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Between Flexibility And Relativism: How Students Deal With Uncertainty In Sustainability Challenges

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BETWEEN FLEXIBILITY AND RELATIVISM: HOW STUDENTS DEAL WITH UNCERTAINTY IN SUSTAINABILITY CHALLENGES

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ABSTRACT

Universities open their doors to society, inviting the complexity of the world to enter engineering education through challenge-based courses. While working on complex issues, engineering students learn to deal with different kinds of uncertainty: uncertainty about the dynamics of a real-world challenge, the knowledge gaps in the problem, or the conflicting perspectives amongst the people involved. Although we know from previous research that students are likely to encounter these uncertainties in sustainability challenges, which metacognitive strategies they use to deal with them is unclear.

We interviewed nine MSc students at the end of a challenge-based course at a Dutch university of technology. We asked the students how they dealt with uncertainty in collaboration with the commissioner, their student team, and the teachers. The interviews were analyzed through grounded, consensus-based coding by two researchers.

Preliminary results show students use three main strategies. First, the different perspectives from peers in their team inform the position of the student. Second, students find expectation management of the commissioner essential, yet students struggle with how to do this in a professional and timely way. Third, students frame the uncertainties they encounter as part of the learning process, which allows them to accept the possibility of failure.

This study provides first insights in metacognitive uncertainty strategies and suggests those strategies should become a more prominent topic in coaching students. When uncertainty becomes an explicit part of challenge-based education, students learn to deal with both the known and unknown in the transition to a sustainable society.

1 INTRODUCTION

Much of the future of engineering eduction lies in the ability of universities to respond to the sustainability challenges of the world (Sterling 2004). Although society has increasingly been aware of the dangers of global warming and the human contribution to it since the 1970s, the impact of sustainability on education is being described by scholars only since the start of this century. In the past two decades, the idea that higher education needs to change significantly to become sustainable has led to the investigation of new pedagogies and competencies for sustainable development (Thomas 2010).

The ability to deal with uncertainty is one of the competences in sustainable education that contributes to the development of new pedagogies (Ingold et al. 2018). The complexity of sustainablity challenges fosters three different kinds of uncertainty: the dynamics of a real-world challenge, the knowledge gaps in the problem, or the conflicting perspectives amongst the people involved (Brugnach et al. 2008). Those uncertainties and the strategies to deal with them are difficult to discuss or model in lectures, case-studies, or essays, they require students to gain

experience with the complexity of problems outside of the conventional learning environment (Wehrmann and Van den Bogaard 2019). Pedagogies such as challenge-based learning (CBL) allow students to practice with the uncertainties of open-ended sustainability challenges in real-life (Gallagher and Savage 2020).

Strong teacher guidance is crucial to the success of learning to deal with uncertainty in CBL. Because CBL relies on the self-directed learning of students, teachers scaffold the skills students need in the process of problem solving (Doulougeri et al. 2022). Previous research shows that if this is not done properly, these kind of problem-based learning environments have the risk of failing (Kirschner, Sweller, and Clark 2006). To provide guidance on uncertainty strategies, teachers require insights on how students recognize and approach uncertainty in CBL courses.

Although we know from previous research that students are likely to encounter uncertainties in CBL, which strategies they use to deal with them is unclear. In other words, we know *what* students are learning, but we do not know *how* they learn it. For teachers to be able to guide the complex process of learning in sustainability challenges, we need a better understanding of how students deal with uncertainty in challenge-based courses (Kirschner, Sweller, and Clark 2006).

In this qualitative study, we investigate the question: What uncertainties do students encounter when working on sustainability challenges and how do they deal with them? We interview nine MSc students at the end of a challenge-based course at a Dutch university of technology. The research is embedded in the theory of metacognition, which we shortly introduce in the next section (2). In section 3, we explain the analysis and coding process of the interviews. The results in section 4 first present the uncertainties students talk about in the interviews and then the three groups of strategies we found they use to deal with them. Finally, we discuss what the implications of this study on uncertainty are for the development of engineering education and sustainability education in the future.

2 THEORETICAL BACKGROUND

Sustainable education is not just about the accumulation of new knowledge, but also about the process of learning (Thomas 2010). Such knowledge about learning processes or, in other words, the awareness and control of one's own thinking is called 'metacognition' (Flavell 1979). Metacognition is a large field of study encompassing psychology and behavioral, learning, and cognitive sciences and our short discussion of the theoretical background here only offers a small glance at the literature.

Metacognition consists of two distinct, but connected elements: (1) the awareness and knowledge of the self and (2) the conscious control and regulation of cognition. Self-directed learning strategies, such as organizing information or asking help from peers, are metacognitive ways to control the process of thinking (Zimmerman 1989).

Uncertainty arises from what we do not know, whether this is because knowledge is not available, contested, or unpredictable (Brugnach et al. 2008). Therefore, to be

able to recognize uncertainty, students need to be aware of the limits of their own knowledge. This requires at least the first element of metacognition: awareness of one's own knowledge. Then, to deal with uncertainty students need to be able to self-regulate their learning, while taking into account what they do not know. To the best of our knowledge, a study investigating specific metacognitive strategies to deal with uncertainty in sustainable education has not been done before.

3 METHODOLOGY

3.1 Case study

We researched student experiences on uncertainty in a challenge-based course for urban sustainability at a university of technology. The 24 ECTS course is part of a two-year MSc program in the Netherlands. In the course, students work in groups of four or five students on a real-life challenge in urban sustainability. Each team is guided by both a coach from university, who offers academic expertise and assesses the students' work, and a commissioner from practice, who is providing the case.

3.2 Data collection and analysis

We conducted in-depth, semi-structured interviews with nine students, each from a different team. The students were selected by an open call amongst all student teams to participate in the research voluntarily. We analysed the answers to the question 'how did you deal with uncertainty during the course?' and the answers to the clarifying questions the researcher asked during the interview.

Two researchers coded the answers in a consensus-based coding process. In the first cycle of coding, the first author created the code book through open coding with 30 codes from 75 quotations. The second researcher used this code book for the second cycle of coding and added 8 codes. Those 38 codes were grouped in two categories: uncertainties (the things students found to be uncertain) and strategies (what they did to deal with those uncertainties). Quotations could have multiple codes, if, for instance, an uncertainty and a strategy to deal with that uncertainty were mentioned in the same sentence. Because of the small group of students in this study, we only present the codes that were mentioned by more than one student.

Table 1. Overview of the codes that were mentioned by more than two students in the interviews.

Code group	Code	Description
Uncertainties	Changes during the project	Through new insights during the project, the student would have made other decisions when looking back.
	Conflict commissioner	Challenges, tensions, or conflicts that arise from working with the commissioner.
	Unclarity assignment	Unclartiy about the expectations of assignments.
	Usefulness results	Uncertainty about the quality of the outcome and the usefulness for practice.
	Lack of knowledge	Student was unable to find certain answers or information.
	Expectations	Students are confronted with their own expectations of the course turning out different in reality.

	Unclarity roles	Searching for the position of the student or student team in collaboration with others.
Strategies	Attitude	Student describes dealing with uncertainty as a specific attitude towards not knowing (embracing uncertainty).
	Conversations commissioner	Talking to the commissioner about uncertainty (for instance in roles or differences in expectations).
	Conversations coach	Talking to the coache about uncertainty (for instance to clarify assignments).
	Conversations team	Discussing challenges with other team members to resolve them or get a better understanding of them.
	Acceptance of conflict	Accept that conflict can be part of the process.
	Learning process	Framing the uncertainties or challenges as a valuable part of the learning process.
	Persistency	Stick to the plan and convincing others of this direction.
	Understanding other perspectives	Empathy towards others that might have caused uncertainty.
	Acceptance of failure	Accept that certain knowledge is not available.
	Relativism	Student describes embracing or accepting the not knowing.
	Taking a break	Going home early or taking a walk.

4 RESULTS

4.1 Uncertainties

In the interviews, we found sixteen different uncertainties, seven of which were mentioned by more than one student (Fig. 1). The most often mentioned uncertainty was ‘changes during the project’ (7 times). As new insights arose while working on the challenges, it caused students to rethink their previous steps. Student 1 said:

> ‘If we had known beforehand that the commerical applicability of wood would not have been wortwhile to research, I think we would have focused much more on the reuse of material within the municipality. Because the entire financial motive [to research this] fell away.’ [1:16]

In this context, two students said they believed unpredictability was an inherent part of doing research. For example, student 6 said:

> ‘I know that it is alright not to know what direction the research is going, for whatever reason.’ [5:2]

The second most mentioned uncertainty students experience was about conflict with the commissioner (6 times). Also codes such as ‘unclarity roles’ and ‘expectations’ refer to uncertainty in collaboration with the partner from outside of the university. Especially at the start of the course, students said they struggled with managing the expectations of the commissioner and giving direction to the research.

Furthermore, students experienced uncertainty in the usefulness of the results for the commissioner (4 times). The applicability of the results in practice was an important goal to some of the students. Student 1:

> ‘In my case, the uncertainty was mostly the quality of the data and the applicability of the results.’ [1:1]

When students mentioned that the assignment was unclear (5 times), they talked about different assignments in the course. Student 7 said to experience stress because of unclarity on the assignments in all stages of the project.

> ‘At the start, we did not know what we had to do. In between, the uncertainty was about what we were going to make for the commissioner. At the end, we had difficulty deciding what to write down in the report.’ [6:3]

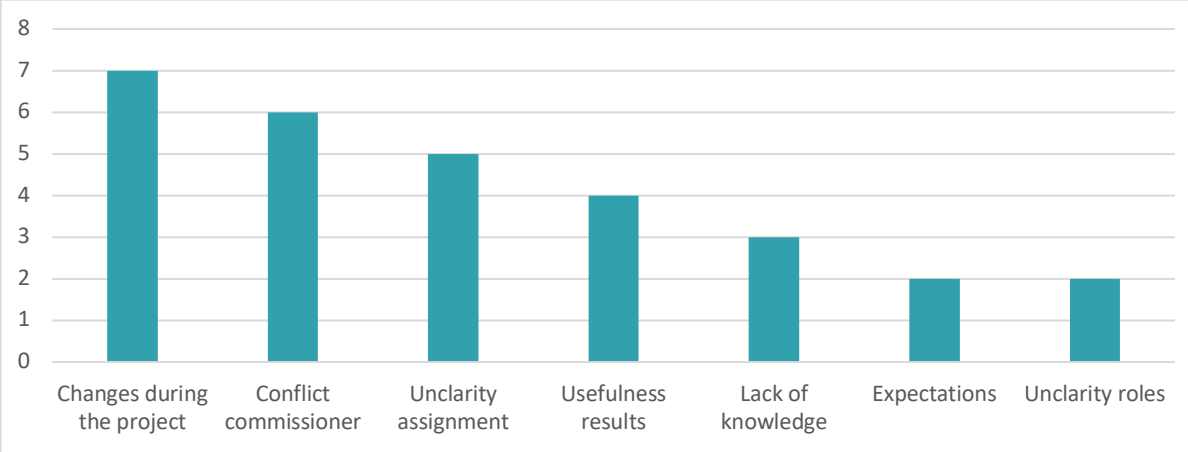

Fig. 1. Bar chart showing how often students mentioned specific uncertainties in the interviews.

4.2 Metacognitive strategies

Within the 22 coded strategies (Fig. 2), we found three groups: talking about uncertainty, developing a specific attitude to deal with uncertainty, and practical strategies for managing uncertainty.

First, the most prominent strategy to deal with uncertainty for the interviewed students was to talk about it, whether this was in conversations with the commissioner (6 times), coach (6 times), or their team members (5 times). Different uncertainties were resolved in those discussions. In conversations with the commissioner, students talked about the unclarity of roles in the process or managed expectations about the results. In conversations with the coach, students sought clarity on the assignments and avise on how to deal with their role and the role of the commissioner in the process. The conversations in the team were also about all these relational uncertainties, bus at the same time students also discussed uncertainties arising from tasks. Student 4, for example, said:

> ‘Especially from the moment we divided the tasks, if it was unclear to one of use how to proceed, we discussed together.’ [4:4]

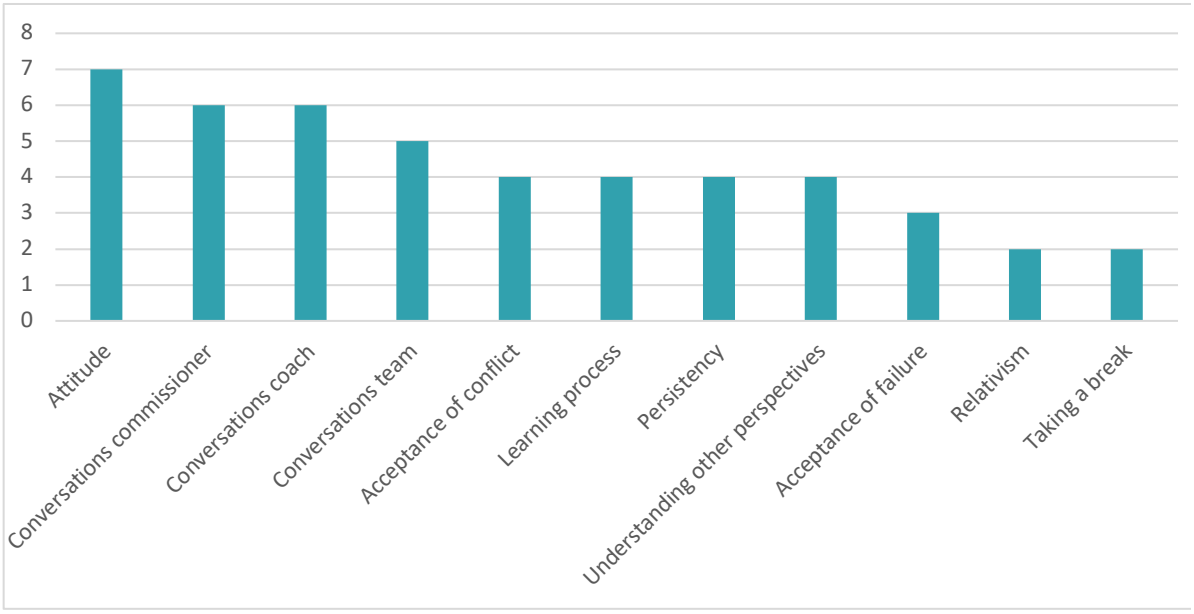

Fig. 2. Bar chart showing how often specific strategies to deal with uncertainty were mentioned by the students in the interviews.

Furthermore, students talk about their attitude towards uncertainty (7 times) as a way to deal with uncerainty. Student 3 said about embracing uncertainty:

> '[…] so part of dealing with it [the uncertainty] was also kind of letting go of the idea that you needed to know stuff before you could move on, or you could decide to just kind of accept it.' [9:2]

Similar to student 3, several students mention acceptance specifically as part of their strategy to deal with uncertainty, for instance, accepting the possibility of failure (3 times) or accepting that conflict is part of the process too (4 times). Two students said that failure or conflict were part of the learning process in the course. Another attitude towards uncertainty we found was 'relativism' (2 times), when a student doubts to what extent the world is knowable. Student 1 said:

> 'I'm quick in thinking, I don't know things, than all of it is nonsens.' [1:11]

One student described how the change in attitude led to different actions in the project:

> 'If you do not know the answer to something, you find a way to accept this and deal with it and find a different way to approach the problem.' [5:1]

Four times 'persistency' was mentioned as an attitude towards uncertainty. Those students describe how they tried to persuade others of their story, solution, or interpretation of the problem.

Finally, students mention several practical strategies to deal with uncertainty, such as taking a break (2 times) when feeling stuck or to ask for feedback (1 time). One student said to make use of examples of the reports from last year in the course to

deal with the unclarity of the assignment. Such metacognitive strategies are often related to uncertainty in specific tasks.

5 DISCUSSION AND CONCLUSION

5.1 Discussion

The unpredictability in sustainability challenges is one of the most common uncertainties to the students we interviewed. Brugnach et al. (2008) ascribe this to the complexity of the societal transitions that sometimes show non-linear and chaotic behavior. For them, accepting these dynamics as they are and embrace the notion that their unpredictability will not change in the foreseeable future is the way to deal with this kind of uncertainty. Attitudes accepting conflict and failure that the students in our study adopted correspond with this, yet were not the only attitudes students fostered towards uncertainty.

Students' attitudes towards uncertainty not only seem to be highly individual and personal, but also depending on the kind of uncertainty they are confronted with. Dealing with a lack of knowledge, because, for instance, data or people were not accessible, could lead to students responding with the flexibility to seek other approaches to achieve their goals or relativism, where students lost some of their confidence of what they were doing was still going to succeed.

'Seeking social assistance' is one of the self-regulated learning strategies defined by Zimmerman (1989) that is clearly recognizable in the results from our study as 'conversations with commissioner, coach, and peers'. At the same time, students perceive the collaboration with a commissioner as a source of uncertainty related to 'multiple knowledge frames' (Brugnach et al. 2008). The coach is only mentioned in relation to seeking strategies to deal with uncertainty but not a source of uncertainty itself. This shows that different roles within CBL also have a different function in the learning process.

Several authors have found explicit teaching of metacognition to be effective (Perry, Lundie, and Golder 2018; Muteti et al. 2021). Additionally, the instruction of teachers becomes more effective when those teachers are aware of the learning strategies of students (Newell et al. 2004). Therefore, metacognition in sustainable education seems to be a key area for further investigation in order for teachers to guide the process of choosing the right strategies.

5.2 Limitations and suggestions for future research

This study is limited by its explorative and qualitative character. The in-depth interviews that form the heart of the methodology are necessary to get to difficult to measure concepts such as uncertainty and attitude. However, the conclusions presented here should be seen in the context of a single case study in a graduate (MSc) programme, where students are relatively academically mature. Such an in-depth qualitative study with only nine students prepares qualitative and quantitative research on a larger scale. That research is necessary to present the metacognitive strategies we found with more clarity. Furthermore, research on how to explicitly

teach metacognitive strategies could offer support to teachers in their changing role as coach in CBL courses.

5.3 Conclusion

This study provides first insights in metacognitive uncertainty strategies used by students in challenge-based education. In nine in-depth interviews, we asked students which uncertainties they experienced in the sustainability challenge they worked on and how they dealt with those uncertainties.

The results show students use three main strategies. First, conversations with commissioners, coach, and their team members allow students to gain a better understanding of the uncertainty. Second, students develop different attitudes towards not knowing. Third, students use practical strategies, such as taking a break or asking for feedback, to deal with uncertainties related to specific tasks.

Although this study is small scale and more research is necessary to get a better understanding of uncertainty in the context of CBL, it underscores the importance of conversations between commissioners, coaches, and students as part of the learning process. Furthermore, the implications for engineering education based on this study are that dealing with uncertainty helps to grow selfawarenes and are very much dependend on the self-regulated learning strategies students employ. Ultimately, selfknowledge allows students to critically reflect on what they know, on what they don't know and, most importantly, on what they can know. It is the task of this generation of students to anticipate what knowledge is needed to make strategic next steps towards a sustainable society.

6 ACKNOWLEDGEMENTS

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