Engineering values: An approach to explore values in education and practice

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Abstract: *We might imagine that what we do as engineers and why we do it, is based on our underlying values. However, rarely in engineering education is any consideration taken of our values, what they are and where they come from. Helping professors and students, as well as practitioners begin to examine their values and consider the implications of work based on those underlying values requires some means to expose these. In this study we present an emerging methodology to create a values mapping approach for engineering, such that students, teachers, engineers and engineering organizations might better understand the decisions they make and the impact these will have on the various communities in which we work.*

Background and Research Question

Values guide our action—what we choose and how we choose. Mitchell and Baillie (1998) suggest, "Our values are the lens through which we view the world: they stem from our underlying beliefs and assumptions, which are generally neither articulated nor questioned" (p. 15). Further they suggest that students as well as engineers need to recognize their own values and perspectives and what influences their point of view when they make scientific and engineering judgements. Kapadia and Joshi (2008) believe that "Values education in engineering is an effective way to sew the seeds of humanity in the young brains in order to enable them to grow as real professionals and multifaceted personalities who could live meaningful lives and serve the long run interests of (hu)mankind in general" (p.1). However, there is very little support, in terms of knowledge, materials or funding, for value-based education pertinent to engineering.

Either personal or cultural, values are beliefs that influence our thoughts, feelings, actions, and attitudes. Values evolve from human interactions with the external world (Santrock, 2007). They are related to the norms of a culture, but they are more general and abstract than norms. Norms are rules for behavior in specific situations while values identify what should be judged as good or bad (Santrock, 2007). In any society and culture there are ways of thinking that are common sense or what Gramsci (2008) called 'hegemonic' that result from norms and turn into values. As an example of hegemonic culture and of specific enculturation Aderlof and Kranton, speak about changing US Army "cadets' preferences" and their "identities" so that they can identify themselves 'above all else, as officers in the U. S. army' (Aderlof & Kranton, 2005). We can say that this is a norm of West Point which rules the behavior of cadets to motivate them psychologically to become loyal. These are the 'values' implanted into the psyches of trainees. West Point aims to "develop leaders of character" and the fundamental value both explicit and implicit in its development programs is honesty. The ability of West Point to educate, train and inspire outstanding leaders of character for our Army is predicated upon the functional necessity of honesty.

We maintain that Engineering has its own hegemonic values, which need to be exposed, articulated, owned and even transformed, if engineers are to act in a 'response-able' manner. We are not talking about enculturation or indoctrination to a particular value system but in contrast to the above we are interested in freeing up the student to realize what they value and why, and to make free choices about

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these values in the future. Values in engineering are usually only discussed in relation to ethics and even then this can be easily transformed into questions of liability. Catalano (2006) examined the US Professional Institution ethical codes, which govern the behavior of engineers and noted that they focus on safety, honesty and loyalty to work. Very little attention is paid, even today, to the environment and none to issues such as poverty. Furthermore, the practice of helping students to understand ethics, is often limited to that of micro ethics – issues of whistle blowing and individual workplace concerns. Macro ethics, or issues of the broader society are usually not dealt with. The notion that our ethical appreciation is based on our values – what we value and why – is an extremely difficult one for students to grasp. Helping professors and students, as well as practitioners begin to examine their values and consider the implications of work based on those underlying values requires some means to expose/clarify these.

A process describing the guidelines of a values clarification approach was formulated by Simon et al (1995). Values change over time in response to changing life experiences. Recognizing these changes and understanding how they affect one's actions and behaviours is the goal of the values clarification process. Values clarification will not tell you what your values should be, it simply provides the means to discover what your values are. For the purpose of values clarification, Steele and Harmin (1983) and Simon et al (1976) identified seven criteria that must be met if a value is to be considered a full value. These criteria can be divided into three categories: choosing, prizing and acting. To be a full value, the value must be chosen freely from a list of alternatives, only after thoughtful consideration has been given to the consequences of each alternative. The value must be cherished and made known to other people. The value must also be translated into behaviours that are consistent with the chosen value and integrated into the life style. Accordingly if some concept is to be considered valued then: (1) It was chosen from alternatives; (2) It was chosen freely; (3) It is prized; (4) It is affirmed; (5) It is acted upon; and (6) It is acted upon repeatedly, over time. Michael Adams (2003) has recently conducted a huge study of values across North America. Starting with the development of questions realted to values and a questionnaire based on these, he went on to develop values maps pertaining to gender, country, age etc. This paper presents the emergence of a methodology adapted from Adams work to create a values mapping approach for engineering, such that students, teachers, engineers and engineering organizations might better understand the decisions they make and the impact these will have on the various communities in which we work. It is not intended to create a reductionist instrument which 'types' individuals or organizations but to lay bare the value systems within which we work and to create a tool for discussion and evaluation of these and their impact on our actions.

Approach

The key approach of this work is to create and utilise contextually modified versions of the 'Social Values map' as described in Michael Adam's 'Fire and Ice: The United States, Canada and the Myth of converging values' (Adams, 2003). In this huge study, Adams developed questionnaires to locate the prevalent social values of different groups of citizens in the US and in Canada. From the data, he created maps, which showed potential differences between these groups, such as between US citizens and Canadians, between men and women etc. Figure 1 gives the US values map with the emergent values presented. Adams further discovered that it was not possible to capture all Canadian values on the US values map and hence created a Canadian social values map from the Canadian data (Fig 2).? In this work an attempt has been made to adopt the overall concept and apply it to the profession of engineering.

Methodology

McMillan and Schumacher (2001) suggested that an exploratory qualitative study is appropriate when new areas are being examined. In this study, the categories of exploration were not fixed beforehand but discussions hosted in workshops in Canada and in the US, over the last three years were used to develop the categories of variation of the interviewee's values pertaining to *engineering practice*. Questions and statements were then created to capture various aspects of these values, which were subsequently used to form the basis of a questionnaire to which engineers and students were asked to respond. 16 open-ended but structured questions were developed. An example question is given here:

Your company has decided to outsource your computer department to Southern India. Huge savings will be made on salaries as labour is much cheaper in Bangalore. Do you think this is a good idea?

It was hoped that the values of the respondent would emerge from the selected response to the question and the parameters they chose to explore. Responses to the questions were collected from 54 volunteer engineering professors and students, in the US and in Canada. In some cases the responses were given verbally, as in an interview and in some cases the respondents wrote their answers down. It should be noted that as this study is to explore an emerging methodology, no attempt was made to compare professors' with students' responses, nor breakdown the data in any other way. There is not sufficient data nor an appropriate sampling to do this. Neither is the resulting map considered to be representative of all engineering professors and students in North America. It is biased towards those who were interested in being interviewed for this study.

Data Analysis Procedures and results

We began the analysis one question at a time following an inductive analysis procedure to construct patterns that emerged from the participants in response to the interview questions (Gay & Airasias, 2003). In order to analyze data from each question, firstly we categorized all similar responses together and tried to identify any major themes that participants emphasized. We then organized and summarized all the emergent common themes and individual themes into a table and extracted the value/values that emerged from the participants' view points or statements. Figure 1 below demonstrates this first stage. The first column of the table details evolving values in response to the question: 'How might the source of funding for your work affect what do you do and how you do it?' The second column highlights the total respondents who hold that particular value and the third column describes the participants' position in response to the questions.

Emergent Values and Groups of the Respondents

Perceived Values	Total Respondents	Remarks
Power of Money	7	These respondents believe that money greatly influences what engineers do and how they do it. A focus on the power of the money not the source of funding constraints the length of the research.
Introspection and Empathy	17	This group of engineers shares a common belief that the sources of funding greatly influence engineering work both positively and negatively. They have the awareness of how different organizations and institutions play different roles as funders in the engineering research. It is observed that the result of a research depends on where the researcher gets funds from. They do not take sides but like to be aware of the situation.
Ethical Resolution	9	These engineers are also aware of the reality that source of funding influences engineers' work as well as the result of the research. However, these people mainly valued the ethical resolution of the engineers. They prefer to work on principles regardless of the source of funding. They do not feel comfortable getting funds from an unethical or illegal source. Their stand point is: "ethics and morals are not for sale" (code-33).
Honesty and Loyalty to Work	2	The perception of this group is: work ethics rules over everything. Therefore, it does not matter to them from where the funding is coming, but the standard and the quality of the work should not be compromised or affected by any source of funding.

Figure 1

After having analyzed each of the 16 questions, we found a large number of values that various professors and engineering students shared. We clustered the values under one broad value system that grouped together those with parallel meanings. For example, we identified several values from participants' responses such as: Global ecological awareness, Environmental sustainability, Ecological health, Awareness of environmental health, Environmental health, Impact on the environments and placed them together under one value "**Awareness of Ecological Health."** In the same way, all moral and ethical values that we extracted from participants' responses such as: Moral and ethical balance, Living on principle, Ethical resolution, Hatred of unethical schemes, Ethical issues, we placed under the broad umbrella "**Ethical Balance and Resolution"**. In this way, we identified 30 values that the participants held. Below we list all the value groups that emerged from this study:

*Awareness of Ecological Health; Belonging to the Global Village;*Comfortable Mobility and Safety; Confidence in Big Business;*Confidence in Engineering;*Critical View; *Dream of Engineering Career; *Empowerment of Individual; Enthusiasm for Technological Advance; *Ethical Balance and Resolution; Family Motivation for Profession; Financial and Material Success; *Financial Security for Own People; Fulfillment through Work; *Governmental Regulation; Honesty and Loyalty to Work; *Humanity and Social Development; Introspection and Empathy; Intuition and Impulse; *Market Demand; National Pride; Own Survival; *Peace; *Power of Money; *Potential Impact of Engineering; *Safety and Training; Social and Moral Responsibility; Social Learning; Sustainable World; *Usefulness of the Work.*

We are aware that the labels do not fully reflect the underlying value system and in some cases it is difficult to see how these are 'values'. In order to address this we considered these items as issues which we 'place value on' within our idea of engineering. Fourteen of the terms used were in fact the same as those adopted by Adams in his work on social values and we have used his terms to describe these. However, sixteen are newly emergent values that are not mentioned in the generic social values work (2003). The newly emergent values are indicated by an asterisk above. In next step of the analysis, we first tried to map-out all thirty evolving values within the four quadrants of Adams' contextual "American/North American Socio-cultural Value Map" (Figure 2) (Adams, 2003).

AUTHORITY			
S U R V I V A L	**The Status and Security** Comfortable Mobility and Safety Demand Dream of Engineering Career Family Motivation for Profession Governmental Regulation Safety and Training	**The Authenticity and Responsibility** National Pride Ethical Resolution Introspection and Empathy Potential Impact of Engineering Social and Moral Responsibility	**F U L F I L L M E N T**
	The Exclusion and Intensity Confidence in Big Business Enthusiasm for Technological Advance Financial and Material Success Financial Security for Own People Intuition and Impulse Own Survival Power of Money	**The Idealism and Autonomy** Awareness of Ecological Health Empowerment of Individual Confidence in Engineering	
INDIVIDUALITY			

Figure 2 Michael Adam's American Socio Cultural Values map

CONFORMITY AND EXCLUSION			
O U T E R - D I R E C T E D	**Social Success, Materialism, and Pride** Confidence in Big Business Financial and Material Success Intuition and Impulse National Pride Power of Money	**Security, Stability, and Exclusion** Financial Security for Own People Own Survival Safety and Training	**I N N E R - D I R E C T E D**
	Openness and Experience Belonging to the Global Village Enthusiasm for Technological Advance Introspection and Empathy Social Learning	**Autonomy and Well-Being** Awareness of Ecological Health Empowerment of Individual Fulfillment through Work Humanity and Social Development Usefulness of the Work Sustainable World	
IDEALS AND INDIVIDUALISM			

Figure 3 Michael Adam's Canadian socio-cultural values map

However we discovered that we could not fit all the developing values within the framework. Therefore, in the next step, we tried to arrange these emergent values within Adam's Canadian Socio-Cultural Values Map (Adams, 2003) Fig 3. However, here we also found some values which did not appear to fit within these four quadrants. The preliminary results of this study indicated that the Adams' original social values map would be an appropriate lens through which our data analysis might take place to explore engineering values, but also emphasized the need to create a new values map that might be more appropriate for the emergent 'engineering values'. It is worth noting at this point that Adams had also been forced to create a new values map for Canadian social values when he found that these did not all map onto the US social values map. Below we present a new values-map: The North American Engineering values-map (Figure 4).

<table>
<tr><td colspan="4">CONFORMITY / AUTHORITY</td></tr>
<tr><td rowspan="2">PROFESSION/ENG</td><td>Confidence in Big Business
Confidence in Engineering
Market Demand
Family Motivation for Engineering- Profession
Power of Money
Usefulness of the Work</td><td>Balance and Resolution
Comfortable Mobility and Safety Ethical
Governmental Regulation
National Pride
Survival
Social and Moral Responsibility
Safety and Training</td><td rowspan="2">SOCIAL/SOCIETY</td></tr>
<tr><td>Dream of Engineering Career
Enthusiasm for Technological Advance
Financial and Material Success
Fulfillment Through Work
Honesty and Loyalty to Work
Potential Impact of Engineering</td><td>Awareness of Ecological Health
Belonging to the Global Village
Critical View
Empowerment of Individual
Financial Security for Local People
Humanity and Social Development
Introspection and Empathy
Intuition and Impulse
Peace
Social Learning
Sustainable World</td></tr>
<tr><td colspan="4">IDEALS /AUTONOMY</td></tr>
</table>

Figure 4 North American Engineering Values map

In the map in Fig 4 the Western axis is: "Profession/Engineering" and the Eastern axis is "Social/Society." On the left of the map, we place values that hold in focus and major importance, the Profession of Engineering. On the right side of the map, we place values which hold in focus or major importance, social impact and society. The Northern axis is "Conformity/Authority" and the Southern axis "Ideals and 'Autonomy'. In the upper boxes we place values which hold in focus authority, tradition, norms, and expectations. In the lower boxes we place values which are more focused on idealism and individual autonomous decision making, as opposed to 'swallowed' values of an external authority. In this way, those values in the top left or NW box relate to the authority of the engineering profession. Participants expressing these, value above all, money, career, profession, status, security, and usefulness of the work they do/ will do. Those values in the top right or NE box relate to the authority of society, the Government, nation state religion, etc. Participants expressing these, value above all, national pride, law, government regulation and control. They are also ethical and believe in acts of charity towards less privileged members of the society; however they do these because of a sense of duty, rather than because of any ideals. Values in the bottom left or SW box relate to the profession of engineering but focus on ideals and autonomy within this. Participants expressing these, value above all engineering as their dream career, they are technological determinists who believe that engineering solutions will solve the world's problems. Values in the bottom right or SE box relate to societies, communities and social issues, as well as idealism and autonomy. Participants expressing these, have strong ideals and value people and the environment. Here we find those who focus on environmental sustainability and social justice as well as those who believe that we have a choice.

Summary thoughts

In this paper, we have presented the emerging pathway towards a methodology for mapping engineering values. Based on original work by Adams and adapting it to the engineering context, an open ended questionnaire was developed. Questions were derived from workshops in the US and Canada with students and professors of engineering to allow open conversation whereby the underlying values of the participants could be discovered. Data for each question were analyzed and grouped into clusters of potential values. These values were compared with the US and Canadian social values developed by Adams. Having decided that the Values maps of the US and Canada did not fit all data, a new Engineering Values map was developed which appeared to represent in four quadrants all values emerging from the study. It does appear that the approach taken, of using open ended questions to uncover underlying values is potentially useful and that from these it is possible to develop a map of such values. More data from engineering students, professors and practicing engineers are needed to test and expand the map and the methodology. It is possible once the methodology has been tested through future studies that individuals or organizations could have their values mapped onto these frameworks and comparisons could be made between different groups and individuals. This would then be an important pedagogical tool, to help engineering students consider whether they are in fact valuing what they thought they were, or whether they have unconsciously 'swallowed whole' values from parents, school, society, which they would freely prefer not to put at the forefront of their work as an engineer. It is also possible that these maps could be used to help engineering employees and employers think about their roles and impact within society and help engineering organizations move towards more socially responsible actions.

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