ANALYZING STUDENT-TEACHER INTERACTIONS IN CHALLENGE-BASED LEARNING

K.I. Doulougeri[1]
Eindhoven University of Technology
Eindhoven, the Netherlands
ORCID 0000-0001-6981-4529

J.D. Vermunt
Eindhoven University of Technology
Eindhoven, the Netherlands
ORCID 0000-0001-9110-4769

G. Bombaerts
Eindhoven University of Technology, the Netherlands
Eindhoven, the Netherlands
ORCID 0000-0002-8006-161

M. Bots
Eindhoven University of Technology, the Netherlands
Eindhoven, the Netherlands

Conference Key Areas: *Student Engagement, Fostering Engineering Education Research*
Keywords: *challenge-based learning, self-regulated learning, portfolio*

ABSTRACT

Challenge-based learning (CBL) exposes students to the complexities of open-ended and real-life challenges and encourages them to be in the lead of their learning. The role of teachers remains important but shifts from being the expert to the role of a coach who gradually scaffolds students into becoming independent learners. Accordingly, the interplay between teachers' and students' regulation of

[1] *Corresponding Author*
K.I Doulougeri
k.i.doulougeri@tue.nl

doi:10.5821/conference-9788412322262.1389

teaching and learning can result in friction and influence students' learning experience. This study explores incidents of constructive or destructive friction between student and teacher regulation during a 9-week CBL course for first-year engineering students. Thematic analysis is employed to identify critical incidents of friction during students' learning via analyzing students' weekly learning portfolios. Results suggest that students' experience in CBL is not linear, and there is a constant interplay between students' ability to regulate their learning and teachers' scaffolding. Initial exposure to CBL was characterized by friction in student and teacher interactions. Several students increased their self-regulated learning skills by resolving the initial friction by adopting a more proactive approach to their learning by actively asking questions and feedback from their teachers. The findings of this study are particularly relevant for CBL, where much attention is paid to students' autonomy, self-directedness, and collaboration. Building on the insights of this research, we make recommendations for further research and educational practice.

1 INTRODUCTION

Engineering universities are increasingly adopting active learning pedagogies to foster students' disciplinary and professional knowledge and skills [1]. Challenge-based Learning (CBL) is a pedagogical approach that engages students in learning knowledge and skills through open-ended and real-life challenges [2]-[5]. The concept of self-regulated learning (SRL) is central to CBL [2]. Learners in CBL are expected to show increased agency, autonomy, and self-directedness individually and as a group [3].

Given the self-directedness expected by students in CBL, the role of the teacher is different compared to traditional teaching approaches [2]. The teacher is viewed as a coach and subject expert who guides students toward self-regulated knowledge construction [2],[3].

Currently, little is known about students' SRL in CBL and teachers' role in this process. A recent systematic review on the implementation of CBL in engineering curricula highlighted that teachers have various roles in a CBL course. These include designing the challenge and developing learning material to provide students with theoretical input, coaching students and providing feedback, and assessing students' achievement in terms of competency development and project outcomes [6].

However, one of the main challenges experienced by teachers and students was the imbalance between expected SRL from students and teachers' provided guidance and scaffolding [6].

Thus the present study aims to assess how students experience the friction between their regulation of learning and teachers' regulation in CBL.

1.1 Theoretical framework: interaction between students' and teachers' regulation of learning

In CBL, students are expected to be in the lead of their learning [1]. Self-regulated learning is a process that describes how students manage their thoughts, behaviors, and emotions in order to successfully navigate their learning experiences and attain learning outcomes [7].

Vermunt and Verloop [8] identified three categories of learning functions that students engage in during a course. These include cognitive, meta-cognitive, and affective/motivational functions. Students engage in cognitive processing functions to process the subject matter, and those activities can directly lead to learning outcomes in terms of knowledge, understanding, and skills. Metacognitive regulation functions are those used by students to regulate and steer their learning processes and lead indirectly to learning outcomes. Finally, affective/motivational functions involve regulating emotions that arise during learning and lead to affective states that may influence students' learning process and progress in a positive, negative or neutral way.

SRL develops through the interaction between the student and the learning environment [9]. The role of the teacher is crucial in students' development of SRL and influences students' learning and motivation [8],[9]. The interplay between students' self-regulation and teachers' regulation can have various forms. For example, in complex learning environments, where the uncertainty and complexity of learning tasks are high, tension and friction can arise [9].

This friction can promote (constructive friction) or hinder (destructive friction) students' learning [9]. For example, constructive friction can occur when students experience the course requirements challenging enough but feel they have the necessary skills to match the requirements. On the other hand, destructive friction occurs when the learning environment does not provide support, but students have a problem in self-regulating their learning.

1.2 Research objectives

In this study, we aim to understand better how students regulate their learning in a CBL course and how they perceive their interaction with teachers in cases of friction. The research questions we formulated include:

- What incidents of friction do students experience in a CBL course?
- How does the interaction between students' and teachers' regulation in incidents of friction influence students' development of SRL?

2 METHODOLOGY

2.1 Context and participants

This study focuses on one CBL course, taking place in Eindhoven University of Technology. This course is part of the educational initiative E3 (Eindhoven

Engineering Education). The course E3-Challenge2 is a 10 ECTS course, with 5 ECTS on the ethics of technology and 5 ECTS on data analytics. The course took place during the academic year 2021-22 and it lasted 11 weeks. Forty-three first-year bachelor students from different engineering departments were enrolled. Students were asked to apply and contextualize the data analysis skills and ethical considerations to a real-life challenge related to smart grids, smart health, and smart mobility. Students in E3- Challenge 2 course worked in multidisciplinary groups consisting of 4-5 members.

2.2 Teaching and learning activities

SRL is a core principle of the E3- Challenge 2 course. Students were expected to be proactive and act autonomously, individually, and as a group. The course consisted of an interdisciplinary team of teaching staff (one ethics lecturer, one data analytics lecturer, three coaches, five expert generalists, and nine teaching assistants (TAs) supporting students in their learning process.

The course included different learning activities to support students' learning. The Ethics workshops brought in ethics materials and evoked ethics discussions. The teaching assistants provided feedback to student groups. Students could ask the remaining questions in the expert meeting and stakeholder meetings. An assigned coach met weekly with each group of 4 students for 30 minutes to discuss matters related to their professional development and individual and group learning process. Fig 1, provides an overview of a typical week of the course. To support students' self-regulated skills, students had to write at the end of every week a 1-page reflection on a learning experience that was important for them during the week and discuss their learning development with their assigned coach every week.

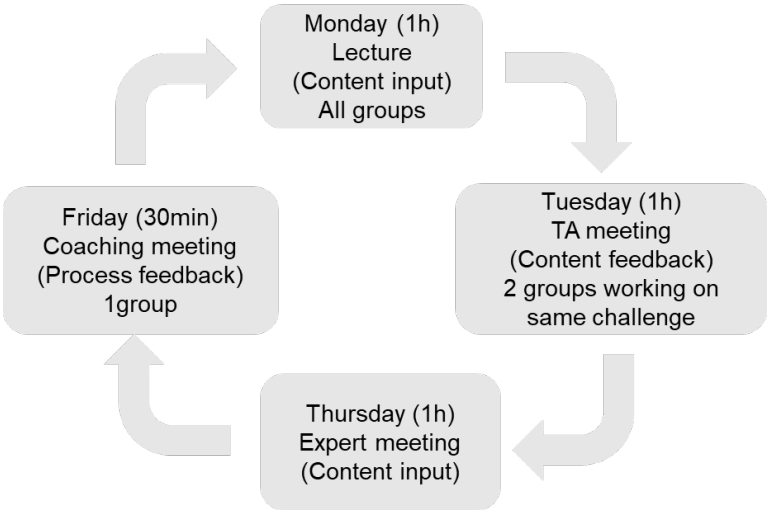

Fig. 1 Weekly cycle of learning activities in E3Challenge2

2.3 Data collection

Students participating in the Challenge-based course E3-Challenge 2 were invited to participate. Forty-three students participated in the course, and thirty-nine of them

have permitted us to use their weekly learning portfolios as input for this research. Each student's portfolio consisted of 9 weekly reflections and 1 final reflection, which resulted in 10 submissions per student and in total in 380 submissions, as some students skipped some submissions during the course. The Ethics Review Board of the University has approved this study.

2.4 Data analysis

Thematic analysis was used to identify, analyze, and report patterns within data [10]. Our analysis included a balance of deductive coding (derived from the theoretical framework developed by Vermunt and Verloop [8] and inductive coding (emerging from a student's portfolio). For the analysis, the portfolios were read, and emerging codes were assigned to segments independently by the first author. We identified 1) all incidents of friction where students described their interactions with the teaching staff, 2) identified learning functions that students described in those interactions, and 3) reported tecahers'regulation of the aforementioned learning functions. The data analysis was conducted using ATLAS.ti [10]. The main researcher analyzed all portfolios, and an auditing procedure among all researchers was conducted to discuss the results of the coding process.

3 RESULTS

3.1 Students' SRL through their weekly reflections

The portfolios provided a good way to assess students' skills in regulating their learning and their development throughout the course. For most students, the initial weeks were characterized by **a) uncertainty** related to the **content of the course** and how to apply ethics and data analytics in the challenge and **b) uncertainty** related to **the learning process** and how to navigate such an open-ended course individually and as a group.
Among the most frequently mentioned difficulties for students in the course included 1) establishing an understanding as to what is expected in the course 2) narrowing down the broad challenge to a specific problem to focus on and setting clear goals 3) applying content knowledge (ethics and data analytics) to the challenge 4) diving the tasks among group members 5) managing the time 6) managing group processes.

3.2 Incidents of student-teacher interactions

We analyzed 92 reported interactions between students and the teaching staff involved in the course. Students engaged with all teaching staff during the course, but interaction with teaching assistants was the most frequently mentioned (see Table 1).

Table 1. Summary of reported interactions between students and teaching staff

Student- Teacher interactions	N
Teaching Assistants	67
Coaches	13
Experts/lecturers	12
Total	92

3.3 Experienced friction in CBL

After carefully analyzing the 92 reported interactions, we identified sixty-six incidents that offered in-depth information about friction experienced by students**.** When analyzing the incidents of constructive and destructive friction, we identified which learning function students needed support with and what was teachers' regulation. Table 2 summarizes the most important

Table 2. Reported frequencies of learning functions and teachers' regulation activities as reported in students' weekly reflections

Learning function	N	Teacher regulation
Cognitive	89	• Feedback on reports, and presentations (N= 22) • Answering questions related to the challenge purpose (n=19) • Helping students narrow down the problem they had to tackle (N=9) • Providing support on data analysis or ethics applications (N=16) • Providing explanations of concepts/examples/ (N=9) • Teaching new concepts (N=9) • General discussion on topics related to ethics and ethics application (N=5)
Motivational/affective	10	• Dealing with students' frustration (N=6) • Dealing with students' lack of motivation (N=4)
Meta-cognitive	15	• Provide support in goal setting (N=7) • Provide support in the planning of tasks and activities (N=5) • Provide support/coaching on team functioning and task division (N=3)

The majority of incidents represented ***incidents of constructive friction***. They were related to a) perceived unclarity of the course in terms of what was expected from students and how to apply content knowledge and b) perceived lack of guidance by teachers. More specifically, the openness and freedom of the course were appreciated by students but in reality, in combination with the limited time frame, many of the students wished for more guidance and clarity on what they were expected to deliver.

We identified 89 references to ***cognitive functions*** where students received support from teaching assistants and experts/lecturers. The most frequent topic of interaction among students and teaching assistants or experts/ lecturers was asking for feedback on ongoing progress and deliverables or asking questions. Teachers supported students by asking questions, clarifying concepts, teaching new ones, and helping students with knowledge application. Support from experts and lecturers was experienced as helpful in learning.

> *I did not know where to start so I asked for help during the TA Session. TA and some fellow students explained the concept of business ethics and gave me the hint to start with writing down the vision of XXX. In that way, I could write an ethical issue based on XXX vision. This was a good tip that helped me to get started. Eventually, I wrote about how to protect the users' privacy and how to prevent discrimination when tracking the users' data because in my understanding, business ethics is about the rules a company has to follow to be ethically responsible. However, when finishing my first draft, I still doubted if I did implement business ethics in our report as it should be. Therefore, I asked [the ethics expert] for feedback (Student 1, Challenge A, week 5).*

When students reported difficulties related to ***motivation and metacognitive functions***, students discussed that with teaching assistants or the coaches. In these cases, teaching assistants and coaches provided support to students to make necessary changes in the working plans, discussed different ways to deal with team processes, set goals and make appropriate plans, and define all necessary tasks to be completed. For example, one student reported

> *My learning experience occurred during the coaching session: my teammate and I had a key discussion with our coach. We were explaining how confused we still felt about the course, not knowing clearly in which direction to move forward. We were suggested to take the initiative of choosing our own challenge, rather than waiting for precise instructions from the professors, as in most courses. This gave us the freedom to choose our own goals: we decided on two main objectives, one ethics-related and the other concerning the data analysis. As the week evolved, we gathered feedback from the experts about our ideas (Student 2, Challenge B, week 2)*

Teachers emphasized the importance of self-regulation, but many students, especially at the start of the course, were not capable of demonstrating SRL skills.

Incidents of destructive friction were mainly reported in the first few weeks due to perceived uncertainty and stress related to the course's overall aims and inability to go from a broad and vague challenge to defining a specific problem to tackle. Below is an example of destructive friction where students feel that their concerns about uncertainty are not addressed and that the provided set-up of the course does not meet their need for clarity and guidance.

> *This course started, though, because we were all so confused about the goal of the challenge and about what it was the client wanted from us. Therefore, the first two/three weeks were a bit unpleasant. We did not really like the set-up of the course, which resulted in less motivation for this course (at least this was the case for me). The TA and expert sessions were very time-consuming and not helpful (because we did not really have so much to share at those moments) (Student 4, Challenge C, week 4).*

Destructive friction was also experienced when students showed reluctance to share with their teachers their uncertainty and ask for guidance. Below, a student described an incident of destructive friction arising from his fear of asking questions.

> *During the coaching session, the question that was brought up was, "Why didn't you talk to the TA?". I find this question very difficult to answer, but the first answer that comes to mind (I also learned this is often the best one) is "respect". I always look up to teachers and TAs and they deserve a lot of respect in my opinion; that's why there was (and probably still is) some mental barrier that is stopping me from just reaching out and telling them my concerns or struggles (Student 3, Challenge B, week 3)*

3.4 Resolving the friction and development of SRL

Several students increased their self-regulated learning skills by resolving the initial friction and by adopting a more proactive approach to their learning. Students realized the importance of being proactive in asking questions to get better feedback, showing a proactive attitude as a group, spending time establishing a common understanding with other group members, and establishing teamwork processes early in the course.

> *The first week was intimidating in terms of the lack of structure provided by the organizers. The expected outcome was not clear, and I was expecting more input to proceed. However, this week I figured that this was not the right approach. During the TA Session, I stepped out of my comfort zone by asking questions and suggesting ideas without worrying about their quality of them. The improvement in my understanding was significant. I now have a direction,*

and I am aware that I will not be fed with the information that I need. This acknowledgment taught me to be confident in my opinions also when talking to authorities. (Student 4, Challenge B, week 2)

Final reflections were analyzed for references to students' interactions with teachers and SRL development. Students mentioned a positive overall experience with teachers as supportive during the course and they appreciated the multiple opportunities and sources of feedback they had on a weekly basis.

4 DISCUSSION

This study aimed to explore the student-teacher interactions reported in students' weekly portfolios in a CBL course. The role of teachers was very important, especially at the beginning of the course, when students needed more scaffolding in terms of content and working processes. The greatest need for support was related to students' cognitive functions, This finding can be explained because the content students had to learn as well as the challenge they had to tackle was new to them. On the other hand, students reported fewer incidents of interaction with teachers related to motivational/meta-cognitive functions by the teachers. This can be because students who selected this course were already intrinsically motivated and had prior experience with group work and planning group work from previous courses or because they relied on themselves and their peers to regulate those functions and did not expect teachers' support.
The majority of students gradually adopted a more proactive attitude by asking actively for help when things were unclear, going better prepared for meetings with teachers, and using the feedback more critically.
Within the duration of 11 weeks course, it is not possible to identify significant changes in students' SRL, but the portfolios revealed that students at the end of the course were much more aware of the proactive attitude students need to exhibit in CBL as well as how to make use of all the available resources.
To conclude, the interplay between teachers' regulation and students' self-regulation in CBL can be complex [11], [12]. Friction can arise especially if students have no prior experience with the increased autonomy that CBL entails. Given the autonomy and self-regulation expected from students, the role of teachers is also different compared to traditional teaching approaches [6]. The teacher in CBL is viewed more as a coach than an expert who guides students through the process [3], [5], [6]. The role of teachers in CBL courses is essential to reduce the gap between teaching and learning by providing the right amount of scaffolding and guidance by supporting cognitive, meta-cognitive, and motivational aspects of students' learning [12].

4.1 Recommendations for practice

The study suggests that SRL is important in CBL, but students need more support and scaffolding in regulating their learning, especially cognitive functions. Therefore, the study highlights the importance of teachers' role to support students' regulation of

learning via frequent feedback activities, especially at the early stages of learning [14]. Depending on students' educational level and prior experience with CBL, teachers should set clear boundaries in the project and within those boundaries adapt the amount of support and scaffolding they provide to students [12]
In addition, we found that reflective assignments can provide opportunities to dive deep into the processes that allow students to take control of their learning [13].

4.2 Limitations and Future directions for research

The study focused on a specific course, and the included sample was small. Thus more general conclusions can not be drawn. Another limitation of the study is the focus on SRL within the limited time of one course. In addition, learning in CBL is not only individual but also collaborative. Thus, other forms of regulation, which occur with a group of students, are also relevant and should be explored. Future studies should explore the influence and experiences of the aforementioned social types of regulation as well [15]

Acknowledgments

We thank all students of E3 Challenge 2 course (2021-22) for participating in our study

REFERENCES

[1] Tranquillo, J. (2017).The t-shaped engineer," *Journal of Engineering Education Transformations*, vol. 30, no. 4, pp. 12–24.

[2] Gallagher, S. E., & Savage, T. (2020). Challenge-based learning in higher education: An exploratory literature review. *Teaching in Higher Education*, *0*(0), 1–23. https://doi.org/10.1080/13562517.2020.1863354

[3] Membrillo-Hernández, J., de Jesús Ramírez-Cadena, M., Ramírez-Medrano, A., García-Castelán, R. M. G., & García-García, R. (2021). Implementation of the challenge-based learning approach in Academic Engineering Programs. *International Journal on Interactive Design and Manufacturing (IJIDeM)*, *15*(2), 287–298. https://doi.org/10.1007/s12008-021-00755-3

[4] Membrillo-Hernández, J., J. Ramírez-Cadena, M., Martínez-Acosta, M., Cruz-Gómez, E., Muñoz-Díaz, E., & Elizalde, H. (2019). Challenge based learning: The importance of world-leading companies as training partners. *International Journal on Interactive Design and Manufacturing (IJIDeM)*, *13*(3), 1103-1113.https://doi.org/10.1007/s12008-019-00569-4

[5] Malmqvist, J., Rådberg, K. K., & Lundqvist, U. (2015). Comparative analysis of challenge-based learning experiences. *Proceedings of the 11th International CDIO Conference*, Chengdu, China, (pp. 1-13). https://research.chalmers.se/en/publication/218615

[6] Doulougeri, K., Vermunt, J. D., Bombaerts, G., & Bots, M. (submitted). A systematic literature review of challenge-based learning implementation in engineering education.

[7] Zimmerman, B. J. (2002). Becoming a Self-Regulated Learner: An Overview. *Theory Into Practice*, 41(2), 64-70. https://doi.org/10.1207/s15430421tip4102_2

[8] Vermunt, J. D., & Verloop, N. (1999). Congruence and friction between learning and teaching. *Learning and Instruction*, *9*(3), 257–280.

[9] Vermunt, J.D. (2007). The power of teaching-learning environments to influence student learning. *British Journal of Educational Psychology Monograph Series II*, 4, 73-90, 2007. https://doi.org/10.1348/000709906X162406 *Research in Psychology*, *3*(2), 77–101. https://doi.org/10.1191/1478088706qp063oa

[10] Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative* Harks, B., Rakoczy, K., Hattie, J., Besser, M., & Klieme, E. (2014). The effects of feedback on achievement, interest, and self-evaluation: The role of feedback's perceived usefulness. *Educational Psychology*, *34*(3), 269–290. https://doi.org/10.1080/01443410.2013.785384

[11] Doulougeri, K., Bombaerts, G., Martin, D., Watkins, A., Bots, M., & Vermunt, J. D. (2022). Exploring the factors influencing students' experience with challenge-based learning: a case study. In M. Jemni, I. Kallel, & A. Akkari (Eds.), *Proceedings of the 2022 IEEE Global Engineering Education Conference, EDUCON 2022* (pp. 981-988). [9766574] Institute of Electrical and Electronics Engineers. https://doi.org/10.1109/EDUCON52537.2022.9766574

[12] Doulougeri, K., Van den Beemt, A., Vermunt, J. , Bots, M., & Bombaerts, G. (in press). Challenge-Based Learning in Engineering Education: Towards mapping the landscape and guiding educational practice. In: Vilalta-Perdomo, E., Membrillo-Hernández, J., Michel-Villarreal, R., Lakshmi, G., & Martínez-Acosta, M.J. (eds). The Emerald Handbook of Challenge-Based Learning. Emerald Publishing Group

[13] Doulougeri, K., Vermunt, J., Bombaerts, G., Bots, M., & de Lange, R. (2021). How do students regulate their learning in Challenge Based Learning? An analysis of students' learning portfolios. In Proceedings of the 49th SEFI Annual Conference: Blended Learning in Engineering Education: challenging, enlightening - and lasting?

[14] Hattie, J., & Timperley, H. (2007). The Power of Feedback. *Review of Educational Research*, *77*(1), 81–112. https://doi.org/10.3102/003465430298487

[15] Järvelä, S., Kirschner, P. A., Panadero, E., Malmberg, J., Phielix, C., Jaspers, J.,Koivuniemi, M., & Järvenoja, H. (2015). Enhancing Socially Shared Regulation in Collaborative Learning Groups: Designing for CSCL Regulation Tools. *Educational Technology Research and Development*, *63*(1), 125–142.