9. Drake, M. J., Griffin, P. M., Kirkman, R. and J. L. Swann (2005). Engineering ethical curricula. Assessment and comparison of two approaches. *Journal of Engineering Education,* 94 (2), 223 – 234.
   (a) Compares two approaches to the curriculum of ethics for engineering students i.e. the self-contained course taught by another department, or the teaching of ethics within an engineering module.
   (b) The terms "moral" and "ethics(al)" are used interchangeably. They "indicate reasoning or judgment concerning values and obligations in any context".
   (c) Kohlberg's theory of moral development is summarised (and his changes noted). It provides a philosophical base for the study.
   (d) Consequently the Defining Issues Test (DIT) in an updated version (DIT2) that takes into account recent theoretical developments was used. It is noted that this approach focuses on moral judgment rather than how the individual thinks about moral problems and arrives at decisions. Other assessments were also made.
   (e) A quasi-experimental design was used with students at all levels of the undergraduate curriculum. A control group was incorporated.
   (f) Conclusions are offered with caution. The limited ethics course did not improve the moral reasoning skills of the students, but neither did the full course when compared with the control group. Work needs to be done to construct a comprehensive approach to ethics education. A particular constraint may be that a general measure of moral judgment may not reflect discipline specific judgment. Therefore, an instrument that reflects engineering oriented dilemmas might resolve this issue. There is a need for a longitudinal study.
   (g) An interesting finding of this study is that engineering students were not found to be significantly different compared to arts students in their moral reasoning.
10. Hipp, C. (2007). An integrated approach to teaching engineering ethics. *Proceedings Annual Conference of the American Society for Engineering Education*, AC 2007 – 2313, 6 pgs.
   (a) Briefly describes outcomes from two developments in ethics teaching related to ABET 2000. First, a dialogue surrounding content and its delivery. Second, pedagogical delivery whereby content is related and goals realized. This paper is concerned with latter.
   (b) Summarises four pedagogical approaches and the criticisms levelled against them Micro-ethics: Macro/Meta ethics heuristics: Casuistry.
   (c) Proposes that the difficulties can be overcome if these approaches are integrated as three interwoven cores which he calls Foundations, guidelines and applications which are described in detail.
   (d) Argues that the approach seeks to meet students where they are at but there is no discussion in detail of this point.
11. Marra, R., Shen, D., Jonassen, D., Lo, J. and V. Lohani (2008). Fostering engineering ethics problem solving through cognitive flexibility hypertext. An application of multiple perspectives, making connections and crisscrossing. *Proceedings of the American society for Engineering Education Annual Conference & Exposition*, AC 2008 – 150, 19 pgs.
   (a) Describes E.Y.E. (Engineering Your Ethics) computer based learning environment so support the teaching of engineering ethics.
   (b) Takes account of pedagogical weaknesses identified by Hipp, 2007.
   (c) Argues the need to train students in solving ill-structured and complex problems. EYE is designed to support this.
   (d) Based on cognitive flexibility theory
      - See Spiro, R. J. and J. C. Jehng (1990). Cognitive flexibility and hypertext: Theory and technology for the nonlinear and multidimensional traversal of complex subject matter, in D. Nix and R. J. Spiro (eds) *Cognition, Education and Multimedia. Explorations in High Technology*. Erlbaum, Hillsdale, NJ.
   (e) Learning environment to provide inter-connected web like environment as a result of "crisscrossing".
   (f) Crisscrossing can be fostered by embedded links but there may be learning difficulties with this approach that might be overcome by links that are in the form of questions. Crisscrossing is "revisiting the same material at different times and rearranged contexts for

different purposes and from different conceptual perspectives"

(g) It had been argued that levels of epistemological beliefs are related to learning performance in these environments. The study aimed to evaluate this point.

(h) Two versions were used among two groups of first year students. One had the normal embedded links the other used questions as links.

(i) Epistemological development was assessed by Moore's Learning Environment Preferences (LEP)

- Moore, W. S. (1989). The learning environment preferences. Exploring the construct validity of an objective measure of the Perry scheme of intellectual development. *Journal of College Student Development,* 30 (6), 504 – 514.

(j) Evaluation of a case analysis showed the students using the question link environment did significantly better than those using the embedded links environment. Epistemological level was not a significant predictor of performance.

(k) This paper preceded a very long paper in which the material is discussed in great detail: Jonassen, D. H., Shen, D., Marra, R. M., Cho, Y-H., Lo, J. L. and V. K. Lohani (2009) Engaging and supporting problem solving in engineering ethics. *Journal of Engineering Education,* 98, (3), 235 – 254.

12. Harding, T. S. (2008). The psychology of the 'ought.' *Proceedings of the Frontiers in Education Conference*, S4H, 13 – 17.
    (a) An approach to the teaching of ethical dilemmas grounded in Kohlberg's theory of moral development.
    (b) Uses a five step holistic teaching model that originates with Narvaez.
    - Kohlberg, L. (1984). *Essays in Moral Development Vol 2. Psychology of Moral Development*, Harper and Row, New York, NY.
    - Narvaez, D. (2008). Human flourishing and moral development. Cognitive and neurobiological perspectives in virtue development, in L. P. Nucci and D. Narvaez (eds.) *Handbook of Moral and Character Education*. Routledge, New York, NY.
13. Riley, D. (2008). Ethics in context, ethics in action: getting beyond the individual professional in engineering ethics education. *Proceedings of the American Society for Engineering Education Annual Conference & Exposition,* AC 2008 – 851, 18 pgs.
    (a) Describes a course (Science, Technology and Ethics) designed to introduce macroethics to upper level engineering students.
    (b) Topical units are technology & control, science & social inequality, consumption & materialism, and agency & resistance.
    (c) Philosophy of the course drawn from pedagogies of liberation, feminist, and post colonial pedagogies, as well as critical theory.
    (d) The challenging of assumptions and the development of a critical stance require new approaches to teaching and assessment.
    (e) A key assumption challenged is that "technology is neutral".
14. Bowen, W. R. (2009). *Engineering Ethics. Outline of an Aspirational Approach*. Springer-Verlag, London.
    (a) A major response (criticism of) to the focus that engineers have on technical ingenuity.
    (b) Purpose is to "*provide engineers with an inspiring view of the overall ethical direction of their profession in a way that has direct practical outcomes*."
    (c) Engineers can learn from other professions especially business and medicine.
    (d) Inspiration is drawn from the philosophies of Buber and MacIntyre.
    - Buber, M. (Trans.) (2004). *I and Thou.* Continuum, London.
    - MacIntyre, A. (1985). *After Virtue.* 2nd edition. Gerald Duckworth, London.
15. Johnson, D. G and J. Wetmore (2009). *STS and Ethics. Technology and Society. Building our Sociotechnical Future.* MIT Press, Cambridge MA. Include considerations of science and technology studies (STS) in engineering ethics.
16. Holsapple, M., Carpenter, D., Sutkus, J., Finelli, C.,Walczak, K. and T. Harding (2010). Understanding the differences between faculty and administrator goals and students' experiences with ethics education. *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*, AC 2010 – 1615, 18 pgs.
    (a) The questions for research were (i) In what ways do the faculty and administrative goals for and perception of ethics educators differ

from the experience of the institutions' students? (ii) How do communication channels and noise in the communication process affect these differences?
(b) Separate focus groups of faculty and students and personal interviews with senior faculty and administrators across 18 institutions.
(c) Theoretical framework based on Shannon and Weaver's transmission model of communication to determine how "noise" interferes with messages that are being transmitted by teachers.
(d) Administrators/faculty say they want a balanced education between knowledge of ethics, ethical reasoning and ethical behaviour but students do not perceive they get this; they perceive an imbalance in favour of knowledge.
(e) It was found that there was considerable variation provided, and a few students did not believe they had had any ethics education at all. There would appear to be a "lack of clear and consistent approaches to ethics education […]".
(f) Noise (i) An institutional environment of academic pressure (overloading) and stress leads students to unethical behaviours (e.g., cheating). (ii) Ethics programs are often based on academic ethics and focus on academic integrity and punishment as a method for dealing with cheating. Ethics education comes to focus on rules and how to avoid consequences.
(g) The authors note that Shannon and Weaver's model appears to be generalizable.

17. Walezak, K., Finelli, C., Holsapple, M., Sutkus, J., Harding, T. and D. Carpenter (2010). Institutional obstacles to integrating ethics into the curriculum and strategies for overcoming them. *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*, AC 2010 – 1506, 13 pgs.
(a) From the same study as Holsapple et al (2010). It focused on 110 faculty and 37 administrators from 18 faculty focus groups.
(b) Obstacles to integrating ethics were (i) a full curriculum with little room for ethics educations (ii). Faculty lacked adequate training. (iii) Little in the way of incentive to incorporate ethics training into the curriculum (iv) Institutional growth is taxing resources.
(c) Suggestions are made as to how these might be overcome but they do not tackle the issue of course overloading head-on.

18. Chinn, G., Raman, V., Walton, S. and T. Litzinger (2010). Using technology-mediated collaboration in teaching of ethics and globalization. *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*, AC 2010 – 1273, 16 pgs.
(a) Aims to give students the opportunity to practice making and defending decisions and to help them formulate "sophisticated ethical positions".
(b) Completed within the context of courses that explore complex economic and international issues.
(c) Intention that ethical frameworks learnt in class including utilitarian, relativism, situational, egoism and deontological are used by the students to develop and defend a position.
(d) International technologies are analyzed and ethical problems identified.

19. Craig, T., Zoltowski, C., and W. Oakes (2010). Integrating ethics curriculum within a service-learning design context. *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*, AC 2010 – 1428, 13 pgs.
(a) Overall goal to meet ABET Criteria that students have an understanding of ethical issues.
(b) Examined student reflections on a previous course against the question were students able to recognize ethical issues in their project work.
(c) Kohlberg's model of moral development was chosen to indicate where the student's reasoning skills could be located. Students should be aware of their thinking in terms of this model.
(d) Ethics instruction should be authentic. It should be related to the students' user-centred design experience.
(e) A principal objective that students should be able to develop an awareness of ethical situations.

(f) Students should be aware of multiple frameworks –utilitarianism, duty ethics, rights ethics, virtue ethics.

Additional Readings of Interest:

20. Zandvoort, H., van de Poel, I. and M. Brumsen (eds.) (2000). Ethics in the engineering curricula: Topics, trends and challenges for the future. *European Journal of Engineering Education*, 25 (4), 291 – 302.
21. Herkert, J. R. (2000). Engineering ethics education in the USA: Content pedagogy and the curriculum. *European Journal of Engineering Education,* 25 (4), 303 – 313.
22. Sutkus, J., Carpenter, D., Finnelli, C., and T. S. Harding (2008). Work in progress: Building the Survey of Engineering Ethical Development (SEED) instrument. *Proceedings of the Frontiers in Education Conference*, S4C, 14 – 15.
23. Loui, M. C. (2005). Ethics and the development of professional identities. *Journal of Engineering Education,* 94 (4), 383 – 390.
24. Loui, M. C. (2006). Assessment of an engineering ethics video: Incident at Morales. *Journal of Engineering Education,* 95 (1), 85 – 92.
25. Rayne, K., Martin, T., Brophy, S., Kemp, N. J., Hart, J. D. and K. R. Diller (2006). The development of adaptive expertise in biomedical engineering ethics. *Journal of Engineering Education,* 95 (2), 165 – 174.
26. Martin, T., Rayne, K., Kemp, N. J., Hart, J. and K. R. Diller (2005). Teaching for adaptive expertise in biomedical engineering ethics. *Science and Engineering Ethics,* 11, 257-276.
27. Johnston, S., McGregor, H., and E. Taylor (2000). Practice –focused ethics in Australian engineering. *European Journal of Engineering Education,* 25 (4), 315 – 324.
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X. Engineering Culture

Operational (working) philosophy arises from the culture – so that if philosophy is to change the culture will have to change. Culture also needs to be analyzed.

1. Godfrey, E and L. Parker (2010). Mapping the cultural landscape in engineering education. *Journal of Engineering Education,* 90 (1), 5 – 22.
   (a) "Culture" and "cultural change" are important concepts in the debate about the nature of engineering education.
   (b) Although recognized engineering culture is rarely defined. Various assumptions are summarised, and the available literature reviewed.
   (c) The theoretical foundation of this paper is based on Schein
      - Schein, E. H. (1992). *Organizational Culture and Leadership.* 2nd ed. Jossey Bass, San Francisco, CA.
   (d) The purpose is to develop a conceptual framework for understanding culture in the context of engineering education.
   (e) A case study was conducted and from the data six cultural dimensions emerged that could be used by institutions for the purpose of studying their own cultures.
   (f) the dimensions are: An engineering way of thinking: an engineering way of doing: being an engineer: acceptance of difference: relationships: relationships to the environment.

2. Barrington, L. and J. Duffy (2010). Maximizing benefits of service learning in engineering. *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*, AC 2010 – 2149, 19 pgs.
   Brief statement of the philosophy of service learning.
3. Akili, W. (2010). On implementation of problem-based (PBL) pedagogy approaches to engineering education: multi-variant models and epistemological issues. *Proceedings of the American Society for Engineering Education Annual Conference & Exposition*, AC 2010 – 444, 11 pgs.
   (a) Of interest because it considers the problem of defining active learning.
   (b) Provides list of engagement strategies

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