Issues Influencing Assessment Practices of Inter-Program Challenge-Based Learning (CBL) in Engineering Education: The Case of ISBEP At TU/e innovation Space

ISSUES INFLUENCING ASSESSMENT PRACTICES OF INTER-PROGRAM CHALLENGE-BASED LEARNING (CBL) IN ENGINEERING EDUCATION: THE CASE OF ISBEP AT TU/E INNOVATION SPACE

A. Valencia[1]
Eindhoven University of Technology, TU/e innovation Space
Eindhoven, The Netherlands

M. Bruns
Eindhoven University of Technology, TU/e innovation Space
Eindhoven, The Netherlands

I. Reymen
Eindhoven University of Technology, TU/e innovation Space
Eindhoven, The Netherlands

B. Pepin
Eindhoven University of Technology, 4TU.Center for Engineering Education
Eindhoven, The Netherlands

***Conference Key Areas**: Interdisciplinary education, Challenge based education*
***Keywords**: Challenge-Based Learning, Inter-Program Education, Interdisciplinary Education, Assessment Practices*

ABSTRACT

This paper reports on 11 issues influencing the assessment practices of ISBEP, an inter-program Challenge-Based Learning (CBL) project facilitated by TU/e innovation Space. To this end, we first identified four characteristics of inter-program CBL guided by the existing literature. Building on an exploratory, qualitative research study conducted over a period of seven months with students and coaches of the TU/e innovation Space Bachelor End Project (ISBEP), we identified the issues arising from those characteristics that had an influence on assessment. Our results and discussion are framed around the theory of constructive alignment, and suggest the need for more time to navigate a challenge; clarity on roles and expectations across the multiple stakeholders involved in the learning process; agreement on learning goals that foster the development of disciplinary knowledge and broad skills; and design and evaluation of assessment practices that are uniform across departments in the institution.

[1] *Corresponding Author*
A. Valencia
a.m.valencia.cardona@tue.nl

1 INTRODUCTION

Challenge-Based Learning (CBL) is an educational concept with ever-growing relevance in engineering education. In CBL, students collaborate to develop solutions to open-ended challenges of societal relevance. CBL is considered a rich learning environment, where engineering students can broaden their professional skills by engaging in interdisciplinary, real-life, multi-stakeholder situations, and by designing solutions to complex problems [1]. CBL is at the core of the education strategy of Eindhoven University of Technology (TU/e), where the goal is to have CBL as the main characteristic of the on-campus education by 2030[2]. CBL has now been explored in several educational experiments at the bachelor and master level. One of these experiments is the innovation Space Bachelor End Projects (ISBEP), an interdisciplinary final project offered to all bachelor students of TU/e.

The novelty of ISBEP is that it is an *inter-program* project offered as an alternative to the 'traditional' Bachelor End Project (BEP). In contrast to a regular BEP, which takes place at and is coordinated by the different departments, ISBEP is conducted in a team and offered and coordinated by TU/e innovation Space (the centre of expertise for CBL and student entrepreneurship a TU/e[3]). As an inter-program CBL project, engineering students from all TU/e departments join to work in *interdisciplinary* teams towards solutions to challenges of societal relevance. These challenges are offered by companies, institutions or university research groups and student teams, which are officially known as challenge owners.

With respect to assessment, students have the same learning goals as established by the departments in relation to their programs, plus an additional set of learning goals related to the context in which ISBEP takes place (i.e. interdisciplinary, challenge-based, of relevance to society). Formative assessment is supported by TU/e innovation Space, on aspects related to interdisciplinarity (e.g. communication and integration of ideas), and by the different departments, on aspects related to the development of projects from a disciplinary perspective. Furthermore, challenge owners provide feedback to students on the relevance of ideas and overall project direction. The final (summative) assessment is individual, and it is led and conducted by each of the departments.

The ISBEP program has been running for three consecutive years. The experiment has been periodically evaluated, and there are continued efforts to improve the educational concepts. Overall, the response from students, staff and challenge owners has been positive. However, reports from practice suggest there are opportunities for improvement, particularly in relation to *assessment*. In an effort to understand the characteristics and issues influencing assessment in inter-program CBL, a research study has been initiated. This paper reports on the finding from the first part of the project, the exploratory study. In this paper we pose the following research question:

What issues/characteristics of inter-program CBL influence assessment practices?

---

[2] *https://www.tue.nl/en/news/news-overview/03-09-2018-tue-launches-strategy-2030/*

[3] *https://www.tue.nl/en/tue-campus/tue-innovation-space/*

The remaining paper first offers an overview of the theories framing our research project. In subsequent sections, the methodology is explained, followed by results of our study. We conclude the paper with a discussion on the implications of our research findings for the design of assessment practices.

2 THEORETICAL FRAMEWORK

We use the theory of Constructive Alignment to frame our research. Constructive Alignment (CA) is a student-centred approach to designing education [2]. CA is achieved when teaching/learning activities and assessment are designed to support the achievement of learning outcomes. It has been associated with high quality learning outcomes and student satisfaction (e.g. [2], [3]). Learning experiences should be designed aligning the (1) learning goals, (2) teaching/learning activities and (3) assessment practices, to maximize the intended learning of students. CA has been widely used in higher education and has been reported as a relevant approach in the design of interdisciplinary education [3]. Below we characterize CBL in relation to these three elements, based on preliminary research available on CBL.

2.1 Characteristics of CBL

In relation to *learning activities*, students of CBL are said to frequently engage in multidisciplinary teamwork [1] [4]. Students participate in problem formulation activities; they are presented with general concepts from which they must derive a challenge to work on. Students need to arrive to a specific problem definition by themselves by answering a series of questions, which are called essential questions [5][4]. CBL involves work on real-world problems of societal impact [4] [6]. Projects are typically multi-stakeholder and involve a wider community [1]. Furthermore, students engage in projects that are solution oriented [6]. CBL is a 'learning through doing' approach, where students work towards tangible or experiential solutions, involving prototypes and other manifestations [7].

In relation to *intended learning outcomes*, CBL is said to involve the development of disciplinary knowledge and broad skills [1]. The reported learning outcomes of broad professional skills involve: communication, collaboration and organization, stimulated by working on real-world problems and the interaction with multiple stakeholders [5][1][4] as well as 'identifying, formulating and managing complex problems in a critical, independent and creative manner' [1].

In relation to *assessment practices,* research linking CBL and assessment practices is highly underdeveloped. However, reports from practice, such [7] and [8], suggest formative and summative assessment as being actively used in the CBL context. Formative assessment is highlighted as an important tool to help students develop self-regulating skills for life-long learning [7], which is recurring and guides decision making. CBL is self-directed, for which the role of educators is that of making sure students are on track [5] [6]. Similarly, the role of educators changes from 'dispensing-information' to guiding the construction of knowledge [4] and the process [7].

In regards to summative assessment, [8] emphasize three areas: content knowledge, mastery of real-world skills, and process. Summative and formative assessment tasks are said to be intertwined for CBL and providing clarity to students on what activities constitute a basis for summative assessment is advised [7]. Evidence for summative assessment is described as varying in format, such as reports, final presentations, debates and portfolios [7]. Self-reflection is encouraged and used as part of the assessment[4], [6]. Overall, assessment criteria is described in relation to intended learning outcomes and aligned with the theory on CA previously described.

2.2 Constructive Alignment and Assessment Design for Inter-program CBL

Borrego and Cutler (p. 366) state that "decisions about assessment evidence should be driven by the learning outcomes, and decisions about learning experiences should be guided by helping students develop the ability to provide this evidence" [3]. CA is key for the design of assessment in inter-program education, as intended learning outcomes, learning activities and assessment might be prioritized differently by the departments involved. Lack of alignment in inter-program CBL could lead to important repercussions for assessment and learning of students. Existing literature of CBL has focused on illustrative cases describing the implementation of CBL in higher education (e.g. [9]–[11]), or on highlighting the benefits of CBL when compared to traditional engineering classroom (e.g. [6], [12], [13]). However, implications of inter-program CBL for assessment design have, to our knowledge, not been documented and are key for the further development and upscaling of CBL. In this paper, we investigate this underexplored context by trying to identify the characteristics and issues, which can influence assessment design. Our main goal is to illustrate the intricacies of assessment in inter-program CBL, and contribute to the design and evaluation of similar (well aligned) programs in engineering education.

3 METHODOLOGY

3.1 Data Collection

We followed a longitudinal, exploratory research approach on ISBEP for a period of seven months (from July 2019 through January 2020). Our methods included different qualitative techniques, such as in-depth interviews, contextual inquiry, group interviews, focus groups and observations. Combined, these techniques granted us with rich contextual information to understand the intricacies of ISBEP of relevance to our research goals [14].

Participants

Participants included the different stakeholders involved in ISBEP and were selected to reflect the variety in perspectives of those involved:

Students: Three interdisciplinary teams working on ISBEP projects. Teams were formed by a total of 11 students in the third and final year of their bachelor program.

Departments: Seven academic coaches. The four academic coaches of students participating in the research (some coaches coached multiple students), and five coaches from a past version of ISBEP. Together these brought the perspective of seven different departments.

TU/e innovation Space: Two TU/e innovation Space coaches.
Challenge Owners: Three Challenge Owners, one for each of the ISBEP projects.
All participants joined the research voluntarily and were informed of the ethical aspects of the research through an Informed Consent Form. No compensation was offered.

Procedures

Our research was executed in two phases: Problem exploration and detailed study of ISBEP. The goal of phase one was to attain an initial picture of the studied situation. Furthermore, this phase allowed us to fine tune our research questions and design of methods. The problem exploration was completed by carrying out semi-structured in-depth interviews with five academic coaches from five different departments (from a previous version of ISBEP). Phase two focused on the detailed research of a full ISBEP cycle during which several activities were conducted: First, observations [15] combined with contextual enquiry [16] of interactions of students working on the interdisciplinary projects, interactions of student teams and coaches, as well of other learning activities. The goal was to capture the experiences of students and coaches while engaging in learning activities and formative assessment practices. Second, semi-structured, in-depth, group interviews with ISBEP teams [17], and semi-structured, in-depth interviews [18], with (academic) coaches of ISBEP projects at three points in time: at the start of the project (to reflect on early learning experiences, as well as expectations towards formative assessment practices); halfway (to reflect in more detail about the role of coaches and other stakeholders as well as formative assessment practices); and at the end of the project (to capture impressions and experiences towards summative assessment and revisit the overall experience with ISBEP). Third, two focus groups with academic coaches, innovation Space coaches and challenge owners [18]: halfway and at the end of the project (to evaluate learning activities, (formative) assessment, and other aspects, such as the organization/design of ISBEP, which could have an impact on assessment practices).

3.2 Data Processing

All interviews were transcribed verbatim. Atlas.ti was used to analyse the data by using a conventional content analysis approach [18]. A first set of seven interviews and minutes from two focus groups were open-coded by the main researcher, leading to a total of 134 codes. The large set of codes reflected the varying views brought in by the different participants. This set of codes was reviewed by the research team for analysis triangulation [18] leading to the identification of a preliminary set of themes and constructs. Field notes and secondary sources, such as internal reports, were also used for triangulation.

4 RESULTS

We identified four characteristics of Inter-Program CBL and related them to the three elements of constructive alignment as discussed in the theoretical framework. These characteristics led to 11 issues in inter-program CBL (Table 1). The following sections report on the characteristics and respective issues, based on the partial analysis of seven interviews and two focus group interviews.

Table 1. Overview of Results

Elements of Constructive Alignment	Characteristics of Inter-program CBL	Issues in Inter-program CBL	Sample quote from the interviews
Learning activities	Open-ended Challenges	Longer period to navigate the challenge.	*"It takes time to rephrase that into a project for yourself […] the major chunk, maybe even up to four weeks of the start of the project, the students are still like not sure what they're going to do, and the others are full speed ahead." Academic Coach 1*.
	Multi-stakeholder	Managing and balancing the needs of a larger set of stakeholders.	*"Coming from [department], it is quite important that I have both the [discipline-specific content], but also a technical component […] And I managed to send [academic coach] an email about that. And he did confirm that I couldn't neglect it [that] it would be negative on my end grade […] So that has been hard to sort of bring into... with the challenge owners as well." Student 1*
		Maintaining the overview of roles and responsibilities.	*" I'm eventually grading the students and if I tell the student that what [he/she is] doing now is not sufficient from our [department] perspective, that [he/she] should do something different, then who should [take care of it]? Is it her problem? […] should the challenge owner solve it? or there's also someone, like [TU/e innovation Space Coach, who is in fact supervising all the projects for the process?" Academic Coach 4*
		Reduced feeling of accountability.	*"here in my department, if I put forward a proposal, and then a student is assigned to a proposal. And then one day I say I don't want to do this anymore, it's a very bad thing, I would get fired. But that's not the case for ISBEP. And we saw several cases where students sign up for a project, and then the [Challenge Owner] who proposed the project, drop it […]" Academic Coach 3*
Intended learning outcomes	Development of disciplinary knowledge and broad skills.	Balancing individual and team goals.	*"I think everyone is still figuring out how to do their part. And for me, and for [Student 11], we don't really have, like, you have to do this for your faculty […] we all don't really know what to do for our faculty." Student 12 / "I think the projects are nice and okay. But it's difficult for the students to find their own separate topic. Because if I wouldn't have forced them to find their own topic, and to make separate projects in the end, or make separate reports, they would have continued to do this as a group, and work as a group on exactly the same thing all the time." Academic Coach 4*
		Maintaining interdisciplinarity (motivation).	*"I am being unable to concretely define a final product of some kind […] that we can all work on together to achieve. And for me that's been difficult because it was a huge motivator for me to work in a group and to work commonly together towards a goal. And that's why I wanted to do the innovation space BEP." Student 1*
		Achieving enough disciplinary depth (fulfilling assessment criteria).	*"of course, part of the project is the multidisciplinary part and that's an important one, because it's also one of their learning goals […] But they should also come up with something in depth, something where they show that they can do [program] on a bachelor end level. And that's a bit tricky" Academic Coach 3*
		Creating high quality evidence for disciplinary development.	*"I was just really afraid that the quality wasn't a high enough standard for a bachelor university" Student 3*
Assessment Practices	Diversity in rules and regulations	Unclarity about assessment procedures and criteria.	*"I have no idea whether I checked all the, how do you say that, the demands for delivering a proper bachelor's end project" Student 11*
		Discrepancy between perceived learning outcomes and assessment criteria.	*"to me, it...you can't see from the [report] the amount of things that people have learned while doing this. So the learning for the student, I think, is much more valid, because they learn in a much more complex setting" Academic Coach 1 / "Being Challenge-Based has more of a focus on the process. So there should be more indication that it is not about the result that you get in the paper, but that it is about the process" Student 1*
		The need to adapt procedures and practices.	*"The way I see is, we either have a joint committee, and these ISBEPs are of a different category. And a separate day in a different building with a mix. So that the assessment committee should reflect the multidisciplinarity aspect of the project. Or these kids do a plus. And then they come to us, and they assessed on the [disciplinary] content. And then they have another forum where they assess on their business" Examiner*

4.1 Learning activities: Open-Ended and Multi-Stakeholder Challenges

One of the main features of inter-program CBL at TU/e innovation Space is that students work on open-ended challenges. These challenges were characteristically ill-defined, i.e. abstract, with no clear set of goals/outcomes, and typically unstructured, with no predefined set of steps of processes to be followed. Having open challenges as a starting point facilitated that students from different programs found a focus within the challenge suited to their respective disciplines.

Furthermore, the process and steps to be followed were project-dependent and identified by students themselves. Accordingly, ISBEP students dedicated the first weeks of the project to explore the challenges and identify well-defined problems to focus on. However, this led ISBEP students to need considerably ***longer periods to navigate the challenge***; particularly when compared to the traditional Bachelor End Projects (BEPs), for which the process was sometimes perceived as 'inefficient'.

In accordance with existing literature, inter-program CBL at TU/e innovation Space is multi-stakeholder, but the number of stakeholders surpassed our suppositions. Stakeholders involved TU/e innovation Space coaches and tutors, academic coaches, and challenge owners, who supported the process by providing close feedback on the execution of the project. In addition, ISBEP involved other stakeholders, such as experts, secondary examiners, and assessment committees, which are not formally part of the project but influenced the learning experience/outcomes of students; for example, in setting a direction for the project, in making decisions on project execution, and making resources available. Importantly, we found that stakeholders varied per student for inter-program CBL, even within the interdisciplinary team. As a consequence, students struggled to ***manage and balance the needs of a larger set of stakeholders***. Inter-program CBL is a new and complex scenario for students, where maintaining the overview of stakeholders and their needs was experienced as demanding.

However, the large number of stakeholders also brought challenges for coaches, challenge owners, and other stakeholders, who struggled *to* ***maintain the overview or roles and responsibilities in the projects*****.** For example, there were misunderstandings in relation to project ownership. Similarly, there were questions related to the responsibility for ensuring that students have access to the necessary resources to complete their projects. Moreover, the large number of stakeholders was perceived to ***reduce the feeling of accountability*** of some stakeholders. In the case of ISBEP, commitment from challenge owners and their involvement/continuity in projects, were brought forward as aspects of concern by academic coaches. Overall, misunderstanding on roles and expectations negative influenced the execution of projects, resulting in delays for students, and compromising the development/depth of their disciplinary knowledge.

4.2 Intended Learning Outcomes: Developing Disciplinary Knowledge and Broad Skills

Inter-program CBL at TU/e innovation Space supports the development of disciplinary knowledge and broad professional skills. ISBEP students were encouraged to define

individual and team development goals. To support the setting of individual goals related to their personal and professional development, TU/e innovation Space set up activities via a Learning Management System (LMS), which students engaged in periodically. Activities contained questions that were meant to stimulate students' self-regulated learning; to help them monitor their progress in relation to their goals, and to reflect on/adapt their learning strategies. Its goal was to support reflections by students when meeting their academic coaches, who would simultaneously encourage students to think of learning goals, from a disciplinary perspective.

At the same time, teams were encouraged to define team goals for the interdisciplinary project, which was supported by TU/e innovation Space through weekly coaching meetings and encouraged through 'mid-term' presentations involving the key stakeholders. At these presentations students were actively asked about their envisioned end-results, as well as the integration of individual contributions. Consequently, students had to find a ***balance between individual and team development***, which was not easily achieved. The pull between the two was constant throughout the projects, and was felt as intense by students and coaches alike, albeit the consequence of not achieving this balance varied. For students who centred too much on their disciplinary development, ***maintaining the interdisciplinarity of the project*** was difficult, while interdisciplinary work was an important motivator, and a key reason for students to join ISBEP. When interdisciplinarity was lost, students failed to see the value of ISBEP, compared to regular bachelor end projects. For students who centred too much on interdisciplinary work**, *achieving enough depth in the disciplinary (individual) projects*** was a testing, as well as ***providing high quality evidence for their disciplinary development*.** This could be attributed to problem definitions promoting interdisciplinarity, which then sometimes fell out of departmental expertise. As such, students struggled to determine the relevance of information related to their projects and some academic coaches struggled to guide students on the disciplinary content, and to connect them to relevant experts.

4.3 Assessment *Practices:* Diversity in rules and regulations

Inter-program CBL at TU/e innovation Space was characterized by a large diversity in rules and regulations due to the internal policies of the different participating departments. This diversity brought about different issues. First, there *was* ***unclarity among students about assessment procedures and criteria***. For participants in this research, the fact that they were assessed following the criteria of regular BEPs was particularly confusing (as they expected ISBEP specific criteria). Moreover, students expected part of the summative assessment to be conducted by TU/e innovation Space coaches and challenge owners. Students were often surprised to find out that summative assessment was mainly conducted following a disciplinary perspective and led by academic coaches and other members of the specific programs. Second, there was a perceived ***discrepancy between the learning outcomes of students and the criteria by which they are evaluated*.** A large portion of learning activities and perceived learning outcomes related to

team/interdisciplinary work. Consequently, students expected (part of) the summative assessment to be related to the learning outcomes associated with this. Third, some academic coaches expressed the ***need to adapt procedures and practices*** to this new context of inter-program CBL. Academic coaches needed to familiarize themselves with ISBEP, its learning activities and expected outcomes. Some coaches perceived the departmental assessment practices as not fitting (i.e., not well aligned) with ISBEP. For example, having to create flexibility in the current procedures, or including additional steps, to provide students with a fair assessment.

5 IMPLICATIONS FOR ASSESSMENT

In the case of inter-program CBL, constructive alignment (or lack thereof) appeared to be particularly influenced by the **larger number of stakeholders** taking part in the projects, and their varying perspectives. At the level of *learning activities*, the impact of a larger set of stakeholders was well reflected in the difficulty to maintain an overview of roles and responsibilities of those involved facilitating learning. In terms of *learning outcomes*, the varying and unaligned expectations of stakeholders influenced the attainment of learning goals. And at the level of *assessment practices*, the larger number of stakeholders brought about varying departmental assessment procedures and criteria, which created uncertainty.
Diversity in rules and regulations also proved to be an important barrier in the delivery of a significant learning experience to students. In this regard, Fink proposes a model for institutional effectiveness [19], and positions rules and regulations as an important element in promoting/blocking the implementation of effective learning–one in which learning goals, learning activities and assessment practices are well integrated (i.e. well aligned). Furthermore, in discussing constructive alignment across the institution, Biggs and Tang describe teaching as a multi-layered ecosystem [2]. Under this perspective, modules and their design are teacher dependent, and influenced by departmental rules and regulations, which are in turn influenced by institutional policies in education. Thus, for inter-program CBL to be successful, there has to be an important focus in aligning learning goals, learning activities and assessment practices–and regulations–across departments, but also between department and the intuitional vision on education.
Achieving this **alignment across the institution** can potentially address several of the reported issues in terms of: more clarity on roles and expectations across stakeholders; agreeing on learning goals that foster the development of disciplinary knowledge and broad skills; and designing and implementing assessment practices that are uniform across departments, student-centred, and promoting the attainment of learning goals. To achieve such clarity, Evans proposes several tactics for reaching assessment literacy [20] which in the case of ISBEP, would imply directing efforts at increasing the clarity regarding the roles of stakeholders, by making their roles, expertise, and what/when students can reach out to them for more explicit feedback/coaching. Finally, in designing well aligned interdisciplinary learning experiences, Borrego and Cutler advice seeking involving multiple sources [3] to reach agreement across programs on the expected learning outcomes of this type of

education, and at this educational level. In conclusion, constructive alignment might not be easily attainable in the context of in inter-program CBL, but is key to promote the design and implementation of student-centred assessment practices (and learning activities), which promote the achievement of learning goals [2], [21].

REFERENCES

[1] Rådberg, K. K., Lundqvist, U., Malmqvist, J., and Hagvall Svensson, O. (2020), From CDIO to Challenge-Based Learning experiences – Expanding student learning as well as societal impact? *European Journal of Engineering Education*, Vol. 45, No. 1, pp. 22–37. doi: 10.1080/03043797.2018.1441265.

[2] Biggs, J. and Tang, C. (2015), Constructive Alignment: An outcomes-based approach to teaching anatomy, *Teaching Anatomy*, Vol. 1, pp. 31–38. doi: 10.1007/978-3-319-08930-0_4.

[3] Borrego, M., and Cutler, S. (2010), Constructive alignment of interdisciplinary graduate curriculum in engineering and science: An analysis of successful IGERT proposals, *Journal of Engineering Education*, Vol. 99, No. 4, pp. 355–369. doi: 10.1002/j.2168-9830.2010.tb01068.x.

[4] Johnson, L. F., Smith, R. S., Smythe, J. T., and Varon, R. K. (2009), *Challenge-Based Learning: An Approach for Our Time*, Austin, Texas: The New Media Consortium.

[5] *7 Things you should know about...Challenge-Based Learning* (2012), Retrieved from: https://library.educause.edu/-/media/files/library/2012/1/eli7080-pdf.pdf

[6] Gaskins, W. B., Johnson, J., Maltbie, C., and Kukreti, A. (2015), Changing the learning environment in the college of engineering and applied science using Challenge Based Learning, *International Journal of Engineerting Pedagogy*, Vol. 5, No. 1, p. 33-41. doi: 10.3991/ijep.v5i1.4138.

[7] Magnell, M., and Högfeldt, A. K. (2015), Assessment and evaluation, in M. Magnell (Ed.), *Guide to challenge driven education. ECE Teaching in Higher Education no 1*, Editabobergs, pp. 60–76.

[8] Nichols, M., Cator, K., and Torres, M. (2016), Assessment, in *Challenge Based Learning Guide*, Digital Promise and The Challenge Institute, pp. 24–26.

[9] Clegg, J. R., and Diller, K. R. (2019), Challenge-based instruction promotes students' development of transferable frameworks and confidence for engineering problem solving, *European Journal of Engineering Education*, Vol. 44, No. 3, pp. 398–416. doi: 10.1080/03043797.2018.1524453.

[10] Félix-Herrán, L. C., Rendon-Nava, A. E., and Nieto Jalil, J. M., (2019), Challenge-Based Learning: An I-semester for experiential learning in Mechatronics Engineering, *International Journal of Interactive Design and Manufacturing*, Vol. 13, No. 4, pp. 1367–1383. doi: 10.1007/s12008-019-00602-6.

[11] Malmqvist, J., Rådberg, K. K. and U. Lundqvist, (2015), Comparative Analysis of Challenge-Based Learning experiences, *Proceedings of the 11th international CDIO conference*, Chengdu University of Information Technology, Chengdu, Sichuan, P.R. China, June 8-11.

[12] Roselli, R. J., and Brophy, S. P. (2006), Effectiveness of challenge-based instruction in biomechanics, *Journal of Engineering Education*, Vol. 95, No. 4, pp. 311–324. doi: 10.1002/j.2168-9830.2006.tb00906.x.

[13] O'Mahony, T. K., Vye, N. J., Bransford, J. D., Sanders, E. A., Stevens, R., … Soleiman, M.

K. (2012), A comparison of Lecture-Based and Challenge-Based Learning in a workplace setting: Course designs, patterns of interactivity, and Learning Outcomes, *Journal of Learning Sciences*, Vol. 21, No. 1, pp. 182–206. doi: 10.1080/10508406.2011.611775.

[14] Design-Based Research Collective (2007), Design-Based Research: An emerging paradigm for educational inquiry, *Educational Researcher*, Vol. 32, No. 1, pp. 5–8. doi: 10.3102/0013189x032001005.

[15] Bassey, M. (1999), Doing qualitative research in educational settings: Case study research in educational settings. Oxford: Marston Book Services Limited.

[16] Beyer, H., and Holtzblatt, K. (1999), Contextual design, *Interactions*, Vol. 6, No. 1, pp. 32–42.

[17] Frey, J. H., and Fontana, A. (1991), The group interview in social research, *The Social Science Journal*, Vol. 28, No. 2, pp. 175–187. doi: 10.1016/0362-3319(91)90003-M.

[18] Patton, P. M. (2002). *Qualitative research and evaluation methods*, 3rd ed. Thousand Oaks, CA: SAGE Publications.

[19] Fink, L. D., (2013), *Creating significant learning experiences : An integrated approach to designing college courses*. San Francisco: Jossey-Bass.

[20] Evans, C (2020), Enhancing assessment feedback practice in higher education: The EAT framework.

[21] Biggs, J., Medland, E., and Vardi, I. (2013), Aligning teaching and assessing to course objectives, *Assessment & Evaluation in Higher Education*, Vol. 38, No. 5, pp. 1–16. doi: 10.1080/02602938.2012.670197.