SKILLS ASSESSMENT IN INNOVATION AND ENTREPRENEURSHIP EDUCATION INITIATIVES

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ABSTRACT

Skills assessment is a topic within experiential learning teaching pedagogy, such as challenge-based learning (CBL), which calls for attention. Most university teachers know how to assess and judge the knowledge levels of their engineering students but need to learn more about assessing the so-called 21st-century skills (e.g., leadership, problem-solving, empathy, communication) and how the assessment influences the learning process. Therefore, this paper aims to study the connections between the learning process and skills assessment in innovation and entrepreneurship education (I&E) initiatives and discuss how to assess student's skills in a transparent and safe way. To achieve that scope, we compare and critically discuss four I&E education experiences from the University of Trento (Italy) and Linköping University (Sweden), considering different variables such as learning goals, contents, team formation, teamwork, and expected outcomes. We identify four main findings: (i) facilitation and coaching are an essential ingredient in the courses, (ii) development-oriented feedback from teachers helps students to acquire new knowledge and improve their skills, (iii) formative assessment - both informal and formal - through matrices can help teachers in measuring progressions and difficulties in individual students, (iv) ENTRECOMP framework can support the soft skills evaluation. In conclusion, we underline the importance of assessing skills on two levels (the individual and the team) through recognized and well-described tools. Secondly, personalized self-directed learning tools, such as structured learning reflection and tailor-made learning criteria, are also beneficial but have limitations. Finally, formative assessment matrices, with defined requirements for different levels, also seem helpful.

KEYWORDS

Innovation and Entrepreneurship Education, 21st-century skills, Self-directed Learning, Formative and Summative Assessment, Challenge-based Learning, Standards: 1, 2, 7, 8, 9, 10, 11

INTRODUCTION

Skills assessment is a topic within experiential learning teaching pedagogies, such as challenge-based learning (CBL), which calls for attention. Most university teachers know how to assess and judge the knowledge levels of their engineering students. Still, they are less knowledgeable about assessing 21st-century skills (González-Pérez, & Ramírez-Montoya, 2022). Hence, they need "educational models and formal and informal educational practices that scale the development of 21st-century competencies" (ibid p. 26). According to Geisinger (2016), 21st-century skills can be (i) cognitive, (ii) technical, (iii) interpersonal, (iv) and intra-personal. Cognitive skills include problem-solving and critical thinking, while technical skills encompass entrepreneurship and finance. Interpersonal skills include executive function and self-management; intra-personal skills encompass social skills such as communication and collaboration. As these skills are included in the learning outcomes of most engineering programs, it is crucial to find efficient ways to assess them and understand their impact on the learning process.

Over the years, our assessment instruments, particularly for knowledge assessments, have become more sophisticated. For example, the SOLO (Structure of Observed Learning Outcomes) taxonomy (Biggs & Collis, 1982) enables us to grade students' efforts. However, university education is not, as emphasized above, just about theoretical knowledge; it also involves developing skills necessary to address present and future challenges. To prepare students for the VUCA world of volatility, uncertainty, complexity, and ambiguity (Bennett & Lemoine, 2014) and enable them to be successful engineers that can engineer (Crawley & al, 2007), we need to consider the interplay between acquiring both knowledge and skills. This is especially relevant as new technologies such as AI, robotics, and complex data management are entering the scene and calling for educational innovation that matches industrial development (González-Pérez, & Ramírez-Montoya, 2022).

In this context, frameworks such as the Entrecomp (Bacigalupo & al, 2020) and EPIC (HEI Innovate initiative) are relevant. Previous research has explored the connections between challenge-based learning (CBL) and the CDIO (Conceive, Design, Implement, Operate) framework (Gunnarsson & Swartz, 2022), as well as how the project model method is used to assess CDIO skills (Svensson & Gunnarsson, 2005). The general application of assessing students' cognitive learning process using the SOLO taxonomy concerning learning outcomes (Biggs & Collis, 2014) has also been studied. However, no examination has examined how to measure and assess skills transparently and fruitfully. In order to address the lack of optimal assessment in higher education, specially dedicated to engineering education, we aim to discuss how to measure skills in a meaningful and possible way and how to treat skills obtained prior to versus within the course. Second, we elaborate on measuring the students' skills development in innovation and entrepreneurship (I&E) education initiatives such as curricular and extracurricular courses, hackathons, and challenges. Finally, we also handle the need to manage issues of objectivity of the teacher employing what affects the teacher's assessments.

Based upon the above-identified problems and research gaps, this paper aims to study the connections between the learning process and skills assessment in innovation and I&E education initiatives and discuss how to assess skills transparently and securely for the students. To reach this purpose, we will identify, test and evaluate some of the present tools for assessment. The paper is organized as follows; it starts with a theoretical background about CBL and self-assessment approaches and tools. This is followed by the research method used and the empirical setting for the study, followed by the discussion of findings and conclusions.

FRAME OF REFERENCE

Challenge-based learning

CBL is an innovative approach to education that focuses on engaging students in solving real-world problems through collaboration, critical thinking, and problem-solving skills (Observatory Tecnológico of Educational de Monterrey, 2015). The literature on CBL is growing, and in this paper, we follow the definition of Norrman et al. (2022, p. 762), where CBL is described "as an experiential learning approach that starts with wicked, open and sustainability-related real-life challenges that students, in cross-disciplinary teams, take on in their way and develop into innovative and creative solutions that are presented in open forums." Challenges are provided by companies, public institutions, associations, and communities that deal with real problems and seek sustainable solutions. This way of working strengthens not only the educational results but also the regional innovation ecosystem as it joins together all parts of the "knowledge triangle" (EIT, 2012) or the so-called quadruple helix (university, industry, government, civil society). Companies and organizations giving challenges are named challenge providers - abbreviated CPs from here on - (Norrman et al., 2022). The CBL approach is based on the idea that students are more motivated and engaged when presented with challenging and authentic problems to solve rather than being given pre-determined answers, as usual in traditional teaching.

CBL promotes student-centered learning and fosters 21st-century skills, including creativity, critical thinking, and collaboration (Thomas, 2012). CBL also requires students to apply the knowledge and skills they have previously learned, which goes well with the CDIO framework's ideas (Gunnarsson & Swartz, 2021). This "new" way of learning can be traced back to the thoughts of Dewey (1938; 1963) and is rooted in constructivism, a pedagogic theory that posits that knowledge is constructed by the learner through active engagement with the environment (Piaget, 1971; Vygotsky, 1978). This theory emphasizes the importance of student-centered learning and self-directed learning (SDL) since the role of the learner is crucial in the learning process (Jonassen, 2002). Deci and Ryan (2000) and Ryan and Deci (2000) explicitly show that motivation plays a crucial role in learning. For all these characteristics, CBL is gaining momentum at various Higher Education Institutions (HEIs) worldwide (Vignoli et al., 2021). Some of the reasons that make CBL popular are that: (1) it provides instructive and experiential learning for students who can have a bath in a real job context, (2) it delivers real solutions and outcomes that the companies can implement, (3) it revolutionize the way of teaching and the role of the teachers who become coaches and mentors, or as in ECIU named "teamchers" (Eldebo et al., 2022).

Moreover, CBL has societal impacts. Students usually work to solve real problems and are often encouraged to work with peers from different disciplines - i.e., in what is mentioned as cross-disciplinary teams (Pérez-Sánchez et al., 2020). Since students approach complex problems, the learning experience becomes multidisciplinary and includes stakeholder perspectives (Kohn Rådberg et al., 2020).

Formative VS summative assessment

Formative and summative assessment, generated from the formative and summative evaluation (Lau, 2016), is used in schools worldwide, not least within the compulsory education system. Formative assessment aims to promote student learning, which is done through feedback and clearly expressed knowledge requirements for each grade, see, e.g., the SOLO taxonomy by Biggs (2014). Feedback is essential in formative assessment as it supports cognitive and professional development (Svensäter & Rohlin, 2022). According to Hattie & Timperley (2007), effective feedback must address goals, progress, and matters for improvement. It is also essential to be aware of how and in which way we communicate and

give feedback to promote the individual student's learning process. Yorke (2003) means that formative assessment can be both formal and informal - or both planned and interactive, which according to Yorke, are similar to Cowie and Bell's (1999) distinction. According to Yorke (2003), formal formative assessment (FFA) is defined as "those that take place about a specific curricular assessment framework" (p. 478).

Using frameworks as assessment matrices are expected, not least within the Swedish school system. These matrices contain activities the student must perform or knowledge requirements/criteria to achieve a specific grade. After the completed activity, the effort is assessed. The assessment of the student's activity includes feedback from which the student can learn. In this way, it is clear that FFA is connected to the student's learning process. The summative assessment focuses on measurable results, such as the number of points on a written exam or the level of a report, i.e., it measures students' knowledge by summing up the students' results of assignments and for the course as a whole. In this way, summative assessment has a clear connection to knowledge assessment. Lau (2016) points out that formative and summative assessments complement each other and must work together rather than be seen as contradictions. By combining formative and summative assessments, we achieve a blended assessment form. Svensäter & Rohlin (2022) mean that in "a blended form of assessments, formative assessment is a tool to improve students' summative performance, and formative assessment is in this way a real precursor to summative assessment" (p.150). Other concepts, such as continuous and interim assessments, are also used (Ghiatău et al., 2011) to describe formative and summative assessment mixtures.

Self-directed learning and self-assessment approach

SDL relates to the self-assessment approach, which evaluates one's performance and understanding of a task or concept (Butler & Winne, 1995). This approach is rooted in the theory of self-determination (Deci & Ryan, 2000; Ryan & Deci, 2000), which posits that individuals have innate psychological needs for autonomy, competence, and relatedness. According to this theory, when these needs are met, individuals are more motivated and engaged and perform better in their learning (Reeve, Jang, Carrell, Jeon, & Barch, 2004). Self-assessment or self-reflection is related to metacognition which refers to the awareness and regulation of one's cognitive processes (Flavell, 1979). It involves monitoring and controlling one's learning, which leads to better understanding and performance (Barkley, Cross & Major, 2014), a fact pointed out also in the pioneering works of Dewey (1938; 1963).

In CBL, as mentioned before, it is essential to stimulate 21st-century skills acquisition. The assessment of these skills is crucial, especially in I&E education initiatives (Fiet, 2001). This new learning model requires new assessment tools that monitor the soft skills acquisition process (Scroccaro & Rossi, 2022). Specifically, reflective learning tools can support this assessment by remembering acts and events, exploring why things went a certain way, and taking possible actions for different experiences. Changing the way of teaching and learning impacts the assessment, particularly on learning goals and skills assessments.

METHODOLOGY

We base our paper on our teaching practice and on a comparison between four I&E education initiatives that have been given at our universities (1) the InnoCore Challenge, (2) the AI industrial challenge, (3) the inGenious course, and (4) the Innovative entrepreneurship course. The first two initiatives were run at the University of Trento (Italy), while the third and fourth were run at Linköping University (Sweden). This article's authors managed one or several programs: Dr. Alessandra Scroccaro was part of the staff for programs (1) and (2), dr. Milena Bigatto managed the program (2), Cia Lundvall was part of the program (3), and Dr. Charlotte

Norrman was involved in courses (3) and (4). Dr. Jeanette Engzell was part of the staff for the course (4).

All these courses are challenge-based, cross-disciplinary, and offered to engineering students. The InnoCore Challenge is also addressed to biotech students. The inGenious course is open to students from all faculties and universities, although the majority applying to the course are engineering students. In these courses, we have, over the years, tested several instruments in the domain of the self-directed learning approach to assess skills such as entrepreneurial-, leadership-, project management, teamwork-, communication- and presentation skills. For programs 1 and 2, we tested the learning agreement, learning diaries, and reflection reports (Gibbs' reflective cycle). In courses 1, 2, and 4, the EPIC (Entrepreneurial Potential and Innovation Competences) tool was elaborated by the HEInnovate (EU Commission and OECD initiative) Higher Education Institutions Innovate initiative based on the ENTRECOMP (Entrepreneurial Competences). For programs 3 and 4, we tested matrixes for formative assessment and group contracts, and for reflections in course 3, we also used the so-called GROW model (Whitmore, 1994) - Goal, Reality, Options, and Will/Way forward. The following sub-paragraphs describe the abovementioned tools and our experience using them.

Learning agreements, learning diaries, and group contracts

The learning agreement is a document negotiated between the supervisors and the students to ensure that certain activities are undertaken to achieve an identified learning goal (Knowles, 1986). Students discover and partly choose their learning objectives and identify what strategies and resources they can mobilize to achieve them.

Learning diaries are one-pager reports delivered during the course to evaluate the team's quality of work and understanding of the undergoing process. Questions can include (1) What went well in the teamwork during a specific phase? (2) What did we learn as a team? (3) What to improve in your teamwork to work better together? (4) What will they put into practice? Starting from the lessons learned, teams had to identify what they would do practically to work better. Group contracts are agreements with roots in project management, following a structured form and set up by the students to regulate how they will interact throughout their project - their codes of conduct, roles, and goals. They also discuss the resources, actions, and risks of their projects.

Reflection reports

The reflection report (Gibbs, 1988) is a document that guides students through 6 stages to learn from the experience that they had just left behind them and give them a chance to put some order, identify what went well and what did not go well, and plan their following actions.

1. Description: Students have a chance to describe the challenge experience in detail—the main points to include here concern what happened.
2. Feelings and thoughts: Students explore feelings or thoughts during the course and how they may have impacted the experience.
3. Evaluation: Students evaluate what worked and what did not in the experience, trying to be as objective and honest as possible by focusing on both the positive and the negative aspects of the experience.
4. Analysis: The analysis step is where students can understand what happened by extracting meaning from it, targeting different aspects that went well or poorly, and asking themselves why.
5. Conclusions: In this section, students can conclude what happened during the challenge.

6. Action plan: Students plan for what they would do differently in a similar or related experience in the future. It can also be beneficial to think about how they will help themselves to act differently.

The EPIC tool from the ENTRECOMP framework

The EPIC course assessment tool is designed by HEI Innovate, a project made up of the European Commission's DG Education and Culture in partnership with the OECD to help educators measure the effectiveness of their entrepreneurship courses. The EPIC tool is connected with the ENTRECOMP (Bacigalupo et Al., 2020). This standard reference framework identifies 15 competencies in three key areas (Resources, Ideas, Opportunities, and Into Action) that describe what it means to be entrepreneurial. The assessment works with a set of statements across five thematic areas with which course participants can assess their development: (1) entrepreneurial competencies, (2) entrepreneurial intentions and attitudes, (3) enterprising behaviors, (4) entrepreneurial strategies, and (5) educational effects. The EPIC tool is a self-assessment tool through which students can assess their level of entrepreneurial competencies at the beginning and the end of the I&E course. Thus, this tool is part of the SDL tools. Following Geisinger's (2016) view of skills and skills assessment, we can conclude that tools such as ENTRECOMP could be a good instrument for measuring skills development.

THE EMPIRICAL CASES

The following sub-paragraphs describe the four I&E education initiatives we have compared.

The InnoCore Challenge (University of Trento)

The InnoCore challenge is an online and in-presence I&E education initiative created by the University and Trento and HIT (Hub Innovazione Trentino Fondazione) that took place in 2022. The challenge is part of a European project (Erasmus +). The project is driven by five other European partners from the academy and business world to shape qualified professionals on cutting-edge enabling technologies and innovation management for Biotech Core Facilities. The 25 European participants (Ph.D. and Master students) with biotech backgrounds were divided into five teams and asked to find and present, through a 7-minutes pitch, sustainable solutions for five companies.
In the first few days of the challenge, students were asked to fill in the Initial EPIC questionnaire and an individual learning agreement to identify the main learning goals, activities, and strategies and evaluate their achievement. During the challenge, teams had to monitor their progress and teamwork through learning diaries and focus on what went well (strength points of their teamwork), what did they learn, what should be improved (weak points of their teamwork), and what they would take into practice (strategies to improve actions for the next steps). After the experience, individuals had to fill in again the Final-EPIC questionnaire and a final reflection report. As the InnoCore challenge is an extracurricular initiative, all the deliverables and the final pitches are not graded.

The AI Industrial Challenge (University of Trento)

The "Industrial AI Industrial Challenge" is an open innovation contest organized by the Department of Information Engineering and Computer Science of the University of Trento and HIT. In its first edition, the Industrial AI Industrial Challenge was held online from September until December 2021; students, researchers, industry experts, and experts from regional start-ups worked together to improve the companies' industrial processes thanks to the adoption of artificial intelligence techniques. The teams committed to solving the challenges proposed by nine selected companies by analysing large datasets and creating algorithms and predictive

models based on machine learning methods. Challenges regarded the workforce planning's optimization, predictive maintenance, quality control, logistics, and supply chains in various industries, such as manufacturing, production, and distribution of electricity, pharmaceutics, food, and water treatment.
While for most students, the challenge was an extracurricular activity, though assigning three additional ECTS (European Credit Transfer and Accumulation System), two teams of students completed the challenge in the context of a master course they were attending (AI for Innovation), though receiving additional support from university professors. Altogether, the initiative involved 45 students from four different departments, 25 professionals from the 9 selected and participating companies, and nine mentors from nine AI start-ups from the region. Students had to fill in a final individual reflection report. As the challenge is an extracurricular initiative, all the deliverables and the final pitches are not graded.

The inGenious Course (Linköping University)

The inGenious course (799G52) is a challenge-driven cross-disciplinary project course, given in cooperation between Linköping University and Almi East Sweden AB. The pedagogy used in this course is CBL. Cross-disciplinary work and communication are a vital part of the course and are practiced in the group work process. Examinations are done by written reports and reflections and oral presentations in case of" pitches" in open forums. The challenges are connected to the UN SDGs and come from companies, organizations, and the public sector in the region.
The course acts as a "bridge" between students and the trade and industry and promotes the CPs' sustainability development. In addition, students can apply their theoretical knowledge practically and gain experience in a challenging and complex process. Students gain essential skills by reflecting on the group processes and group dynamics in collaboration with other professions, reflecting on the work process from different perspectives such as business, sustainability, and ethics. The course's activities could include writing a group contract, the "Shitty Prototyping" serious play, a seminar on pitch technique, training workshops (including Value Creation Forum), pitch occasions, and a workshop on responsible innovation. The students are facilitated throughout the course. The course is designed so that the students can contribute with their knowledge and competencies, which they take into their projects, but also provides new knowledge. At the end of the course, the students write a thorough individual learning reflection where they reflect upon the course purpose and learning goals and use the GROW model to identify what and how they have learned.

The "Innovative Entrepreneurship" Course (Linköping University)

The overall purpose of the course "Innovative Entrepreneurship" (TEIO06) is for students to acquire knowledge and abilities within the general areas of I&E, focusing on business planning for new, innovative ventures. The course is at an advanced level. The pedagogical approach used in the course is CBL, following the approach of ECIU. The course starts with an "Idea jam" presenting open challenges connected to the UN SDGs. During this jam, students are engaged by external speakers representing the CPs (e.g., organizations, firms, or ventures/projects). Individually, they choose a challenge and form groups during the seminar. During the course, they gather information about their challenges to identify business opportunities that imply a commercial solution. Finally, they concretize and describe their business idea in a business plan. Throughout the course, the students are supported with theoretical lectures giving them tools for investigating and analyzing the idea. Examinations are in case of a couple of reflections and a group work report. A couple of pitching occasions and creative workshops focusing on skills are included in the latter. Grades are failed, 3, 4, and 5, where 3 implies pass, and 5 is the highest grade. Skills-related parts, including a learning reflection, are graded pass/fail based on participation. Although this course aims to

give the students both knowledge and skills, only knowledge is assessed and graded. Hence, better tools for skills assessment would help improve the examination.

DISCUSSION AND FINDINGS

Table 1 below compares and summarizes at the same time the four initiatives mentioned above through criteria such as syllabuses issues and CDIO framework.

Table 1. A comparison of the four I&E Education initiatives

Course	**AI Industrial Challenge**	**InnoCore Challenge**	**InGenious**	**Innovative entrepreneurship**
Learning goals	Analysis of large datasets, creation of algorithms and predictive models	Personal goals, Teamwork, Communication	Skills and knowledge-oriented goals	Skills and knowledge-oriented goals
Challenge Contents	Industrial processes, thanks to AI	Core facilities, knowledge transfer, project writing and management, communication	Challenges relating to the UN SDGs (above all, SDG 11)	Create business models that solve challenges related to UN SDGs
Credits and duration	9 ECTS 4 months	6 ECTS 4 months	8 ECTS 4 months	6 ECTS 2 months
Team formation and teamwork	45 students 9 teams Cross-disciplinary	25 students 5 teams Cross-disciplinary	15-40 students per semester, 2-8 teams Cross-disciplinary	75-110 students, 16-20 teams Cross-disciplinary
External collaborations and challenge providers	9 companies 9 Mentors from local start-ups	5 companies 2 mentors in each team, and corporate tutors	2-8 companies, public bodies, and NGOs	Research groups, companies, municipalities, or regional actors
Expected outcomes	Challenge solutions presentation in front of a jury with companies	Challenge solutions presentation in front of a jury with companies	Challenge solutions described in reports and presented in an open forum	Challenge solutions described in business plan format and oral presentations in open forums
Type of assessment	Formative and Summative	Formative and Summative	Formative and Summative	Formative and Summative
Skills assessment and Assessment tools	Self-reflection approach; Reflection reports; Final project	Self-reflection approach; Learning agreement; diaries; EPIC survey; Final project	Self-reflection approach; Group contract, project plan, final report, individual reflection paper	Self-reflection approach, literature review, and business plan report
CDIO framework	Conceive, design, and implement	Conceive, design, and implement	Conceive, design, and implement	Conceive, design, and implement

The following considerations are the outcome of two analysis levels. The first comes from analysing all data collected through the tools presented in the Methodology section. We considered the written answers given by students, as individuals or as a group, to the tools

provided, such as the learning agreement, the learning diaries, the reflection reports, and the formative matrices. The second one comes from Table 1 and compares the four educational initiatives. We have found that the AI Industrial challenge students have learning goals that are more quantitative-oriented compared with the other I&E education initiatives. However, competencies such as workforce planning, predictive maintenance, quality control, logistics, and supply chains were also part of the challenge, which are also related to skills and knowledge. Not surprisingly, most learning goals focused on skills and knowledge-oriented goals but with different contents and contexts of their challenges. The AI Industrial Challenge content focused more on industrial processes/collaboration than InnoCore, which fosters knowledge and technology transfer in the project partner national ecosystems and supports the development of the local economy. Comparing the two other courses, inGenious and Innovative Entrepreneurship, they aim to work with challenges relating to the UN SDGs but also incorporate external CPs such as the region, the municipalities, research groups, and private actors (ventures and firms) from trade and industry. All the courses combine theory and practice as they use the challenges to create a real-life context for learning. The time frame is critical since it facilitates more time for the learning and reflection process. Students are more likely to incorporate new knowledge and experience and to reflect on their process, but the issue of assessing the students is the same.

However, comparing the student groups in the different initiatives, we have experienced differences regarding the number of students involved in each initiative. The largest student group, 75-110 students, is in the Innovative Entrepreneurship course. The number of students/participants in the teams care similar, about 4-6 participants per group. The context and CPs differ between the four initiatives. The AI Industrial Challenge, InnoCore Challenge, and inGenious course rely on their external collaborations, mainly with companies and additional mentors. The Innovative Entrepreneurship course, instead, has many different collaboration partners such as research groups, companies, municipalities, or regional actors. In the case of Innocore Challenge, one of the five companies, as a follow-up, signed a contract with one of the universities and involved one of the Ph.D. students in the result's exploitation. In the inGenious course, all CPs and all students sign contracts with Almi East Sweden AB. The CPs also have the opportunity to buy back what the students have developed, and in such cases, Almi East Sweden AB acts as an intermediary.

In the Innovative entrepreneurship course, no contracts are written, and the CPs' engagement differs from high to modest engagement based on the individual preferences of the CPs. Projects of the AI Industrial Challenge and InnoCore challenge are presented as final projects through an oral pitch in front of a jury. Professors and companies make the jury. The examination of the project report for both inGenious and Innovative entrepreneurship is both presented in reports and presented in open forums. In the Swedish courses, the students present in open forums, on an open stage in inGenious, and at a mini trade fair in the Innovative Entrepreneurship course. In all courses, all initiatives are assessed in both a formative and summative way. All have the self-reflection approach with varying aspects, such as learning agreements, diaries and surveys, and group contracts. Comparing these four initiatives helps to understand the differences and similarities between I&E education initiatives, and we came out with four main findings. Below we present the main findings justified through citations extracted from students' feedback, reflection reports, and matrices.

Finding 1. The Role of Facilitation and Coaching in I&E education initiatives

"I also enjoyed the individual pitch training […]. Moreover, getting feedback from [the facilitators] who have watched many people pitch felt luxurious. I thought it was a productive session where I got to try different ways of pitching, see how others pitch, and learn more about what suits me best." (from a reflection report in the inGenious course 2022). The first finding is that facilitation and coaching are essential ingredients in the courses, which correlates with

the findings on feedback in previous research (Hattie & Timperley, 2007; Svensäter & Rohlin, 2022). Facilitation (e.g., teachers or teamchers giving feedback, peer feedback, external mentors evaluations) or the so-called mentorship can be seen as a formative assessment in the future. Mentors or teamchers can ask questions that make them "find their way" or the correct answer when facilitating the students. The facilitation also allows them to reflect upon their learning process. As a facilitator, the teacher sees the learning process. Based on a matrix or model, the facilitator should be able to follow and document the individual student's (or group's) progress and development. This would be a type of informal formative assessment that could be interesting to explore further.

Finding 2. Feedback from teachers in I&E education initiatives

"We consider that our teacher's involvement in directing us towards outside sources of information was of consequence to our learning outcomes since we recognize that the lack of this would have limited our ability to reproduce the same level of performance in our project work." (from reflection report in Innovative entrepreneurship). The second finding is that a teacher's development-oriented feedback and response (e.g., the formative approach) will help the student gain new knowledge and skills and grow. That this is important for the students has become apparent when reading their learning reflections. That is why it is essential to pay attention to the manner through which the teacher/teamcher gives a response. Teamcher as a facilitator should focus more on how students can develop, explain and add, not on what is wrong, what students have failed, and what is missing.

Finding 3. Matrices for measuring progressions and difficulties

Assessment matrices help the student clarify how they are assessed. "If you know what to do, it reduces the stress of what to deliver. I think it is a splendid example of how a course should convey what is important to learn." (from a student in Innovative Entrepreneurship). The third finding is that informal and formal formative assessment through matrices can help teachers measure progressions and difficulties in individual students. Matrices are also helpful for the students, as shown by the citation above, as they show what is expected to be obtained. Hence they are a complementary tool that can help teamwork during the course and guide teachers to refine their way of teaching in similar courses. Matrices can make transparent both the students' difficulties and weaknesses and their substantial factors, which, taken together, can affect the learning experience and the achievement of the learning outcomes. However, matrices could also entail drawbacks. One student in the innovative entrepreneurship course posed this as follows; "it [the matrice] might be a problem since it can make the studies be based purely on passing the assignments and not to learn the content of the course." (from a student in Innovative Entrepreneurship). The conclusion is that matrices are helpful, but it must be made clear that formative assessment tools are, on the first hand, guides for improvement - not lists of minimal viable achievements to pass, even though some are regarded as such.

Finding 4. EPIC from ENTRECOMP as a reference for entrepreneurial skills evaluation

The fourth finding is that the EPIC tool and ENTRECOMP framework are valuable for international comparative studies in this field. The EPIC tool created for its measurement allows us to collect valuable data to analyse over time and space the effectiveness of measures to develop one of the skills identified by the European Commission as crucial for the future. In addition, through the full implementation of that tool in two courses (the AI Industrial Challenge and the InnoCore Challenge) and an ongoing attempt in a third course (Innovative Entrepreneurship), we have identified the efficacy and consistency of this instrument for the I&E education initiatives. This tool can support the evaluation of students' soft skills' progression, even if it does not necessarily support summative assessment. For both courses where full implementation was done, we encountered that students improved their

entrepreneurial skills by comparing the initial and final evaluations. EPIC tool evaluates three areas of entrepreneurial skills. On average, 65% of applicants perceived a progression in skills of ENTRECOMP Ideas and opportunities area, such as identifying opportunities for innovative value creation, anticipating which opportunities will be of high value, selecting the most valuable opportunity when faced with multiple options, coming up with innovative ideas or find new ways of solving problems, assess the social and ecological impact of their ideas. On average, 80% of applicants perceived a progression in skills of ENTRECOMP Resources area, such as achieving goals and performing unfamiliar tasks, finishing started tasks despite setbacks and failures, actively networking in order to increase the number and quality of contacts, finding the right people, estimate a budget for a new project, read and interpret financial statements, make people enthusiastic about ideas, convince others to engage in your activities. On average, 70% of applicants perceived a progression in skills of ENTRECOMP Into Action, such as being the one who takes the initiative, make difficult decisions, quickly assess complex situations, create a project plan, organize and structure tasks in a project, set project goals, deal with uncertainty when implementing new activities, work under stress and pressure, actively participate in teamwork, promote ideas and opinions when working in a group, look for new opportunities to develop new knowledge and skills, learn from challenging tasks.

CONCLUSIONS

This paper aims to study the connections between the learning process and skills assessment in I&E education initiatives and discuss how to promptly and securely assess students' skills. We also aimed to identify, test and evaluate some of the present tools for assessment. As mentioned above, CBL is an SDL approach. Learners learn, set goals, identify resources, and evaluate their progress (Knowles, 1975). Students become co-responsible for their learning processes and outcomes (Mercer-Mapstone et Al., 2017) and are invited to co-design and evaluate their experience. This approach is disruptive from what they were used to because it denied top-down teaching and learning and proposed a proactive involvement from them.

SDL focuses on motivation and favors a self-centered and reflective approach since students can evaluate the quality of their work, measure their performance with their learning goals, identify the strengths and weaknesses of their work, and plan for iterations and improvements. If students take charge of their learning, the teacher or teamcher has to help them improve by showing what can be developed and how - i.e., pursue guidance and criteria for what is needed for each grade and how the students can improve. In that sense, formative assessment is vital, which focuses on the learning process and motivates students to perform. We have found that skills assessment was essential but tough to handle in practice, especially when balancing the assessment between the team- and individual levels.

In the courses mentioned above, we have tested several tools. The conclusions from these tests are the following: First, assessing skills through recognized and well-described tools is urgent as this implies transparency and legal security. If this is omitted, there is a risk that the assessments are made on subjective grounds. A recent study by Mehic (2022) showed that this could happen. Although criticized, it showed a correlation between facial attractiveness and grades which is highly unwanted in education contexts. Secondly, personalized self-directed learning tools, such as structured learning reflection and tailor-made learning criteria, are also beneficial but have limitations. Finally, formative assessment matrices, with defined requirements for different levels, are also helpful but have the potential for improvements.

FURTHER RESEARCH

The Entrecomp framework has proven to be efficient. However, more comprehensive implementation and analysis are needed to reach its full potential. Hence it is essential to implement it also in more extensive courses. Another critical task that calls for further investigation and development is, as highlighted by, e.g., González-Pérez, & Ramírez-Montoya (2022), to consider the technology development of industry 4.0 and 5.0 (see, e.g., Zambon et al. 2019) and match this with education efforts that match industrial development. Working in such a way enables engineers to also engineer in the future, which is the mantra of the CDIO (see, e.g., Crawley et al. 2007).

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REFERENCES

Bacigalupo, M., Weikert Garcia, L., Mansoori, Y., & O'Keeffe, W. (2020). *EntreComp Playbook. Entrepreneurial learning beyond the classroom* (No. JRC120487). Joint Research Centre (Seville site).

Barkley, E. F., Cross, K. P., & Major, C. H. (2014). *Collaborative Learning Techniques: A Handbook for College Faculty*. Hoboken, NJ: John Wiley & Sons.

Bennett, N., & Lemoine, G. J. (2014). What a difference a word makes: Understanding threats to performance in a VUCA world. *Business Horizons*, *57*(3), 311-317.

Biggs, J. B., & Collis, K. F. (1982). *The psychological structure of creative writing*. Australian Journal of Education, 26(1), 59–70.

Biggs, J. B., & Collis, K. F. (2014). *Evaluating the quality of learning: The SOLO taxonomy (Structure of the Observed Learning Outcome)*. Academic Press.

Butler, D., & Winne, P. (1995). *Feedback and Self-Regulated Learning: A Theoretical Synthesis*. Review of Educational Research - REV EDUC RES. 65. 245-281. 10.2307/1170684.

Cowie, B., & Bell, B. (1999). *A model of formative assessment in science education. Assessment in Education: Principles*, Policy & Practice, 6(1), 101-116.

Crawley, E., Malmqvist, J., Ostlund, S., Brodeur, D., & Edstrom, K. (2007). *Rethinking engineering education*. The CDIO Approach, 302, 60-62.

Deci, E.L., & Ryan, R.M. (2000). The 'What' and 'Why' of Goal Pursuits: Human Needs and the Self-Determination of Behavior. Psychological Inquiry 11(4): 227–268.

Dewey, J. (1938; 1963). *Experience and education*, The Kappa, Delta, Pi Lecture Series, Macmillan Publishing company: New York

EIT (2012) "Catalysing Innovation in the Knowledge Triangle: Practices from the EIT Knowledge and Innovation Communities," *European Institute of Innovation and Technology* (EIT), https://eit.europa.eu/sites/default/files/EIT_publication_Final.pdf

Eldebo, K., Lundvall, C., Norrman, C. A., & Larsson, M. (2022). How to make good teachers great in challenge-based learning. *18th CDIO Proceedings Conference* in Reykjavik, Iceland, 13-15 June 2022

Fiet, J. (2001). *The Pedagogical Side of Entrepreneurship Theory*. Journal of Business Venturing. 16. 101–117. 10.1016/S0883-9026(99)00042-7.

Flavell, J. H. (1979). *Metacognition and cognitive monitoring: A new area of cognitive–developmental inquiry*. American Psychologist, 34(10), 906–911. https://doi.org/10.1037/0003-066X.34.10.906

Geisinger, K. F. (2016). *21st-century skills: What are they, and how do we assess them?* Applied

Measurement in Education, 29(4), 245-249.

Ghiatău, R., Diac, G., & Curelaru, V. (2011). *Interaction between summative and formative in higher education assessment: students' perception*. Procedia-Social and Behavioral Sciences, 11, 220-224.

Gibbs, G. (1988). *Learning by Doing: A guide to teaching and learning methods. Further Education Unit*. Oxford: Oxford Polytechnic.

González-Pérez, L. I., & Ramírez-Montoya, M. S. (2022). Components of Education 4.0 in 21st century skills frameworks: systematic review. *Sustainability*, *14*(3), 1493.

Gunnarsson, S., & Swartz, M. (2021). Applying the CDIO framework when developing the ECIU University. In *17th International CDIO Proceedings Conference* (pp. 106-115).

Gunnarsson, S., & Swartz, M. (2022). On the connections between the CDIO framework and challenge-based learning. *The European Society for Engineering Education (SEFI) Conference Proceedings*.

Hattie, J., & Timperley, H. (2007). *The Power of Feedback*. Review of Educational Research, 77(1), 81–112.

Knowles, M. (1975). *Self-Directed Learning: A Guide for Learners and Teachers*. Chicago, IL: Follett Publishing Company.

Knowles, M. (1986). *Using learning contracts: Practical approaches to individualizing and structuring learning*. London: Jossey-Bass Publications.

Kohn Rådberg, K., Lundqvist, U., Malmqvist, J., & Hagvall Svensson, O. (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.

Lau, A. M. S. (2016). *'Formative good, summative bad?'–A review of the dichotomy in assessment literature*. Journal of Further and Higher Education, 40(4), 509-525.

Mehic, A. (2022). Student beauty and grades under in-person and remote teaching. Economics Letters, p. 219, 110782.

Mercer-Mapstone, L., Dvorakova, S. L., Matthews, K. E., Abbot, S., Cheng, B., Felten, P., Knorr, K., Marquis, E., Shammas, R. & Swaim, K. (2017). *A systematic literature review of students as partners in higher education*, International Journal for Students as Partners, 1 (1). doi:10.15173/ijsap.v1i1.3119.

Norrman, C., Lundvall, C., Eldebo, K., Boierts, S. & Stel, F. (2022). Making good challenges great - engaging external parties in CBL activities, *18th CDIO Conference Proceedings* in Reykjavik, Iceland, 13-15 June 2022

Observatory Tecnológico of Educational de Monterrey (2015). *Edu Trends: Challenge Based Learning*, Oct. 2015, Observatory Tecnológico of Educational de Monterrey. https://publications.jrc.ec.europa.eu/repository/handle/JRC101581

Pérez-Sánchez, E. O., Chavarro-Miranda, F., & Riano-Cruz, J. D. (2020). *Challenge-based learning: A 'entrepreneurship-oriented' teaching experience*. Management in Education, 0892020620969868.

Piaget, J. (1950). *The psychology of intelligence*. New York: Routledge.

Reeve, J., Jang, H., Carrell, D., Jeon, S., & Barch, J. (2004). *Enhancing Students' Engagement by Increasing Teachers' Autonomy Support*[1]. Motivation and Emotion, 28(2), 147–169. https://doi.org/10.1023/B:MOEM.0000032312.95499.6f

Ryan, R. M., & Deci, E. L. (2000). *Self-determination theory and the facilitation of intrinsic motivation, social development, and well-being*. American Psychologist, 55(1), 68–78. https://doi.org/10.1037/0003-066X.55.1.68

Scroccaro, A., & Rossi, A. (2022). *Self-directed approach as an opportunity to learn in Challenge-based learning (CBL). A CBL experience with cross-disciplinary learners at the University of Trento*. Handbook on Challenge-Based Learning. The Emerald Publishing, pp. 227–249, doi:10.1108/978-1-80117-490-920221010.

Svensäter, G., & Rohlin, M. (2022). *Assessment model blending formative and summative assessments using the SOLO taxonomy*—European Journal of Dental Education.

Svensson, T., & Gunnarsson, S. (2005). Using a project model for assessment of CDIO skills. In *1st annual CDIO conference Proceedings* (pp.7–8).

Thomas, L. (2012). *Building student engagement and belonging in Higher Education at a time of change*. Paul Hamlyn Foundation.

Vignoli, M., Balboni, B., Cotoranu, A., Dosi, C., Glisoni, N., Kohler, K., Mincolelli, G., Mäkinen, S.,

Nordberg, M., & Thong, C. (2021). *Inspiring the future change-makers: reflections and ways forward from the Challenge-Based Innovation experiment*. CERN IdeaSquare Journal of Experimental Innovation, 5(1), 1–4. https://doi.org/10.23726/cij.2021.1323

Vygotsky, L. S. & Cole, M. (1978). *Mind in society: Development of higher psychological processes*. Boston, MA: Harvard University Press.

Whitmore, J. (1994). Coaching for performance: A practical guide to growing your own skills. Pfeiffer & Company by arrangement with N. Brealy Publ.

Yorke, M. *Formative assessment in higher education: Moves towards theory and the enhancement of pedagogic practice*. Higher Education 45, 477–501 (2003).

Zambon, I., M. Cecchini, G. Egidi, M. G. Saporito, & A. Colantoni. 2019. Revolution 4.0: industry vs. agriculture in a future development for SMEs. *Processes* 7(1): 36.

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