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Understanding Ill-Structured Engineering Ethics Problems Through a Collaborative Learning and Argument Visualization Approach

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Understanding ill-structured engineering ethics problems through a collaborative learning and argument visualization approach[1]

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Abstract
As a committee of the National Academy of Engineering (NAE) has recognized, ethics education should foster the ability of students to analyze complex decision situations and ill-structured problems. Building on the NAE's insights, we report about an innovative teaching approach that has two main features: first, it places the emphasis on deliberation and on self-directed, problem-based learning in small groups of students; and second, it focuses on understanding ill-structured problems as they arise, for example, in the context of emerging technologies. The first innovation is motivated by an abundance of scholarly research that supports the value of deliberative learning practices. The second results from a critique of the traditional case-study approach in engineering ethics. A key problem with many standard cases is that they are described in such a fashion that renders the ethical problem as being too obvious and simplistic. The practitioner, by contrast, may face problems that are ill-structured.

In the collaborative learning environment described here, groups of students use interactive and web-based argument visualization software called "AGORA-net: Participate – Deliberate!". The main function of the software is to structure communication and problem solving in small groups. Students are confronted with a variety of tasks that focus on identifying possible stakeholder positions and reconstructing their legitimacy by constructing justifications for these positions in the form of graphically represented argument maps. The argument maps are then presented in class so that these stakeholder positions and their respective justifications become visible and can be brought into a reasoned dialogue. Argument mapping provides an opportunity for students to collaborate in teams and to develop critical thinking and argumentation skills.

Introduction: A New Focus in Engineering Ethics Education

Traditionally, the main objective of engineering ethics courses has been to foster awareness of and to stimulate reflection on the responsibilities of professionals in technological fields. A well-established method to pursue this learning objective is to provide students with case studies from engineering practice. The case studies typically focus on everyday ethical issues such as taking a bribe from a vendor. However, a key problem with many of the commonly-used cases is that they describe the ethical problem in such a fashion that renders it as being something that is too simplistic. The more obvious the wrongdoing is, the easier it is to determine what should have been done. Students can certainly learn something from reading about a real historical case where, for example, an engineer decided to include falsified or fabricated data in a technical report. However, there may be no true ethical "challenge" presented in that type of case because the ethical problem and its best solution are fairly obvious.

[1] A shorter version of this paper, with different examples, was presented at the ASEE 2012 Annual Conference and published in the proceedings of the conference.

Clearly, the simplicity of some of the standard ethics cases stands in contrast to the complexities of the real-life situations students will encounter after graduation. Aristotle astutely recognized in the first sentence of his *Nicomachean Ethics* that "every action and undertaking seems to seek something good" (Aristotle 2002). No professional wants something bad to happen. At times, the problem is not the engineer's intentions but his or her inability to predict or prevent a bad outcome in spite of all the good intentions. The most fundamental challenge from an ethical perspective is thus the fact that we need to realize, first of all, that there is an ethical challenge connected to one's decisions.

Engineering ethics education needs to better prepare students for this kind of challenge. This conviction is conveyed within a workshop report on "Ethics Education and Scientific and Engineering Research" that the National Academy of Engineering (NAE) organized in 2009. The report emphasizes that the following skills should be developed in ethics education (Hollander and Arenberg 2009):[2]

- Recognizing and defining ethical issues.
- Identifying relevant stakeholders and socio-technical systems.
- Collecting relevant data about the stakeholders and systems.
- Understanding relevant stakeholder perspectives.
- Identifying value conflicts.
- Constructing viable alternative courses of action or solutions and identifying constraints.
- Assessing alternatives in terms of consequences, public defensibility, institutional barriers, etc.
- Engaging in reasoned dialogue or negotiations.
- Revising options, plans, or actions.

This list highlights the complexity of the issues that engineers may confront. The actions of engineers can have effects on stakeholders whose existence, perspectives, and values they are not even aware of. Engineers do not always directly interact with the people whose lives are being altered as result of their decisions. Obviously, engineering students need to refine their technical competence. But it is crucially important that they develop "soft skills" as well (Shuman et al. 2005). Among these skills is the ability to identify hidden ethical challenges.

Ill-Structured Problems

A key educational challenge is developing learning opportunities for students so that they can acquire the ability to identify and structure complex situations. This ability is an important precondition for problem solving, for decision making, for designing, and for planning. Several decades ago, Horst Rittel and Melvin Webber (1973) recognized this as "one of the most intractable problems" in their seminal paper "Dilemmas in a General Theory of Planning." Rittel and Webber came to the conclusion that the real challenge is not "tame" or "benign" problems that are clearly specified and that allow for a clear determination as to whether a solution has been achieved—for example, a standard ethical problem in a textbook. The real challenge is what they called "wicked problems" or what we refer to as "ill-

[2] See also National Research Council. *The Engineer of 2020: Visions of Engineering in the New Century*. Washington, DC: The National Academies Press, 2004.

structured problems," a term that is also used by other authors in the engineering ethics literature (Jonassen et al. 2009; Jonassen and Cho 2011). We prefer "ill-structured" because in common parlance, the term "wicked" carries with it the connotation of something being ethically wrong and this could be misleading; it is not a feature that we intend to capture. However, even though we are using different terminology, "ill-structured problems" is intended to mean the same thing as Rittel and Webber's "wicked problems" (see also Buckingham Shum 2003; van Bruggen et al. 2003).

Among the ten defining characteristics of a wicked problem that Rittel and Webber (1973) delineated, the most important for our purposes is the first one: "There is no definitive formulation of a wicked problem." Any sufficiently detailed description of what the problem "is" is already predetermined by a certain vision of its solution—a vision that is often biased by diverse values and interests. This results from the fact that in pluralist societies, in which a multitude of world views and values compete, the determination and formulation of a problem as well as the assessment of its "solution" are in themselves controversial and open to discussion. Based on differing belief and value systems, problems and solutions can be "framed" in a variety of ways, and it is contentious whether anyone can legitimately claim the authority to decide who is right and who is wrong. This is called the "perspectivity" of ill-structured problems. It depends on the perspective, the vantage point, of who is involved in a complex situation how exactly a problem is perceived and framed.

Further characteristics of wicked problems are a direct consequence of perspectivity. As Rittel and Webber (1973) state, "Solutions to wicked problems are not true-or-false, but good-or-bad." This is because there are many parties with potentially varying interests, value-sets, and ideological predilections who are more likely to assess a solution as "better or worse" or "satisfying" or "good enough." In addition:

> Wicked problems do not have an enumerable (or an exhaustively describable) set of potential solutions, nor is there a well-described set of permissible operations that may be incorporated into the plan.

The fact that certain perspectives on an ill-structured problem might be overlooked is important because of two other characteristics of Rittel and Webber's wicked problems that are crucial for engineering in particular. There is "no immediate and no ultimate test of a solution" to it because any "solution, after being implemented, will generate waves of consequences" which "may yield utterly undesirable repercussions which outweigh the intended advantages." And: "Every solution to a wicked problem is a 'one-shot operation'…It leaves 'traces' that cannot be undone. One cannot build a freeway to see how it works, and then easily correct it after unsatisfactory performance."

The concept of an ill-structured problem presented here refers to the fact that engineers are often confronted with situations that require structuring. Most worrisome are those situations that seem to be straightforward but are not. For the professional, the biggest challenge is to realize, first of all, that there might be perspectives on a problem other than his or her own. As Coughlin (2008) notes, it can be difficult to imagine, and take seriously, a perspective that is in opposition to one's own (see also Jonassen and Cho 2011; Jonassen et al. 2009). The challenge is to identify the ethical dimensions of a decision especially in those situations where they are not obvious or are hidden, and where available descriptions do not contain any hint of the complexity and multi-perspectivity of the problem.

According to Rittel and Webber (1973), the multi-perspectivity of wicked problems implies that they should be approached "based on a model of planning as an argumentative process in the course of which an image of the problem and of the solution emerges gradually among the participants, as a product of incessant judgment, subjected to critical argument." Their insight about the importance of argumentation—which has been proven highly influential in educational sciences (Andriessen 2006; Andriessen 2009; Kirschner et al. 2003; Okada et al. 2008)—has helped to inform and guide the educational approach described here.

The emphasis on argumentation as a "powerful pedagogical strategy" in engineering ethics is shared also by Jonassen and Cho (2011). Following Haws's argument that students should become familiar with ethical theories and "the language of ethics" in order to acquire the "theoretical grounding" that is necessary to "formulate, articulate and defend their ethical resolutions to the broader community" (Haws 2001), Jonassen and Cho (2011) emphasize that students should also "acquire the ability to evaluate alternative solutions from different perspectives." A precondition for evaluating those perspectives is to understand them, and understanding can be achieved by reconstructing the *arguments* on which stakeholder positions are based. "Because ethics problems have multiple solutions, those arguments must not only pose a solution and support that solution but also anticipate alternative solutions and anticipate the counterarguments in support of those solutions" (Jonassen and Cho 2011).

An Overview of the Educational Approach

A major objective of engineering ethics education should be to provide opportunities to acquire the skills that are necessary for engaging in such an "argumentative process." Ethics education should foster the ability to cope creatively and constructively with ill-structured or "wicked problems" in the sense described by Rittel and Webber. The educational challenge, as we see it, can be summarized in the following formulation that is built upon the list of skills identified in the aforementioned NAE report.

> A precondition for making ethical decisions that meet the challenges posed by ill-structured problems is the ability to analyze complex decision situations in a way that the involved stakeholders can be identified and their varying perspectives and values understood. Appreciating another person's needs, interests, and the resulting intellectual or ideological position presupposes the ability to grasp the arguments that justify this position. Thus, ethical decision making in complex situations requires an argument-based dialogue about a wide range of stakeholder perspectives and their justifications that can lead to imagining alternative courses of action and hopefully better decisions.

Promoting this ability requires a new focus in engineering ethics education. Thus, we present one possibility of how this challenge can be met. It is an educational approach that includes four main components:

1) Students are confronted with a specific form of ill-structured problems, namely those that Berry refers to as "fractious problems" (Berry, Borenstein, and Butera 2012). According to Berry, a fractious problem has five defining features, including that this type of problem is "complex", "unavoidably public", and "socially divisive". An assignment

could be framed, for example, by placing the students in the hypothetical role of being a task force that is charged with presenting its findings to a government committee. They would need to identify possible stakeholders and affected populations, formulate reasonable positions that these stakeholders might hold, and develop an argument that seeks to defend the legitimacy of each of these positions.

2) An educational environment in which small groups of students collaborate on projects. This component is motivated by research that supports the effectiveness of Problem-Based Learning (PBL) and collaborative learning (Barrows and Tamblyn 1980; Duch et al. 2001; Gijbels et al. 2006; Hmelo-Silver 2004; Hmelo-Silver and Barrows 2008; Newstetter 2005; Woods 1996; Deslauriers et al. 2011). This strategy aims to increase student engagement, provide opportunities for peer-to-peer (P2P) learning, and stimulate creativity. It also seeks to improve student-faculty interaction, communication skills, and critical thinking.

3) An interactive and web-based software tool (AGORA-net) that (a) challenges students to develop the rational reconstruction of an argument that stakeholders might provide to justify their position; this offers the students a means through which they can understand the stakeholders' needs, interests, beliefs, and values, and (b) provides system-generated step-by-step guidance to create those arguments in the graphical form of an "argument map."

4) A class discussion on group presentations of those argument maps that focuses (a) on the quality of the argument or arguments provided; (b) on identifying the ethical principles, values, and factual assumptions that become visible in the maps; (c) on a critical reflection of those ethical and factual components; and (d) on providing class and instructor feedback that motivates a revision of the maps in a final round of group collaboration before the maps are submitted for grading.

The AGORA-net software[3] has been developed to guide and support collaboration in small groups that work more or less autonomously on projects such as the task-force project mentioned above. We will elaborate on these four components in the following sections based on the discussion of an exemplary project in which groups of students deliberated by means of argument mapping the ethical ramifications of bringing a Neanderthal to life, as it might be pursued to study the significance of genetic differences between Neanderthals and modern humans. Before that, however, we will provide a more comprehensive description of the "AGORA collaborative learning approach."

The AGORA Collaborative Learning Approach

[3] See http://agora.gatech.edu/. By clicking on "Enter the AGORA-net," a Flash application opens in the user's browser. Every entry is saved on a central server so that synchronous and asynchronous online collaboration on argument maps from all over the world is possible. According to http://www.statowl.com/flash.php (accessed Oct 1, 2012), the Adobe Flash Player runs worldwide on approximately 95% of all computer systems, across browsers and platforms without installation. AGORA-net should not to be confused with the software "Agora" which is available at http://www.ethicsandtechnology.com and described by van der Burg and van de Poel (2005). Whereas AGORA-net is a tool for the presentation of arguments in graphical form for all sorts of purposes, Agora focuses on the integration of ethical theories and codes of ethics in case-based engineering education. It provides theories, codes, cases, and exercises, and it offers templates and hints that structure user input in the form of texts.

Traditional engineering ethics courses normally focus on the major concepts, cases, and problems in engineering ethics and introduce students to professional codes of ethics and to theoretical approaches to ethical decision making. We call this the "content side" of engineering ethics education; it refers to the convincing assumption that certain core content and materials about ethics should be covered within the engineering curriculum.

However, there is another side that might be more important when it comes to the complexities of the real-life situations students will encounter after graduation. These real-life situations require, first of all, certain skills and abilities. We call this the "skill side" of engineering ethics education. The new approach to teaching engineering ethics that we are in the process of developing will focus primarily on two skills: first, the ability to cope with complexity and ill-structured problems and second, the ability to collaborate in teams.

While there is general agreement that the experience of team work, problem-based learning (PBL), and developing the skills necessary to cope with problems of communication is crucial for the education of future generations, realizing these goals in practice can be problematic. Research on PBL in small groups has shown that collaboration in these settings works only when it is supported and guided by an experienced facilitator. "The facilitator helps monitor group discussions, guides students in the learning process, pushes them to think deeply, and models the kinds of questions that students need to be asking themselves" (Hmelo-Silver and Barrows 2008). The PBL approach, for example, that has been implemented by the Department of Biomedical Engineering at Georgia Tech pairs each group of six to eight students with a facilitator (Newstetter 2006). This means that PBL environments can be much more resource intensive than traditional instruction. In times of limited resources, this poses a serious threat to the quality of ethics education.

The AGORA-net approach addresses this problem by providing a web-based software application called "AGORA-net: Participate – Deliberate!". The AGORA-net software guides the activities of small groups of students (about four students per group) who collaborate on challenging problems and cases. The guidance and "scaffolding" provided by the software allows the integration of an AGORA-net component in classes without the need of facilitators; an instructor who is familiar with the AGORA-net approach will be sufficient to organize this innovative learning experience and to support the groups.

The key idea of the AGORA-net approach is to confront small groups with the task of identifying and reconstructing different stakeholder positions on a challenging and controversial case and to defend these positions in a graphically represented argument map by means of the interactive AGORA-net software. The software guides students step by step through a process of argument mapping. In contrast to other Computer Supported Argument Visualization tools (CSAV tools), AGORA-net is specifically designed to direct and guide students' activities and collaboration in small, independent learning groups. The software provides the sort of guidance and scaffolding that otherwise a facilitator would need to contribute. Thus, AGORA-net can overcome the problems of existing CSAV tools that have been identified in previous research.[4]

[4] Hoffmann (2007, 2008). See also Carr (2003) and Bell (2004). With regard to the function of CSAV to enable students to cope with ill-structured problems, see Andriessen et al. (2003); Conklin (2003); Kirschner et al. (2003); Okada et al. (2008); and van Gelder et al. (2004).

Under our proposed framework, an engineering ethics course could be structured in two parallel tracks. This is based on a teaching schedule with two class meetings per week so that each track is mainly realized on the same day of the week. In this setting, one track focuses on content issues, the other on skills that will be acquired in project work. Whereas the content track focuses, in the beginning of the semester, on ethical theories, codes of ethics, and ethical terminology which the students will need for the projects, the initial stages of the skill track provides opportunities to become familiar with the AGORA software and learn how to map the structure of simple arguments.[5] The guidance that the software provides is mainly achieved by the fact that it supports only the construction of logically valid arguments. That means, however, that students will need training in argument mapping.

Students then confront an open-ended problem in a homework reading and have the task of imagining possible stakeholder perspectives and their respective justifications. Preliminary testing of the approach has taken place since the fall of 2011 in five 3-credit hour courses offered by Dr. Michael Hoffmann.[6] In these courses, one of the tasks was to answer the question whether it would be appropriate to bring an extinct species such as Neanderthals back to life (Saletan 2008). The framing of this particular problem derives directly from a colleague's work.[7] As a result of the lessons learned during these courses, we suggest structuring a student project assignment in the following manner:

1) Students read a case description that is accompanied with a set of tasks which they have to submit as a homework assignment before they come to class. This is to help ensure that each student prepares for the project. During the project, students are encouraged to search for additional materials and to prepare it for the group work. In our example, the hypothetical situation refers to the possibility that a research group in the state might soon be able to bring a Neanderthal to life from DNA fragments. The students would have to create a list of people (individuals or groups) who are affected by this research in one way or another, and to imagine one or more distinct positions that each of these "stakeholders" in this issue might formulate. Positions have to be formulated as normative statements, that is, as statements that say very specifically what *should* be done.

2) In class, students collaborate in small groups (e.g., four members). Each group produces a shared list of stakeholders and their possible positions. In a test run during fall 2012, for example, students listed stakeholders such as scientists, the public, the state government, animal and human rights activists, religious people, and the Neanderthals themselves. Then the groups formulate for each stakeholder a certain position on the possibility to

[5] Tasks for training with comments for instructors are available in Hoffmann (2011). Instructors are invited to contact the first author of this article to become a member of the AGORA-project "AGORA instructors" where exemplary solutions can be found.

[6] Before that, Dr. Hoffmann taught approximately ten courses in which students used the freely available concept mapping software Cmap (http://cmap.ihmc.us/) to perform "Logical Argument Mapping (LAM)" in similar, project-based settings. LAM presupposes that students learn the basics of propositional logic. This is no longer necessary since the rules on which LAM is based are implemented in the AGORA software. A first AGORA-based version of an Engineering Ethics class was taught simultaneously at the Georgia Institute of Technology and at Bauman Moscow State Technical University in the fall of 2011.

[7] The Neanderthal problem was created by the research team for a recently concluded grant project. Dr. Roberta M. Berry, Georgia Institute of Technology, served as the principal investigator and the project title was "Ethically Contentious Research and Innovation: An Interdisciplinary and Inter-institutional Experiment in Ethics Education and Assessment," NSF EESE Program, Award ID SES-0832912. The Neanderthal problem and four other "fractious problems" created for the project are available at the University of Illinois Ethics CORE (Collaborative Online Resource Environment) <http://nationalethicscenter.org/resources/808>.

recreate a Neanderthal, reflecting these stakeholders' interests, values, and belief systems. According to one group, for instance, scientists could argue for the position "bringing Neanderthals to life should be allowed." Animal and human rights activists, proposed another group, would argue, by contrast, that "the Neanderthal should not be brought to life," while religious people might argue—as yet another group suggested—that "there should be no research on bringing Neanderthals to life."

3) The center piece of the project is then to construct an argument for each of the stakeholder positions by means of the interactive argument visualization software AGORA-net. This could take two or more class meetings. At least one computer with an internet connection must be available for each group. Since the software allows synchronous online collaboration, students can work from their own computers on the same argument map. All maps are stored on the AGORA-net server, but they are parts of "Class Projects" to which only members have access. Maps can also be published in the system for everybody to see and contribute. In this phase of the project it is crucial that the instructor provides detailed feedback to the groups. As a "member" of each AGORA project, the instructor will have access to all of the student maps. Feedback should be provided in two forms. First, in between the class meetings the instructor can insert "objections" or "comments" to specific premises in the argument maps. Since in AGORA-net all arguments are constructed in logically valid form, there is in every argument one premise, called the "enabler" (see below), that represents the relation between the reasons provided and the conclusion. The instructor has to focus especially on the acceptability of this enabler, because this premise is about the relation between reasons and conclusion. A second way is to go from group to group, ask them what they are doing, and then provide advice. Here it should be important to encourage students to justify normative statements by ethical principles and theories, and factual statements by scientific evidence.

4) After completing a set of argument maps in class—and outside, if necessary—the groups present their argument maps in class, followed by a class discussion. Depending on the class size, the presentations will take several class sessions. In the past, groups were given twenty minutes to present and discuss their results but this will not be enough time if the groups present a larger number of argument maps (maps can be very large and sophisticated, because the main challenge for the students is to defend a main argument by further arguments for the reasons provided, and so on).

5) After the presentations, the groups are given the opportunity to revise their argument maps based on the feedback that they receive in the discussion and submit it for grading (argument maps can be exported as pdf files). Since all of the groups are working on the same schedule, they have to collaborate outside of class on the maps if they need additional time.

How to Create an AGORA Argument Map

The process of creating an argument map always starts with a prompt by the software to enter the main claim of an argument (e.g., "we should study today"). Then users are asked to provide a reason that supports this claim (e.g., "we want to earn a good grade"). After that, the AGORA software offers a selection of logical argument schemes, such as *modus ponens* or *modus tollens*, which structure the connection between the claim and the supporting reason in a logically valid way. After selecting a scheme and a corresponding language form, such as “if-then” for *modus ponens*, the software automatically completes a logically valid argument (see Figure 1; the premise underneath the “therefore” is always automatically created by the software based on user input; it is called the “enabler” because it “enables” the reasons provided to guarantee the truth of the conclusion if all the premises are true—including the enabler—as it is characteristic for logically valid arguments). The software then motivates students to offer additional reasons to support the initial claim or a previously stated reason. It also gives others who are viewing the argument map the ability to refute those reasons and offer counterarguments. (After clicking on the white triangle at the bottom of text boxes in Figure 1, a navigation bar appears that allows the user to “Add…” different things).

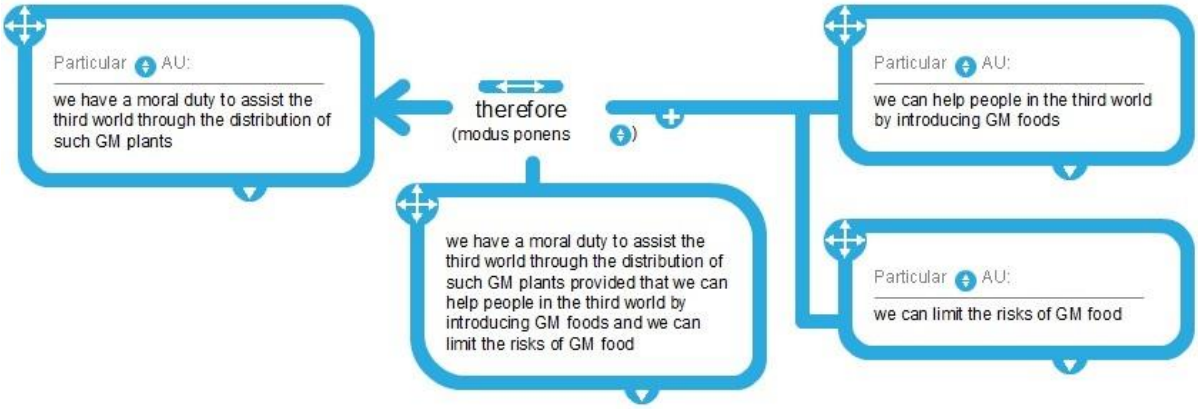

Figure 1: An excerpt of an AGORA-net argument map that has been created by a small group of students based on an article written by Lucy Carter, titled “A Case for a Duty to Feed the Hungry: GM Plants and the Third World” (Carter 2007).[8] *This is from a project on genetically modified crops in which stakeholder positions and arguments were provided in the form of readings. Note that in this argument map the two reasons on the right are presented as mutually dependent, that is: both are necessary to guarantee the truth of the conclusion. A critical reflection on this argument in class should highlight the fact that in this case the ethical principle in the conclusion is a deontological principle (“duty”) which is justified by what seems to be a utilitarian principle. This utilitarian principle is expressed in the argument’s “enabler” underneath the “therefore.” The enabler is often the place where ethical principles or values become visible.*

A significant part of the complexity of ill-structured problems is identifying who the stakeholders even are, and for some engineering ethics problems this can be a very difficult task to accomplish. Due to the nature and complexity of these problems, students have a fair amount of creative freedom at their disposal and could potentially focus on various different facets of the issue at hand in their argument maps. For example, the foremost concern for some students might be to discuss the empirical studies that have a bearing on the topic at hand; others might more consistently discuss considerations that are more explicitly ethical in nature. The variability that one might see in the students’ argument maps can occur in part due to the fluidity of the process, especially as they are grappling with an ill-structured

[8] Reproduced here with the permission of Erik Robbins, Romeo Cabanban, and Darren Samuel Harris.

problem. What the students decide to emphasize will likely be highly influenced by their discipline of study, how the other students react to the argument that is presented, and how the course instructor frames the assignment. Relating to the last point, it is important that the instructor place significant emphasis on ethical principles and concepts during the content portion of the course and while explaining the guidelines for the argument map assignment in order to increase the chances that ethical considerations will play a prominent role in a resulting map.

AGORA-net and the Ethics of Resurrecting Extinct Species

To more concretely illustrate how the AGORA software can be used for ill-structured problems, we describe in this section how two groups of students in a recently taught engineering ethics class "mapped" the argumentations of two conflicting stakeholder positions about the ethics of bringing Neanderthals back to life. Figure 2 depicts one of two main arguments that a group had for a position which scientists themselves might embrace. The group defended the reason on the right by further arguments (which are not shown here). The entire argument map contains about 50 text boxes.

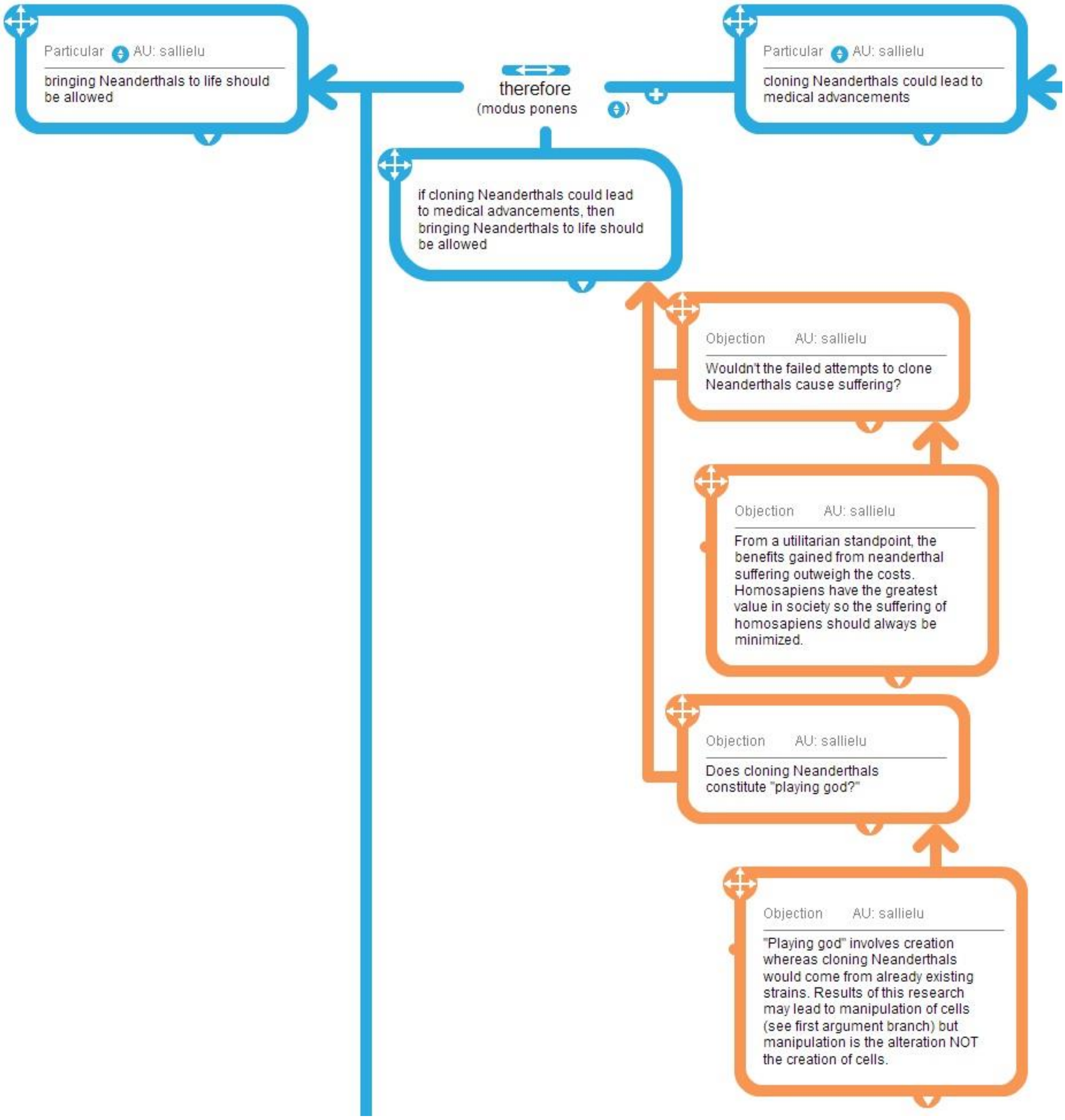

Figure 2: In this excerpt of an AGORA-net argument map the students considered two possible objections against their argument and defeated each by a counter-argument to strengthen the position. This map has been reproduced with the permission of Sallie Lu, Rajitha Siyasena, and two students who preferred to remain anonymous.

Figure 3 shows the main argument of what the group constructing it called the position of a "human rights activist." The reasons are again defended by further arguments. The argument for the third reason, which says that "it cannot be guaranteed that the Neanderthal's rights would not be violated" is represented in Figure 4. The entire map includes about 40 text boxes.

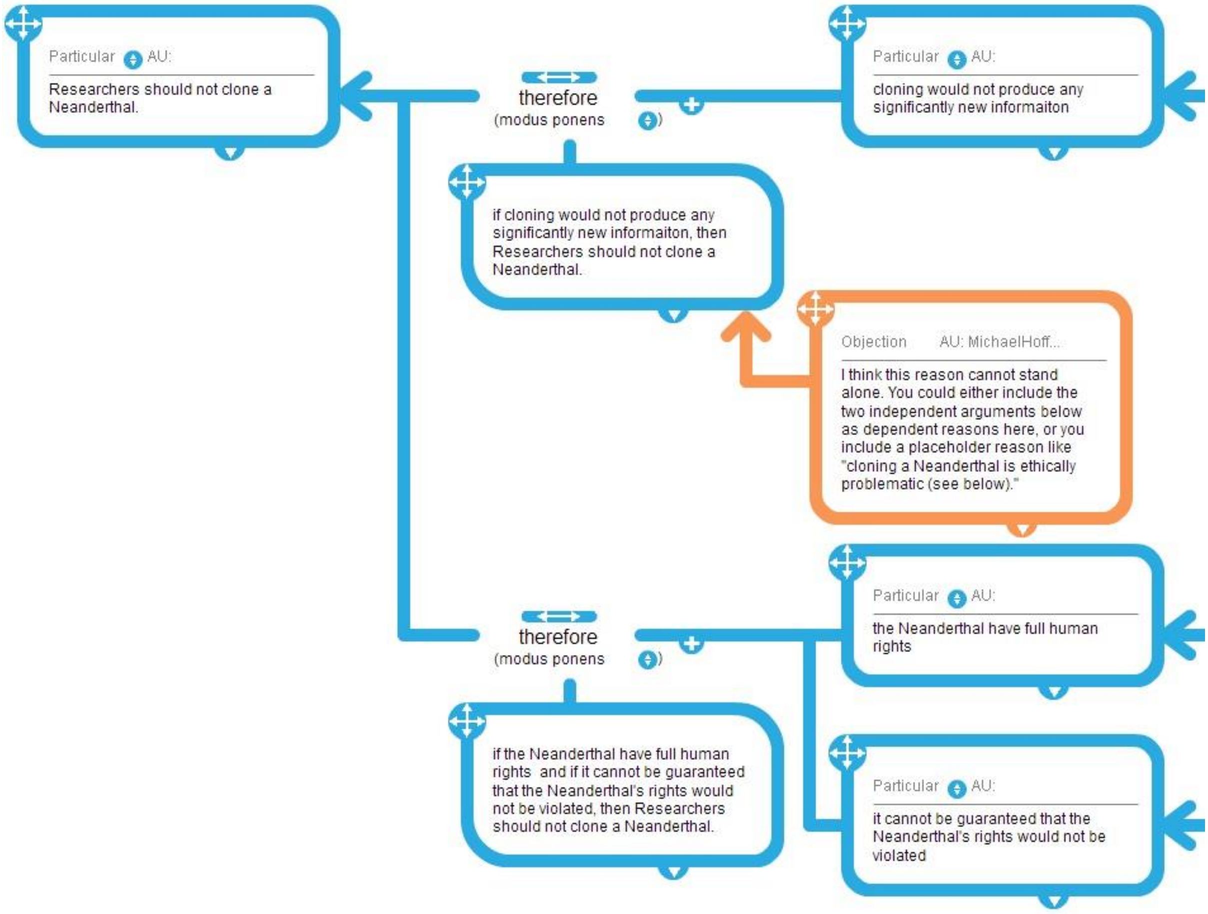

Figure 3: This group argued for a position as it might be proposed by human rights activists. The objection has been formulated by the instructor. This and the following map have been reproduced with the permission of Kim-Quyen Thi Tran, Robert DePietro, Thomas Pilliod, and one student who preferred to remain anonymous.

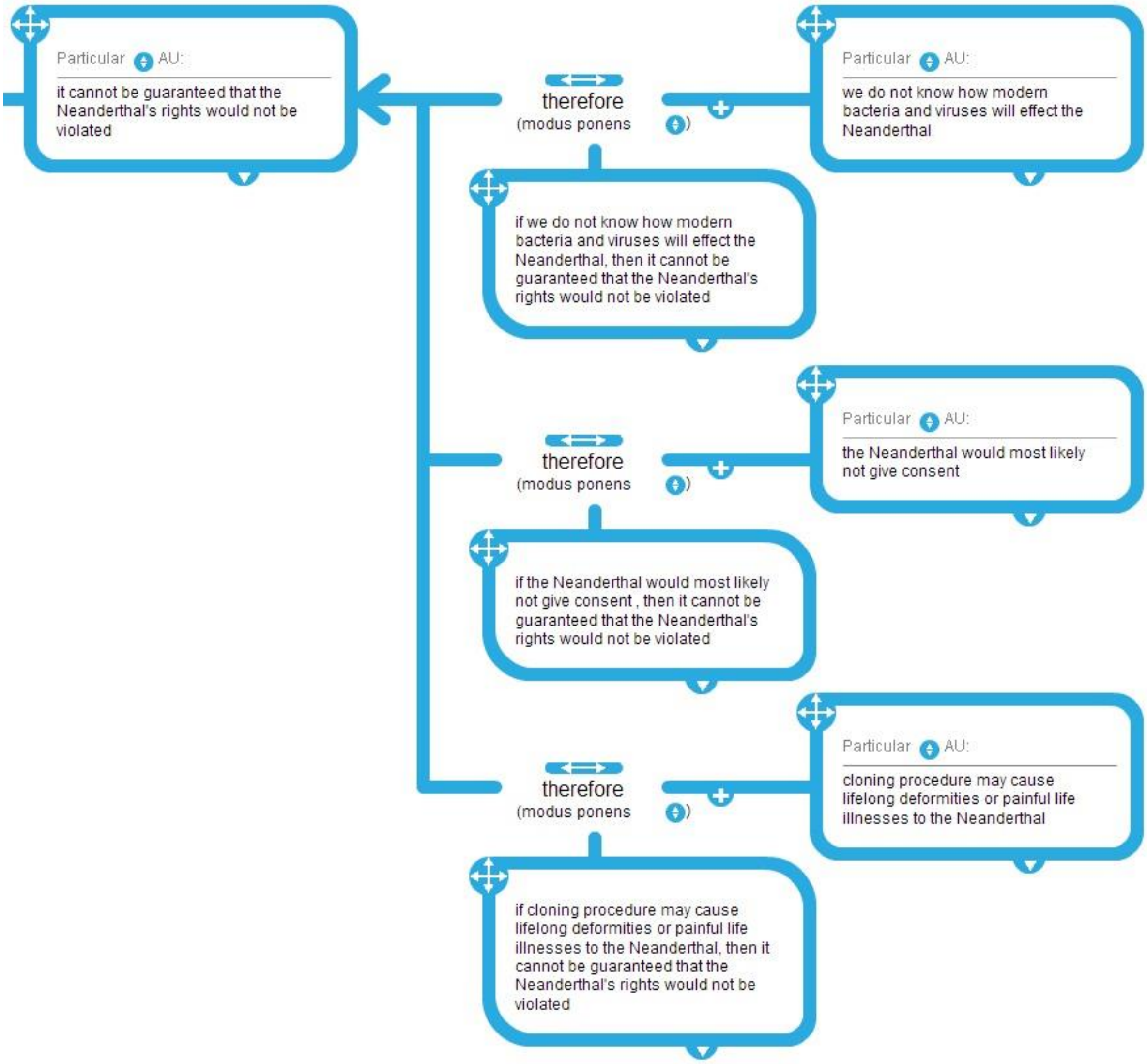

Figure 4: This excerpt shows how the group that constructed the map in Figure 3 justified the reason at the bottom of Figure 3 by three independent arguments. Each of them is again defended by further arguments (which have not been reproduced here).

The class discussion resulting from these and other argument maps focused extensively on questions such as whether a Neanderthal is entitled to rights; what the risks of resurrections could be; whether suffering in both successful and unsuccessful experiments could be justified from a human or animal rights point of view; what the benefits for science could be; and whether a utilitarian or deontological (rights-based) strategy of ethical argument should be applied.

The argument maps and the discussions demonstrated the complexity and multi-perspectivity of the problem. Students seemingly came to the realization that the overall problem cannot be sufficiently grasped from one vantage point alone. And they seemed to appreciate that ethical responsibility can only be achieved when their own point of view is seen in comparison with other perspectives whose legitimacy became visible in the argument maps presented.

Collaborative argument mapping with the AGORA software, as it turns out, can be a successful strategy to structure and organize peer-to-peer learning about ill-structured problems. This could help students to develop the skills that are necessary to cope with these problems, even in situations where a clear "solution" cannot be achieved. From an ethical point of view it should always be a first step to understand the needs, interests, concerns, values, and belief-systems of all those that are involved, either directly or indirectly, by a certain decision or project. Students need to realize that the ethical dimensions of real-life problems cannot be seen if their own frame of reference is limited to one stakeholder's point of view. Moreover, as students make their own implicit assumptions visible to themselves and to others in the form of an argument map, the hope is that their reasoning about complex engineering ethics issues will become more sophisticated as a result. However, given that undergraduate students, including those in engineering programs, may lack familiarity with ethical concepts and principles, they may need a fair amount of guidance and coaching from their instructors before ethical considerations are going to appear in their arguments.

Conclusion

In many engineering ethics courses, a typical strategy is to give students hypothetical and historical cases with an ethical problem that is fairly clear and which has a solution that is rather intuitive. However, in order for students to develop necessary skills, ill-structured problems should be more fully integrated into these courses. In this paper, we describe one way of accomplishing this goal through the use of the web-based tool called AGORA-net. The overarching hope is that this will enable students to grapple with messy and complex problems, ones that require creative and critical thinking.

The AGORA-net learning approach aims to help students understand the justifications of a multitude of stakeholder positions through projects in which they reconstruct these justifications in the form of graphically represented logical argument maps. Argument mapping in problem-based learning environments provides an exciting opportunity for students to develop critical thinking skills and the ability to collaborate in teams. But first of all, they provide an opportunity to experience the multi-perspectivity of ill-structured problems, the limitations of one's own point of view, the need to identify involved stakeholders, and to understand their varying perspectives, sensitivities, and values. Such an understanding becomes possible when the legitimacy of stakeholder perspectives is visualized in an argument map. Discussing those arguments in class provides an opportunity to enter a reasoned dialogue about possible perspectives on an ill-structured problem, and to develop the sort of sensitivity that is crucial for making ethical decisions.

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