EVERYTHING YOU WANT TO KNOW AND NEVER DARED TO ASK — A PRACTICAL APPROACH TO EMPLOYING CHALLENGE-BASED LEARNING IN ENGINEERING ETHICS

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ABSTRACT

Challenge-based learning (CBL) for engineering ethics tasks students with identifying ethical challenges in cooperation with an external partner, e.g., a technology company. As many best-practice parameters of such courses remain unclear, this contribution focuses on a teacher-centric introduction into deploying CBL for engineering ethics. Taking Goodlad's curriculum typology as a point of departure, we discuss practical issues in devising, maintaining and evaluating CBL courses for engineering ethics both in terms of the temporal dimension (before, during and after the course) as well as in terms of the people involved. We will discuss selecting learning objectives, forms of knowledge acquisition, supporting self-organization, and fostering discursive etiquette, as well as cooperative, yet critical attitudes. Additionally, we will delve into strategic

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matters, e.g., ways to approach potential external partners and maintain fruitful cooperations.

1 INTRODUCTION

Conceptualizing, establishing and maintaining courses that draw upon innovative educational concepts, such as problem- or challenge-based learning (PBL/CBL), requires a host of separate and intertwined decisions geared towards adapting all course parameters to local conditions, such as student clientele and resources available. At least to some degree, deciding upon appropriate learning objectives also often lies at the discretion of the teaching staff responsible. If desired learning outcomes are set, the primary guide behind particular decisions on course parameters usually focuses on how to aid students in reaching these objectives, typically in trade-offs concerning the efficient utilization of resources such as time available to teaching staff, facilities and technical equipment. However, while much is being reported on the educational concepts themselves, details on their implementation to accommodate and account for local conditions is rarely addressed. The present contribution tries to fill this gap based on experience obtained in implementing two challenge-based engineering ethics courses in different universities. Accordingly, we would like to contribute to the field of higher engineering ethics education utilizing CBL approaches by highlighting practical issues that one might face and how to possibly address them. We will offer arguments and experience-based insights from several iterations of and discussions about our courses. The remainder of this contribution is structured as follows. We will first briefly introduce the concept of CBL and its use in engineering ethics courses in higher education. In reference to Goodlad's curriculum topology [1] we will then proceed to tackle relevant aspects before, during and after the course.

2 BACKGROUND

2.1 Challenge-Based Learning

Challenge-based learning lets learners collaboratively define their own challenges based on real-life problems [2]. Students work on challenges under guidance of lecturers and external stakeholders, reflect on them and—if possible—solve them. The starting point is usually an overarching question, from which to derive more specific questions with regard to a self-imposed challenge. Challenge-based course designs typically incorporate public final presentations of student projects. This, e.g., achieves a multiplier effect, i.e., of conveying learnings, heightened awareness and the corresponding solution space also to the general public.

Challenge-based learning has mostly been deployed for teaching engineering development processes marking a shift away from pure knowledge acquisition towards focusing on application, cf. [3]. However, little experience has been gathered in different contexts. Especially its adoption to ethics is relatively new [4, 5]. The working hypothesis for the present contribution rests on the notion that—even though the activity takes place in a specific context, e.g., engineering—it also explicitly requires students to not exclusively identify solutions from a search space confined to

the disciplinary context. Instead, students are encouraged to think in inter- and transdisciplinary ways. E.g, technological solutions often might involve accompanying socio-technical solutions concerning work processes, communication strategies as well as a gradual implementation via inclusive participatory processes. Hence, CBL for engineering ethics can be perceived as a way of encouraging transdisciplinary education rather than purporting a disciplinary focus.

2.2 Two Dimensions of Managing Challenge-Based Courses: Time and People

For the purpose of communicating and reflecting upon course design choices, we adapt the curriculum typology of Goodlad, Klein and Tye [1], which distinguishes the ideal, formal, perceived, operational and experienced curriculum. These five aspects can be broadly construed as the dimension of time, which we will more simply structure into phases of before (or intended, as referring to the ideal and the formal planning), during (or implemented as referring to the course as perceived and operated by all involved) and after (as referring to the experience reflected upon as a whole including deducting next steps). The following sections will traverse this temporal dimension and will iterate through relevant considerations of lecturers in their interaction with students and external stakeholders. Goodlad originally considered also the educational institution and external stakeholders, while the latter refered to citizens and policy-makers [1]. However, due to space limitations we will focus on students and external stakeholders more closely in terms of the companies involved in the CBL course scheme to limit the scope, while we do not deny the significance of the institutional and societal perspective. Further, we will add considerations of operationalization to the experiential post-implementation phase.

3 BEFORE THE COURSE

The preparatory and planning phases in CBL courses involve extensive commitments of both lecturers and external stakeholders, while the students' ability to engage themselves in and adapt to CBL needs to be taken into account.

3.1 Lecturers

When designing CBL courses, a crucial question rests on the role the lecturers should (ideally)—but also are willing and able to (formally and practically)—assume: The ideal choice of role should reflect the pedagogic goal pursued. Its matching with the realities of resources available as well as local study conditions and culture, in turn, should instruct the formal planning. In terms of an ideal CBL approach, lecturers should be facilitators by providing an overarching question that students refine, derive a concrete challenge from, and develop a solution for.

However, lecturers must ask themselves whether they will be comfortable guiding through challenge-based coursework ad-hoc, or whether they will want to restrict both the scope and topics to be able to either resort to existing knowledge (bases) or read up on the issues beforehand. Besides skill, this is also a question of the time available both before and during the term, and the extent to which lecturers may indulge in producing preparatory material or be available for frequent counseling. The nature of

ethical inquiry in engineering makes these considerations central, as the case studies presented by the external stakeholders might incur vastly different socio-ethical and (socio-)technological aspects. Consequently, the amount and type of canonical knowledge to be presented to students during the term (if any) can—and probably will—largely influence the directions the student projects will take. To alleviate, one may develop an ever-increasing knowledge base and set of modules about specific ethical aspects to point out to student groups at an appropriate time.

A central question to consider is about student expectations and experience with both CBL course concepts and the subject matter of engineering ethics. If students are vastly unfamiliar with self-organized learning and CBL, significant overhead should be granted not only for conveying the general idea, but also for gaining familiarity with all modes of interaction, knowledge acquisition and handing in potential deliverables. If students are also unfamiliar with engineering ethics (which they most probably will, assuming there is only a single undergraduate engineering ethics course in the curriculum), they might be subjected to a doubly steep learning curve. Such general unfamiliarity might require lecturers to make significant concessions, e.g., by enveloping the CBL course concept within a more traditional lecture and exercise structure that might be more familiar to engineering students. For instance, the lecture material might consist of presentations with interactive discussions about a set of issues relevant to the stakeholder projects, traversing from the canonical to increasingly specific ones. Exercises could amount to weekly group meetings to reflect upon the lecture's content in relation to the project and to advance towards identifying a specific challenge. Furthermore, by adjusting the degree of freedom in identifying challenges, students could, e.g., be given initial pointers in varying degrees of specificity, or left with only a general explanation about the external stakeholders' technological case. In addition, by discussing both course organization and expected learning progress during the first few meetings of the course, the lecturers could, e.g., discuss previous case studies as examples from previous instances of the course.

Many more considerations need to be made, e.g., with respect to the number of lecturing staff available, and, hence, the attainable ratio between students and supervisors, lecturers' disciplinary specialties and modes of exchange among these.

3.2 External Stakeholders

The acquisition of external stakeholders willing to participate as real-world case studies in a CBL scheme is a delicate matter that involves a convincing communication strategy, expectation management, sensitivity regarding the stakeholders' corporate viewpoint and available resources as well as negotiations concerning the degree of influence exerted on the student projects. In terms of convincing stakeholders to participate, it may pay off to commit to a longer term partnership with a local business association that can lend its reputation for raising the interest of its members. Despite lacking the perspectives of larger enterprises, a start-up accelerator might make a good partner to regularly interest companies-in-the-making. In fact, the acquisition of start-ups as external stakeholders allows to perceive the interaction in CBL courses

as a partnership, avoiding prejudicial tropes of enterprises focused solely on maximizing return-of-investment. Since a start-up will not yet have the resources to perform in-depth ethical analyses, students can step in as agents for constructive and friendly criticism. With product development still in its infancy, students' conceptual contributions could allow for meaningful pivoting.

However, even though acquiring the participation of external stakeholders via partnering with a start-up accelerator may be elegant and convenient, this does not mean that fewer efforts need to be taken to understand and respect each potential stakeholder's corporate identity, viewpoint and needs. For instance, while regular meetings between students and stakeholders may be preferable, flexibility is needed to accommodate a stakeholder's resources. Similarly, stakeholders should be given some room for expressing and realizing their expectations: While ideally deciding upon the students' degree of freedom in choosing a particular challenge is a pedagogical question, stakeholders might want to direct attention towards their most pressing issues. At the same time, lecturers should not give rise to exaggerated expectations with regard to the students' final results. An honest communication about what to expect, including the possibility that weaker students might opt for a particular stakeholder's project resulting in weak outcomes, lays groundwork for a trusting relationship between lecturers and stakeholders.

4 DURING THE COURSE

Key aspects during course implementation concern management, roles and modes of interaction and the coordination of the project work.

4.1 Students

A crucial question for course management is the right combination of knowledge transfer and the CBL-approach: How can the course's schedule ensure that students are exposed to the right material at the right time during their project work? Two basic approaches as well as intermediates are conceivable: One may allow access to all material from the beginning, opening up the possibility of getting an overview over general topics and identifying potentially interesting aspects regarding the "stakeholder project" already in an early stage. Alternatively, topics and access/presentation order are designed to approach ethics from general issues (e.g., basics of moral philosophy, responsible research and innovation) to specifics (e.g., trust, privacy, algorithmic bias), taking into consideration that the material might be very new to students and requires a careful progression. A mixture of both in the sense of allowing quick tabulated overviews (e.g., date, type of lecture/tutorial, building/room, topic, requirements) and making more advanced material available upon request would also be conceivable. It should be considered that not only ethics input is required, but also input for project management (e.g., planning, collaboration, group dynamics) to achieve proper and successful project work.

Ongoing student-student and student-lecturer interaction needs to be carefully fostered. Our experience here shows, e.g., that regular feedback (graded assignments

or non-graded feedback sessions) maintains a high ratio of attendance and attention to the material. Interactions within student groups can be promoted by anticipating when lecturers may need to change roles from guiding instructor to accompanying affiliate and vice versa. Additionally, fostering an atmosphere of open exchange as well as cooperative and social learning, cf. [6], facilitates long-term motivation and commitment, e.g., by being upfront about etiquette or being inclusive by specifically encouraging students that tend to be silent[2]. Likewise, additional consulting to mitigate intermediate low motivation will likely be necessary. In addition to proposing creative methods to provide an enjoyable experience of ethical reflection, these may include highlighting the benefits of engineering ethics through real case studies and anecdotes, e.g., by demonstrating thought processes. It is also necessary to consider ways of ensuring a critical, yet friendly attitude of students towards external stakeholders. Continuous effort is needed to respond to attitudes and to encourage students to speak freely and not feel intimidated. Identifying challenges also may imply that stakeholders will (typically) develop defensive argumentation and—at first glance—they may often succeed. Students might need further encouragement to follow up on their early argumentation by highlighting that the stakeholder's initial deflection may only be valid from a business perspective.

During the course, efforts required to support the students' project work in terms of content, coordination and acquiring specific competences (argumentation, reflection, communication, presentation) should not be underestimated. This kind of support scaffolding is an open process, involving many supportive discussions and careful observations to determine what additional activities may help. While tasks such as developing posters to connect lecture contents with stakeholder projects seem to foster creative thinking, argumentative skills may be better developed via written exercises, or enacting debates in role-playing—but all of them require feedback and, ideally, educational material as a reference. It should be taken into account, however, that each student project group needs an individual level of supervision in its project management. Hence, the effort required for supervision can and will vary.

4.2 External Stakeholders

The interaction with external stakeholders requires constant attention for aligning business interests, student interests and capabilities as well as intended learning outcomes. Among other things, this requires to take into account and balance the desire of the external stakeholders to gain new insights within a solution-oriented frame for ethical analysis, at times highly inconsistent student motivation and capabilities as well as the pedagogical premise that ethical challenges need to be identified independently by the students. Additionally, stakeholders are usually short on time, but while students progress, they typically would like to inquire more frequently and more deeply. Primarily though, lecturers need to aid in converging perspectives by both pushing the envelope in terms of what businesses might assess

[2] *In addition, the experiences of CBL during the pandemic, such as diminished interaction, may be addressed. However, an exhaustive consideration goes beyond the scope of this paper.*

as responsibilities they might realistically assume as well as by asking the students to turn critical assessments into actionable plans for improvement.

For this purpose, the interaction of stakeholders and lecturers occurs on two levels: First, a bilateral dialog between lecturers and stakeholders allows the management of expectations and sharing assessments to inform the stakeholders about the actual progress of the project. This as well offers the option to personally intervene if there are any communicative misgivings and challenges, e.g., it may be appropriate to evoke sympathy for struggling students. Second, during the meetings that include all partners (stakeholders, students and lecturers), besides enabling the critical yet friendly attitude of the students, lecturers might need to assume the roles of arbiters, striking compromise between the students' theoretical demands and business realities. In that regard, concepts from ethics might also be novel to the stakeholders, which requires lecturers to support student explanations, but also to continuously argue for why ethics is relevant on a business and societal level.

5 AFTER THE COURSE

After the course, the lecturers' tasks are often strategic and need to focus on sustaining and perhaps even institutionalizing the CBL concept.

5.1 Students

A great strength of CBL is that the students' learning progress can be observed quite transparently. For instance, the quality of regular assignments (such as poster slides on the reflection of engineering ethics topics in the context of a stakeholder project) can be continually assessed in terms of learning outcomes, argumentative skills, etc.. In contrast to conventional teaching approaches such as lectures or seminars with discussion elements, here the steady progress of student work can be tracked.

In engineering ethics, grading is an act of balancing expectations given that this is typically the students' first encounter with ethics. This makes it crucial to clearly communicate requirements by providing grading rubrics, e.g., in terms of clarity and structure, showcasing comprehension and use of literature as well as critical independence and relevance. Detailed and structured feedback will contribute to student learning. Grading group work always carries the risk of allowing free-riding, but transparent grading schemes involving a weighted averaging of individual and group performances can keep the need for discretionary decisions at a minimum.

Student work is subject to privacy regulations, but if students allow, work can be forwarded to the external stakeholders. After completion of the course, further interactions between students and stakeholders may be encouraged, e.g., as a possible opportunity for employment. Students having shown particularly good performance may also continue to be involved as teaching assistants or ambassadors for the same course in the next academic year. To present the results of the students' work to the outside world, public events can be organized. However, it should be noted that the more time passes, the more difficult it can be to motivate students to

participate actively. Hence, early on, plans should be communicated and an informal, or even formal, contact to a group of course graduates maintained.

5.2 External Stakeholders

Beyond university-wide platforms and support to engage with external stakeholders, individual lecturers in CBL must consider the steps they can take to ensure a sustained cooperation with stakeholders, or meta-organizations like, e.g., start-up accelerators. Extensive networking and forming a visibility of the group of lecturers committed to CBL appears to be of the essence. This way, stakeholders can pinpoint their partners from university by brand—such as a specific or collective of research groups. In addition, more personal relations should be fostered, with lecturers showing genuine interest into the effects student projects may have had on the external stakeholders' work. Ideally, a successful consideration of student output by a stakeholder is openly and clearly communicated to the students, lecturers and even higher-level university representatives. Such communication could be institutionalized by establishing a CBL course-specific "landing page" that features news and project results, both as a means to advertise, acknowledge and maintain relations. For such an instrument, agreements about the extent to which information on both student progress and case studies may be published need to be made.

A prospect for stakeholders to continue relations is viewing CBL courses as a pool for future talent. Ethics CBL courses may appear less suitable, as students are tasked to showcase their ethics more so than their engineering prowess. As the students' ethical analyses might well include highly critical stances, sustained relations are likely to only be possible with stakeholders that prioritize open discourse over managing reputation. However, economical success often appears to strongly benefit from the later, which makes managing relations a delicate task.

6 CONCLUSION

With this contribution, we have provided an extensive list of considerations for conceptualizing and establishing, maintaining and implementing as well as sustaining and further developing challenge-based courses in engineering ethics. We have been inspired by Goodlad's curriculum typology to structure our exposition according to the two dimensions of time and people under consideration, while we focused on what the lecturers responsible for the course need to take into account, may initiate and should act on. Since the prevailing circumstances at different institutions from higher education will vary significantly, we have formulated our contribution in terms of open-ended questions and considerations, highlighting exemplary choices and their corresponding reasoning where possible, but refrained from overly generalizing into a single or few correct choices. While our list of considerations may be extensive, it is by no means exhaustive and much more needs to be said about the potentialities of course design choices, management issues, an understanding of roles and means of interaction and stakeholder relations. We hope to have contributed to a discussion on these practical issues of conducting CBL engineering ethics courses.

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