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Practice Paper

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Intended Learning Outcomes on Process Level in an Engineering Course with Knowledge-Based Learning Outcomes

Peter A. M. Ruijten-Dodoiu [1]
Eindhoven University of Technology
Eindhoven, The Netherlands
0000-0003-1900-3415

Ana Valencia
Eindhoven University of Technology
Eindhoven, The Netherlands
0000-0003-3479-1659

Eugenio Bravo
Eindhoven University of Technology
Eindhoven, The Netherlands
0009-0002-4607-629X

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ABSTRACT

This practice paper introduces an approach to learning outcomes within the context of the Innovation Space Bachelor End Project (ISBEP), which underscores the transition from traditional outcome-focused education to a process-level learning paradigm at a Technical University in the Netherlands. At the core of ISBEP's methodology is competence development through challenge-based learning, encouraging interdisciplinary collaboration and engagement with societally relevant challenges. The paper discusses the effectiveness of process-level learning outcomes, highlighting the importance of reflection, self-awareness, and iterative learning in fostering a growth mindset among students.

We then outline the application of this process-oriented approach to knowledge-based learning outcomes, an area traditionally dominated by outcome-based assessments. By segmenting educational progress into distinct stages—beginning,

[1] *P.AM. Ruijten-Dodoiu*
p.a.m.ruijten@tue.nl

emerging, proficient, and advanced—this approach facilitates a more engaged and reflective learning process. It encourages students to actively participate in their knowledge acquisition, applying critical thinking and synthesis to complex problems.

The proposed methodology is set to be tested in the "Automotive Societal Factors" course within the Master program in Automotive Technology, a course that focuses on the societal impacts of autonomous driving. This course will assess students' self-reflection on personal development, aiming to foster intrinsic motivation and a growth mindset that may extend to other areas of their education. This exploration into process-level learning outcomes represents a significant shift in educational philosophy, offering a comprehensive framework for enhancing learning engagement and understanding in various settings.

1 DEFINING LEARNING OUTCOMES ON PROCESS LEVEL

The Innovation Space Bachelor End Project (ISBEP) stands at the vanguard of educational innovation, embodying the principles of challenge-based learning (CBL) (Doulougeri et al., 2024). This approach is encapsulated in the course's core characteristics: interdisciplinary collaboration (i.e., different disciplinary backgrounds, such as mechanical engineering and electrical engineering), focus on societally relevant challenges, and partnership with a broad spectrum of stakeholders.

ISBEP promotes both skill and (disciplinary) knowledge development. Assessment of disciplinary knowledge is performed by specialists from each student’s own department. Assessment of skills is performed through a set of individual and team-based learning outcomes. Individually, students strive to understand the nuanced needs of stakeholders, to dissect interdisciplinary problems into manageable components, and to navigate the murky waters of situations with no clear answers while applying or deepening their respective disciplinary knowledge. Collectively, their goal is to synthesize their findings into a cohesive, experiential demonstrator, showcasing their ability to apply knowledge across disciplines and to collaborate effectively.

1.1 Skill-Based Learning Outcomes on Process Level

Central to ISBEP's educational philosophy is the transition from traditional outcome-focused metrics to an approach that emphasizes process-focused metrics. In other words, the focus is less on showcasing abilities at the end of the course, and more on guiding students in the process that leads them to acquire the necessary skills.

This philosophy underlines the understanding that learning is an iterative journey, unfolding over time and across various stages of comprehension and competence (i.e., skills, knowledge, attitudes) development. By articulating these process-level outcomes, ISBEP offers students guidance along their educational journey, enhancing their engagement with the learning activities and facilitating a deeper understanding of the challenges and successes they can expect in the interdisciplinary collaboration. It encourages a growth mindset, which is shown to enhance intrinsic motivation to learn (Ng, 2018). Fostering a growth mindset encourages the development of new talents (Dweck, 2009), and as such empowers students to take charge of their own learning progress. It also encourages students to set goals for themselves, and in the field of academic performance, studies show that self-based goals are associated with higher motivation and engagement (Martin & Elliot, 2016; Yu & Martin, 2014).

This methodology proves particularly effective for several reasons. First, it provides students with clear milestones in their learning progression, helping them identify their current stage in the development of learning outcomes and the steps needed to advance further. This clarity is crucial for fostering awareness among students regarding their learning process, enabling them to seek appropriate support and resources as they progress. Furthermore, by delineating the stages of learning, students are encouraged to engage in reflective practices, (self-)assessing their strengths and areas for improvement in relation to the defined learning outcomes.

The organization of ISBEP thus facilitates a learning environment where reflection (i.e. actively thinking about one's own learning), iterative learning (i.e. continuous improvement through small steps), collaborative learning, and practical application have become the cornerstone of the educational experience. Students are not merely passive recipients of knowledge; they are active participants in a learning journey that emphasizes growth, development, and the practical application of skills.

1.2 The Role of Self-Reflection

Reflection plays a pivotal role in ISBEP, serving as a mirror for students to examine their learning processes, both as individuals and within their teams. Through coaching sessions, guided reflection, and self-assessment, they gain insights into their growth, challenges, and achievements. A digital platform serves as a canvas for their self-reflection, offering graphical overviews of their growth in individual learning outcomes and a holistic view of their competencies through spider diagrams.

ISBEP delineates four stages of process orientation: beginning, emerging, proficient, and advanced. Each stage represents a milestone in the student's journey towards becoming engineers who are more aware of their interdisciplinary competencies. At the start of the course, students carry out a first self-assessment in relation to their overall development and gain awareness of their starting point in the learning journey within ISBEP.

- **Beginning**: This initial stage is characterized by foundational learning, where students are introduced to new concepts and begin to engage with the learning activities and their project. The expectation at this level is foundational knowledge and basic application.
- **Emerging**: At this stage, students start to display an increased understanding of the competencies they are developing, their role within the team, and contribution to the challenge. Moreover, they can apply concepts in more varied contexts. Expected outcomes include a deeper engagement with the project and the beginning of critical thinking regarding the subject matter.
- **Proficient**: Proficiency is marked by a significant level of mastery over the project, with students demonstrating the ability to apply knowledge in complex situations and engage in higher-level thinking and problem-solving.
- **Advanced**: The advanced stage signifies a deep and comprehensive understanding of the subject matter, with the ability to engage in creative problem-solving, contribute original ideas, and synthesize information across various contexts.

ISBEP places a strong emphasis on reflection as a mechanism for learning. Reflection, both guided and self-driven, allows students to internalize their experiences, understand their thought processes, and critically evaluate their own work. This approach is structured in several layers:

- **Team / Individual Work**: Encourages collaborative learning as well as individual study, providing a balanced environment for knowledge acquisition.
- **Coaching Sessions**: These sessions offer personalized guidance, helping students navigate challenges and gain deeper insights into their learning process.
- **Guided Team Reflection**: Facilitated by process coaches, guided reflection helps students identify key learnings, challenges, and areas for improvement.
- **Self-Assessment**: Students engage in a personal review of their learning journey, fostering self-awareness and personal growth.

2 APPLICATION IN AN ENGINEERING COURSE

The process approach to intended learning outcomes has shown to be successful when applied to a course with only skill-based learning outcomes. Most of the courses at our university do not (only) contain skill-based learning outcomes, but are designed to help students obtain knowledge-based learning outcomes. Knowledge-related learning outcomes are those through which knowledge acquisition is being assessed.

2.1 From Skill-based to Knowledge-based

Expanding the principle of process-level learning beyond broader competence (i.e., skills, knowledge, attitudes) development and into the realm of knowledge-related learning outcomes, marks a significant evolution in educational philosophy. This extension involves reimagining traditional content acquisition as an exploratory, iterative process. The segmentation of the educational process into stages would suppose the enhancement of students' ability to engage with complex problems, but knowledge acquisition also becomes an active, engaged process that emphasizes critical thinking, reflection, and synthesis.

Despite the advantages of a process-oriented approach (as experienced in ISBEP), its implementation, particularly within the context of knowledge-based learning outcomes, is met with several challenges. Traditional educational frameworks often prioritize outcome-based assessments and discipline-specific knowledge, presenting obstacles to the adoption of process-oriented strategies.

When relying on self-reports to assess learning gains, there are some limitations to consider. For instance, Rogaten et al. (2019) highlight that students may exhibit overconfidence in their knowledge. This tendency tends to amplify over time (Mathabathe and Potgieter, 2014; Rogaten and Rienties, 2021; Varsavsky et al., 2014). Additionally, scholars emphasize that self-reported measures constantly compare students' perceived learning gains against their subjective "feeling" of learning or "feeling of knowing" (Rogaten and Rienties, 2021). Self-reflections thus are inherently subjective, as they represent individual students' perceptions of their learning experiences and progress. This subjectivity poses a difficulty in evaluating self-reflections against standardized criteria, as interpretations of learning progress can vary widely among students.

One potential solution to this challenge is taking a learning analytics approach, where linguistic indicators of personal development could be examined in reflective writing (Kovanović et al., 2018). Another approach is integrating self-reflections with other types of evidence in course deliverables. By comparing the elaborations in self-reflections to tangible outcomes and artifacts produced during the course, educators can achieve a more comprehensive and objective assessment of student learning. This comparative analysis allows for a triangulation of evidence, wherein self-reflections provide insights into the students' self-perceived growth and learning processes, while course deliverables offer concrete evidence of their skills and knowledge application. This method not only enhances the reliability of assessments but also encourages students to consistently align their reflective practices with their practical work, fostering a holistic approach to learning.

2.2 Context of the Engineering Course

This approach will be put to the test by applying it in an engineering course that has knowledge-based learning outcomes. The course is a core course in the first quartile of the Master program Automotive Technology; Automotive Societal Factors. The course addresses the relation between a car or other vehicle, its human driver, and its dynamic environment. It is especially concerned with technological, social, and legal perspectives of autonomous driving. Apart from lectures students will work in groups on an assignment that incorporates many of the topics of the course: societal dimensions of autonomous driving, future mobility and traffic, user perception, legal issues, and ethics.

2.3 Knowledge-Based Learning Outcomes on Process Level

The intended learning outcomes of the course are based on four levels of Bloom's (1956) taxonomy and are the following:

After completion of the course, students are able to

- **Apply** human-centred design methods and evaluation metrics within an automotive context
- **Analyse** a driving task in terms of perceptual, attentional, environmental and societal processes
- **Analyse** connections between key theories and principles within the automotive context
- **Evaluate** their own personal development on the learnings outcomes throughout the course
- **Create** a (VR) simulation/experience showing automated driving in context

These learning outcomes are then each split into the four process-levels. For the learning outcome "Analyse a driving task in terms of perceptual, attentional, environmental, and societal processes", this leads to the following:

- **Beginning**: Students recognize the components of driving tasks but cannot articulate how perceptual, attentional, environmental, and societal factors influence these tasks.

- **Emerging**: Students can describe how each of the specified factors affects driving tasks but struggle to integrate this understanding into a coherent analysis.
- **Proficient**: Students provide a thorough analysis of driving tasks, clearly explaining the interplay between perceptual, attentional, environmental, and societal factors. They can predict task performance outcomes based on these analyses.
- **Advanced**: Students offer deep insights into the driving task analysis, incorporating cutting-edge research and theoretical frameworks. They are adept at forecasting the implications of these factors on future automotive technologies and societal impacts.

3 IMPLEMENTATION IN THE COURSE

The Automotive Societal Factors course starts in September 2024, and this will be the first rendition in which students' self-reflection on personal development is assessed. The design of the assessment itself (the assessment criteria and descriptors of the different levels) will look as follows: at the end each week, all groups submit a new part of their assignment to Canvas (the Learning Management System used by TU/e). At the same time, students individually complete an assignment in which they reflect on their personal development. They indicate for each ILO which level they have achieved, and elaborate on their choices by answering one open question. Assessment of the reflection will be based on two components. The first is the extent to which the indicated levels on individual level correspond with the quality of the work on group level. The second is the quality of the elaboration on the reflection itself (i.e. showing a deeper understanding of one's own capabilities and what is needed to reach the next step would make a student get a more positive assessment).

Our expectations are that students will become intrinsically motivated to study for the course, as the process focus will nudge them into obtaining a growth mindset. This will be evaluated by measuring students' mindset several times throughout the course (at the start and at the end, and one or two more times in between). We expect that the educational approach of the course will foster more growth mindsets, which ultimately could spill over into other courses in the program, preparing students for a successful educational path.

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