The Formal and Hidden Curricula of Ethics in Engineering Education

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INTRODUCTION

In recent years, a commitment to professional ethics and professional responsibility has been included among the learning outcomes required of engineering education programmes in many counties [1, 2]. There is evidence - both within engineering

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education and more widely - that discussing ethical dilemmas in formal education does lead to increases in measured moral reasoning ability [3, 4, 1]. However, alongside the 'formal curriculum' of engineering programmes there also exists a 'hidden curriculum' of things students learn implicitly through the social and organizational nature of their studies. It is possible that courses addressing ethical issues may be swimming against the hidden cultural tide of the programme as a whole.

This paper explores the role of the hidden curriculum in engineering education, drawing on quantitative data from a very large study of moral reasoning among engineering students. It describes how moral reasoning of engineering students can be understood and highlights how (i) implicit ways of understanding the nature of knowledge (epistemologies) and (ii) assessment competition, may actually counteract the impact of ethics education. This paper begins, however, with by exploring the place of ethics in engineering education.

1 ETHICS IN ENGINEERING EDUCATION

1.1 Teaching ethics, learning ethics

In recent years, a commitment to professional ethics and professional responsibility has been included among the learning outcomes required of engineering education programmes in the US, Europe and Australia, among other places [1, 2, 7]. There seems a general agreement that ethics issues are best approached through the use of case studies or dilemmas [1, 4, 11], ideally supplemented by a focus on moral reasoning skills and perhaps service learning (i.e. community work placements) [9, 12]. Colby and Sullivan have argued that the most prevalent means of teaching engineering ethics in the US is now the case discussion [13]. The data from engineering matches the evidence from studies of moral education more generally [3], which typically find that moral reasoning development is more effective when conducted through programmes which involved peer discussion of dilemmas and opportunities for self-reflection, and is less effective when programmes take the form of academic courses which emphasise the content of humanities, social sciences, literature or contemporary issues. While there is broad agreement on the value of opportunities to discuss dilemmas and case studies, there has been some criticism of the content of some of the case studies that are commonly used. Bucciarelli [5] for example has argued that case studies used are often overly simplistic and present an asocial and context-less view of the individual engineer carrying the weight of an individual personal responsibility. Didier [14] suggests that in addition to understanding engineering ethics at a micro level (the types of problems that individual engineers meet in their professional practice), it should also be understood at meso level (competition between technical systems and institutions) and at macro level (where technical developments are understood as embedded within a wider social context).

At the same time it must be acknowledged that the key issue for engineering ethics education is not so much the methodologies used or the content addressed, but rather the lack of time and effort devoted to it within engineering education programmes. While there is apparent agreement on the importance of ethical practice as a learning goal in engineering education, many programmes appear not to contain much by way of ethical content. At the turn of this century, Herkert [9] noted that nearly 80% of engineering graduates in the US came from schools that did not have a required ethics-related course, while McGinn found that almost 70% of Stanford engineering students who participated in his study said that ethical issues had never been discussed (as opposed to just mentioned) in any of their technical

engineering classes [10]. Colby and Sullivan reviewed practices in 100 US engineering programmes and concluded that a broad-based, planned approach to ethics instruction was rare, and that it was common for professors, even programme leaders, to be unaware of the ethics content within their programmes. When ethical content was included in programmes it was not very likely to be assessed [13].

In this context, the concept of the "hidden curriculum" is useful. A key idea in curriculum studies is that there is a gap between the formally planned curriculum (what it is planned to teach) and the experienced curriculum (what students actually learn). Some of this gap represents a "hidden curriculum" – the tacit learning that students engage in during their programme [15]. Such tacit learning may come from the structure of the programme (which may give implicit messages about what is and is not important), from the nature of examinations (which may implicitly tell students about the relative values of individualism and group work or about what counts as important knowledge), or from the role models provided (which may tell them how professionals are expected to act).

Although the term hidden curriculum is not explicitly used, it is evident in Newberry's analysis of the systematic barriers to effective ethics education in engineering: "…an examination of any typical engineering curriculum will elicit one clear and inescapable impression—what is of ultimate importance is technical learning. Passionate teaching of ethics notwithstanding, the technical content of the curriculum is a massive black hole whose gravitational pull inexorably absorbs the students' attention, time, and fidelity" [8]. To understand the impact of the implicit messages that are communicated to students, it is useful to first clarify what is meant by the development of ethical thinking.

1.2 Moral reasoning and ethical practice

The dominant tradition in psychological work which seeks to understand how people come to act ethically is known as the Minnesota approach. It is based on the idea that as humans grow they go through a series of different stages of moral reasoning [16]. The first of these stages, associated with younger children, sees people make decisions based on fear of punishment or desire for reward. For an engineer this might mean that when faced with an ethical dilemma they ask themselves, "Might I get punished, and what might I gain?" The second stage, as children get older, involves becoming aware that their wider community has codes, laws or norms of ethical practice. At this stage, people typically make ethical decisions based primarily on following the norms, codes or conventions of their cultural group. For an engineer, this might mean that when faced with an ethical dilemma their reasoning process would be to ask "What does the code of ethics say?" In the third stage, when people are confronted with ethical questions they move beyond a tendency to follow rules and instead ask themselves, "What will have the best outcome for people more generally?" These three stages of moral reasoning development are referred to in order as the *pre-conventional stage*, the *conventional stage*, and the *post-conventional stage*. Although these were originally seen as being separate stages with a person moving from one to another, more recently researchers have tended to see these as being three different ways of thinking about the world ('schemas') each of which can be more or less present in any person at any given time.

There are a few points worth clarifying here. This approach to moral decision making states that there are more developed and less developed (we might say more simply "better" or "worse") approaches to thinking about ethical issues. What is seen as better or worse however is not the decision itself, but the *thinking approach* which led to the decision. Acting out of fear of punishment (pre-conventional) is seen as less

developed than seeking to follow codes or norms of practice (conventional) which in turn is less developed than considering the impact of a decision on the wider community and then taking personal responsibility for the decision (post-conventional). Secondly, it is not claimed that having higher or lower levels of moral reasoning makes someone a more or less ethical person; moral reasoning is only one of four different elements which combine to give rise to ethical behaviour (the others are moral sensitivity, motivation to act morally, and character to withstand external pressures). Someone may well have post-conventional moral reasoning but lack to motivation or the character to act ethically, for example. Finally, such moral reasoning can be assessed by giving people short dilemmas and asking them what sort of factors do they take into account in coming to a decision. The psychometric test used to assess a person's level of moral reasoning is called the Defining Issues Test (DIT) and is the most commonly used test in moral reasoning research – it has been used in hundreds of published academic studies. It has been used in engineering and in a wide variety of other contexts [3, 4, 16].

One problem with tests like the DIT is their quite general nature. Since the dilemmas they present are drawn from a variety of contexts and situations, they may not adequately reflect the specifics of how engineers would react in engineering-type situations. For this reason, a Georgia Institute of Technology team developed an engineering-specific test modelled on the DIT. This is called the Engineering and Science Issues Test (ESIT) [6].

1.3 Hidden curriculum and moral reasoning

So how might the hidden curriculum of an engineering programme impact upon the moral reasoning of students? As noted above, the very limited focus on ethics in engineering programmes might lead students to conclude that ethics is not a terribly important part of the life of the engineer. More than that, programmes which have a significant focus on basic sciences in the early years, may encourage students to implicitly adopt an epistemology based on the application of known or agreed principles or laws. This epistemology may lead students to come to see problems which do not have a single correct answer as being "simply a matter of opinion" rather than an opportunity to engage in a different way of constructing their understanding of the world. This type of epistemological perspective may encourage conventional moral reasoning. Another feature of early engineering education – particularly in the French-speaking world – is its highly competitive nature. While post-conventional moral reasoning is based on examining how particular behaviour impacts upon others, a highly competitive and individualistic exam system may encourage students to think in more pre-conventional ways.

These are the hypotheses which this study explores.

1.4 Context of the study

The Ecole polytechnique fédérale de Lausanne (EPFL) is an engineering and science university in French-speaking Switzerland. Like its sister institution in Zurich (ETHZ) it is one of the most highly rated engineering schools in mainland Europe and it regularly appears in rankings as the world's top ranked French-speaking university.

As a federal institution, EPFL is open to all students who have completed an academic, upper-secondary school programme in Switzerland. For the vast majority of students there is no entrance exam, with the main selection of students taking place at the end of first year which acts as something equivalent to the preparatory courses and *grand concours* within French engineering schools. Passing rates in first year are typically between 40% and 50%. The focus in this first year is on

providing a common polytechnic base to all students, with a heavy focus on mathematics and physics.

In 2014 EPFL introduced a new first year course called Global Issues, which presented an integrated, thematic approach to major global challenges such as climate, disease, migration and communication. Students chose a single theme and were taught by a pair of teachers, one from social and human sciences and one from science and technology (11 different thematic strands were offered to cater for about 1,700 first year students). The course consisted of a series of lectures which addressed the theme in an integrated way, after which students worked in interdisciplinary teams to complete a project and make a poster presentation related to their chosen theme. The data presented here was collected as part of an analysis of the impact of the Global Issues course, although, since the course was taken by all students and there was no control group, the data serves more as a tool for analyzing the impact of the second semester of the first year of studies.

2 METHODOLOGY

2.1 Participants

First year, second semester EPFL students were invited to complete the evaluation instruments at the end of the first lecture in the Global Issues course and again after they had completed an exam which formed part of the assessment of the course in either the second last or last week of term. Participation in the study was voluntary (a detailed participant information sheet was given to each student explaining the purpose of the study, its voluntary nature, and the treatment of data). Students were asked to provide their ID in order that the first and second iterations of the questionnaires could be matched. In total 1,732 students completed either the first or questionnaire. Not all students included valid ID numbers, and not all students answered all questions. The large sample size meant it was possible to be very conservative in deciding what data to use and so cases with a missing ID or any missing data were removed. This left 1,042 cases.

Although personal data was not collected from students, the profile of EPFL students shows that the vast majority were aged 18 to 20, with circa 30% being female.

2.2 Instrument

The original English-language ESIT was provided by the Georgia Institute of Technology team. This was translated into French by the EPFL team and the translation was verified through a reverse translation process. The translated test was piloted. As a result of the piloting, and to ensure it could be administered in a single class period, the test was shorted from six scenarios to four scenarios. It was administered as a pen and paper test.

The ESIT contains a number of “nonsense” items designed to identify if the student is genuinely understanding the test or is simply picking items that sound “academic” or “philosophical” (for example, one nonsense item is: “Is the inversion of the safety factor an example of the *post hoc* fallacy?”). Students who had an unacceptably high ‘nonsense score’ were excluded from the analysis. This left 953 cases for analysis.

3 FINDINGS AND DISCUSSION

3.1 Findings

The mean and standard deviation scores for the 953 participants are presented in Table 1. Three things are immediately evident from this data. First, participants are most likely to think about the dilemmas presented using a post-conventional schema.

At the start of term, on average, the students' post-conventional reasoning score is 0.53 (on a 0 to 1 scale) (for comparison, Borenstein and colleagues found a pre-test post-conventional score of 0.50 in their original ESIT study [6]). This compares to an average pre-conventional score of 0.17 and a conventional score of 0.29. Secondly, the standard deviations for each of the three scores is quite high, reflecting a very wide variation of scores within the student body.

The third thing that is evident is that the average post-conventional score of the students actually declined over the term (from 0.53 to 0.47). This decline is statistically significant ($t=9.930$, $df=952$, $sig<0.001$), and is moderately strong (Cohen's $d=0.37$). Although the size of the increase in pre-conventional and conventional scores is much lower, the large sample size means that in both cases it is statistically significant ($t=2.255$, $df=952$, $sig=0.024$ for the conventional score and $t=5.053$, $df=952$, $sig<.001$ for the pre-conventional score).

Table 1. Pre-conventional, conventional and post-conventional moral reasoning scores (scored on a 0 to 1 scale)

	Start of term		End of term	
	Mean	Standard deviation	Mean	Standard deviation
Pre conventional	0.17	0.12	0.19	0.14
Conventional	0.29	0.12	0.30	0.14
Post-conventional	0.53	0.15	0.47	0.17

If the results found here were associated in some way with the ways in which Global Issues course were taught, we might expect differences in the extent to which moral reasoning changed between the 11 different class groups. In fact differences between teacher groups were not statistically significant.

3.2 Discussion

If the data is seen as a representation of the reasoning skills of EPFL students, the data is quite positive – students typically show a bias towards higher levels of moral reasoning and pre-conventional moral reasoning plays, on average, a small part of their judgement process in engineering related ethical dilemmas. The findings for the EPFL students are comparable to those found in the original ESIT study [6]. Being able to benchmark our students' moral reasoning in this way is, in itself, enormously useful. The existence of a French-language version of the ESIT will now allow for similar studies for moral reasoning development to be carried out in the Francophone world. This is a major development in itself.

Of course it should not be enough that students engage in higher level moral reasoning – ideally we would like our programmes to improve their moral reasoning. This did not happen – in fact the opposite happened. It was noted above that there may be features in some engineering education programmes that may discourage post-conventional moral reasoning in students and may actually encourage pre-conventional and conventional reasoning. These include the development of an epistemological belief that single, 'correct' answers can be found through finding the appropriate principle or law and applying it (this may encourage conventional moral reasoning) and assessment methods which emphasise individualism and competition (this may encourage pre-conventional moral reasoning). It is clear that during the second semester of their studies, the students here did, on average, show evidence

of such a shift away from post-conventional reasoning, despite the fact that they were participating in a course designed to get them to consider the way social and ethical issues interact with technical issues in major global problems like climate, transport, communication and nutrition. Whatever positive impact Global Issues may have had (and there is no direct evidence of an impact) it appears to that it may have been more than washed out by the broader culture of the programme. The fact that the negative effect is consistent across all classes and teacher teams reinforces the view that what we are seeing here is a programme effect rather than something linked to the way the course was taught. This has implications beyond the direct teaching of ethics. For example, it has been suggested that there is a need to ensure that students grapple with open-ended questions early in their programmes [17]. This may cause them to begin to see that the identification and application of "always true" rules or laws in order to find a finite number of "correct answers" is actually only one way of approaching knowledge construction, and that other, more open-ended and less definite, approaches may also be valid, depending on the context. This may be one element in a process of helping them to make explicit for themselves the epistemological models which they find implicit in basic science disciplines and to aid them in coming to understand these as being epistemological models among others. Other issues however, (the highly competitive and individualistic exam culture, for example) may not be amenable to change.

The idea of the hidden curriculum draws our attention to the fact that students do not just learn from what we say but also from what we do. Study programmes which encourage students to act in individualistic ways or which encourage them to take a "rule following" approach to problem-solving are probably a necessity that cannot be avoided. Indeed, individual initiative and a tendency to follow (some) rules is probably also a good thing. We should, at the same time, be aware of unintended negative consequences of these aspects of programme structure and we should perhaps even encourage students themselves to question them.

This would certainly provide them with an open-ended and complex ethical question upon which to reflect.

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