A Constructivist Approach to the use of Case Studies in teaching Engineering Ethics

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Abstract. Our paper aims to explore the effectiveness of a constructivist approach to the teaching of engineering ethics through case studies, by putting forward a contextualization of the much discussed case study "Cutting Road Side Trees" [12] in light of the constructivist frame suggested by Jonassen [8]. First, we briefly analyse how the use of case studies for the teaching of engineering ethics eludes the complexity of the engineering professional environment before arguing that constructivism is a learning theory that can help to address this complexity. The final section proposes a constructivist reworking of the case method in a manner that aims to correct the deficiencies identified, followed by a discussion of the results of applying the contextualized exercise to First Year group of engineering students. The key findings reveal that the contextualized scenario enhances, in some respects, students' understanding of the social dimension of the engineering profession.

Keywords: Engineering education · Engineering ethics
Social dimension of engineering · Case studies · Role-playing · Constructivism

1 Case Studies in the Teaching of Engineering Ethics

Case studies presenting moral dilemmas faced by engineers have been a dominant teaching method in engineering ethics, and as Colby and Sullivan [3] highlight, discussion of cases is still the most prevalent means of teaching ethics in engineering colleges in US. This approach has recently attracted criticism pointing to its weakness in capturing the dynamics and realities of the work place [2, 4, 11]. The method appears to elude the metaphysical characteristics of the engineering profession, related to the nature of the artefacts produced [7, 14], engineering practice [1, 13] and the professional environment [5, 6]. Colby and Sullivan ([3], p. 330) further note that "few schools had instituted systematic programs to educate for this broad sense of professional responsibility […] and engineering ethics is not usually taught with this kind of scope," with engineering programmes lacking the integration of "technique with the social meaning and broader ethical context of engineering practice." It is thus crucial to enquire what learning theory could support such a broad pedagogical approach. In light of this line of criticism, the teaching of engineering ethics needs to make students aware that:

M. E. Auer et al. (eds.), *Teaching and Learning in a Digital World*,
Advances in Intelligent Systems and Computing 715,
https://doi.org/10.1007/978-3-319-73210-7_23

(i) the artefacts created incorporate social and political values
(ii) the decision and design process of creating an artefact is also a social process
(iii) even if identifying the moral thing to do is a necessary first step for being a socially responsible engineer, acting upon it depends on wider structural factors.

Constructivism appears to be a learning theory that responds to the need of broadening the teaching of engineering ethics beyond the individualistic outlook, in a way that reflects the context in which engineering is practiced and the metaphysical complexity of the profession. In what follows we explore how social constructivism addresses the first two metaphysical characteristics of engineering practice, seen from an ethical lens.

As the Challenger case shows, the meaning of the values an engineer operates with is fluid, subject to modifications brought by different factors related to one's past experience, organizational culture and structure, or the personal characteristics of individuals. Constructivism is focused on meaning making. Knowledge is "constructed, negotiated, propelled by a project and perpetuated for as long as it enables its creators to organize their reality in a viable fashion" ([9], p. 8). Knowledge and learning are thus active social processes resulting from the interaction of different subjectivities.

A constructivist teaching frame encourages students to see how their views about the meaning of engineering values change as an outcome of their interaction. Considering the *Cutting Roadside Trees* exercise, the solution proposed and the method to reach it reflect a particular understanding of what counts as an acceptable compromise or what students understand by sustainability. Working in groups, as students enrolled in the *Professional Practice* course do, "requires the learner to produce an output by acting on the world in some way […] It demands more than discussion, argument, question and answer: it demands also group consensus on producing an output" ([10], p. 57). This is a first step in familiarizing students with the way in which a collective represents a structure that can affect the outcome, and also encourages them to devise a solution given the constraints of their own micro-professional structure.

Jonassen ([8], p. 220) notes that the physical, organizational, and sociocultural context in which the problem is set should always be included. According to Jonassen [8], rich contexts for group projects or role playing exercises can raise students' awareness of the many factors that contribute and influence the output of their task. This helps in drawing attention to the way in which the different subjectivities of the agents encountered in the workplace will affect the decision making process and the creation of engineering artefacts as future professionals.

Thus, by situating learning within a social context and considering engineering decision making and artefact creation as a collective endeavour, constructivism manages to reflect *some* of the major metaphysical characteristics of the professional environment of the engineering profession.

2 Cutting Roadside Trees: A Constructivist Contextualization

At Dublin Institute of Technology, we have put in practice for the course *Professional Practice* a contextualization of the much discussed case study "Cutting Road Side Trees" [12] in light of the constructivist frame suggested by Jonassen [8]. Thus, to the scenario designed by Pritchard [12], we have added a contextual description for the three main characters of the case study, which highlighted their professional experience and status within the organization and community, their values and feared outcome (see Box 1), followed by a set of questions related to the scenario (see Box 2).

Box 1. The contextualized "Cutting Road Side Trees" case study

"Kevin Clearing is the engineer for the Verdant County Road Commission (VCRC). VCRC has primary responsibility for maintaining the safety of county roads. Verdant County's population has increased by 30% in the past 10 years. This has resulted in increased traffic flow on many secondary roads in the area. Forest Drive, still a two lane road, has more than doubled its traffic flow during this period. It is now one of the main arteries leading into Verdant City, an industrial and commercial center of more than 60,000 people.

For each of the past 7 years at least 10 persons have suffered a fatal automobile accident by crashing into trees closely aligned along a 3 mile stretch of Forest Drive. Many other accidents have also occurred, causing serious injuries, wrecked cars, and damaged trees. Some of the trees are quite close to the pavement. Last year two law suits have been filed against the road commission for not maintaining sufficient road safety along this 3 three mile stretch. Both were dismissed because the drivers were going well in excess of the 45 mph speed limit.

Members of VCRC have been pressing Kevin Clearing to come up with a solution to the traffic problem on Forest Drive. They are concerned about safety, as well as law suits that may someday go against VCRC. Clearing now has a plan – widen the road. Unfortunately, this will require cutting down about 30 healthy, longstanding trees along the road.

Clearing's plan is accepted by VCRC and announced to the public. Immediately a citizen environmental group forms and registers a protest. Tom Richards, spokesperson for the group, complains, "These accidents are the fault of careless drivers. Cutting down trees to protect drivers from their own carelessness symbolizes the destruction of our natural environment for the sake of human 'progress.' It's time to turn things around. Sue the drivers if they don't drive sensibly. Let's preserve the natural beauty and ecological integrity around us while we can."

Many letters on both sides of the issue appear in the Verdant Press, the issue is heatedly discussed on local TV, and Tom Richards presents VCRC with a petition to save the trees signed by 150 local citizens." [12]

Correspondingly, the three character description we added are:

-**The young engineer**

You are Kevin Clearing, an engineer who graduated 6 years ago and is now working as an engineer at the Verdant County Road Commission. You enjoy your work and hope to get in the next 6 months a promotion as engineering manager, knowing that your professional trajectory within VCRC depends on the board and how satisfied they are by your decisions. In your work you value practical solutions and you take pride in considering sustainability in your decisions.

-**The top manager**

You have worked for VCRC for more than 30 years. Back in the days Verdant was a small community with light traffic, which saw one lethal car accident every few years. The current traffic brings new challenges for your line of work and you fear that losing a lawsuit would have disastrous consequences for the public image of VCRC and for an already strained budget. You value decisions that protect the image of VCRC and are cost effective.

-**The influential environmentalist**

You are Tom Richards, and have been living in the Verdant County since you were born, 60 years ago. You appreciate its natural scenery, and consider that the forest lining up besides each side of the road, home to so many wild species, is an invaluable part of the city Verdant. The recent urban developments have already led to some of the county's green areas get torn down to make room for industrial buildings, and now you fear that the new deforestation plans of VCRC will continue such a trend. The group you represent aims to protect the natural habitat that makes Verdant County unique. You value nature and want your grand-children to enjoy the same landscape and quality of air that you have benefitted from.

Box 2. Assignment questions

CONTEXTUALISED CASE STUDY (3 STUDENT DIVISIONS)

(Q1) What is the main problem you (Kevin Clearing/ VCRC/TR) have to solve?
(Q2) What do you (Kevin Clearing/VCRC/TR) consider to be the best solution?
(Q3) What do you (Kevin Clearing/VCRC/TR) think are the main barriers for achieving this solution?

After answering these questions by yourself, discuss the scenario with your group by adopting the stance of the character you represent and agree on a solution or line of action (20 min). Then answer the following questions (15 min):

(Q4) What solution was reached following the discussion?
(Q5) What criteria or values have been considered to reach this solution?

(Q6) Was the solution agreed by all or did it result from one person imposing their views on others? Why do you think this happened?
(Q7) Do you personally agree with the solution reached? Why/Why not?

ORIGINAL CASE STUDY (CONTROL GROUP: 1 STUDENT DIVISION)

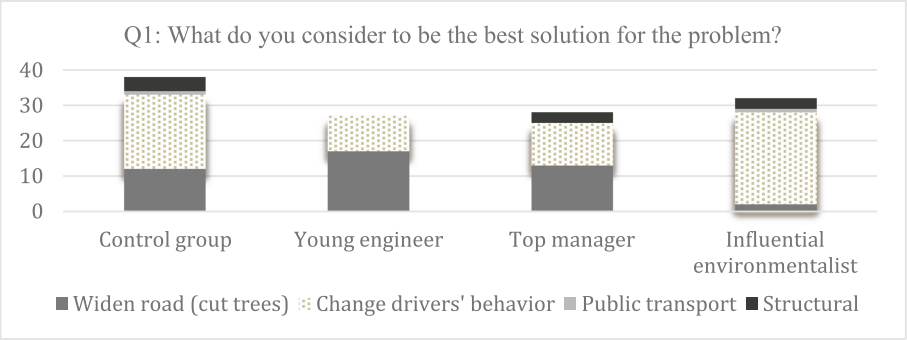
1. Discuss how Kevin Clearing should proceed at this point. Think about the following questions for 5 min by yourself:
   What is the main problem that Kevin has to solve?
   What is the best solution?
2. Discuss the two questions in your groups and arrive at agreement on an answer (15 min)
3. Pick one member of your group to report back.

The sample group to which this exercise was applied consisted of 112 first year students enrolled in four divisions of the *General Engineering* programme, in the course *Professional Practice*, during the spring semester of the academic year 2016–17. The control group consisted of one division of 23 students, split into groups of 4–5, who received the original case study without the contextualisation. The other three divisions totalling 89 students were split into groups of 3–5 and given different roles, of a young engineer, a top manager or an influential environmentalist, as described in Box 1. The exercise required students to discuss and propose a solution to the dilemma informed by the contextual information provided. They had to answer in writing a set of questions, as seen in Box 2, which invited participants to reflect on what they consider to be the problem presented by the scenario given their character description, a solution and possible barriers to implement it, then following a joint discussion to name the solution agreed, the values behind it and how it was reached. The answers were collected and represent the data on which this paper draws. The key findings reveal that the contextualized scenario enhances students' understanding of the *social dimension of the engineering profession*.

As such, in the pre-discussion stage, when the control group with no role assigned and the three divisions of students were asked about their preferred solution given the scenario, there was no marked difference in the solution proposed between the control group and the top manager and young engineer typologies, while there was a difference between them and those who took on the role of the influential environmentalist.

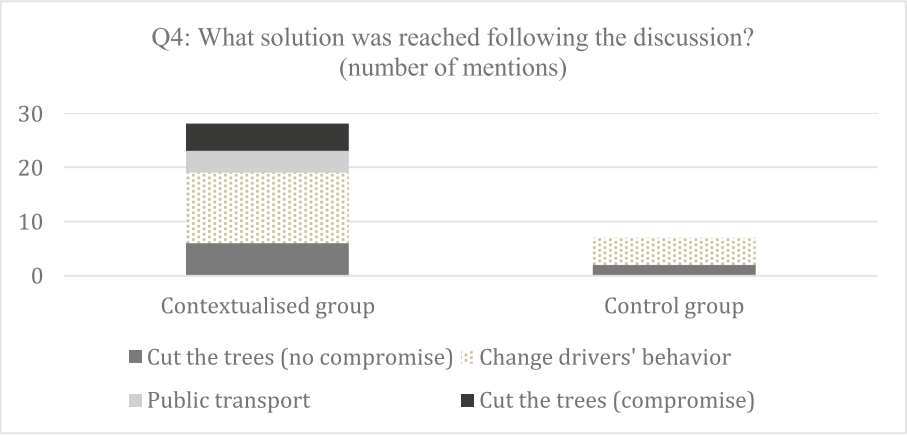
As can be seen from Table 1, the role adopted by students informed their preferred approach. The students assigned an environmental role were more focused on solutions for changing drivers' behaviour through constructing speed barriers or implementing sanctions, that would thus avoid cutting trees. The assignment of differential roles thus generated a greater variety of solutions based on the students' perceptions of what values might inform the approach of those occupying the roles they were assigned. This created then the need to engage with each other, as bearers of different values, to arrive at a solution on which all could agree.

Table 1. Student solution to the "Cutting roadside trees" scenario



The final solution was reached after discussions in small groups comprised of the three different roles. As such, as seen in Table 2, given the number of students who had indicated the need to cut the trees in the pre-discussion stage, there was a diminished number of proposals to cut the trees. This suggest that the process of discussion and persuasion led to changes in some students perspectives. It is notable that the groups with assigned roles developed a greater variety of solutions than the control groups. Thus the assignment of roles has the potential to increase awareness that engineering design and decision making is also a social process, and that the characteristics of the different actors involved in the stages of design and decision making are ultimately embedded in engineering artefacts.

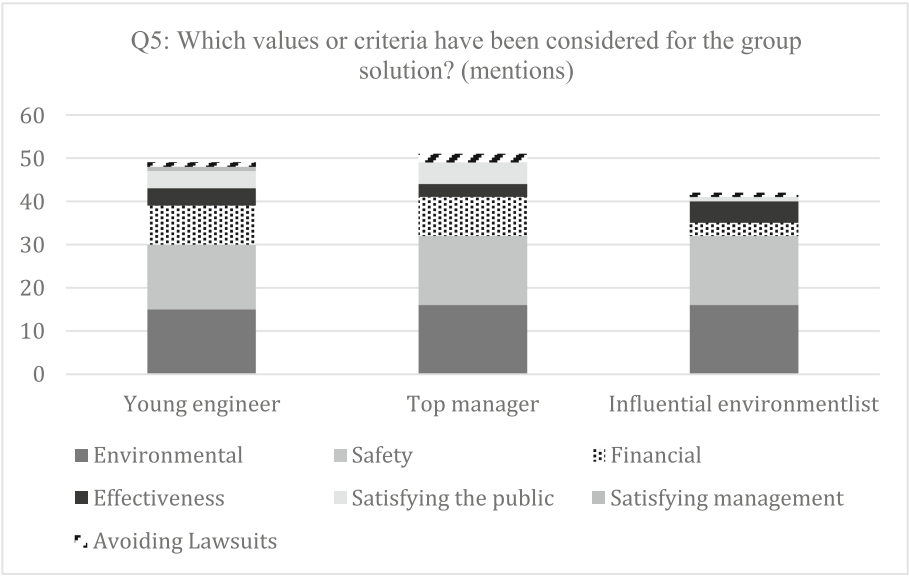
Table 2. Students' solution for the "Cutting roadside trees" scenario



Further evidence for this is derived from a question about what the students considered to be the barrier to achieving their desired solution in the pre-discussion stage. Across all three roles the most mentioned barrier is one of the other roles. So, of those playing the role of top manager, 65% said environmentalists were the main barrier. Of those playing the role the young engineer 67% identified the environmentalist as the main barrier. The environmentalists were less likely to name the other two parties and more prone to identify several different actors (such as the public, drivers or big companies). While students assigned top manager roles were more likely to identify resource barriers. We can also note that there is a lower concern with structural factors, such as "population increase" or a "decision making style oriented towards quick solutions," and more on how different actors can affect the solution to the problem.

One way in which different actors are seen to contribute and affect an engineering solution is suggested by the answer to the question about the values and criteria which contributed to the final decision that followed each discussion. Table 3 shows a wide spread of values, with numerous mentions each, revealing that there was no single value or perspective imprinted on the solution. The engineering solution and the proposed artefact that resulted from the discussion is the outcome of the different values brought in by different actors. The results show that the role playing scenario conveys to students awareness of the *social values embedded in engineering artefacts and decisions*.

Table 3. Values and criteria influencing the solution to the scenario



According to the data collected, the answers of the students who were presented a contextualized scenario were diverse and complex, reflecting an awareness of how the interplay between agents with different goals and values influences the engineering process. By receiving a description of different actors involved in the design and decision-making process of the engineering profession, students can see that the practice of engineering contains a strong social component, namely that *engineering artefacts contain social values* and that *the process of design and decision-making are social processes*. This leads us to suggest that to better capture the metaphysical characteristic pertaining to the social dimension of the engineering profession, case studies can benefit from more contextual information that details the actors' characteristics.

A shortcoming of the exercise is that while students gained insight into engineering practice as a social process (aims 1–2 in Sect. 1) there was less of a focus on the social structural dimension of engineering practice (aim 3). This may be to expect too much from a "small case" [11] used with first year students who may lack wider knowledge about the social and organizational context in which they may work in the future. "Larger cases" may be needed to explore the wider constraints on engineering practice and the possibilities for addressing them [11].

3 Conclusion

The pedagogical exercise of contextualising the case study "Cutting Roadside Trees" is informed by a macroethical outlook driven by the ideal of enabling engineers to change the economic and social context in which they work as to promote the development of sustainable and safe solutions. A prerequisite for achieving this is to increase students' awareness about the constraining or enabling factors present in the workplace, the inherent imbalance of power and institutional dynamic, and how different subjectivities interact and shape the decision making process in the workplace. We believe that the pedagogical exercise proposed manages to convey *some* of the metaphysical characteristics of the engineering profession, those related to its social dimension, and to increase student awareness of the complexity of engineering practice.

Acknowledgment. The authors want to thank Kevin Kelly and the DIT - School of Multidisciplinary Technologies, for the support in the implementation of the contextualized "Cutting Roadside Trees" exercise and facilitating the presentation of key findings at ICL 2017.

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