Defining Intended Learning Outcomes (ILO's) of inter-program CBL towards achieving constructive alignment in the context of ISBEP

DEFINING INTENDED LEARNING OUTCOMES (ILO'S) OF INTER-PROGRAM CBL TOWARDS ACHIEVING CONSTRUCTIVE ALIGNMENT IN THE CONTEXT OF ISBEP

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ABSTRACT

We present a framework that connects identified competence areas with Indented Learning Outcomes (ILO's). Such a framework is likely to be useful for the design of inter-program Challenge-Based Learning (CBL) in engineering education. The framework was developed out of a need to increase the constructive alignment (CA) of ILO's, learning/teaching activities, and assessment of the Innovation Space Bachelor End Project (ISBEP); an inter-program CBL initiative at Eindhoven University of Technology (TU/e). The framework was developed based on a co-creation session, and set up around the definition of ILO's as departing point to reach CA. We contribute a comprehensive framework listing the ILO's associated with inter-program CBL at the third-year, bachelor level, and identify three categories related to design and research processes, professional skills, and professional identity and self-directed learning. Furthermore, we illustrate our findings with practices from ISBEP, highlighting the influence of ILO's on our efforts to reach alignment. Finally, we discuss the implications for CBL design, propose future work, and draw attention to possible limitations in the use of the framework.

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1 INTRODUCTION

Kim is a third-year biomedical engineering student at Eindhoven University of Technology (TU/e). Kim is about to graduate, and to do so has joined the innovation Space Bachelor End Project (ISBEP). ISBEP an alternative for students who wish to graduate in an interdisciplinary team. Kim's team is composed of a biomedical engineer, a mechanical engineer, and an industrial designer. For the last five months, Kim and her team have worked on an open-ended challenge brought in by a local hospital (the challenge owner). Throughout the project, Kim's team has interacted with ISBEP coaches, who overlooked the interdisciplinary aspects of the project; academic coaches, who oversaw the disciplinary development of students; and the challenge owner, who provided valuable input, and resources for the project.

Kim's project is coming to an end. The team is proud of their results. For Kim, ISBEP has been a formative experience. Through the interdisciplinary project, Kim has developed her professional skills, such as the ability to communicate with other disciplines. The project has allowed Kim to dive into topics of relevance to her discipline. Kim feels confident about her performance and professional growth.

Unfortunately, Kim's assessment does not develop in the way she expects. Kim is assessed following the criteria and procedures of a traditional (individual, non-challenge based) final bachelor project. Members of the examination committee do not fully understand the breath of Kim's learning. Her academic coach intervenes and provides some context for the assessment. After long deliberations, and providing further evidence, Kim's project is approved. Kim's graduation is bitter-sweet. Kim believes her assessment should better reflect the learning outcomes of her project.

1.1 CBL at TU/e, the context of ISBEP

The above illustrates the experience of a graduating student from ISBEP. ISBEP is a Challenge-Based Learning (CBL) initiative, set up and coordinated by TU/e innovation Space. CBL is currently a central topic at TU/e, which sees this approach as effective in developing student's broader skills and content knowledge [2]. ISBEP is characterized by interdisciplinary teamwork and the collaboration with multiple stakeholders, such as challenge owners, ISBEP coaches and academic coaches. Furthermore, ISBEP students work on open-ended challenges, brought in by real-word parties, such as companies and research groups. These, and other characteristics have been deemed descriptive of Challenge-Based education, by among others, [3]–[6]. ISBEP is high stakes because students' performance during the project determines the completion of their bachelor program.

1.2 Challenge of ISBEP as inter-program

A key characteristic of ISBEP is that it is *inter-program*. We define inter-program CBL as education where two or more educational programs (i.e., with distinct learning goals, criteria, and regulations for assessment) collaborate/interact to setup CBL experiences. This characteristic is well reflected in Kim's experience with ISBEP. The varying regulations on assessment from the different involved programs created *unclarity about the assessment procedures and criteria*. This and other challenges associated with inter-program CBL have been previously reported [7]. Among others, the *discrepancy between perceived learning outcomes and assessment criteria,* is highlighted as an important challenge of inter-program CBL. The large number of stakeholders (e.g., students, program directors, academic coaches, ISBEP coaches) plays a key role in the effective design/implementation of *constructively aligned* inter-program CBL. Achieving alignment across the instruction [8], the authors conclude, is key in achieving effective student-centred education.

This paper follows up on [7] and elaborates on the efforts followed to increase the constructive alignment of Intended Learning Outcomes (ILO's), assessment, and learning/teaching activities of ISBEP. The efforts are part of a longitudinal research project, whose aim is to arrive at assessment practices (formative and summative) that align well with inter-program CBL. Particularly, the paper presents a framework for inter-program CBL design in engineering education, using ISBEP as a case. The framework focuses on ILO's as a departing point for design, contributing a comprehensive list of ILO's at the third-year (engineering) bachelor level.

The remaining of this paper is structured as follows. First, we provide the theoretical framework guiding our research efforts. Subsequently, we elaborate on our methods and we present the framework (i.e., results). We conclude with a discussion on the framework, implications for practice and future work.

2 THEORETICAL FRAMEWORK

2.1 Constructive Alignment

Constructive Alignment (CA; [1]) is a well stablished student-centered approach to educational design. The approach is outcomes-based, which means that the definition of ILO's precedes the design of learning/teaching activities and assessment practices in a course or curriculum innovation. A guiding principle of CA is that ILO's drive the actions (i.e., learning/teaching activities) that are expected to construct knowledge for students. Assessment is a tool aligned to ILO's, which help judge whether the intended learning has been achieved. Similar frameworks that highlight the importance of ILO's as departing point to educational design are the Integrated Design Approach [9], and the Curriculum Spider Web [10]. CA has been previously used in the context of higher engineering education, among others by [11].

2.2 Defining ILO's as basis for educational design

ILO's can be defined at the institutional (e.g., across programs), program (e.g., a student's trajectory within a domain) or course level (e.g., a module or project) [1]. A main attribute of ILO's is that they allow students to understand what is expected of them, as and how to demonstrate their learning [12]. In competency-based education (such as that at TU/e), ILO's are linked to competency areas, such as "scientific discipline", "scientific approach" or "communication", and encompass the knowledge, skills and attitudes students are expected to develop [13]. The Academic Competences and Quality assurance (ACQA) framework, for example, presents a comprehensive list of competencies and associated ILO's [14].

ILO's indicate how the content/topic of learning is to be addressed, and its context. In defining ILO's, Biggs & Tang [1] advise distinguishing between declarative knowledge (e.g., disciplines-specific topic) and functioning knowledge (i.e., applied knowledge). ILO's are written in terms of verbs, which express what students can do with the content/topic of learning, and at what level. For example, "identify", "analyze", "reflect", all denote different levels with varying complexities. Hence, it is advised to establish the intended level of understanding/performance expected from students. For instance, the performance expected at the first-year bachelor program versus the master level differs significantly. Existing models used to denote such levels include Bloom's taxonomy (see e.g., [15]), and the SOLO taxonomy [16].

Following the definition of ILO's, teaching/learning activities and assessment are defined. In CA, "knowledge is constructed through the activities of the learner" ([8], pg. 9). For example, through coaching sessions (i.e., teaching/learning activities), students engage with the verb "reflect". Coaching sessions act as a catalyst for learning; students are stimulated to think of their (learning) goals, current performance, effectiveness of their strategies, and to set new goals/strategies [17]. Assessment practices are expected to align with ILO's and learning activities when they inform students about the intended learning and how to attain it [1]. The literature on assessment is wide and presenting an overview of it is outside the scope of this paper. Important to highlight are the two commonly acknowledged types of assessment [18]: *Formative* (i.e., assessment for leaning, such as feedback) and *Summative* (i.e., assessment of learning, such as checking that students have met certain criteria). Under the CA framework, concepts such as *fit-for-purpose* assessment (see programmatic assessment, [19]) gain relevance. Here, the idea is to select assessment in relation to the purpose of the learning activity (i.e., ILO's). ILO's, learning/teaching activities and assessment are aligned to maximize learning.

2.3 ILO's in CBL

CBL is attributed to the development of both disciplinary knowledge and professional skills [6]. In relation to broad professional skills, reported outcomes include communication, collaboration, organization, stimulated by the work on real-life cases (and scenarios), and the interaction with multiple stakeholders [4], [6], [20]. Furthermore, by engaging in CBL, students learn to 'identify, formulate and manage complex problems in a creative and critical manner' [6]. CBL is said to promote self-directed learning and to help students embrace uncertainty [20]. Similarly, in a study exploring the perceived learning gains of engineering students, van Uum & Pepin [21] report five strands of learning associated to CBL: *Disciplinary conceptual and procedural knowledge* (i.e., subject matter knowledge), *General cognitive learning* (e.g., forming ideas & setting goals; designing, implementing & operating); *Affect, thought, and learning* (e.g., taking initiative, motivation, lifelong learning; taking into account the societal context); *Entrepreneurial learning* (i.e., communication & collaboration with stakeholders); and *Teamwork and communication*.

While the above information provides insights into the intended learning associated with CBL, the learning goals for CBL and similar educational environments (i.e., promoting the learning of 21st century skills) remain vague [22]. This need has been highlighted for similar learning environments, such as sustainable learning [23]. Information on ILO's for CBL remain scattered, and the link between ILO's, assessment and learning activities is rarely addressed. In this paper we contribute to this need by exploring the ILO's for inter-program CBL, using ISBEP as a case study. As ISBEP is a third year, final bachelor project, it sheds light into the intended learning for students at the highest engineering bachelor level, in a context where the development of content knowledge and broad professional skills are both key. Furthermore, we explore ILO's in relation to their associated learning/teaching activities, as a first step in increasing the CA within ISBEP. Our aim is to provide information relevant for the design/implementation of constructively aligned CBL.

3 METHODOLOGY

Our research interests were addressed by means of a co-creative workshop [24], to bring in the varying views of relevant stakeholders in the design and implementation of ISBEP throughout TU/e. The goal of the session was to arrive to new ILO's for ISBEP, which serve as a basis for its constructively aligned redesign.

3.1 Participants and setup

The session lasted two hours and was set up as a combination of plenary and breakout sessions. Discussions in the plenary and breakout rooms were guided by facilitators. Three questions guided these discussions: 1) What do students learn by engaging in CBL?; 2) How do the ILO's for CBL relate to those of TU/e's Bachelor College?, and 3) What should the Intended Learning Outcomes of ISBEP be? The questions acted as a funnel, from general to specific, starting with general learning associated to CBL, and ending with learning specific to ISBEP.

Two platforms were used during the sessions: MS Teams and Miro. MS Teams was used for audio/video communication and to video-record the sessions. Miro is an online collaboration tool that allows remote and active participation. Boards were created in Miro with the guiding questions to stimulate the discussion between participants. Outcomes of the session were captured by means of digital post-its.

To stimulate alignment across the institution [8], different stakeholders, including, students, educators, final project coordinators, program directors, policy advisors, and administration staff were invited to take part in the activity. Invitations were sent via email. An initial list of possible participants, representative of the various views/expertise within the university was made. However, the invitation was open, and invitees were encouraged to extend the invitation to other colleagues. This resulted in 28 participants (out of 61 invitees; 7 facilitators, 6 students, 5 educators, 5 educational researchers, 3 educational strategists, 2 administration officers), divided across 6 teams. Team were allocated making sure varying views were represented in each team. All participants agreed to taking part in the research voluntarily and consented to the use of the collected data for research purposes.

3.2 Data Analysis

We followed a thematic-analysis approach to data analysis [25]. First, data were processed; videos and post-its were reviewed, allowing the main researchers to familiarize with the data. When post-its where not self-explanatory, they were revised and fine-tuned based on the audio/video information. Next, data/post-its were reviewed, identifying themes descriptive of the different ideas discussed during the session. For example, post-its reading “think out of the box”, “ideating”, and “solving”, were grouped in the theme “thinking creatively”. This inductive analysis was followed for all post-its and questions, leading to the identification of a first potential list of learning areas and competencies linked to ISBEP. These results were triangulated by two separate researchers, increasing the validity and reliability of the analysis. The independent results were discussed and used for the final development of ILO’s and framework, and fine-tuned through several iterative sessions with the ISBEP team.

4 RESULTS

172 post-its were generated, of which 58, clustered in 14 themes, were associated with the question “*What should the Intended Learning Outcomes of ISBEP be?* (See Appendix A; basis for results). Table 4.1 depicts the framework of ILO’s for ISBEP (i.e., inter-program CBL, third-year bachelor level). The framework lists 10 ILO’s (i.e., knowledge, skills, and attitudes), related to 3 areas of learning (i.e., design and research process, professional skills, and professional identity); and 7 competence areas. Furthermore, we provide examples of learning/teaching activities from practice within ISBEP, to illustrate the first steps increasing CA based on defined ILO’s.

ILO1 relates to the competency “defining problems” within the complexity of the open challenge. In ISBEP, students navigate the challenge during the first weeks of the project. Students *identify* the interdisciplinary problem to be addressed, as well as their individual contributions (i.e., disciplinary components). Exploratory sessions with different stakeholders (e.g., challenge owners) support this ILO. Information gathered in this activity serves as input to write down an interdisciplinary problem statement.

ILO2 relates to the competency “need finding”. Students *identify* the varying needs of stakeholders (e.g., challenge owners, academic coaches), and *integrate* them in a viable solution. A learning activity supporting the development of this competency are the several alignment meetings with stakeholders. This activity stimulates students to think in terms of project goals, ask questions in relation to their development (individual/interdisciplinary project), allowing them to fine-tune the problem statement/scope (as the project matures).

ILO3 and ILO4 relate to the competency “systems thinking”. While ILO3 focuses on *identifying, assessing* relevant theories from their own (i.e. individual) disciplines, ILO4 focuses on *applying* those knowledge in the project, and *integrating* them into a viable (interdisciplinary) solution. “Systems thinking” thus relates to the interconnectedness of disciplinary contributions and identifying the boundaries of the project. In terms of learning activities, discussions with experts, and workshops on system mapping, provide students with the necessary tools to attain these goals.

Table 1. Framework of ILO's for ISBEP and Associated Learning Activities

Area of learning	Competence Area	Intended Learning Outcomes (ILO's) for ISBEP	Associated Learning Activities
Design & Research Process	**Defining problems**	**1.** *Identify* the interdisciplinary problem that needs to be solved, and the disciplinary components.	• Exploratory sessions with stakeholders (e.g., challenge owners, academic coaches). • Alignment meetings with stakeholders throughout the project. • Problem analysis and statement in group discussion supported by coaching.
	Need finding	**2.** *Identify* the needs of different stakeholders, and *integrate* them in the viable solution.	• Exploratory sessions with stakeholders (e.g., challenge owners, academic coaches). • Alignment meetings with stakeholders throughout the project. • Workshop on mapping tools/models (i.e., map of stakeholders; systems mapping).
	Systems thinking	**3.** *Identify* relevant theories from their own discipline, assess their relevance.	• Sessions with academic coaches on disciplinary aspects of the project. • Collaborative discussion groups (students from same discipline). • Discussion with (disciplinary) experts on topics relevant to the projects.
		4. *Apply* the knowledge from different disciplines in a project & *integrating* them into a viable solution.	• Workshop on mapping tools/models (i.e., map of stakeholders; systems mapping). • Alignment meetings with stakeholders throughout the project.
	Prototyping	**5.** *Integrating* the individual components (i.e., individual contributions) into a working/experiential prototype.	• Peer-to-peer feedback sessions on how to prototype solutions. • Workshop on prototyping. • Mid-term project market. • Final presentations.
Professional Skills	**Interdisciplinary Collaboration**	**6.** Be able to *identify* the roles & contributions within a team.	• "Roles & goals" session. • Coaching sessions. • Retrospective sessions (self-reflection, peer- feedback).
		7. *Demonstrate* the ability to communicate and collaborate with people from other disciplines while working on a real-world case.	• Pitching exercises. • Workshop on interdisciplinary communication. • Retrospective sessions (self-reflection, peer- feedback). • Alignment meetings with stakeholders throughout the project.
	Organizing & Planning	**8.** *Manage* a situation where there is no clear answer to their problem.	• Coaching sessions on process. • Alignment meetings with stakeholders throughout the project.
Professional Identity & Self-directed learning	**Reflecting on learning**	**9.** *Reflect* on the role that they have played in the interdisciplinary team, and its impact on professional identity.	• Retrospective sessions (self-reflection, peer- feedback). • Final presentations. • Writing reflection.
	Understanding the position as a type of engineer in relation to the societal context/challenge	***10.*** *Demonstrate* an awareness of what their personal contribution can be to the societal challenge.	• Writing reflection.

ILO5 relates to the competency “prototyping”, where students *integrate* the individual contributions into a working/experiential prototype. For ISBEP, this is an important deliverable at project completion. A prototype can be a mock-up, video, or other media that allows stakeholders to experience the solution. Students are encouraged to present their mock-ups or ideas for prototyping during the midterm presentation and justify their decisions. This allows for formative feedback from key stakeholders and peers, to further fine-tune their plans/strategies.

ILO6 and ILO7 relate to the competence “interdisciplinary collaboration”. ILO6 centers on students’ capacity to *identify* the roles/contributions of members in the interdisciplinary team (i.e., professional skills, e.g., leading). A learning activity supporting this ILO is the “roles & goals” session, where students are encouraged to discuss their personal development goals. This session is guided by (ISBEP) coaches. ILO7, on the other hand, centres on students *demonstrating* the ability to communicate and collaborate with people from other disciplines. The development of this skill is supported through a workshop on interdisciplinary communication.

ILO8 addresses the competence “organizing and planning”. The competence relates to students engaging in the abstract open-ended challenge (no predefined set of goals/outcomes), and students’ competence in *managing* said situation. The learning activity most directly linked to this ILO are the weekly sessions with ISBEP coaches, which help students reflect and set new directions/strategies for the project.

Finally, ILO9 and ILO10 concern the competence “reflecting on learning” and “Understanding the position as a type of engineer”. Particularly, students *reflect* on the role they played in the interdisciplinary team, and its impact their professional identity. Moreover, they *demonstrate* an awareness of what their personal contribution can be to the societal context/challenge. “Retrospective sessions” (i.e., where students discuss as a team what went well, what should be improved) support this learning.

5 DISCUSSION

This study investigated Intended Learning Outcomes in inter-program CBL. Overall, the ILO’s show alignment with previously learning associated with CBL (e.g., [4], [6], [20]). The framework points to the development of both disciplinary knowledge and broad professional skills as key in this context. The domain of disciplinary knowledge stands out as particularly important in the third year, high stakes, bachelor level, but framed in relation to the interdisciplinarity. We choose to link this to the competency “systems thinking”, as it relates not only to the identification of relevant theories from own discipline, but also to their integration in the interdisciplinary project/solution.

Competencies related to the design and research process (i.e., defining problems, need finding, systems thinking, prototyping) remain a central part of the ILO’s associated with ISBEP. The development of the broad professional skills relates particularly to the process, facilitated by the openness of the challenge, the interaction with stakeholders, and the hands-on approach characteristics of CBL. In our context, these ILO’s were perceived as characteristic of ISBEP, and generally lacking in the regular BEP (i.e., non-CBL alternative). Similarly, professional identity is an area not generally addressed in the regular BEP, as these projects are framed within the disciplines. When finalizing ISBEP, graduates are expected to have a better account on their identity as an engineer in relation to other engineers, as they have a better insight into their role in the challenge. This is not assessed in current practice but highlights the competences an individual has gained throughout their development in the Bachelor Program, and more explicit for this group of students.

The followed approach allowed for a rich discussion on the ILO's associated with CBL at TU/e. The workshop highlighted the varying views on learning, particularly in the inter-program CBL context. The workshop was valuable as a first step in reaching alignment across the institution [8], and highlighted the need for open and constructive communication in the design/ implementation of inter-program CBL. Our advice in designing similar initiatives is to co-define/create CBL with different stakeholders, and to involve students in this process whenever possible.

An important question is whether the defined intended learning aligns well with the expected level of students engaging in CBL. In our case, some resulting ILO's were not always aligned with the intended learning of TU/e' Bachelor College. When comparing our resulting ILO's to the ACQA framework [14], for example, working on complex, 'real-world' challenges is linked to the knowledge, skills and attitudes of students at master level. This points to the need to look at students 'intended learning through CBL at a curricular level.

An important limitation of our work is that the findings are highly linked to our institutional culture and vision on education. While the framework can serve as inspiration for discussing the intended learning of new CBL initiatives, the institution's vision on education ought to be considered. This may also be reflected in the learning activities and assessment practices chosen to support the learning of students. A second limitation is that the present paper does not reflect the depth and breadth of the process of defining ILO's; particularly in inter-program CBL. Defining ILO's is an iterative process that requires the involvement of the different programs. This process goes beyond our reported method, and requires organization of evaluative meetings with program directors, final bachelor project coordinators, among others. These efforts are directed towards evaluating the list of ILO's (i.e., clarity, validity, overlap) but also, furthering the alignment across the institution.

Finally, the current framework focuses on the definition on ILO's as starting point for educational design towards CA. The framework links learning activities from ISBEP to exemplify how this alignment can be reached. These learning activities, however, ought to be validated. Furthermore, the present framework does not cover assessment, which is a key component in reaching alignment. Our next steps thus focus on assessment. Particularly, on defining performance indicators that strengthen the link between ILO's, learning activities and assessment practices. This could, among others, result in the development of new assessment tools (e.g., rubrics) which can guide development of students. Our goal is to design a learning experience for students, such as Kim, which is perceived as valuable and coherent by students and educators alike, along the three elements of CA.

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APPENDIX A: OVERVIEW OF CODES AND GROUPS

	“What should the Intended Learning Outcomes of ISBEP be?		
Themes/grouping	**Number or associated post-its**	**Examples post-its (Repeated post-its omitted for clarity purposes)**	**Link to Intended Learning Outcomes (ILO's) ISBEP**
Analysing an open-ended challenge and defining a relevant problem & Contextualizing Problems/solutions	2	Identify problems in a context, to be able to define a complex problem.	ILO1,
Appling disciplinary knowledge to real-world challenges	6	How to do applied research, putting theory into practice, learn by doing, application of theory, working in real-life cases, challenge.	ILO 3, ILO4
Demonstrating command of disciplinary knowledge	4	Learning to perform research, able to argue at scientific level about design choices, shows a good understanding of his/her own discipline and beyond.	ILO3, ILO4
Following a Systems approach to problem analysis/solving	2	Systems approach to complex problems, students learn the whole process/start with the challenge and ends with solution.	ILO1, ILO2, ILO3, ILO4.
Integrating ideas (from different disciplines) into a solution	3	Integrate-part solutions, connecting knowledge of multiple areas, prototype the solution/know how to test the solution from different perspectives.	ILO2, ILO 5
Thinking Creatively	7	Think big, think outside the box, design/create, solve problems.	ILO1, ILO2, ILO3, ILO4, ILO5.
Working/Collaborating interdisciplinarily	7	Collaborate, multidisciplinary learning, connect to various disciplines, working together, collaborative learning, how to design in a team, develop multidisciplinary learning skills.	ILO6, ILO7.
Acquiring communication skills for the interdisciplinary project	3	Effectively communicate with people from other disciplines, experience and learn soft skills.	ILO6, ILO7.
Dealing with uncertainty & managing a project	5	Deal with uncertainty, able to steer their (learning) process under guidance, execute plans, learning how to take ownership.	ILO8.
Self-directed learning	8	Learning how to learn, learning to be in control of own learning, acquiring the skill of life-long learning, define own learning path.	ILO9, ILO10.
Reflecting	3	reflect on learning process/outcomes, processing feedback, reflect on the role of engineers in solving the problems of society.	ILO9, ILO10.
Developing professional identity	4	Finding out what you like to do, identify and follow own interests and preferences, develop your professional identity.	ILO10
Developing a solution of societal relevance	4	Contributing to society, contribute to real-world challenges.	IL010
TOTAL Post-its	58		