



WHAT DO WE NEED TO CONSIDER WHEN DESIGNING AND RESEARCHING STUDENT LEARNING IN CHALLENGE-BASED LEARNING?

K Helker¹

Eindhoven University of Technology
Eindhoven, Netherlands
0000-0003-3384-566X

J Lazendic-Galloway

Eindhoven University of Technology
Eindhoven, Netherlands
0000-0003-0166-1647

M Bruns

Eindhoven University of Technology
Eindhoven, Netherlands
0000-0002-9172-0323

I M M J Reymen

Eindhoven University of Technology
Eindhoven, Netherlands
0000-0002-8654-0950

J D Vermunt

Eindhoven University of Technology
Eindhoven, Netherlands
0000-0001-9110-4769

Conference Key Areas: *Fostering Engineering Education Research, Teaching methods*

Keywords: *Challenge-Based Learning, learning process, learning gains, context*

ABSTRACT

Challenge-Based Learning has become specifically popular in higher engineering education. CBL addresses the key characteristics of future engineering programs by embracing authentic, active learning, offering choice in problem-solving and learning practices as well as enabling training in interdisciplinary teamwork and decision-

¹ Corresponding Author: K Helker k.helker@tue.nl



making. This responds to the desire of many students for a sense of meaning in their education. Just as with many other educational innovations, we see a large variety of many different initiatives under the CBL label which is why much research is being conducted on the characteristics of CBL implementation. But the goal for researching different characteristics of CBL experiments is to, in the long run, understand whether CBL influences student learning, and in which way, since prior research suggests positive effects of such active learning approaches. In this short paper we present a framework for capturing the prerequisites, context, process and outcomes of student learning in Challenge-Based Learning. We take a close look at CBL as an educational concept in contrast to the prior ways in which student learning has been described. We put forward a heuristic analytical framework that will allow researchers and educators to capture the different aspects of the CBL process and context that could guide further education innovation and research to foster student learning gain in CBL.

1 INTRODUCTION

Higher education institutions worldwide have implemented Challenge-Based Learning (CBL) as a response to calls for more future- and student-oriented education. While CBL puts students at the center of the teaching and learning processes, most CBL research has focused on CBL design characteristics and has not yet systematically integrated existing research on student learning. This short paper therefore presents a framework for capturing the prerequisites, context, process and outcomes of student learning in Challenge-Based Learning.

2 THE FUTURE OF ENGINEERING EDUCATION

Today's societal, political, and economic changes in the world yield numerous challenges that are often complex, open-ended, and ill-defined [1] and call for competencies, often referred to as 21st-century skills, that go beyond workers' traditional tasks and responsibilities. This is specifically true for future engineers, who need to possess a T- or Π-shaped profile, mastering in-depth disciplinary knowledge as well as broader professional skills that will allow them to develop technical solutions to current problems.

These requirements are also presenting new challenges for engineering education, as traditional teaching approaches focusing on transmission of knowledge have started to lose their functionality [2]. Thus, many educational practitioners have strived to create modern and powerful learning environments that allow for students' distributed and co-operative learning through social interactions in representative authentic, real life contexts that have a personal meaning for them.

3 CHALLENGE-BASED LEARNING

One relatively new approach, that has become specifically popular in higher engineering education is Challenge-Based Learning (CBL). CBL aims at creating “a



learning experience where the learning takes place through the identification, analysis and design of a solution to a sociotechnical problem. The learning experience is typically multidisciplinary, takes place in an international context and aims to find a collaboratively developed solution, which is environmentally, socially and economically sustainable.” [3, p.4]. In order to achieve these aims, CBL usually involves open-ended challenges or problems from real-world practice that require students to work in interdisciplinary teams. The uncertainty that naturally arises in such authentic project work is expected to trigger students’ self-regulation and motivation as students can make sense of their education [4]. Apart from students’ improved technical and problem-solving skills as well as a deeper understanding of disciplinary knowledge [5], students in CBL settings are also expected to interact in real-world settings, acquire knowledge and develop skills they can apply to respond to any kind of complex problems in the future, such as self-awareness, self-leadership, teamwork, and an entrepreneurial mindset [6].

Given these advantages of combining experience, cognition, and behaviour, CBL has become especially popular in higher engineering education with a large variety of approaches that are being adapted to and shaped by different contexts, needs and learning objectives [7, 5, 8]. Whether the advantages of students’ active involvement in their learning that have been shown in prior research [9] also apply to student learning in CBL however is not clear, as the two fields have not yet been systematically integrated. In the following, we therefore suggest a framework for capturing the prerequisites, context, process, and outcomes of student learning in CBL.

4 STUDENT LEARNING IN CHALLENGE-BASED LEARNING

The framework for capturing student learning in CBL can be seen in Figure 1. We will present the parts in the following, starting from the core of the framework, students’ learning patterns, before turning to students’ learning outcomes, and finally personal and contextual factors specific of CBL environments.

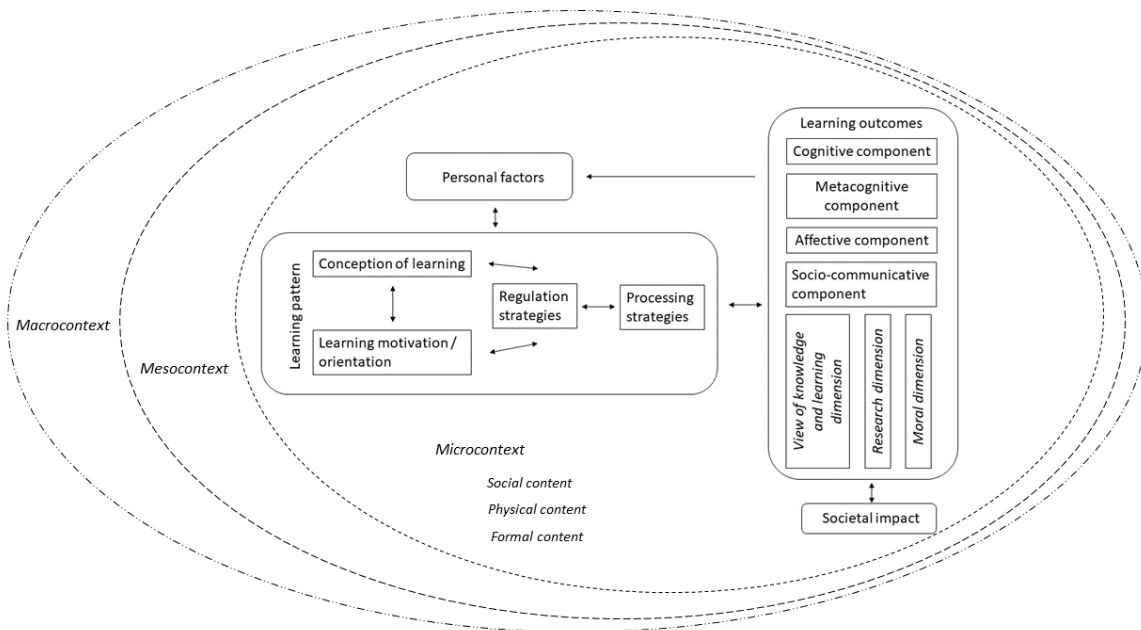


Fig. 1. Student learning in Challenge-Based Learning

4.1 Student learning patterns

A student's learning pattern has been conceptualised in prior research as “a coherent whole of learning activities that learners usually employ, their beliefs about learning and their learning motivation” [10]. These comprise students' cognitive processing strategies (what activities students employ to process subject matter), metacognitive regulation strategies (students' activities to plan, monitor, and evaluate learning processes), (metacognitive) conceptions of learning (students' views and beliefs about learning), and students' learning motivations and orientations (students' aims and goals). These strategies then result in four different learning patterns, i.e., reproduction-directed learning, meaning-directed learning, application-directed learning, and undirected learning [10]. Whether students' employ more or less beneficial learning patterns affects students' learning outcomes and is affected by students' personal and contextual factors, all of which will be described in the following.

4.2 Student learning outcomes

For describing the variety of student learning outcomes in CBL, we draw on Vermunt and colleagues' framework of learning gains in higher education, referring to “students' change in knowledge, skills, attitudes, and values that may occur during higher education across disciplines” [11]. This change may refer to the cognitive, metacognitive, affective, and socio-communicative components and three dimensions (view of knowledge and learning, research attitude, and moral reasoning) of learning gains. In CBL, specific emphasis lies on the socio-communicative component with students developing a professional identity, creative/innovative and entrepreneurial thinking. Specifically important are the discussions of



the cognitive component of student learning gains, as the specific contexts of CBL will allow for a large variety of learning outcomes. Further outcomes of students' work and learning in CBL, are that their solution or product developed in response to the challenge may have a societal impact, which may again affect student motivation and perceived usefulness of the CBL process [12].

4.3 Personal factors

Personal factors that affect student learning are usually described to be age, personal background, prior knowledge, educational experience, and epistemological stance. In our framework, we assume that students' experience with interdisciplinary and collaborative work in general and with CBL specifically, as well as their sense of responsibility for their learning and ability to deal with uncertainty affect them developing more or less beneficial learning patterns.

4.4 Contextual factors

The interplay between students' personal factors and learning patterns, leading to specific learning outcomes can be assumed to be affected by numerous contextual factors. Using a framework of context in higher education by Wosnitza and Beltman [13], these factors can be structured on three levels, namely the microlevel (i.e., the course level context), the mesolevel (i.e., the institutional level), and the macrolevel (i.e., the wider societal, local, national, international context). Each of these levels of context holds different content, namely the social content (e.g., the peers, coaches, teachers, external stakeholders the student interacts with, the frequency of meetings with them, the group atmosphere), the physical content (e.g., learning resources and space available for learners, learning technology), and the formal content (e.g., open-endedness of challenge, assessment/ feedback/ reflection methods, scaffolding on the microlevel, curriculum, institutional and departmental vision of CBL on the mesolevel, and global themes guiding the challenges on the macrolevel).

5 CONCLUSION

While some research has already emerged exploring various aspects of CBL implementation, not enough insights have been gathered about whether and how CBL influences student learning. As a first step, we therefore presented a heuristic analytical framework of student learning in CBL. This will allow researchers and educators to systematically relate the different aspects of the CBL process and context in future education innovation and research. Specifically focusing on the different levels and various content of the CBL context, such as student (interdisciplinary) team work in CBL, will allow for understanding how CBL can foster beneficial student learning patterns and outcomes and what configuration of CBL elements constitutes the most powerful pedagogy for educating future engineers.

REFERENCES

- [1] Gómez Puente, S. M., van Eijck, M., & Jochems, W. (2013), A sampled literature review of design-based learning approaches: a search for key characteristics. *International Journal of Technology and Design Education*,



- 23(3), 717-732. doi: 10.1007/s10798-012-9212-x
- [2] Vermunt, J. D. & Verloop, N. (1999), Congruence and friction between learning and teaching. *Learning and Instruction*, 9, 257-280. Doi: 10.1016/S0959-4752(98)00028-0
- [3] Malmqvist, J., Rådberg, K. K., & Lundqvist, U. (2015), Comparative Analysis of Challenge-Based Learning Experiences. Paper presented at the 11th International CDIO Conference, Chengdu University of Information Technology.
- [4] Graham, R. (2017), The global state-of-the-art in engineering education. Outcomes of Phase 1 benchmarking study. Retrieved from <https://rhgraham.org/resources/Phase-1-engineering-education-benchmarking-study-2017.pdf>
- [5] Gallagher, S. E., & Savage, T. (2020), Challenge-based learning in higher education: an exploratory literature review. *Teaching in Higher Education*, 1-23. doi:10.1080/13562517.2020.1863354
- [6] Van den Beemt, A., MacLeod, M., & Van der Veen, J. (2020), Interdisciplinarity in tomorrow's engineering education. Paper presented at the 48th SEFI Annual Conference on Engineering Education, SEFI 2020.
- [7] Doulougeri, K., Vermunt, J. D., Bots, M., & Bombaerts, G. (2021), Defining key components of challenge-based learning in engineering education: A review study. Paper presented at the 19th Biennial Conference of the European Association for Research on Learning and Instruction, online/ Gothenburg, Sweden.
- [8] Van den Beemt, A., Van den Watering, G., & Bots, M. (2021). Variety in Challenge- based learning in higher education. Paper presented at the 2021 SEFI conference, online/Berlin, Germany
- [9] Hadgraft, R. G., & Kolmos, A. (2020). Emerging learning environments in engineering education. *Australasian Journal of Engineering Education*, 25(1), 3–16. Doi: 10.1080/22054952.2020.1713522
- [10] Vermunt, J. D., & Donche, V. (2017), A learning patterns perspective on student learning in higher education: state of the art and moving forward. *Educational Psychology Review*, 29(2), 269-299. Doi: 10.1007/s10648-017-9414-6
- [11] Vermunt, J. D., Illie, S., & Vignoles, A. (2018), Building the foundations for measuring learning gain in higher education: a conceptual framework and measurement instrument. *Higher Education Pedagogies*, 3(1), 266-301. doi:10.1080/23752696.2018.1484672
- [12] Rådberg, K. K., Lundqvist, U., Malmqvist, J., & Svensson, O. H. (2020), From CDIO to challenge-based learning experiences – expanding student learning as well as societal impact? *European Journal of Engineering Education*, 45(1), 22-37. doi:10.1080/03043797.2018.144126
- [13] Wosnitza, M., & Beltman, S. (2012), Learning and motivation in multiple contexts: the development of a heuristic framework. *European Journal of Psychology of Education*, 26(2), 177-193. doi:10.1007/s10212-011-0081-6