Siara Isaac Joelyn de Lima

Teaching Transversal Skills for Engineering Students

A practical playbook of activities with tangibles

Downloadable handouts & slides

Generously funded by
The LEGO Foundation

3T PLAY

How can we better prepare engineering students to work together on dynamic, complex problems? Transversal skills are essential to maximising the potential of technical expertise, particularly when working across disciplines, cultures, and contexts.

I am proud to be associated with 3T PLAY. This project brings the spirit of playfulness and excitement to learning through practical, hands-on activities. The resources have the capacity to improve how the most critical skills for society are being taught in higher education.

Dr Bo Stjerne Thomsen
Head of LEGO Educational Impact
LEGO Education
Denmark

This book provides a practical approach for developing transversal skills based on the 3T PLAY Trident framework and evidence-informed experiential learning approach.

Designed to enable higher education instructors to improve how transversal skills are taught, this book provides:

- Graphical activity outlines with timing, mode, and materials
- Downloadable handouts and slides
- Review of why transversal skills should be explicitly taught, which skills are under-addressed, and conditions that support students to develop skills
- Evidence-informed conceptual summaries and practice based tips
- A backward design structure to create new activities to teach transversal skills

I implemented the Chapter 3 activity on emotional self-management in my 1000-student 'engineering practice and design' course. It was great to see how students engaged with the activity, moving slightly out of their comfort zones while developing a willingness to provide feedback in their project teams.

Prof. Brian Frank
Smith Engineering
Queen's University, Canada

These resources were created as part of the 3T PLAY project at the Swiss Federal Institute of Technology in Lausanne (EPFL) and generously funded by the LEGO Foundation.

This book enabled me to infuse multiple dimensions of sustainability in engineering curriculum seamlessly. As an engineering education faculty, the structure of the activity guide (Chapter 4) allowed me to easily adapt it to my classroom context. It was a success from the first time and our students participated enthusiastically!

Dr. Rucha Joshi, Associate Professor
Innovation Lab and
Grand Challenges Studio
Plaksha University, India

Siara Isaac and Joelyn de Lima
with
Yousef Jalali, Valentina Rossi, and
Jessica Dehler Zufferey

LEARN
Center for Learning Sciences

EPFL

Teaching Transversal Skills for Engineering Students

A practical playbook of activities with tangibles

Teaching Transversal Skills for Engineering Students

A practical playbook of activities with tangibles

Siara Isaac
Joelyn de Lima

with
Yousef Jalali
Valentina Rossi
Jessica Dehler Zufferey

3T PLAY

BOOK ABSTRACT

This book presents the 3T PLAY approach for teaching transversal skills to engineering students with tangible objects. Chapter 1 explains the evidence-informed 3T PLAY framework and the micro-experiential learning approach. Chapters 2-7 are detailed activity guides for teaching specific transversal skills. The activities seek to increase engineering students' ability to integrate leadership, ethics and sustainability with their technical knowledge. Chapter 8 is a self-guided activity for educators to design new activities employing the trident and a micro-experiential learning approach to teach transversal skills.

This book was created as part of the 3T PLAY project at the Swiss Federal Institute of Technology in Lausanne (EPFL) and generously funded by the LEGO Foundation.

Generously funded by

The LEGO Foundation

EPFL LEARN Center for Learning Sciences

3T PLAY

TABLE OF CONTENTS

THE 3T PLAY PROJECT

Purpose and motivation for the 3T PLAY project

The mission of the 3T PLAY project was to develop and test playful activities with tangible objects to teach process skills to engineering students. These future engineers, with their specialised technical skills, will lead the design and development of structures, systems, and services with far reaching consequences for society. The in-the-moment focus of a playful approach is ideally suited to learning process skills (compared to engineering coursework's typically narrow focus on the product or result) and is also coherent with developing a more holistic skill set that includes elements such as creativity and collaboration. Our activities are designed to increase engineering students' ability to apply strategies for integrating a diverse set of process skills with their technical knowledge. Our goal is to improve students' ability to align their engineering actions with their human and planetary responsibilities, and therefore provide leadership, beyond workplace or professional codes, as participatory global citizens.

We call these process skills "transversal skills" to highlight that they are not specific to a particular job, task, or discipline. Yet to be effective, students must learn how to apply these skills concurrently with their disciplinary, technical thinking. Embedded in a premier engineering school, 3T PLAY employed a research-based approach to identifying skills that are under-addressed in the higher education literature and skills of emerging importance for today's environmental, social and economic challenges.

At EPFL, we are convinced that our graduates must be able to collaborate across interdisciplinary and transdisciplinary teams to shape future innovation and contribute to a just and sustainable society. In response to an identified underrepresentation of transversal skills in our current curriculum, initiatives have been launched across the institution. The Centre for Transversal Skills and Career, the Teaching Support Center, the College of Management, the Discovery Learning Program, and the Center of Learning Sciences are key actors in these initiatives. The 3T PLAY project collaborated with all these partners, and worked directly with teachers to find fun, effective ways to develop students' transversal skills. We remain committed to ensuring that our graduates enter the professional world with the complete skill set they need to reach their full potential and contribute to the extent of their abilities.

The activity guides presented in this book represent the applied output of the project. These resources are open source and available as PDFs via the CERN repository, Zenodo. See urls in the index of this book (page ii of this document) to access them directly.

To access the academic and research-oriented project outputs, please visit our project website https://learn.epfl.ch/wwd_learn/3tplay-tangible-objects-for-developing-transversal-skills-in-technical-universities/

The 3Ts - Transversal skills, Tangibles and Technical universities

Despite the relevance and importance of addressing transversal skills in engineering education, there has been underrepresentation of initiatives that provide practical approaches for development and integration of relevant learning activities. The name of our project, 3T PLAY, was chosen to embody the nature of the project targeting engineering students' transversal skills development using playful activities with tangible objects. The nexus of the 3T Play project is shown in Figure 1, illustrating the interactions between Transversal skills, Technical universities, and Tangible objects.

While transversal skills is the term frequently used in European engineering education, other terminology for these important extra-disciplinary skills includes professional skills

THE 3T PLAY PROJECT

and generic competencies[1]. In European engineering education, transversal skills is the term commonly used. When selecting specific transversal skills to address, we sought to identify those taught less frequently, like emotional self-management. Focusing on our core demographic, we took care to contextualise the skills in ways that made them relevant, challenging, and engaging for engineering students. Using tangible objects, such as LEGO bricks or pasta, is the most unusual element of our three Ts and is key to the innovation. The 3T PLAY approach takes advantage of the affordances of tangible objects to create micro-experiential opportunities for students to practise the target skills.

This book presents two of the main results from the 3T PLAY project. First, the conceptual framework of the 3T PLAY trident for structuring learning activities targeting transversal skills. Second, based on the framework, it presents several 'plug-and-play' activity guides for teaching specific transversal skills.

The 3T PLAY trident describes three aspects essential for robust skills development: *Knowing, Experiencing, Learning from Experience*[1]. This framework structures the activity guides presented in this book, and provides guidance to assist teachers in their implementation and adaptation of the experiential activities. It can also be used to develop new activities, for instance by following the steps in Chapter 8, or to evaluate students' experience of learning activities[1].

The activity guides are designed for teachers and provide a clear set of steps to guide students through an experiential activity focusing on transversal skills. Each activity is constructed around an opportunity, created by tangibles, to practice the target skills and encounter relevant difficulties. The activity guides contain a review of the target skills,

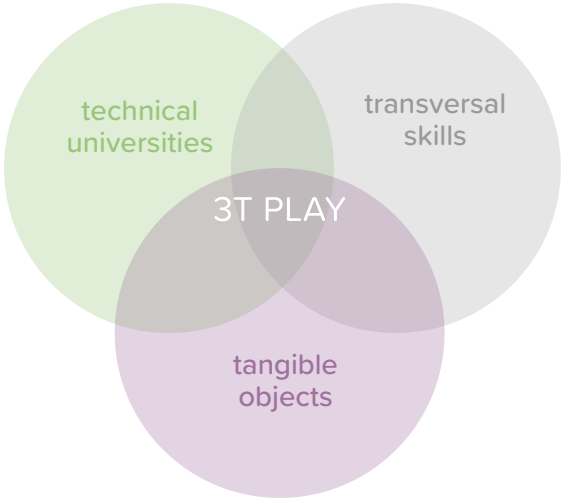


Figure 1: 3T PLAY innovates at the nexus of transversal skills, technical university students and tangibles

instructions, timing, slides and handouts - just add tangibles! The response from the engineering education community has been very warm, and we hope you will also find the materials developed by the 3T PLAY project useful and relevant for teaching transversal skills.

Funding from the LEGO Foundation

The LEGO Foundation is dedicated to building a future where learning through play empowers children to become creative, engaged, lifelong learners. Its work is about re-defining play and re-imagining learning. While the LEGO Foundation generally focuses on children, the 3T PLAY project sought to consider how the *Learning Through Play* philosophy could be implemented for engineering students to continue their journey towards being creative, engaged, lifelong learners. We remain deeply grateful for the joyful, challenging and creative opportunity afforded by the generous funding provided by the LEGO Foundation from 2021 through 2024.

[1]Chapter 1 contains a longer discussion on the nomenclature of these skills and the trident framework.

The Strategic and Executive Boards who guided the 3T PLAY project

The 3T PLAY project was a translational research project, spanning to model generation, empirical studies, and classroom implementation. Accordingly, the guidance of the diverse members of the project's Strategic and Executive boards was an essential element in our success. The whole initiative was overseen by a Strategic board chaired by the (now emeritus) Director of College of Management of Technology (CDM), with input from the LEGO Foundation, an international leader in engineering education research, a representative from Swiss industry, and involving key actors from across EPFL. We express our strong appreciation for the insight and feedback provided, specifically to our three external strategic board members:

Dr. Bo Stjerne-Thomsen
Head of LEGO Educational Impact, LEGO Education
Representing the LEGO Foundation

Prof. Anette Kolmos
Professor in Engineering Education and PBL, Aalborg Centre for Problem Based Learning in Engineering Science and Sustainability
An international leader in engineering education

Laetitia Henriot Arsever
Chief Information Officer, Valora Group
An EPFL alumna representing Swiss industry

And our six strategic board members coming from within EPFL:

Dr. Dominique Foray
Emeritus Director of College of Management of Technology

Prof. Kathryn Hess
Associate Vice President for Student Affairs and Outreach

Prof. Francesco Mondada
Academic Director of the Center for Learning Sciences

Prof. Veronique Michaud
Head of Laboratory for Processing of Advanced Composites

Prof. Vincent Kaufmann
Head of Laboratory of Urban Sociology

Dr. Shirit Cohen
Deputy Head of Department, College of Management

Figure 2: The complete 3T PLAY strategic board and team in 2023 (from left) Dr Yousef Jalali, Marta Ruiz Cumi, Prof Francesco Mondada, Dr Jessica Dehler Zuffery, Pascal Vuilliomenet, Dr Tamara Milosevic, Prof Vincent Kaufmann, Dr Siara Isaac, Dr Joelyn de Lima, Prof Kathyn Hess, Dr Bo Sjerne-Thomsen, Dr Roland Tormey, Laeticia Henriot Arsever, Prof Anette Kolmost, Prof Dominique Foray, Valentina Rossi, Dr Shirit Cohen, Prof Veronique Michaud.

The 3T PLAY project also benefited from the guidance provided by its Executive board, composed of representatives from across the EPFL landscape of teaching transversal skills and experiential learning. We extend our gratitude for the long-running and regular contributions from:

Dr. Jessica Dehler Zufferey
Executive Director of Center for Learning Sciences

Dr. Roland Tormey
Head of the Teaching Support Centre

Pascal Vuilliomenet
Head of the Discovery Learning Program

Dr. Tamara Milosevic
Head of Transversal Skills and Career Centre

We would also like to thank individual teachers and staff from the following units for their active collaboration, creation of opportunities, and relevant, rigorous feedback:

Associate Vice Presidency for Education

Associate Vice Presidency for Student Affairs and Outreach

Professors, lecturers and post-docs from all across EPFL

Coordinators and coaches from the Discovery Learning Program

Excellence, mentorship and study abroad programs

The core 3T PLAY team and collaborators

Dr. Siara Isaac served as project manager and researcher, bringing an evidence-informed, data-driven approach to designing and documenting activities for teaching transversal skills. **Dr. Yousef Jalali** contributed as a researcher, bringing disciplinary expertise in engineering and education. **Dr. Joelyn de Lima** and **Valentina Rossi** are cross appointed at the Teaching Support Center (CAPE), bringing to their work at 3T PLAY a rich understanding of higher education pedagogy, interactive facilitation and institutional relationships. **Marta Ruiz Cumi** appears to have just two hands yet managed to organise and coordinate innumerable practical elements of the project. **Dr. Jessica Dehler Zufferey** provided robust pedagogical perspective, methodological guidance and institutional integration.

Figure 3: The core 3T PLAY team (from left) Dr Jessica Dehler Zuffery, Dr Siara Isaac, Valentina Rossi, Marta Ruiz Cumi, Dr Joelyn de Lima, Dr Yousef Jalali (at the 2024 SEFI conference).

Other key contributions came from Laura Persat, who created and implemented the wonderful graphic design. We are delighted with how the structure and organisation afforded by her design elevates the contributions of this book. Dr. Natascia Petringa, Dr. Veronica Petrencu and Dr. Shirit Cohen provided valuable assistance in the early stages of the project. Finally, the support from Catherine Janssens, Yuka Nojima, and Sarah-Jane Sobczak from the Philanthropy office has been invaluable. Contributors to specific activities are acknowledged in the relevant chapters.

At the time of writing this, we have facilitated workshops for 2500+ students and 1500+ teachers and researchers during the three years of the project. Downloads of the 8 playbook chapters from Zenodo has exceeded 2200. We are so pleased to see the constructive, active engagement with these materials from the engineering education community. And we look forward to the next steps for the 3T PLAY approach.

How to cite this book

Isaac, S. & de Lima, J. (2024). *Teaching Transversal Skills for Engineering Students: a playbook of practical activities with tangibles* (3T PLAY, Ed.). EPFL Press, Lausanne. https://doi.org/10.55430/SJYVJ3TP24

3T PLAY

CHAPTER 1
How to develop engineering students' transversal skills

Generously funded by
The LEGO Foundation
EPFL LEARN Center for Learning Sciences

3T PLAY

CHAPTER 1
How to develop engineering students' transversal skills

CHAPTER INDEX

3T PLAY

CHAPTER 1

How to develop engineering students' transversal skills

CHAPTER DESCRIPTION

Engineering work relies on both the technical and transversal skills of engineers. However, it is well-documented that engineering programs may not adequately develop students' transversal skills. This chapter reviews prior research on transversal skills learning and introduces the 3T PLAY approach to developing these important skills. It explains what we mean by transversal skills and argues that transversal skills must be explicitly taught rather than treated as implicit. It describes how the 3T PLAY trident framework is an effective way to teach transversal skills. The chapter concludes with an introduction to the activity guides presented in the following chapters.

CONTRIBUTORS

- **Writing this chapter:** Dr Siara Isaac, Dr Joelyn de Lima, Dr Yousef Jalali, Valentina Rossi, Dr Samuel Schmid, Dr Roland Tormey, Dr Jessica Dehler Zufferey
- **Graphic design:** Laura Persat

CONCEPTUAL AND PRACTICAL UNDERPINNINGS

What are transversal skills?

Disciplinary skills are those related to the specific work of the discipline, as is evident in how the laboratory skills of a chemical engineer are different from the laboratory skills of a mechanical engineer. However, there are some skills that pertain to aspects of engineering work that are shared across many disciplines, such as those related to the management of design projects and teamwork. These skills are therefore less connected to disciplinary contexts and can be applied in different environments or for different tasks. In this book, we refer to these skills as **transversal skills** - as they cut across not only different fields and disciplines, but also across educational, career, and professional stages. Representative transversal skills include planning, perspective-taking and collaborative decision-making. While critical thinking is an important skill applied in all disciplines, we would not include it as a transversal skill because it is necessarily very different in different disciplines. Well-developed critical thinking skills in genetic engineering are different in application, if not in objective, than critical thinking skills in civil engineering.

Since the 1990s, decision makers within higher education settings have been responding to the increased attention to employability, feedback from accreditation bodies and shifting social contexts to integrate more opportunities for students to develop skills beyond their specific fields[1–4]. While there is a general consensus about the importance of transversal skills, the practical challenges of addressing the skills within educational settings remain current. Changes in requirements for students outcomes, identified by the accreditation bodies, clearly demonstrate the importance given to students' attainment of transversal skills. For instance, the Accreditation Board for Engineering and Technology (ABET) requires engineering programs to prepare students for professional practice addressing both technical engineering skills and professional (transversal) competencies, among them ability to communicate effectively with a range of audiences, ability to function effectively in team, and ability to recognize ethical and professional responsibilities[5]. The EUR-ACE® Framework from the European Network for Accreditation of Engineering Education articulates similar learning outcomes[6]. Transversal skills deemed relevant for graduates are routinely included in institutional documentation of degree programs.

In literature, different terms are used to identify these (categories of) skills, including transversal, transferrable, professional, generic, 21st century, employment and soft skills[7,8]. Further, in the last two decades, the related concepts of competency and of competence, comprising knowledge, skills and attitudes, have been used within the literature[9,10], though some scholars have used the terms interchangeably[11].

Why moving away from the term "soft skills" will improve engineering education

Catherine G. P. Berdanier[7]

"If we shift our language, committing to the essential nature of professional skills, then we have the chance to effect two outcomes. First, we can start naming the elements of professionality that are required for our students to thrive as engineers and changemakers. Teamwork, conflict management, oral communication, written communication, social justice, equity, and ethical reasoning are some of the core competencies required for today's engineers. If we name these skills and assign them merit, then we will legitimize teaching professional skills as equivalent to our derivations of the theory. We will elevate essential professional strengths as core engineering skills."

Why are transversal skills important for engineers and engineering students?

Although students are aware of the importance Current engineering students, i.e. future practising engineers, will be tasked with increasingly complex problems that cannot be resolved by disciplinary skills alone. Transversal skills will therefore be vital to successfully tackle these grand challenges[12], especially related to sustainable development[13,14].

Traditional engineering education focuses on developing students' technical and disciplinary skills[15]. However, multiple stakeholders including current engineering students[16–18], engineering graduates[19,20] and employers[21–24] have stressed on the need for additional training in transversal skills. The importance of including transversal skills training in the engineering curriculum has been further highlighted by researchers[3,25–27], curriculum designers[28], and accreditation bodies[5,6,29]. Transversal skills have also been shown to be predictive of success in students' lives after university[30].

Weinert[31] proposes two frames of reference relevant for transversal skills: normative, i.e., skills engineers should have, and empirical, i.e., skills practising engineers actually use in their work. Recent scholarly work in engineering education literature often employs a normative grounding and incorporates the perceptions of different stakeholders, for instance skills needed to support sustainable development goals[32]. There is an almost universal agreement on the skill categories of communication and teamwork skills in terms of their definition and transversal nature, however methods of classifying and describing other transversal skills remain inconsistent. The challenge of creating coherent frameworks that are useful across contexts and institutions remains current[31,33]. Whatever categorisation system is used, it is clearly essential to provide effective training on transversal skills to engineering students.

Why do transversal skills need to be explicitly taught in engineering programmes?

Responding to the calls from both industry and academia, universities have increased the focus on transversal skills in their curricula. However, including activities in the curriculum that require transversal skills is insufficient for students to initially acquire these skills. Teachers often assume that allowing students to practise transversal skills is sufficient for them to learn and master the skill[34,35]. However, studies in engineering education have shown that skill development requires intentional and precise scaffolding and instruction[36,37]. For instance, in an institutional context that assiduously mapped transversal skills in current curricula and then further enhanced the curricular offerings[38], students still did not perceive significant presence of transversal skills in their training programmes[16,17,39]. Since students' perception of what they are learning influences their actual learning[40,41], pedagogical strategies targeting transversal skill development needs to be explicit and focused, as well as intentional about supporting the transfer of the skills from the classroom to teaching contexts in other disciplines as well as to real life scenarios[42]. In "the global state of the art in engineering education" report[43], one characteristic that is common to both current and emerging leaders in engineering education is the emphasis placed on experiential learning that integrates transversal skills and societal relevance. Additionally the report stated that one of the best practices in engineering education was "student engagement in and understanding of new educational approaches", which is supported by communicating to students about the pedagogical strategies used and how these strategies help develop their skills.

The 3T PLAY approach to teaching transversal skills

Current pedagogical approaches to teaching transversal skills

Students' transversal skill development is poorly supported by teacher-focused approaches precisely because they are practical skills. Thus, projects are the pedagogical environment most often identified as where students will learn transversal skills[37,45]. Yet, as emphasised above, practice alone is insufficient to develop these skills. While there is general agreement that learning transversal skills requires active pedagogies, there is little consistency in how such skills are taught[46] and many instructors have little knowledge about the conditions that support transversal skill development[34,35]. That insufficient pedagogical attention is given to teaching transversal skills is further indicated by instructors stating that they teach transversal skills despite the absence of related learning objectives in course documents[47]. Interviews with engineering instructors on how they teach transversal skills found they used many relevant practices (application, feedback, retrospective discussions) but did not find evidence that teachers employ a clear structure or pedagogical approach for transversal skill development[47]. This lack of an intentional pedagogical method likely means that interventions aimed at transversal skills are less effective because they are incomplete learning experiences. David Kolb's experiential learning cycle[48] describes four stages necessary to transform experience into knowledge: concrete experience, reflective observation, abstract conceptualisation and active experimentation. Kolb emphasises that experiential learning is a holistic and cyclical process, and that learners must engage with each of the steps to create knowledge from their experiences. Kolb's learning cycle is a useful representation of why students do not develop their transversal skills from experience alone[37,49]. While Kolb's learning cycle has been applied at the course level in engineering[50,51], it may not be immediately obvious how teachers can use it to structure teaching interventions for transversal skill development. In engineering, several educators and researchers have proposed models and strategies that focus on teaching specific skills like creativity[52] or sets of transversal skills like collaborative skills[53]. However, there is a need for a practical model that can be applied to transversal skills in general to provide guidance on structuring pedagogical interventions to develop transversal skills. The 3T PLAY project (Tangible objects for developing Transversal skills at Technical universities)* at the Swiss Federal Institute of Technology (EPFL) has provided such an approach.

The 3T PLAY trident framework

To bring more visibility to the characteristics that make an activity effective for the development of transversal skills, we developed the 3T PLAY trident framework shown in Fig. 1.1.

Support for the explicit teaching (of transversal skills)

Hattie and Donoghue[44 (p. 11)]

"Deep understanding … may need to be explicitly taught—as there is no assumption that students will see similarities and differences in contexts by themselves. There is a limit to what we can reasonably expect students to discover, and it may require teaching students to make predictions based on features that were told to them and that they may not notice on their own. Deliberate teaching of these surface features can offer a higher level of explanation that would be difficult or time consuming to discover. A higher level explanation is important because it provides a generative framework that can extend one understanding beyond the specific cases that have been analysed and experienced."

* https://learn.epfl.ch/wwd_learn/developing-transversal-skills/

Each of the three aspects of the 3T PLAY trident framework provides students with an important element for developing robust transversal skills. It is important that each aspect, **Knowing**, **Experiencing**, and **Learning from experience**, is explicitly present in the activity design to ensure that students are developing their skills. While each of the three aspects is essential to skill development, it is appropriate that instructors devote more time to some aspects than others. Creating engaging situations with authentic characteristics for students to apply their transversal skills in context (**Experiencing**) often requires the most time. Comparatively less time is typically necessary to inform students about the skills and strategies (**Knowing**) and for students to analyse their experiences (**Learning from experience**). The three aspects are described in the following paragraphs and illustrated by the examples in **Table 1.1**.

The most visible aspect of the trident framework is **Experiencing**, which represents an opportunity for students to practise the specific transversal skills being developed. Engineering programs have many such opportunities, for instance projects, which require students to use some transversal skills. Yet, as discussed above, students are rarely encouraged to focus on the transversal skills themselves and instead prioritise the quality of the result or product of their work[42]. **Experiencing** moments in any 3T PLAY activity are focused, low-risk opportunities to practise the relevant transversal skills while attending to the process, ideally with rapid feedback and a chance to iterate.

Knowing represents the factual knowledge, concepts, and heuristics that underpin a skill. Despite the fact that engineering courses typically feature a significant amount of conceptual material, for students to effectively learn transversal skills, they also need conceptual knowledge about the transversal skills[37,49]. The Knowing aspect of the trident framework makes explicit the need to provide students with content knowledge related to transversal skills. Teacher presentation, pre-readings or videos are some formats that can be used to share information, such as models or strategies that underpin the transversal skills students are expected to implement. The "global state of the art in engineering education" report (Graham, 2018) highlighted that emerging leaders in engineering education inform students about what they can learn from an activity and how the activity helps develop these skills.

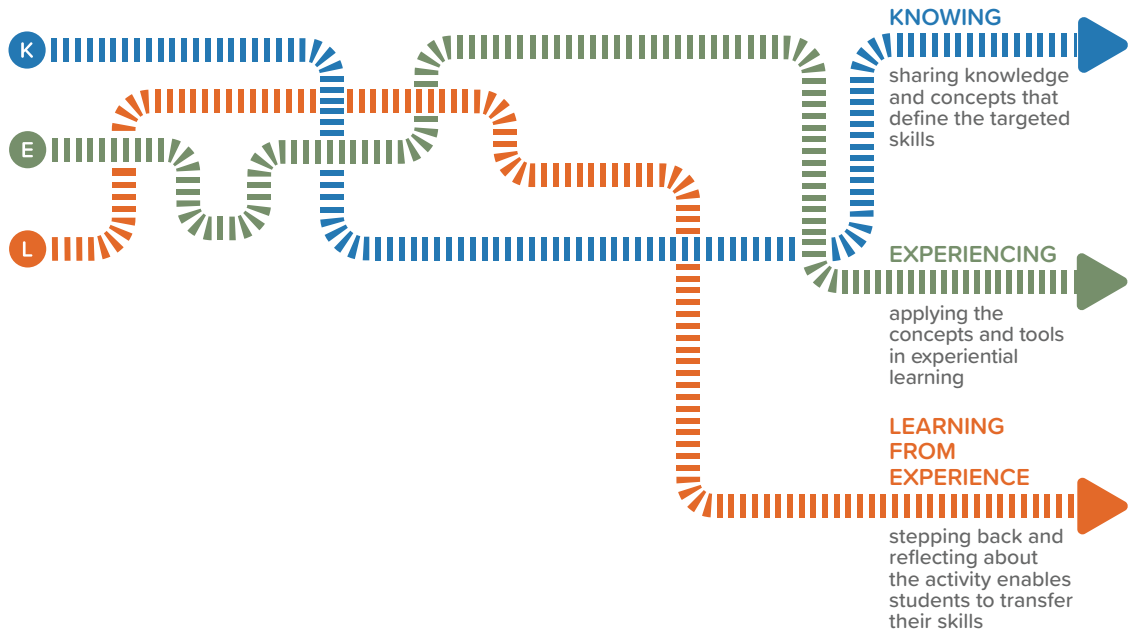


Figure 1.1 3T PLAY trident

Our empirical work identified that the **Knowing** aspect of transversal skills development is not very visible to teachers[35]. Engineering teachers interviewed by Leandro Cruz and Saunders-Smits[47] described using lecturing to 'teach or create awareness' of transversal skills that included 'critical thinking, ideation, financial awareness and writing skills'. These skills have a relatively direct disciplinary context but were also ranked by these instructors as among those where students are strongest. Thus, while these instructors identified several interpersonal skills among students' weakest (including interconnection/ relation ability managing conflict and adaptive communication), no instructors reported providing explicit knowledge or instruction on these topics.

In management and leadership training, activities to develop transversal skills include providing models to assist with understanding different collaboration processes and associated strategies and to help students recognise the key features of their experience. For example, models of distributed leadership can assist teams to understand limitations of classical leadership roles and to adopt strategies that promote more constructive and adaptive modes of collaboration. This type of knowledge appears to be rarely provided to engineering students, who are more often tasked with assignments and projects that require them to implement transversal skills but without training on the skills[37]. Thus, we recommend that students are provided with opportunities to acquire the **knowledge** underpinning the transversal skills they will practise during the activity. This enables them to be intentional in their practice, and to identify authentic implementation difficulties. Encountering the difficulty of not knowing how to do something may make students attentive to the value of the strategy. However, not providing students knowledge on the concepts and strategies deprives students of the opportunity to use their project (or the 3T PLAY activity) to become more proficient in implementing the skill.

Learning from experience is clearly the ultimate objective of an activity targeting the development of transversal skills. We want students to be able to implement the skills they practise in this activity in their future contexts by recognising situations that would benefit from specific strategies and successfully using the strategies to resolve issues or obtain desired results. This requires that students are able to transfer what they learn into new contexts, something that is often inadequately supported in higher education[42]. Reflection is a key mechanism for enabling transfer, allowing students to recognise patterns and causal relationships[4,54]. Drawing on Veenman's work on metacognition[55], we suggest that **Learning from experience** moments should be explicit for students, which means they know that they are analysing their experience with a view to improving future implementation of specific skills. This is an essential aspect for skill development and it should accordingly be integrated into learning activities. Although time is often running short at the end of a session, engineering students have been found to require guidance for reflection[54] and thus activities that prompt students to review their experience are essential for enabling them to transfer their nascent skills to future contexts. We therefore have included **Learning from experience** visually and explicitly in the trident framework to ensure this aspect is adequately addressed.

The 3T PLAY approach to creating conditions for learning transversal skills

The contexts in which engineering students and graduates need to apply their transversal skills are often complex, dynamic, and involve challenges that present themselves differently each time. Clearly, students' need for real, practical skills cannot be developed exclusively from attending lectures and reading. Experiential learning, where students are actively applying their knowledge and skills in context, is ideally suited to the development of competences to be applied in practice.

Table 1.1 Illustrative examples of the three aspects, Knowing, Experiencing, and Learning from Experience, of the 3T PLAY trident

Transversal skill	Knowing	Experiencing	Learning from experience
Emotional self management (example from Chapter 3)[56]	strategies for managing your response when you feel under threat (slide 5, Chapter 3)[56] 5	giving negative verbal feedback to a partner (handout A, Chapter 3)[56] A	reflecting on your emotional response and how you could better manage it in the future (handout B, Chapter 3)[56] B
Negotiation (example from Chapter 4)[57]	principled negotiation and strategies for getting others to see your perspective (slides 6+7, Chapter 4)[57] 6+7	defending your position (handouts B+C, Chapter 4)[57] B C	analysing the strategies that were effective for convincing others (slide 9, Chapter 4)[57] 9

Below, we explore how conditions that support learning of transversal skills inform the 3T PLAY approach to designing activities.

- Real-life challenges in implementing transversal skills often come from **contextual and dynamic factors**. Thus, highly structured tasks following a path determined by the instructor to elicit the accurate performance of procedures is poorly suited to learning transversal skills. We therefore recommend less-structured or more open-ended tasks that create scope for unique micro-experiential learning situations resulting from students' intentions, knowledge, decisions, and team mates. We make a distinction between games, characterised by rules and specific winning conditions, and play[35]. A more playful approach with scope for students to experiment with different approaches can be promoted, as illustrated by the activity guides in this book, by setting small design or collaborative tasks. This approach produces activities that are highly engaging and relevant for students to experience several times.
- Communicating **clear learning objectives** for transversal skills is a fundamental starting point for enabling students to develop these skills. Stating the intended learning objectives is an important initial step in the explicit teaching of transversal skills. It assists students to perceive learning expectations, increasing the visibility of the patterns and strategies related to implementing these skills. Hattie and Donoghue's[44] review of the impact of providing clear learning objectives and success criteria found it increased student attainment significantly. It also helps overcome students' scepticism and increases their engagement[43]. We therefore recommend (1) restricting the skills students are expected to learn from a given activity to a maximum of two, and (2) explicitly informing students about the intended learning objectives as part of the introduction.
- Students are more likely to attain the learning objectives if they are **actively involved in applying and analysing** the concepts and strategies[58–60]. We therefore recommend activities that maximise opportunities for students to be actively constructing their own understanding and skills through active cognitive and emotional engagement.
- Developing new skills requires low-stakes (i.e. non-graded) opportunities for students to practise the specific skill while encountering relevant difficulties, receiving prompt feedback on their implementation, and having

opportunities to try again. This type of learning is called **deliberate practice**. So, while students likely have ample opportunities to implement their transversal skills during their disciplinary course work, the associated timeframes are such that the feedback and repeat opportunities occur months later, if ever. We recommend using the 3T PLAY approach to create the equivalent of initial rapid prototyping feedback loops that include **Learning from experience** reflection prompts and another opportunity to apply the skills. These experiential loops set students up for more advanced implementation of the skills in their disciplinary course work.

- Students will generally persist longer in difficult learning tasks if their mindset focuses more on 'getting better' at something and less on 'showing they are good'[61]. This is referred to as a **mastery mindset** and teachers can encourage students to adopt a mastery mindset in how course activities are structured. In the 3T PLAY approach, we recommend encouraging a mastery approach in several ways, including by (1) designing for incremental improvement, (2) focusing on the process of implementing the skills and not the quality of the final product or output of the work, (3) reflective prompts to examine difficulties and errors as learning opportunities. Together, these conditions can reduce the perceived risk of failure and encourage students to make the most of low-stakes opportunities to work on improving their skills.
- When transversal skills are employed in conjunction with disciplinary skills and concepts, it may require students to simultaneously pay attention to a lot of new things. The range of different things a person is keeping in their working memory at once is called **cognitive load** and this load is highest when learning new things. Ultimately, students will need to be able to apply their transversal skills in context but reducing complexity when first introducing new skills has been shown to improve learning[42]. This is fundamental to the 3T PLAY approach, where we encourage the creation of micro-experiential learning opportunities for students to apply the target skills in a simplified context by using tangibles to replace disciplinary tasks.
- Misconceptions can impede learning[42] and are not exclusive to conceptual knowledge. Problematic conceptual misconceptions about transversal skills include, for example, a limited understanding of leadership as primarily hierarchical that is ill-suited to interdisciplinary teams. Another type of misconception is about the nature of skills. For instance, accepting that some people have inherently better emotional skills as part of their personality rather than taking a growth-mindset approach toward improving emotional skills. Based on research evidence, we recommend directly **addressing misconceptions** to avoid the new knowledge being integrated into students' flawed mental models.

Figure 1.2 Comparing micro-experiential activities to rapid prototyping

USING SIMPLE MOCK-UPS TO TEST AND ITERATE	Test strategies for managing design projects and teamwork	• micro-experiential activities based on brief tasks where we can quickly test and refine our strategies • opportunity to incorporate some authentic contextual factors with lower cognitive load
"FAIL FAST TO LEARN FAST"	Foster a learning culture that promotes experimentation and embraces failure	• supports deliberate practice of key skills • generates analysis and feedback opportunities • encourages creativity and innovation, try out more skills and strategies
BENEFITS FOR SKILL DEVELOPMENT	Reduce "cost" of learning skills by enabling students to identify their weaknesses early	• facilitates multiple, brief iterations • allows experimentation with skills before needing them in a 'full-scale' context (course project, job placement, etc.)

- **Motivation**, especially in the face of difficulty, is essential to learning[62]. Above, we highlighted that learning is an effortful process. Indeed, the discomfort of overcoming the tricky spots is likely where the most relevant learning will occur. Thus, the activity design should keep students engaged and moving forward when encountering difficulties. Deliberate practice requires the challenge of relevant problems – so we don't want to remove the challenges. Rather, we recommend creating a counterweight of rewarding and immersive moments with the playful use of tangibles to maintain motivation. A second important element for student motivation is the perceived value of the skill being learned[62]. As proposed by Bridges and colleagues, informing students about how and when the target transversal skill will be relevant for them should be included in learning activities.

Why tangibles?

The conditions outlined above for teaching transversal skills may look a little daunting. This section describes how the 3T PLAY approach of using tangibles to create micro-experiential learning activities creates excellent conditions for learning transversal skills. The 3T PLAY approach employs tangible objects to create situations or tasks where students can implement relevant transversal skills in contexts that embody conditions that support learning. Given the brief but hands-on nature of these tasks, we refer to our activities as micro-experiential learning.

Tangibles are physical objects that can be perceived by touch, such as a marker, wooden block, or light bulb. Tangible objects have been widely used to facilitate the development of conceptual and procedural knowledge in science and engineering domains, often in the form of real-life or realistic representations. They provide means for visualisation and manipulation to help students learn abstract concepts and principles. For example, hands-on activities with equipment such as thermometers, multimeters, beakers, solid materials, etc., in physics laboratory[63] and the use of three-dimensional molecular model sets in chemistry classes. The emphasis on the use of the body in the process of learning, e.g., creating tangible models, is supported by theories of embodied cognition that demonstrate that the body and the environment assist with integrating and retrieving knowledge[64]. Perceptual experiences are connected to physical actions and human cognition is now understood in its deep relationships with the physical world[65]; learning is thus grounded in interactions with the environment. Despite the potential benefits, there has been limited use of tangible objects to support students' development of transversal skills within engineering education. The 3T PLAY approach provides a practical way to leverage the potential of tangible objects for the development of transversal skills.

As outlined in the section above, conditions that support the development of transversal skills involve creating opportunities to practise and reflect on the application of the target skills. In the activities outlined in this book, we employ tangible objects to create opportunities where students can implement their skills, for instance in collaborative design tasks to produce a makerspace for engineering projects using LEGO bricks (see Chapter 6[66]) or the fastest marble track using pasta and playdough (see Chapter 3[56]). The product of these tasks is not important for students' skill development, rather the 3T PLAY approach focuses on the skills that students implement during the process of creating the product. Specifically, the use of tangibles supports the conditions necessary for the learning of transversal skills in engineering education through:

Opportunities to practise the skills:
Developing transversal skills requires that students practise the skills in conditions that promote learning. Tangibles are ideally suited to creating these conditions. Learning activities addressing transversal skills need sufficient contextualisation but can be impeded by an excessive cognitive load induced by integrating both new technical knowledge and new conceptual knowledge related to the transversal skills. Tangible objects can set up

concrete, brief and focused activities that allow students to perceive and target the development of the relevant skills[35]. The use of tangibles facilitates iterative experimentation in brief time periods and low-stake settings[67,68] through multiple cycles of **Experiencing** and **Learning from experience**. Generalisation of the transversal skill towards transfer in new situations can be supported by varying the tangible or changing other elements of the task context.

Playfulness:
Activities with tangibles are playful because the boundaries of the real world are reduced and there is more scope to try new things and adopt different perspectives. The loose environment creates a safe space for exploration and risk taking with a positive construction of failure[69]. In play, the product is not what is important but rather the process. This makes learning experiences more low-stakes and so enables deliberate practice. For instance, the Chapter 5[70] activity that develops skills for coaching has students build a duck using LEGO bricks and practice responding to questions about the ducks. This playful **approach to learning reduces students' fear of error and fosters a safe and inclusive environment**[71]. While playfulness is beneficial for the whole learning process, it has a specific advantage with regards to maintaining motivation and persistence in the face of difficulty.

Scalable:
Authentic projects offer irreplaceable opportunities for learning. However, authentic student projects also typically require significant material and supervisory resources. Tangibles, in contrast, can provide a safe, easy and low-resource opportunity for students to apply some of the same skills. This means that the 3T PLAY micro-experiential learning opportunities can be used alongside more authentic projects to provide additional, **lower-resource instances for students to practise their skills**. In a period of increasing student enrollments and calls to train more engineers with a broader range of skills, the capacity of tangibles to create accessible micro-experiential learning is highly relevant.

Externalised representation:
Tangibles can provide an alternative to text and other 2D modalities for the representation of conceptual knowledge underpinning transversal skills. Teachers may provide a physical representation of a concept or have students create their own representation, compare different representations and develop them further in order to reach higher levels of understanding. When conceptual knowledge is more abstract, externalised representations offer important benefits for building connections and reducing cognitive load. In the Chapter 4[57] warm-up activity, for instance, students use LEGO bricks to build a representation of what sustainability means to them. This activity helps

Figure 1.3 And play?

Transversal skills are process skills, so their development is fostered by **experiential learning** situations.

BUT when the **outcome is too important** to students, they are less attentive to their process skills

→ For instance, when students see the product as valuable or it affects their grades

Playful activities encourage students to **stay in-the-moment**

experimenting, iterating and **implementing** their transversal skills.

It's about the journey, not the destination or product.

students to create rough representations of a rather complex issue and start exchanging different perspectives. Another major advantage of tangibles in connection with externalisation is the creation of a common reference that is shareable with others and useful for collaborative learning arrangements[68]. Readers can refer to the individual and then collaborative activity described in Chapter 7[72] for an example. **Concrete representations facilitate students' interactions and rapid feedback** which supports the construction of shared definitions and clearing up misconceptions.

Affordances:
Different tangibles have different affordances. Each provides unique properties, e.g., colours and textures, and features for physical manipulation, e.g. ease of creating or changing a certain shape. In the 3T PLAY approach, the constraints and complexity of manipulating the tangibles (attaching, balancing, sculpting, distinguishing) are used to create tasks and contexts that require transversal skills. The tangibles for the activities presented in this book have been chosen to create specific learning opportunities that elicit specific transversal skills, such as emotional self management or negotiation. The same tangible can be used for very simple constructions (i.e. LEGO ducks in Chapter 5[70]) or complex constructions (i.e. LEGO maker space in Chapter 6[66]). When modifying learning activities or designing new ones, teachers should consider which tangible objects are suited to **creating conditions that offer opportunities for students to implement the target skills** and facilitate transfer of the skills.

3T PLAY framework development and implementation

The trident framework was created by the 3T PLAY team[35]. The team referred to published literature about best practices related to teaching transversal skills, focussing on both experiential learning and lacunae in students' skill sets. The framework was developed and refined to provide a practical and evidence-informed approach to teaching transversal skills.

The 3T PLAY trident framework structures the activities for engineering students presented in the subsequent chapters of this book, and has also been used to prepare workshops and learning experiences for STEM educators. Although developed in the context of a Swiss engineering university, the activities have been facilitated for hundreds of people, in multiple countries, across disciplines, and for various audiences.

The framework itself has been presented at higher education conferences on four continents to audiences of STEM and engineering educators, business teachers, educational researchers, pedagogical advisors, administrators, and curriculum developers. Academic articles that report on empirical testing the trident framework and the impact of specific activities are in preparation. We maintain a list of available publications here: go.epfl.ch/3TPLAY.

Assessing the impact of interventions that teach transversal skills

Evaluating students' transversal skills serves two main purposes. First, it is a measure of whether the learning objectives are being met, providing feedback to instructors and institutions that enables them to make adjustments and ensure accreditation requirements are being met. Secondly, evaluating students' transversal skills can promote student learning through opportunities for self-assessment and reflection[73]. Any approach that includes reflective processes that prompt students to set personal goals and to compare their current skills with expected standards, can increase students' awareness of how and when they can improve their skills. This is relevant for both their immediate development, and for self-assessment in general which is a key skill in lifelong learning[74].

As transversal skills are process skills, they are often not directly visible in the final project output and may therefore not figure in the assessment of student projects. This likely has a direct impact on the lack of feedback on transversal skills reported by students[16,17,39] but also contributes to the low visibility of these skills for students.

Thus, an important complement to the explicit teaching of transversal skills is the integration of feedback and assessment activities for transversal skills. In their chapter "Contemporary Approaches to Assessment of Engineering Competencies for Diverse Learners", Douglas and colleagues have presented a socio-cognitive approach to designing assessment to test students' knowledge and skill development[75]. The difficulty of evaluating transversal skills is highlighted by Cruz and colleagues' finding that most of the 99 studies they reviewed lacked clear definitions of the skills and did not provide evidence of validity and reliability[25]. In this section, we review some of these methods with a specific emphasis on evaluating transversal skills.

Questionnaires are a common tool for the assessment of transversal skills. Questionnaire items are often self-assessment or peer assessment, but can also include knowledge verification or case studies. The primary advantage of questionnaires is their ease of creation and rapid administration[25]. Implementing questionnaires at both the beginning and end of a course can measure the development of skills over time, providing a clear indicator of progress from a formative perspective. This setup helps students understand the targeted skills from the outset, enhancing their engagement and reflective thinking throughout the course[74,76]. See the Appendix at the end of this chapter for a model questionnaire. Based on the 3T PLAY trident framework, this questionnaire contains items addressing **Knowing**, **Experiencing** and **Learning from experience**, and therefore provides information on how explicit each aspect was to students. This information can be valuable for instructors to adjust their teaching and is also relevant for students to better understand the skill development process. Questionnaires can also be used in combination with other methods to provide a more comprehensive assessment of students' transversal skills.

Other strategies for assessing students' transversal skills include portfolios[36,77], interviews[78] and observations[25]. Besterfield-Sacre et al.[79] have proposed solutions to mitigate the challenges of the potentially time and resource intensive approach of observations.

In instances when the evaluation of students' transversal skills will contribute to their grade, the use of rubrics with detailed criteria for scoring are recommended to improve reliability and fairness[80]. Rubrics should be developed based on expected learning outcomes and student behaviours during specific tasks to reduce marker bias and increase inter-rater consistency[81–83]. Using rubrics as a checklist to assess students' capacity to demonstrate the predefined skills[84] can facilitate grading and individualised feedback pinpointing students' strengths and areas needing improvement[82].

Evaluating transversal skills has clear benefits, however context is an important element in determining which assessment method to implement. Is the goal to fulfil accreditation criteria, promote life-long learning or collect feedback on learning? Will students receive a grade or formative feedback? What is an appropriate time frame to observe development of a particular skill? In general, feedback on whether students liked the activity is less relevant for learning than their intention to implement the skills in practice[85]. In addition to the model questionnaire in the Appendix, the strategies used in our empirical studies may also be relevant (see go.epfl.ch/3TPLAY for a list). We encourage you to complete the teaching of transversal skills, including the activities presented in this book, with relevant assessment activities that provide relevant feedback and increase visibility of these key skills.

Table 1.2 Rubric with two sample criteria for emotional skills

Criteria	Poor	Good	Excellent (in addition to the capabilities described in 'Good')
Self-awareness	Students can identify basic emotions they are feeling and specific causes of those emotions.	Students can describe their emotions, distinguishing intensity, and articulate what an emotion is telling them about interactions between their goals and environment.	Students can assess if their emotions are contributing to their current activity and use cognitive appraisals to regulate their emotions.
Preparation	Students can identify situations likely to evoke strong emotions, but not emotions of moderate intensity.	Students can accurately identify situations which may trigger emotions of a range of intensities and account for this in their planning.	Students can identify the kinds of thinking required for an activity and identify strategies to regulate specific emotions and their intensity to facilitate that kind of thinking.

How to use this playbook to improve how you teach transversal skills

Overview

This book is a practical collection of resources for teachers. It presents the 3T PLAY approach for teaching transversal skills to engineering students with tangible objects. Although designed for engineering teachers and students, the skills and activities targeted in this book are applicable across STEM higher education. As a transition to the following chapters, we shift to addressing teachers more directly.

This chapter, Chapter 1, presents the evidence-informed trident framework used to structure all the activities in this book. It provides the theoretical grounding for the framework and its 3 aspects: Knowing, Experiencing, Learning from experience.

Each of the Chapters 2 through 7[56,57,66,70,72,86] present a complete activity guide aligned with the trident framework (including slides and handouts) that addresses specific transversal skills. To facilitate your capacity to use these activities directly with your students, the chapters also contain background on the conceptual underpinnings of the skills.

Chapter 8[87] is a self-guided activity for you as an instructor to employ the trident framework to design your own activities to develop specific transversal skills.

Choosing relevant skills to teach

Engineering teachers are among those who perceive transversal skills as important elements that should be included in engineering curricula. You may already have clear ideas about the skills you would like your students to develop, or perhaps you may need to reflect more on your students' current abilities and future contexts to articulate relevant learning outcomes for their transversal skills. Chapter 8[87] starts with some prompts to assist you to identify the skills you wish to teach in your course. Ideally, the specific skills taught in a given course would be part of a coherent plan based on your priorities and the context of your course, the program-level outcomes for graduate attributes defined for the degree program, and the needs/priorities of your students.

Once you have a clear idea about the transversal skill you would like to teach, we propose that you review the titles and descriptions of Chapters 2-7[56,57,66,70,72,86] to see if an activity guide is available in this book. Then,

- if your chosen skill *is* addressed by one of these activity guides, consider how to adapt it to your context (timing, number of students) while ensuring that you maintain each of the 3 aspects of the trident.
- if your chosen skill *is not* addressed by an existing activity guide, you should refer to the self-guided activity in Chapter 8[87] which will help you use the trident framework to design an activity.

Facilitating activities that develop transversal skills

Your role as a teacher during micro-experiential learning activities is primarily one of facilitation, responsible for providing structure, setting the tone, and encouraging students to fully engage with the activity.

DID YOU PREPARE A CLEAR INTRODUCTION?

- Stating the learning objectives and overall time frame is an important element of structure that defines the space for students to engage in the experiential learning.
- Explicitly stating that the activity is about learning (not assessment), that it will include some relevant challenges and also some fun moments, will assist you with setting a constructive tone.

ARE YOU READY TO RELINQUISH SOME CONTROL?

- Facilitating micro-experiential learning may temporarily mean more disorder.
- Allowing your students to become immersed in the activity means stepping back and letting them experience the challenges and decisions points.
- Try organising your classroom into islands (rather than rows) and then literally stepping back from the centre of the room to promote more student-focused sessions.
- A lively buzz of conversation and discussion is a sign that the activity is going well.

WHAT FEEDBACK WILL YOUR STUDENTS RECEIVE?

- Good feedback can have a major impact on learning. Process-level feedback, i.e. feedback that focuses on the processes students apply while working to solve problems, is more effective than feedback on the quality of the final result[88].
- This is particularly true for micro-experiential learning tasks which exist simply to put students in a situation where they can encounter relevant difficulties.
- In formulating your feedback, help students see patterns, concepts and strategies that underpin the transversal skills.
- See the activity on feedback in Chapter 5[7] in this book and Chapter 5 in the book *Facilitating Experiential Learning*[42] for more background.

WHAT QUESTIONS WILL YOU USE TO GUIDE STUDENTS?

- When you provide direct answers to students' questions, it can reduce opportunities for them to learn to solve their own problems.
- Instead, try to respond with questions that guide students towards finding a solution themselves.
- See the activity on questions in Chapter 5[70] in this book and Chapter 4 in the book *Facilitating Experiential Learning*[42] for more background.

DO YOUR STUDENTS HAVE OPPORTUNITIES TO ITERATE?

- While time is always a scarce resource, students' transversal skills will improve from having additional opportunities to practise.
- Repeating the micro-experiential activities, optimally after analysis and feedback, minutes or weeks later provides lower cognitive load, low-risk opportunities for your students to iterate and improve their skills.
- Reframing subsequent iterations to be more contextualised in the relevant discipline will also help your students transfer their learning.

WHAT LANGUAGE WILL BEST SUPPORT YOUR STUDENTS' CAPACITY TO TRANSFER?

While the slides and handouts in this book are mainly in English, cognitive load of non-native speakers can be significantly higher and therefore impede learning. Encourage students to use the language they usually use with their peers.

Appendix

Model Questionnaire to Assess Skill Development

For the Likert-style questions, (1) is **strongly disagree** and (5) is **strongly agree.**

Knowing	**Skill 1**	**Skill 2**
I know the definition and concepts related to this skill.	1 2 3 4 5	1 2 3 4 5
I know strategies or techniques used for this skill.	1 2 3 4 5	1 2 3 4 5
My one-sentence definition or description of this skill:		
One strategy I can use for this skill is:		
Experiencing	**Skill 1**	**Skill 2**
I have implemented strategies or techniques related to this skill.	1 2 3 4 5	1 2 3 4 5
I have received feedback on my implementation of this skill.	1 2 3 4 5	1 2 3 4 5
I am confident in my ability to implement relevant strategies or techniques.	1 2 3 4 5	1 2 3 4 5
One important thing when implementing strategies for this skill:		
Learning from experience	**Skill 1**	**Skill 2**
I have ideas about how to improve my abilities related to this skill.	1 2 3 4 5	1 2 3 4 5
I am able to use my experience to improve my ability with this skill.	1 2 3 4 5	1 2 3 4 5
In one sentence, what I have learned about this skill is:		
In the future, I will use this skill in these contexts:		
In the future, this is the strategy I will implement when using this skill:		

This questionnaire can be adapted for the skills targeted in your activity. It maps on to the three moments of the trident framework: Knowing, Experiencing, and Learning from experience. While you will likely need to modify it, do ensure that there is at least one question that focuses on each of the three aspects of the trident. Administering the questionnaire both before and after your activity/course, if possible, will likely provide you with the most accurate information about learning gains.

References

1. Crawley, E. F., Malmqvist, J., Östlund, S., Brodeur, D. R., & Edström, K. (2014). The CDIO Approach. In E. F. Crawley, J. Malmqvist, S. Östlund, D. R. Brodeur, & K. Edström (Eds.), *Rethinking Engineering Education: The CDIO Approach* (pp. 11–45). Springer International Publishing. https://doi.org/10.1007/978-3-319-05561-9_2

2. Dacre Pool, L., & Sewell, P. (2007). The key to employability: Developing a practical model of graduate employability. *Education + Training, 49*(4), 277–289. https://doi.org/10.1108/00400910710754435

3. Kolmos, A., & Holgaard, J. E. (2019). Employability in Engineering Education: Are Engineering Students Ready for Work? In S. H. Christensen, B. Delahousse, C. Didier, M. Meganck, & M. Murphy (Eds.), *The Engineering-Business Nexus: Symbiosis, Tension and Co-Evolution* (pp. 499–520). Springer International Publishing. https://doi.org/10.1007/978-3-319-99636-3_22

4. Shuman, L. J., Besterfield-Sacre, M., & McGourty, J. (2005). The ABET "Professional Skills" — Can They Be Taught? Can They Be Assessed? *Journal of Engineering Education, 94*(1), 41–55. https://doi.org/10.1002/j.2168-9830.2005.tb00828.x

5. Accreditation Board for Engineering and Technology [ABET]. (2023). *Criteria for Accrediting Engineering Programs, 2023 – 2024 | ABET*. https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2023-2024/

6. European Network for Accreditation of Engineering Education [ENAEE]. (2023). EUR-ACE® Framework Standards and Guidelines. *ENAEE*. https://www.enaee.eu/eur-ace-system/standards-and-guidelines/

7. Berdanier, C. G. P. (2022). A hard stop to the term "soft skills". *Journal of Engineering Education, 111*(1), 14–18. https://doi.org/10.1002/jee.20442

8. Habbal, F., Kolmos, A., Hadgraft, R. G., Holgaard, J. E., & Reda, K. (2024). *Reshaping Engineering Education: Addressing Complex Human Challenges*. Springer Nature. https://doi.org/10.1007/978-981-99-5873-3

9. Ananiadou, K., & Claro, M. (2009). *21st Century Skills and Competences for New Millennium Learners in OECD Countries*. OECD. https://doi.org/10.1787/218525261154

10. Rychen, D. S., & Salganik, L. H. (Eds.). (2003). *Key competencies for a successful life and a well-functioning society* (pp. xii, 206). Hogrefe & Huber Publishers.

11. Binkley, M., Erstad, O., Herman, J., Raizen, S., Ripley, M., Miller-Ricci, M., & Rumble, M. (2012). Defining Twenty-First Century Skills. In P. Griffin, B. McGaw, & E. Care (Eds.), *Assessment and Teaching of 21st Century Skills* (pp. 17–66). Springer Netherlands. https://doi.org/10.1007/978-94-007-2324-5_2

12. National Academy of Engineering [NAE]. (2017). *Grand Challenges for Engineering*. https://nae.edu/187212/NAE-Grand-Challenges-for-Engineering

13. IDG Foundation. (2021). *Framework – Inner Development Goals*. https://innerdevelopmentgoals.org/framework/

14. United Nations [UN]. (2015). *Transforming our world: The 2030 Agenda for Sustainable Development*. https://sdgs.un.org/2030agenda

15. Hernandez-de-Menendez, M., & Morales-Menendez, R. (2019). Technological innovations and practices in engineering education: A review. *International Journal on Interactive Design and Manufacturing (IJIDeM), 13*(2), 713–728. https://doi.org/10.1007/s12008-019-00550-1

16. de Lima, J., Isaac, S., & Zufferey, J. D. (2024). Distinctly Human—Students' Perception of Transversal Skills in Engineering Curriculum. *Proceedings of the 20th International CDIO Conference*.

17. de Lima, J., Isaac, S., & Zufferey, J. D. (2024). Transversal skills priorities and curricular support as experienced by engineering students on their path to becoming responsible engineers. *Proceedings of the 52nd Annual SEFI Conference*.

18. Donald, W. E., Baruch, Y., & Ashleigh, M. (2019). The undergraduate self-perception of employability: Human capital, careers advice, and career ownership. *Studies in Higher Education, 44*(4), 599–614. https://doi.org/10.1080/03075079.2017.1387107

19. Kovacs, H., Capdevila, I., Lermigeaux-Sarrade, I. J. L., & Jermann, P. (2023). From University to Work: Alumni Viewpoints. *Proceedings of the CDIO 2023 Conference*. CDIO 2023. http://www.cdio.org/knowledge-library/documents/university-work-alumni-viewpoints

20. Passow, H. J. (2012). Which ABET Competencies Do Engineering Graduates Find Most Important in their Work? *Journal of Engineering Education, 101*(1), 95–118. https://doi.org/10.1002/j.2168-9830.2012.tb00043.x

21. Craps, S., Pinxten, M., Knipprath, H., & Langie, G. (2022). Different roles, different demands. A competency-based professional roles model for early career engineers, validated in industry and higher education. *European Journal of Engineering Education, 47*(1), 144–163. https://doi.org/10.1080/03043797.2021.1889468

22. Patacsil, F., & Tablatin, C. L. S. (2017). Exploring the importance of soft and hard skills as perceived by IT internship students and industry: A gap analysis. J*ournal of Technology and Science Education, 7*(3), Article 3. https://doi.org/10.3926/jotse.271

23. Ramadi, E., Ramadi, S., & Nasr, K. (2016). Engineering graduates' skill sets in the MENA region: A gap analysis of industry expectations and satisfaction. *European Journal of Engineering Education, 41*(1), 34–52. https://doi.org/10.1080/03043797.2015.1012707

24. Succi, C., & Canovi, M. (2020). Soft skills to enhance graduate employability: Comparing students and employers' perceptions. *Studies in Higher Education, 45*(9), 1834–1847. https://doi.org/10.1080/03075079.2019.1585420

25. Cruz, M. L., Saunders-Smits, G. N., & Groen, P. (2020). Evaluation of competency methods in engineering education: A systematic review. *European Journal of Engineering Education, 45*(5), 729–757. https://doi.org/10.1080/03043797.2019.1671810

26. Passow, H. J., & Passow, C. H. (2017). What Competencies Should Undergraduate Engineering Programs Emphasize? A Systematic Review. *Journal of Engineering Education, 106*(3), 475–526. https://doi.org/10.1002/jee.20171

27. Winberg, C., Bramhall, M., Greenfield, D., Johnson, P., Rowlett, P., Lewis, O., Waldock, J., & Wolff, K. (2020). Developing employability in engineering education: A systematic review of the literature. *European Journal of Engineering Education, 45*(2), 165–180. https://doi.org/10.1080/03043797.2018.1534086

28. Crawley, E. F., Malmqvist, J., Lucas, W. A., & Brodeur, D. R. (2011). The CDIO Syllabus v2.0. An Updated Statement of Goals for Engineerng Education. In M. Vigild (Ed.), *Proceedings of the 7th International CDIO Conference*. https://api.semanticscholar.org/CorpusID:110610803

29. Commission des titres d'ingénieur [CTI]. (2023). *The CTI's Major Criteria and Procedures – CTI – Commission des Titres d'Ingénieur.* https://www.cti-commission.fr/en/fonds-documentaire

30. Heckman, J. J., & Kautz, T. (2012). Hard evidence on soft skills. *Labour Economics, 19*(4), 451–464. https://doi.org/10.1016/j.labeco.2012.05.014

31. Weinert, F. E. (2001). Concept of competence: A conceptual clarification. In D. S. Rychen & L. H. Salganik (Eds.), *Defining and selecting key competencies* (pp. 45–65). Hogrefe & Huber Publishers.

32. Beagon, U., Kövesi, K., Tabas, B., Nørgaard, B., Lehtinen, R., Bowe, B., Gillet, C., & Spliid, C. M. (2023). Preparing engineering students for the challenges of the SDGs: What competences are required? *European Journal of Engineering Education, 48*(1), 1–23. https://doi.org/10.1080/03043797.2022.2033955

33. Jalali, Y., Kovacs, H., Isaac, S., & Dehler Zufferey, J. (2022). *Bringing visibility to transversal skills in engineering education: Towards an organizing framework*. 1252–1259. https://doi.org/10.5821/conference-9788412322262.1251

34. Dokter, L. (2024). *Academics' Perspectives on Transversal Skills: A Case Study in the New Engineering Programme at the Norwegian Military Academy*.

35. Isaac, S., Petringa, N., Jalali, Y., Tormey, R., & Dehler Zufferey, J. (2023). Are Engineering Teachers Ready to Leverage the Power of Play to Teach Transversal Skills? *Proceedings of the SEFI 2023 Conference*. https://doi.org/10.21427/QP3D-B914

36. Kovacs, H., Milosevic, T., & Niculescu, A. (2023). Planned, Taught, Learnt: Analysis of Transversal Skills Through Curriculum Using Portfolio. https://doi.org/10.21427/R0JP-8277

37. Picard, C., Hardebolle, C., Tormey, R., & Schiffmann, J. (2022). Which professional skills do students learn in engineering team-based projects? *European Journal of Engineering Education, 47*(2), 314–332. https://doi.org/10.1080/03043797.2021.1920890

38. Kovacs, H., Delisle, J., Mekhaiel, M., Dehler Zufferey, J., Tormey, R., & Vuilliomenet, P. (2020). Teaching Transversal Skills in the Engineering Curriculum: The Need to Raise the Temperature. *Proceedings of the SEFI 2020 Conference.*

39. Isaac, S., de Lima, J., Jalali, Y., Rossi, V., Tormey, R., & Zufferey, J. D. (2024). Exploring Engineering Students' Perception of Sustainability and Ethics in Their Curriculum Across Disciplines. *2024 IEEE Global Engineering Education Conference (EDUCON)*, 01–05. https://doi.org/10.1109/EDUCON60312.2024.10578603

40. Kuhn, K.-A., & Rundle-Thiele, S. (2009). Curriculum alignment: Student perception of learning achievement measures. *International Journal of Teaching and Learning in Higher Education, 21*(3), Article 3. https://eprints.qut.edu.au/39467/

41. Wijngaards-de Meij, L., & Merx, S. (2018). Improving curriculum alignment and achieving learning goals by making the curriculum visible. *International Journal for Academic Development, 23*(3), 219–231. https://doi.org/10.1080/1360144X.2018.1462187

42. Tormey, R., & Isaac, S. (2022). *Facilitating Experiential Learning in Higher Education Teaching and Supervising in Labs, Fieldwork, Studios, and Projects*. Routledge. https://doi.org/10.4324/9781003107606

43. Graham, R. (2018). *The global state-of-the-art in engineering education*. Massachusetts Institute of Technology. https://www.rhgraham.org/resources/Global-state-of-the-art-in-engineering-education---March-2018.pdf

44. Hattie, J. A. C., & Donoghue, G. M. (2016). Learning strategies: A synthesis and conceptual model. *Npj Science of Learning, 1*(1), 1–13. https://doi.org/10.1038/npjscilearn.2016.13

45. Kolmos, A., Holgaard, J. E., Routhe, H. W., Winther, M., & Bertel, L. (2023). Interdisciplinary project types in engineering education. *European Journal of Engineering Education, 49*(2), 257–282. https://doi.org/10.1080/03043797.2023.2267476

46. Caeiro-Rodriguez, M., Manso-Vazquez, M., Mikic-Fonte, F. A., Llamas-Nistal, M., Fernandez-Iglesias, M. J., Tsalapatas, H., Heidmann, O., De Carvalho, C. V., Jesmin, T., Terasmaa, J., & Sorensen, L. T. (2021). Teaching Soft Skills in Engineering Education: An European Perspective. *IEEE Access*, *9*(9354626), 29222–29242. https://doi.org/10.1109/ACCESS.2021.3059516

47. Leandro Cruz, M., & Saunders-Smits, G. N. (2022). Using an industry instrument to trigger the improvement of the transversal competency learning outcomes of engineering graduates. *European Journal of Engineering Education, 47*(1), 30–49. https://doi.org/10.1080/03043797.2021.1909539

48. Kolb, D. A. (1984). *Experiential Learning: Experience as The Source of Learning and Development*. Prentice-Hall, Inc.

49. Lehmann, M., Christensen, P., Du, X., & Thrane, M. (2008). Problem-oriented and project-based learning (POPBL) as an innovative learning strategy for sustainable development in engineering education. *European Journal of Engineering Education, 33*(3), 283–295. https://doi.org/10.1080/03043790802088566

50. Botelho, W. T., Marietto, M. das G. B., Ferreira, J. C. da M., & Pimentel, E. P. (2016). Kolb's experiential learning theory and Belhot's learning cycle guiding the use of computer simulation in engineering education: A pedagogical proposal to shift toward an experiential pedagogy. *Computer Applications in Engineering Education, 24*(1), 79–88. https://doi.org/10.1002/cae.21674

51. Healey, M., & Jenkins, A. (2000). Kolb's Experiential Learning Theory and Its Application in Geography in Higher Education. *Journal of Geography, 99*(5), 185–195. https://doi.org/10.1080/00221340008978967

52. Zappe, S. E., Huang-Saad, A. Y., Duval-Couetil, N., & Simmons, D. R. (2023). Teaching for Creativity, Entrepreneurship, and Leadership in Engineering. In A. Johri (Ed.), *International Handbook of Engineering Education Research* (pp. 433–456). Routledge. https://doi.org/10.4324/9781003287483-24

53. Mercier, E., Goldstein, M. H., Baligar, P., & Rajarathinam, R. J. (2023). Collaborative Learning in Engineering Education. In A. Johri (Ed.), *International Handbook of Engineering Education Research* (pp. 402–432). Routledge. https://doi.org/10.4324/9781003287483-23

54. Steele, A. L. (2018). Developing Student Meta-Cognition in a Design Course. *Proceedings of the Canadian Engineering Education Association* (CEEA). https://doi.org/10.24908/pceea.v0i0.13031

55. Veenman, M. V. J. (2016). Learning to Self-Monitor and Self-Regulate. In R. E. Mayer & P. A. Alexander (Eds.), *Handbook of Research on Learning and Instruction* (2nd ed.). Routledge.

56. Isaac, S., & de Lima, J. (2024). Chapter 3: How to support students giving each other constructive feedback, especially when it is difficult to hear. In 3T PLAY (Ed.), *Teaching Transversal Skills for Engineering Students: a playbook of practical activities with tangibles*. Center for Learning Sciences, Swiss Federal Institute of Technology Lausanne (EPFL). https://doi.org/10.5281/zenodo.10392344

57. Isaac, S., & de Lima, J. (2024). Chapter 4: How to support students to develop skills that promote sustainability. In 3T PLAY (Ed.), *Teaching Transversal Skills for Engineering Students: a playbook of practical activities with tangibles*. Center for Learning Sciences, Swiss Federal Institute of Technology Lausanne (EPFL). https://doi.org/10.5281/zenodo.10731771

58. Chi, M. T. H., & Wylie, R. (2014). The ICAP Framework: Linking Cognitive Engagement to Active Learning Outcomes. *Educational Psychologist, 49*(4), 219–243. https://doi.org/10.1080/00461520.2014.965823

59. Freeman, Scott., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. *Proceedings of the National Academy of Sciences, 111*(23), 8410–8415. https://doi.org/10.1073/pnas.1319030111

60. Prince, M. (2004). Does Active Learning Work? A Review of the Research. *Journal of Engineering Education, 93*(3), 223–231. https://doi.org/10.1002/j.2168-9830.2004.tb00809.x

61. National Academies of Sciences, Engineering, and Medicine [NASEM]. (2018). *How People Learn II: Learners, Contexts, and Cultures*. The National Academies Press. https://doi.org/10.17226/24783

62. Bridges, M. W., DiPietro, M., Lovett, M., Norman, M. K., & Ambrose, S. A. (2023). *How learning works: Eight research-based principles for smart teaching* (Second edition). Jossey-Bass.

63. Zacharia, Z. C., Olympiou, G., & Papaevripidou, M. (2008). Effects of experimenting with physical and virtual manipulatives on students' conceptual understanding in heat and temperature. *Journal of Research in Science Teaching, 45*(9), 1021–1035. https://doi.org/10.1002/tea.20260

64. Macrine, S. L., & Fugate, J. M. (2022). Embodied Cognition and its Educational Significance. In *Movement Matters: How Embodied Cognition Informs Teaching and Learning* (pp. 13–24). The MIT Press.

65. Wilson, M. (2002). Six views of embodied cognition. *Psychonomic Bulletin & Review, 9*(4), 625–636. https://doi.org/10.3758/BF03196322

66. Isaac, S., Schmid, S., Khorasani, A., & Jalali, Y. (2024). Chapter 6: How to support students to develop risk assessment and planning skills. In 3T PLAY (Ed.), *Teaching Transversal Skills for Engineering Students: a playbook of practical activities with tangibles*. Center for Learning Sciences, Swiss Federal Institute of Technology Lausanne (EPFL). https://doi.org/10.5281/zenodo.11263642

67. Jalali, Y., Bürer, M. J., Petringa, N., & Zufferey, J. D. (2023). What Role Do Tangibles Play in Fostering Design Thinking Skills? An Exploratory Study. *2023 IEEE Frontiers in Education Conference (FIE)*, 1–9. https://doi.org/10.1109/FIE58773.2023.10343272

68. Stigliani, I., & Ravasi, D. (2012). Organizing Thoughts and Connecting Brains: Material Practices and the Transition from Individual to Group-Level Prospective Sensemaking. *Academy of Management Journal, 55*(5), 1232–1259. https://doi.org/10.5465/amj.2010.0890

69. Whitton, N. (2018). Playful learning: Tools, techniques, and tactics. *Research in Learning Technology, 26*. https://doi.org/10.25304/rlt.v26.2035

70. de Lima, J., & Isaac, S. (2024). Chapter 5: How to support students to develop coaching and peer teaching skills. In 3T PLAY (Ed.), *Teaching Transversal Skills for Engineering Students: a playbook of practical activities with tangibles*. Center for Learning Sciences, Swiss Federal Institute of Technology Lausanne (EPFL). https://doi.org/10.5281/zenodo.10931765

71. Forbes, L. (2021). The Process of Playful Learning in Higher Education: A Phenomenological Study. *Journal of Teaching and Learning, 15*(1), Article 1. https://doi.org/10.22329/jtl.v15i1.6515

72. Jalali, Y., Alberink, B., Dehler Zufferey, J., & Mondada, F. (2024). Chapter 7: How to support students to cultivate psychological safety in their teams. In 3T PLAY (Ed.), *Teaching Transversal Skills for Engineering Students: a playbook of practical activities with tangibles*. Center for Learning Sciences, Swiss Federal Institute of Technology Lausanne (EPFL). https://doi.org/10.5281/zenodo.11192095

73. Tormey, R., & Laperrouza, M. (2023). The development, validation and use of an interprofessional project management questionnaire in engineering education. *European Journal of Engineering Education, 48*(3), 502–517. https://doi.org/10.1080/03043797.2023.2171854

74. Eva, K. W., & Regehr, G. (2005). Self-Assessment in the Health Professions: A Reformulation and Research Agenda. *Academic Medicine, 80*(10), S46. https://journals.lww.com/academicmedicine/fulltext/2005/10001/self_assessment_in_the_health_professions__a.15.aspx

75. Douglas, K. A., Neumann, K., & Oliveri, M. E. (2023). Contemporary Approaches to Assessment of Engineering Competencies for Diverse Learners. In A. Johri (Ed.), *International Handbook of Engineering Education Research* (pp. 690–709). Routledge. https://doi.org/10.4324/9781003287483-37

76. Ward, M., Gruppen, L., & Regehr, G. (2002). Measuring Self-assessment: Current State of the Art. *Advances in Health Sciences Education, 7*(1), 63–80. https://doi.org/10.1023/A:1014585522084

77. Martinez-Mediano, C., & Lord, S. M. (2012). Lifelong Learning Program for engineering students. *Proceedings of the 2012 IEEE Global Engineering Education Conference (EDUCON),* 1–6. https://doi.org/10.1109/EDUCON.2012.6201072

78. Dunai, L. D., Prieto, A., Chillaron, M., & Antonino-Daviu, J. A. (2015). Education in electric and electronic engineering via students involvement in innovative projects. *IECON 2015 - 41st Annual Conference of the IEEE Industrial Electronics Society,* 001862–001866. https://doi.org/10.1109/IECON.2015.7392372

79. Besterfield-Sacre, M., Shuman, L. J., Wolfe, H., Clark, R. M., & Yildirim, P. (2007). Development of a Work Sampling Methodology for Behavioral Observations: Application to Teamwork. *Journal of Engineering Education, 96*(4), 347–357. https://doi.org/10.1002/j.2168-9830.2007.tb00944.x

80. Reddy, Y. M., & Andrade, H. (2010). A review of rubric use in higher education. *Assessment & Evaluation in Higher Education, 35*(4), 435–448. https://doi.org/10.1080/02602930902862859

81. Eichelman, K., Clark, R., & Bodnar, C. (2015). Assessing the Impact of Game Based Pedagogy on the Development of Communication Skills for Engineers. *2015 ASEE Annual Conference and Exposition Proceedings*, 26.250.1-26.250.13. https://doi.org/10.18260/p.23590

82. Flateby, T., & Fehr, R. (2008). Assessing and improving writing in the engineering curriculum. *The International Journal of Engineering Education, 24*(5), 901–905. https://dialnet.unirioja.es/servlet/articulo?codigo=7435408

83. Scharf, D. (2014). Instruction and assessment of information literacy among STEM majors. *2014 IEEE Integrated STEM Education Conference, 1–7*. https://doi.org/10.1109/ISECon.2014.6891048

84. Fila, N., & Purzer, S. (2012). Do Students Dream Beyond LEDs? Innovative Qualities of Ideas Generated by First-year Engineering Students. *2012 ASEE Annual Conference & Exposition Proceedings*, 25.475.1-25.475.10. https://doi.org/10.18260/1-2--21233

85. Alliger, G. M., Tannenbaum, S. I., Bennett Jr, W., Traver, H., & Shotland, A. (1997). A Meta-Analysis of the Relations Among Training Criteria. *Personnel Psychology, 50*(2), 341–358. https://doi.org/10.1111/j.1744-6570.1997.tb00911.x

86. de Lima, J., & Isaac, S. (2024). Chapter 2: How to support students to develop skills that improve collaboration, including retrospective discussions. In 3T PLAY (Ed.), *Teaching Transversal Skills for Engineering Students: a playbook of practical activities with tangibles*. Center for Learning Sciences, Swiss Federal Institute of Technology Lausanne (EPFL). https://doi.org/10.5281/zenodo.13328621

87. Isaac, S., & de Lima, J. (2024). Chapter 8: How teachers can use the 3T PLAY trident framework to design activities that develop transversal skills. In 3T PLAY (Ed.), *Teaching Transversal Skills for Engineering Students: a playbook of practical activities with tangibles*. Center for Learning Sciences, Swiss Federal Institute of Technology Lausanne (EPFL). https://doi.org/10.5281/zenodo.10992806

88. Hattie, J. (2023). *Visible Learning: The Sequel: A Synthesis of Over 2,100 Meta-Analyses Relating to Achievement*. Routledge. https://doi.org/10.4324/9781003380542

3T PLAY

HOW TO FIND MORE 3T PLAY MATERIAL

To learn more about the 3T PLAY project and to access academic articles, please visit go.epfl.ch/3TPLAY

To access more teaching materials, please visit https://zenodo.org/communities/3tplay/records

HOW TO CITE THIS CHAPTER

Isaac, S., de Lima, J., Jalali, Y., Rossi, V., Schmid, S., Tormey, R., and Dehler Zufferey, J. 2024. Chapter 1: How to develop engineering students' transversal skills. In 3T PLAY (Eds.), *Teaching Transversal Skills for Engineering Students: a practical playbook of activities with tangibles*, EPFL Press, Lausanne.
https://doi.org/10.55430/SJYVJ3TP24

3T PLAY

CHAPTER 2

How to support students to develop skills that improve collaboration, including retrospective discussions

Generously funded by

The LEGO Foundation

EPFL LEARN Center for Learning Sciences

3T PLAY

CHAPTER 2

How to support students to develop skills that improve collaboration, including retrospective discussions

CHAPTER INDEX

CONTRIBUTORS

- **Activity design + development:** Dr Siara Isaac, Valentina Rossi
- **Writing this chapter:** Dr Joelyn de Lima, Dr Siara Isaac
- **Graphic design:** Laura Persat

3T PLAY

CHAPTER 2

How to support students to develop skills that improve collaboration, including retrospective discussions

ACTIVITY DESCRIPTION

Collaboration and team projects are common in both engineering studies and professional work. While there are clear benefits of working with diverse ideas and perspectives, collaboration also creates challenges including the issue of free-riders who do not pull their weight in the group. This experiential activity sets up a group task with unequal contributions that introduces students to the reasons underlying free-riding and, crucially, the skills to hold effective retrospective discussions to improve team functioning. This chapter provides the outline of an activity designed to teach the skills listed below, material to assist the facilitator to prepare, and the slides and handouts for teaching the activity.

ACTIVITY OUTCOMES

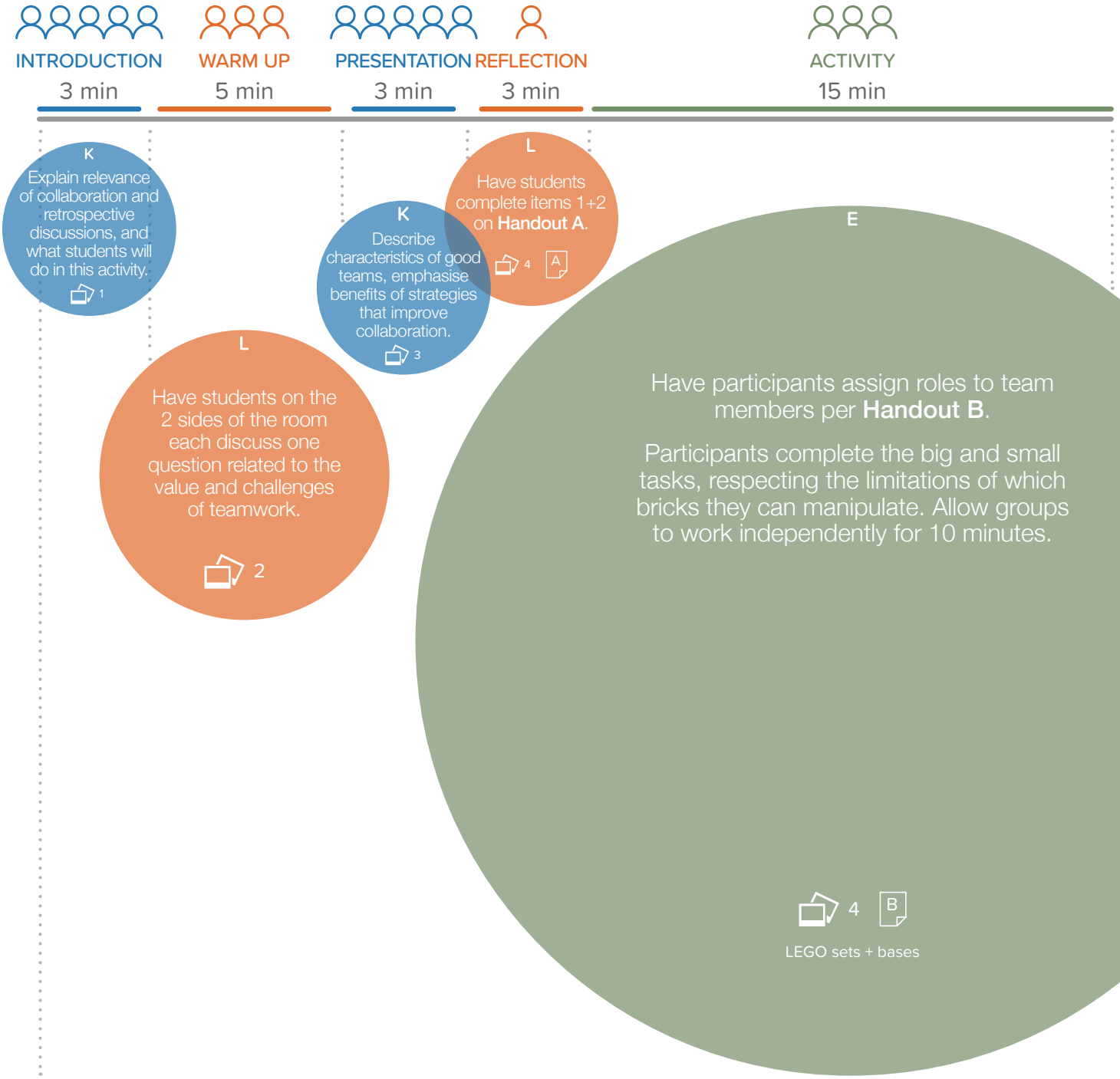
This 60-minute activity is designed for university-level engineering students.

It targets the development of the following skills

1. Collaborating and managing unequal contributions
2. Using retrospective discussions for future improvement

ACTIVITY

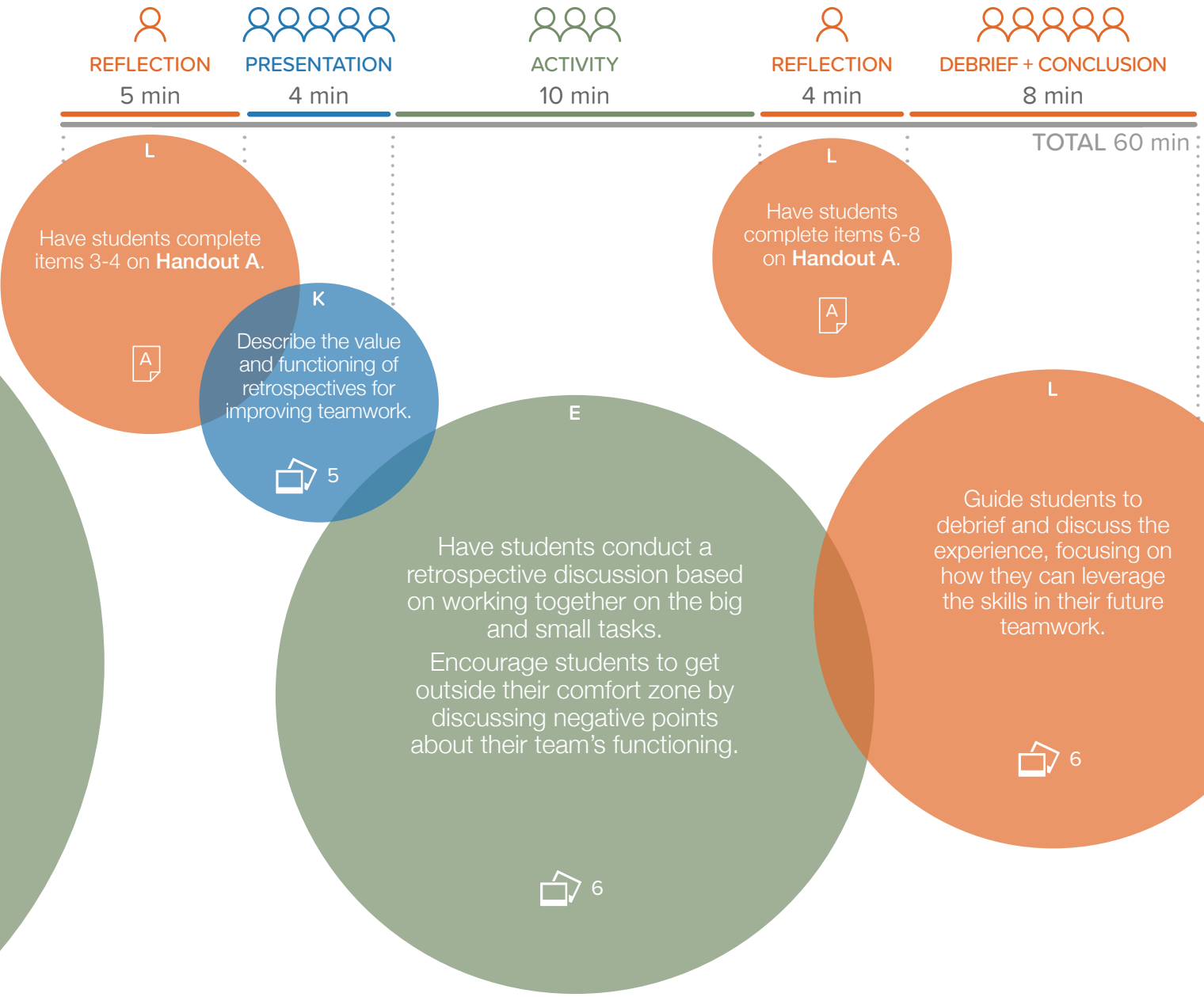
How to support students to develop skills that improve collaboration, including retrospective discussions



PREPARATION

Set up the room to create groups with 4-6 students.

3T PLAY



ALONE

PAIRS

SMALL GROUP

WHOLE GROUP

SLIDES

HANDOUT

K KNOWING
sharing knowledge and concepts that define the targeted skills

E EXPERIENCING
applying the concepts and tools in experiential learning

L LEARNING FROM EXPERIENCE
stepping back and reflecting about the activity enables students to transfer their skills

CONCEPTUAL AND PRACTICAL UNDERPINNINGS OF THE ACTIVITY

What skills will students develop in this activity?

The tasks that engineers are called to accomplish cannot be tackled alone and need collaborative and constructive team work[1,2]. The importance of teamwork has been ingrained in the engineering profession and is reflected in the curricular documents[3,4] that are used to train engineers and the accreditation documents that are used to certify these training programmes[5–9]. In engineering programmes, one way team working skills are taught is in the context of collaborative learning, where group members work towards a common task while helping each other master the skills needed for that task[10], such as in laboratories, semester projects and final programme projects. Collaborative learning in engineering has been shown to be predictive of increased self-efficacy, improved academic performance and decreased stress[11,12]. Problem-based learning, a type of collaborative learning, has been shown to lead to increased students' motivation, enhanced transversal skill development, as well as higher levels of interest in and awareness of issues related to sustainability[13–15].

Effective teams are not the result of luck, but the product of constructive collaborative strategies and team interactions. Fostering these elements is a matter of skill and like any other skill, collaborative and team skills they can and need to be developed. Teachers often assume that putting students in situations where they need to use the skill is sufficient to develop it[16–18], however students need explicit and scaffolded instruction and support[19]. This includes providing them with strategies and heuristics that they can use.

Collaborating and managing unequal contributions

Although engineering students recognise the importance of, and prioritise development of teamwork skills[20,21], they are hesitant to engage in it themselves[22]. One of the biggest barriers to team working is the spectre of free-riders, or social loafing in teams[22–29]. Free-riding can be described as the perception by the group that an individual is failing to contribute equitably to the group project[30]. A study that explored engineering students' perceptions of free-riding in teams found it to be endemic, with 91.8% of the students reported that one or more of their teammates were free-riders, while only 1.3% reported that they themselves were free-riders[31]. This discrepancy is likely partly explained by the finding that while most individuals in engineering student teams contributed less than what was expected of them, this behaviour was situational and varied based on the project[32]. This finding that free-riding is contextual underlines the value of having strong collaboration skills that facilitate teamwork.

Free-riding occurs can have a negative effect on the group dynamics and group members[23,30,33,34], but it also negatively impacts the free-riders themselves[35]. Free-riding occurs when there is conflict between the goals and interests of the collective (team) and the individuals (team members)[29]. Contrary to the common perception that free-riding is always intentional and that free-riders are lazy, apathetic and opportunistic, free-riding can result from other factors[23,25]. For example, a lack of attribution and equity can cause team members to decrease their own contributions because they are unaware of what the rest of the team is doing and believe they are doing most of the work[24]. Free-riding can also be

involuntary when students do not feel capable[35] or even encouraged by other group members, if they perceive that another member has insufficient skills or their contribution would increase time to completion or decrease grades[36].

Students appreciate instructor efforts to reduce free-riding[25,37]. There are multiple strategies [23,26,28–30,32,33,36,38] that can be used to minimise and mitigate the impacts of free-riding. These include:

- Limiting the scope of the project. Smaller projects typically have smaller components that make it easier to perceive contributions and where inequitable contributions also have a smaller impact.
- Reducing group size. In addition to an increased perception of ownership, smaller group sizes allow for more flexibility in managing resources and logistics such as scheduling common times to work.
- Setting out explicit team expectations, including the use of team contracts.
- Early detection of free-riding and team friction, to allow for corrective actions.
- Early, multiple, and specific peer evaluations. These increase perception of the effort put in by all the team members, increase accountability to the team, and allow for formative corrective actions.

Retrospective discussions for future improvement

One strategy that can be effective both in improving collaboration and mitigating the effects of free-riders are retrospectives[29]. Retrospectives are periodical meetings held to reflect on what has been done, learn from the experience, and use this reflection when planning and strategising future actions[39,40]. This technique has been commonly leveraged as part of Agile project management and design methodologies[39,41]. Agile methodologies, like Kanban and Scrum, have short iterative loops which allow for incremental and intentional development[42,43]. In these short iterative loops, retrospectives serve as pivotal moments for teams to reflect on their processes, adapt, and continually improve[44].

In engineering, retrospectives have been shown to have multiple positive impacts[41,45–50], including:

- Increased transparency of progression and therefore increased visibility of team roles.
- Improved collaboration and knowledge sharing in the team.
- Increased the quality and frequency of team communications.
- Timely feedback leading to improved team performance.
- Higher team satisfaction and motivation.
- Greater levels of trust among the team members.
- Improved ability to respond to changes and hurdles in real time.

Although hugely beneficial, retrospectives can also be counterproductive if not done well. Common issues include a lack of preparation for the retrospective, not voicing opinions and ideas, focussing only on the discussion and not on actionable ideas, and being too repetitive[40,44]. Even teams that use the Agile methodology can succumb to the pressure for immediate action and forgo retrospectives, which in turn can lead to lower long-term productivity and stagnation[51].

Therefore, strong collaboration skills should include skills for effective retrospective discussion - which is the focus of the activity in this chapter.

How to interest engineering students in learning these skills?

Although students are aware of the importance of collaboration and communication skills for their careers[52,53], they often find that these are not adequately integrated into their education[20,21]. Students frequently report dissatisfaction with their proficiency in these

areas[54,55] and express a desire to further develop these skills. The discrepancy between students' desire to learn and the lack of support in engineering curricula can be explained by the assumption among educators that group work during studies is sufficient for students to acquire these transversal skills. However, effective skill acquisition requires explicit instruction[19], including providing strategies that students can implement[17].

Therefore, emphasising that good teams are not a matter of luck but can be fostered can assist students to perceive and develop relevant skills. Furthermore, teaching students about these transversal skills can reduce negative attitudes toward group work. For some students, the prospect of collaboration in a group setting is a major source of concern, primarily due to past negative experiences such as uneven contribution among team members and the challenge of coordinating work[23,56]. Teaching students the underlying factors that contribute to free-riding and strategies for conducting effective retrospective discussions can assist them to develop skills relevant for their current and future teams. As well as providing excellent material for responding to job interview questions.

How does this activity help your students to develop these skills?

Project- and challenge-based activities create settings for engineering students to apply their transversal skills. However, the potential for students to develop their transversal skills in such contexts are often diminished by a lack of explicit instruction on and scaffolding of transversal skills[19] and students' difficulty in perceiving the skills as distinct from project tasks and deliverables[57]. In this activity, we created a micro-experiential opportunity that reproduces common teamwork difficulties, such as unequal contributions. This provides a context for students to examine their team functioning and engage in a retrospective discussion on how to improve collaboration. The final reflection assists students to see how this brief experience relates to teamwork challenges in educational and professional settings. In designing the activity, similar to the other activities in this handbook, we benefited from our trident framework as a practical structure for teaching transversal skills, highlighting conceptual underpinnings, procedural skills, and meta-cognitive and meta-emotional reflection. Please see Chapter 1[58] of this book for an in-depth presentation of the framework.

The three aspects of the trident are:

Knowing: the factual knowledge and concepts that underpin a skill. For instance, the definition of retrospective discussions and key challenges to constructive debriefing.

Experiencing: focused, low-risk opportunities to practice the relevant skills while attending to the process, ideally with rapid feedback and a chance to iterate. For example, holding a retrospective discussion after a challenging group task.

Learning from experience: meta-cognitive and meta-emotional reflection about the experience of implementing conceptual knowledge and procedural skills. For example, reviewing how people constructively or detrimentally reacted during the retrospective discussion.

The activity in this chapter has been designed to include each of the aspects from our trident to ensure that students develop a degree of proficiency in the targeted skills that allow them to apply them in their next project. This activity uses LEGO bricks to provide a visual, concrete project output around which students can encounter relevant teamwork difficulties. The construction task can be replaced with another complex task that can be split into subtasks and roles that creates opportunities for coordination difficulties and unequal contributions.

The importance of targeted project skills in this activity, collaboration and retrospective discussions, need to be shared with students, addressing the growing emphasis on teamwork within educational and professional settings. In other words, educators should help students to see the need and relevance of these skills.

In what follows, we explain the details of the activity when mapped onto the trident framework:

Knowing: The relevance of developing targeted project skills is explained [slide 1]. Characteristics of effective teams and how to foster them is presented on [slide 3] and guidelines for conducting retrospective discussions for future improvement on [slide 5].

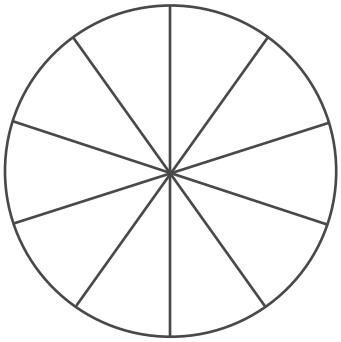
Experiencing: Students complete a 2-part construction task adhering to role assignments that impose unequal contributions from members to the team [Handout B]. The restrictive role assignments seek to reproduce both structural differences (disciplinary skills or professional qualifications) and team dynamics (motivation, personality) through the use of different coloured bricks. Students then engage in a retrospective discussion focusing on how to improve collaboration in the team. Teachers should guide students to focus on aspects under their control (communication, coordination) and not the constraints of the roles themselves. Common difficulties in retrospective discussions include team members not sharing difficult feedback or reacting defensively.

Learning from experience: Prior to starting the building task, students record their anticipated contributions [Handout A]. After the building tasks, students review difficulties and successes encountered. Finally, students complete the section reviewing the retrospective discussion, reflecting on the quality of the discussion and its capacity to improve future collaboration.

HANDOUT A
REFLECTION ON TEAMWORK

Expected Teamwork Distribution

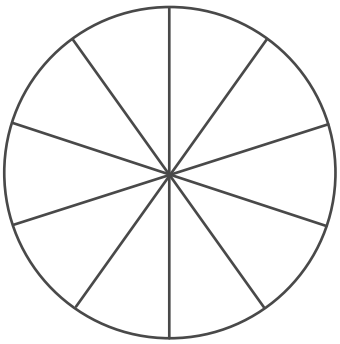
1. Based on your previous team experiences, what % do you personally expect to contribute to your team's collaborative tasks? Record your answer on this chart.
2. List 2-3 points that influenced your answer above (your skills, interests, group members…)



•

•

•



Reflecting on the Collaborative Tasks

3. After completing the 2 constructions, record your personal perception of the % that each person in your team contributed.

4. Working alone, respond to the 3 questions in the table. Consider both practical and psychological (in)actions.

What went well with your team's tasks?	What could be improved in your team?
•	•
•	•
•	•

What strategy should your team implement to improve collaboration?

5. In the second part of your team debriefing, respond together to the 2 points below.

List major collaboration difficulties	List strategies to implement
•	•
•	•
•	•

HANDOUT A CONTINUED

Reflection on the Retrospective Discussion

6. What types of constructive and detrimental behaviours occurred during your team's retrospective discussion? Tick the relevant boxes below:

Actions that discourage constructive debriefing and impede future improvement	Actions that support constructive discussion and future improvement
☐ Making generalisations	☐ Making specific, concrete proposals
☐ Blaming another person or external circumstances	☐ Taking personal responsibility
☐ Comments focusing on a person, rather than the context or roles	☐ Offering assistance
☐ Responding before listening (Yes, but…)	☐ Using active listening, including repeating back what you heard
☐ Arguing back and forth	☐ Sharing positive feedback and celebrating success
☐ Assigning motivations or feelings to others	☐ Contributing different aspects and perspectives to points raised by others
☐ Sharing only positive feedback, resulting in a superficial discussion	☐ Guiding the discussion to focus on the process
☐ Behaviour and comments that indicate the discussion isn't important	☐ Comments and behaviour that recognise people's contributions to the discussion

7. Overall, how would you evaluate the quality of your team's retrospective discussion and its capacity to improve future collaboration?

8. List 2 actions you can personally implement to support your (next) team's capacity to hold constructive retrospective discussions

-
-

HANDOUT B
COLLABORATIVE ACTIVITY

Working as a group, follow the instructions below to build the 2-part model (big task + small task). You will use LEGO bricks in 3 different sizes (small 2-dot bricks, medium 4-dot bricks and large 8-dot bricks) and 4 different colours.

B1. Assign responsibilities to team members. Think of the colours as representing the different skills or disciplinary expertise of each team member (python programming or materials science knowledge, etc.)

NOTE each person can ONLY touch/move/assemble bricks that match their colour.

For your group	corresponding colour	Assign each team member ONE role *if you have more than 4 team members, add a second person for rho + sigma	
κ (kappa)			X
ρ (rho)			*
σ (sigma)			*
ζ (zeta)			X

B2. Review the instructions for the 2 tasks and decide who will work on the small task and who on the big task. Your two sub-teams may now begin to build the big and small structures. <u>You have 10 minutes to complete both structures.</u>

Small task	Materials	number
	colour kappa, small 4-dot bricks	1
	colour rho, large 8-dot bricks	6
	colour sigma, large 8-dot bricks	5
	colour zeta, large 8-dot bricks	2

Steps

1. Start a free-standing structure by placing 3 large colour sigma bricks touching on their long sides.
2. Now make a layer of 6 large colour rho bricks, aligned orthogonally to bricks in the layer and extending equally beyond the second layer on all sides.
3. Check that all colour rho bricks are between layers containing colour sigma.
4. Fourth layer has 2 large colour sigma bricks connecting on their short ends and oriented parallel to the bricks in the second layer. 2 additional large colour zeta bricks to form an X with the colour sigma bricks on this layer.
5. The bottom layer is a single small brick, centred.

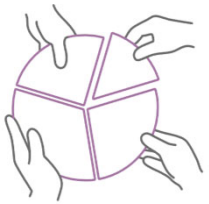
HANDOUT B CONTINUED

Big task	Materials	number
	base plate	1
	colour kappa, medium 4-dot bricks	24
	colour rho, small 2-dot bricks	6
	colour rho, medium 4-dot bricks	2
	colour rho, large 8-dot bricks	4
	colour sigma, small 2-dot bricks	6
	colour sigma, large 8-dot bricks	8

Steps

1. Start with the base plate. Create a single layer square of 24 small colour kappa bricks symmetric around one 4-dot hole in the middle of the base plate and equidistant from all 4 sides of the base plate.
2. For the second layer, add 8 large colour sigma bricks to form a continuous outer wall.
3. The third layer starts with 2 walls each formed by 2 large and 1 medium colour rho bricks.
4. Complete layer 2 by adding 3 small colour sigma bricks on the interior of two opposite walls.
5. Finally, complete the colour rho layer with 6 small bricks connecting opposite walls.
6. In the final model, the colour sigma bricks are between the colour kappa and colour rho layers, resulting in a final 3-layer structure.

3T PLAY



Developing skills to improve collaboration

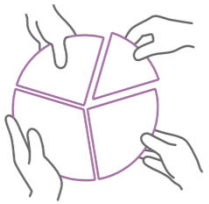
Interdisciplinary teams are central to engineering, requiring us to repeatedly adjust our collaboration approach.

This activity uses the construction of a 2-part structure to create an experiential context to develop skills for productive team retrospectives.

This session will help you improve your skills for

- **Collaborating** and managing unequal contributions
- Using **retrospective discussions** for future improvement

3T PLAY



Warm up

Please discuss your assigned question with your neighbours, writing down your ideas

On the left side of the room, list things that

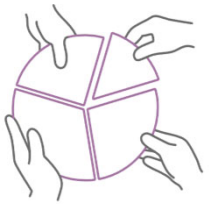
- **make it difficult** to get things done in a team
- **ruin team atmosphere**

On the right side of the room, list things that

- **make it more productive** to work in a team
- create a **pleasant team** atmosphere

Debriefing – Groups take turns sharing <u>one</u> element from their discussion

3T PLAY



Good teams aren’t just the result of good luck - they are fostered by good collaboration stategies

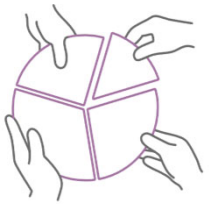
Teams use strategies for

- making **decisions** and setting **goals**
- conducting **meetings**
- sharing **information**
- giving **feedback** to team members
- **tracking progress** towards objectives and deadlines

When these strategies are shared and understood by all team members, it is likely to feel like a « good » team.

Teams can improve their **climate** and **efficacity** by making their strategies **explicit and transparent** to each other

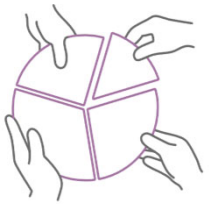
3T PLAY



Building a 2-part LEGO structure

1. Working alone on **Handout A**, answer the **questions 1+2** about *"expected teamwork distribution"*.
2. With your group, complete the **table B1 on Handout B**.
3. Continue with B2 and **build the 2 tasks per instructions**, respecting the **colour assignments** that limit the bricks you can manipulate.
4. Return to Handout A and respond to **questions 3+4** about *"reflecting on the collaborative tasks"*

3T PLAY



Retrospectives are structured team discussions held at the end of project phase to improve how the team works together on the next phase

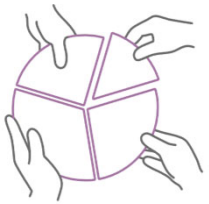
Retrospectives

- make team work more productive and more pleasant
  - feedback and concerns are shared and addressed
- identify what went well, what needs to improve
  - track progress and identify challenges (i.e. free-riding)
- improve collaboration, decision making, and planning
  - implement better strategies

Contributing to a retrospective

- taking personal responsibility
- sharing negative feedback
- making specific, concrete proposals
- sharing positive feedback and celebrating success
- using active listening and communication strategies to promote mutual understanding

3T PLAY



Holding a retrospective discussion

1. Allow each team member 1 minute (uninterrupted!) to share their perspective on the collaborative activity from their Handout A notes.
2. Together, complete **question 5** by listing 3 major difficulties you encountered during your building tasks
3. Working alone, complete **questions 6-8** on Handout A "reflection after retrospective discussion"

Activity development and implementation

This activity was developed for engineering students at a Swiss technical university.

It has since been implemented in diverse contexts and for diverse audiences including:

Countries

Belgium

Denmark

Switzerland

United Kingdom

Audiences

Engineering students

Teaching assistants

Pedagogical advisors

Faculty developers

Higher education teachers

References

1. National Academy of Engineering [NAE]. (2017). *Grand Challenges for Engineering*. https://nae.edu/187212/NAE-Grand-Challenges-for-Engineering

2. The United Nations Educational, Scientific and Cultural Organization [UNESCO]. (2021). *Engineering for Sustainable Development.* https://unesdoc.unesco.org/ark:/48223/pf0000375644.locale=en

3. Crawley, E. F., Malmqvist, J., Lucas, W. A., & Brodeur, D. R. (2011). The CDIO Syllabus v2.0. An Updated Statement of Goals for Engineering Education. In M. Vigild (Ed.), *Proceedings of the 7th International CDIO Conference.* https://api.semanticscholar.org/CorpusID:110610803

4. Crawley, E. F., Malmqvist, J., Östlund, S., Brodeur, D. R., & Edström, K. (2014). The CDIO Approach. In E. F. Crawley, J. Malmqvist, S. Östlund, D. R. Brodeur, & K. Edström (Eds.), *Rethinking Engineering Education: The CDIO Approach* (pp. 11–45). Springer International Publishing. https://doi.org/10.1007/978-3-319-05561-9_2

5. Accreditation Board for Engineering and Technology [ABET]. (2023). *Criteria for Accrediting Engineering Programs, 2023 – 2024 | ABET*. https://www.abet.org/accreditation/accreditation-criteria/criteria-for-accrediting-engineering-programs-2023-2024/

6. Commission des titres d'ingénieur [CTI]. (2023). *The CTI's Major Criteria and Procedures – CTI – Commission des Titres d'Ingénieur.* https://www.cti-commission.fr/en/fonds-documentaire

7. Engineers Australia. (2019). *Accreditation management system | Engineers Australia.* https://www.engineersaustralia.org.au/accreditation-management-system

8. European Network for Accreditation of Engineering Education [ENAEE]. (2023). EUR-ACE® Framework Standards and Guidelines. *ENAEE.* https://www.enaee.eu/eur-ace-system/standards-and-guidelines/

9. The Engineering Council. (2023). *Accreditation of Higher Education Programmes (AHEP).* https://www.engc.org.uk/standards-guidance/standards/accreditation-of-higher-education-programmes-ahep/fourth-edition-implemented-by-31-december-2021/

10. Göl, Ö., & Nafalski, A. (2007). Collaborative Learning in Engineering Education. *Global Journal of Engineering Education, 11*(2).

11. Lapitan, L. DS., Chan, A. L. A., Sabarillo, N. S., Sumalinog, D. A. G., & Diaz, J. M. S. (2023). Design, implementation, and evaluation of an online flipped classroom with collaborative learning model in an undergraduate chemical engineering course. *Education for Chemical Engineers, 43,* 58–72. https://doi.org/10.1016/j.ece.2023.01.007

12. Stump, G. S., Hilpert, J. C., Husman, J., Chung, W., & Kim, W. (2011). Collaborative Learning in Engineering Students: Gender and Achievement. *Journal of Engineering Education, 100*(3), 475–497. https://doi.org/10.1002/j.2168-9830.2011.tb00023.x

13. Boelt, A. M., Kolmos, A., & Holgaard, J. E. (2022). Literature review of students'perceptions of generic competence development in problem-based learning in engineering education. *European Journal of Engineering Education, 47*(6), 1399–1420. https://doi.org/10.1080/03043797.2022.2074819

14. Kolmos, A., & de Graaff, E. (2014). Problem-Based and Project-Based Learning in Engineering Education: Merging Models. In A. Johri & B. M. Olds (Eds.), *Cambridge Handbook of Engineering Education Research* (pp. 141–160). Cambridge University Press. https://doi.org/10.1017/CBO9781139013451.012

15. Servant-Miklos, V., Holgaard, J. E., & Kolmos, A. (2023). Sustainability Matters: The Evolution of Sustainability Awareness, Interest and Engagement in PBL Engineering Students. *Journal of Problem Based Learning in Higher Education, 11*(1), Article 1. https://doi.org/10.54337/ojs.jpblhe.v11i1.7374

16. Dokter, L. (2024). *Academics' Perspectives on Transversal Skills: A Case Study in the New Engineering Programme at the Norwegian Military Academy. Proceeding of the SEFI 2024 Conference*.

17. Isaac, S., Petringa, N., Jalali, Y., Tormey, R., & Dehler Zufferey, J. (2023). Are Engineering Teachers Ready to Leverage the Power of Play to Teach Transversal Skills? *Proceedings of the SEFI 2023 Conference.* https://doi.org/10.21427/QP3D-B914

18. Sá, M. J., & Serpa, S. (2018). Transversal Competences: Their Importance and Learning Processes by Higher Education Students. *Education Sciences, 8*(3), Article 3. https://doi.org/10.3390/educsci8030126

19. Picard, C., Hardebolle, C., Tormey, R., & Schiffmann, J. (2022). Which professional skills do students learn in engineering team-based projects? *European Journal of Engineering Education, 47*(2), 314–332. https://doi.org/10.1080/03043797.2021.1920890

20. de Lima, J., Isaac, S., & Zufferey, J. D. (2024). Distinctly Human—Students' Perception of Transversal Skills in Engineering Curriculum. *Proceedings of the 20th International CDIO Conference.*

21. de Lima, J., Isaac, S., & Zufferey, J. D. (2024). Transversal skills priorities and curricular support as experienced by engineering students on their path to becoming responsible engineers. *Proceedings of the 52nd Annual SEFI Conference.*

22. Pineros-Rodriguez, M., Deparis, S., Hess, K., & de Lima, J. (2024). Reluctance Despite Recognition: Student Perceptions of Benefits of Group Work. *Proceeding of the SEFI 2024 Conference.*

23. Hall, D., & Buzwell, S. (2013). The problem of free-riding in group projects: Looking beyond social loafing as reason for non-contribution. *Active Learning in Higher Education, 14*(1), 37–49. https://doi.org/10.1177/1469787412467123

24. Latané, B., Williams, K., & Harkins, S. (1979). Many hands make light the work: The causes and consequences of social loafing. *Journal of Personality and Social Psychology, 37*(6), 822–832. https://doi.org/10.1037/0022-3514.37.6.822

25. Lavenex, P., & Serry, S. (Forthcoming). *Free-riding: Faciliter l'inclusion dans le travail en équipe*. Pédagogies en Pratique.

26. Shimazoe, J., & Aldrich, H. (2010). Group Work Can Be Gratifying: Understanding & Overcoming Resistance to Cooperative Learning. *College Teaching, 58*(2), 52–57. https://doi.org/10.1080/87567550903418594

27. Simms, A., & Nichols, T. (2014). Social loafing: A review of the literature. *Journal of Management, 15*(1), 58–67.

28. Borrego, M., Karlin, J., McNair, L. D., & Beddoes, K. (2013). Team Effectiveness Theory from Industrial and Organizational Psychology Applied to Engineering Student Project Teams: A Research Review. *Journal of Engineering Education, 102*(4), 472–512. https://doi.org/10.1002/jee.20023

29. Tenenberg, J. (2019). Factors affecting free riding on teams: Implications for engineering education. *International Journal of Engineering Education, 35*(6A), 1703–1724.

30. Aggarwal, P., & O'Brien, C. L. (2008). Social Loafing on Group Projects: Structural Antecedents and Effect on Student Satisfaction. *Journal of Marketing Education, 30*(3), 255–264. https://doi.org/10.1177/0273475308322283

31. Pabico, J. P., Hermocilla, J. A. C., Galang, J. P. C., & De Sagun, C. C. (2008). Perceived Social Loafing in Undergraduate Software Engineering Teams. *Proceedings (CDROM) of the 6th National Conference on IT Education (NCITE 2008)*. 6th National Conference on IT Education (NCITE 2008, University of the Philippines Los Baños, College, Laguna, Philippines. https://arxiv.org/abs/1507.08345v1

32. Kopec-Harding, K., Eraslan, S., Cai, B., Embury, S. M., & Jay, C. (2023). The impact of unequal contributions in student software engineering team projects. *Journal of Systems and Software, 206*, 111839. https://doi.org/10.1016/j.jss.2023.111839

33. Brooks, C. M., & Ammons, J. L. (2003). Free Riding in Group Projects and the Effects of Timing, Frequency, and Specificity of Criteria in Peer Assessments. *Journal of Education for Business, 78*(5), 268–272. https://doi.org/10.1080/08832320309598613

34. Jassawalla, A., Sashittal, H., & Sashittal, A. (2009). Students' Perceptions of Social Loafing: Its Antecedents and Consequences in Undergraduate Business Classroom Teams. *Academy of Management Learning & Education, 8*(1), 42–54. https://doi.org/10.5465/amle.2009.37012178

35. Webb, N. M. (1997). Assessing Students in Small Collaborative Groups. *Theory Into Practice, 36*(4), 205–213. https://www.jstor.org/stable/1477365

36. Börjesson, P. O., Hamidian, A., Kubilinskas, E., Richter, U., Weyns, K., & Ödling, P. (2006). *Free-riding in Group Work - Mechanisms and Countermeasures: 4:e pedagogiska inspirationskonferensen, 2006*. Pedagogiska Inspirationskonferensen, Lund, Sweden. http://www.lth.se/fileadmin/lth/genombrottet/konferens2006/p_o_b_rjesson_mfl.pdf

37. Maiden, B., & Perry, B. (2011). Dealing with free-riders in assessed group work: Results from a study at a UK university. *Assessment & Evaluation in Higher Education, 36*(4), 451–464. https://doi.org/10.1080/02602930903429302

38. Fronza, I., & Wang, X. (2021). Social loafing prevention in agile software development teams using team expectations agreements. *IET Software, 15*(3), 214–229. https://doi.org/10.1049/sfw2.12019

39. Beck, K., Beedle, M., van Bennekum, A., Cockburn, A., Cunningham, W., Fowler, M., Grenning, J., Highsmith, J., Hunt, A., Jeffries, R., Kern, J., Marick, B., Martin, R. C., Mellor, S., Schwaber, K., Sutherland, J., & Thomas, D. (2001). *Manifesto for Agile Software Development.* https://agilemanifesto.org/

40. Przybyłek, A., Albecka, M., Springer, O., & Kowalski, W. (2021). Game-based Sprint retrospectives: Multiple action research. *Empirical Software Engineering, 27*(1), 1. https://doi.org/10.1007/s10664-021-10043-z

41. Sandstø, R., & Reme-Ness, C. (2021). Agile Practices and Impacts on Project Success. *255-262.* https://doi.org/10.2478/jeppm-2021-0024

42. Kumar, G., & Bhatia, P. K. (2012). Impact of agile methodology on software development process. *International Journal of Computer Technology and Electronics Engineering (IJCTEE), 2*(4), 46–50.

43. Sunner, D. (2016). Agile: Adapting to need of the hour: Understanding Agile methodology and Agile techniques. *2016 2nd International Conference on Applied and Theoretical Computing and Communication Technology (iCATccT)*, 130–135. https://doi.org/10.1109/ICATCCT.2016.7911978

44. Matthies, C., Dobrigkeit, F., & Ernst, A. (2019). Counteracting Agile Retrospective Problems with Retrospective Activities. In A. Walker, R. V. O'Connor, & R. Messnarz (Eds.), *Systems, Software and Services Process Improvement* (pp. 532–545). Springer International Publishing. https://doi.org/10.1007/978-3-030-28005-5_41

45. Duehr, K., Efremov, P., Heimicke, J., Teitz, E. M., Ort, F., Weissenberger-Eibl, M., & Albers, A. (2021). The Positive Impact of Agile Retrospectives on the Collaboration of Distributed Development Teams – A Practical Approach on the Example Of Bosch Engineering Gmbh. *Proceedings of the Design Society, 1*, 3071–3080. https://doi.org/10.1017/pds.2021.568

46. Hummel, M., Rosenkranz, C., & Holten, R. (2015). The Role of Social Agile Practices for Direct and Indirect Communication in Information Systems Development Teams. *Communications of the Association for Information Systems, 36*(1). https://doi.org/10.17705/1CAIS.03615

47. McHugh, O., Conboy, K., & Lang, M. (2011). Using Agile Practices to Influence Motivation within IT Project Teams. *Scandinavian Journal of Information Systems, 23*(2). https://aisel.aisnet.org/sjis/vol23/iss2/3

48. McHugh, O., Conboy, K., & Lang, M. (2012). Agile Practices: The Impact on Trust in Software Project Teams. *IEEE Software, 29*(3), 71–76. IEEE Software. https://doi.org/10.1109/MS.2011.118

49. Mesquida, A.-L., Karać, J., Jovanović, M., & Mas, A. (2017). A Game Toolbox for Process Improvement in Agile Teams. In J. Stolfa, S. Stolfa, R. V. O'Connor, & R. Messnarz (Eds.), *Systems, Software and Services Process Improvement* (pp. 302–309). Springer International Publishing. https://doi.org/10.1007/978-3-319-64218-5_25

50. Pikkarainen, M., Haikara, J., Salo, O., Abrahamsson, P., & Still, J. (2008). The impact of agile practices on communication in software development. *Empirical Software Engineering, 13*(3), 303–337. https://doi.org/10.1007/s10664-008-9065-9

51. Babb, J., Hoda, R., & Nørbjerg, J. (2014). Embedding Reflection and Learning into Agile Software Development. *IEEE Software, 31*(4), 51–57. IEEE Software. https://doi.org/10.1109/MS.2014.54

52. Direito, I., Pereira, A., & Duarte, A. M. de O. (2012). Engineering Undergraduates' Perceptions of Soft Skills: Relations with Self-Efficacy and Learning Styles. *Procedia - Social and Behavioral Sciences, 55*, 843–851. https://doi.org/10.1016/j.sbspro.2012.09.571

53. Donald, W. E., Baruch, Y., & Ashleigh, M. (2019). The undergraduate self-perception of employability: Human capital, careers advice, and career ownership. *Studies in Higher Education, 44*(4), 599–614. https://doi.org/10.1080/03075079.2017.1387107

54. Brunhaver, S. R., Korte, R. F., Barley, S. R., & Sheppard, S. D. (2018). Bridging the Gaps between Engineering Education and Practice. In R. B. Freeman & H. Salzman (Eds.), *US Engineering in a Global Economy* (pp. 129–163). University of Chicago Press. http://www.nber.org/chapters/c12687

55. Kovacs, H., Capdevila, I., Lermigeaux-Sarrade, I. J. L., & Jermann, P. (2023). From University to Work: Alumni Viewpoints. *Proceedings of the CDIO 2023 Conference.* CDIO 2023. https://cdio.org/knowledge-library/documents/university-work-alumni-viewpoints

56. Burdett, J. (2003). Making groups work: University students' perceptions. *International Education Journal, 4*(3), 177–191.

57. Tormey, R., & Isaac, S. (2022). *Facilitating Experiential Learning in Higher Education Teaching and Supervising in Labs, Fieldwork, Studios, and Projects*. Routledge.

58. Isaac, S., de Lima, J., Jalali, Y., Rossi, V., Schmid, S., Tormey, R., and Dehler Zufferey, J. (2024). Chapter 1: How to develop engineering students' transversal skills. In 3T PLAY (Eds.), *Teaching Transversal Skills for Engineering Students: a practical playbook of activities with tangibles*, Centre for Learning Sciences EPFL, Lausanne. https://doi.org/10.5281/zenodo.13328581

3T PLAY

LIST OF MATERIALS

- ◯ Slides to facilitate this activity
- ◯ 1x Handout A per student
- ◯ 1x Handout B per team, single sided*
- ◯ LEGO for the two tasks (64 bricks total + 1 base)††, per team of 4-6 students
  - ◯ base plate square with minimum 10 dots per side (1x)
  - ◯ colour kappa†:
    - ◯ medium 4-dot bricks (25x)
  - ◯ colour sigma:
    - ◯ small 2-dot bricks (6x)
    - ◯ large 8-dot bricks (13x)
  - ◯ colour rho:
    - ◯ small 2-dot bricks (6x)
    - ◯ medium 4-dot bricks (2x)
    - ◯ large 8-dot bricks (10x)
  - ◯ colour zeta:
    - ◯ large 8-dot bricks (2x)

* This 2-part building task can be substituted with another collaborative task where team members can be assigned distinct roles.

† Varying colours to each team makes it easier to provide the required bricks and reduces copying between teams

†† To see a video example of how the tangibles are used, visit **go.epfl.ch/videoCh2**

MORE ABOUT 3T PLAY

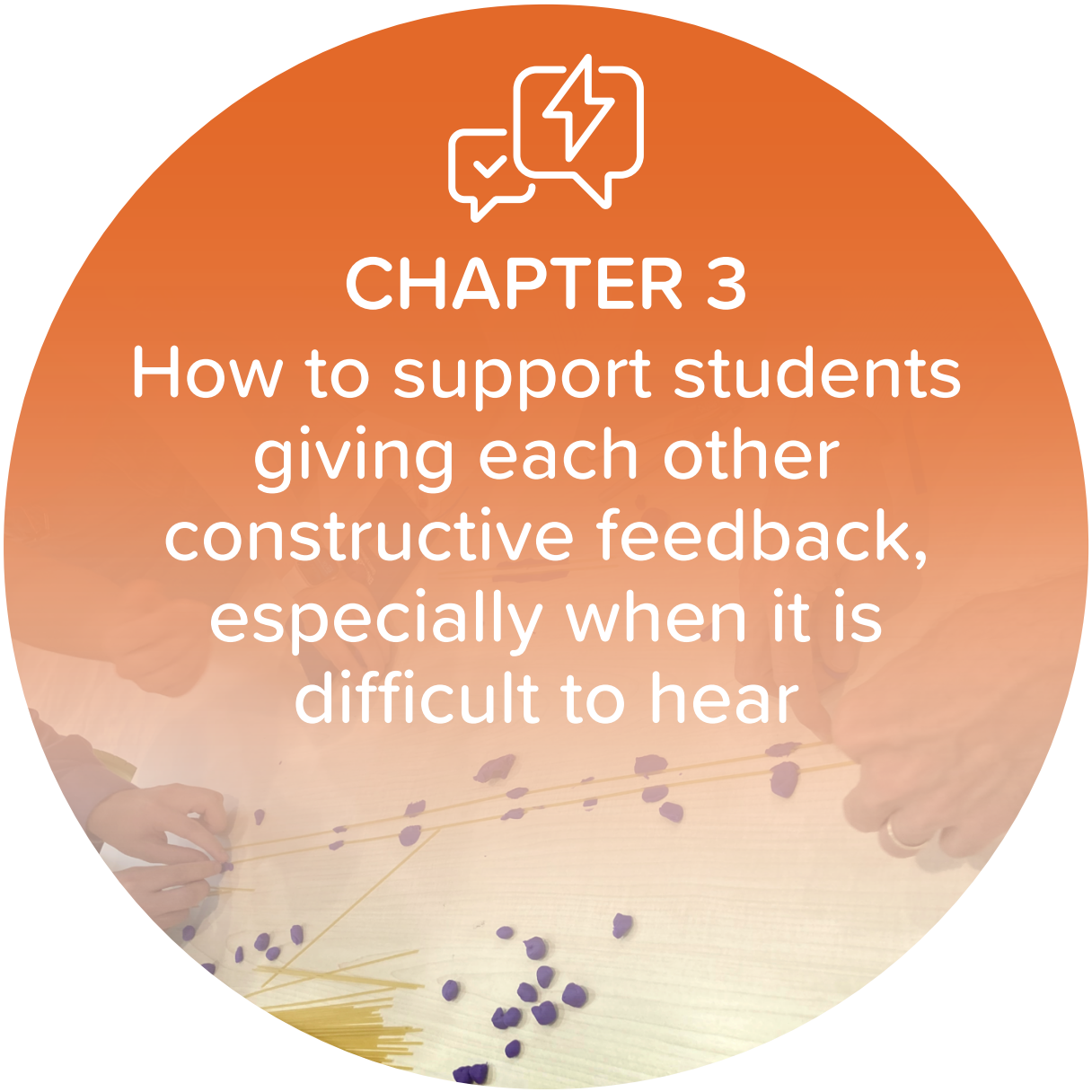
To learn more about the 3T PLAY project and access research output, please visit **go.epfl.ch/3TPLAY**

To access more teaching materials, please visit **https://zenodo.org/communities/3tplay/records**

HOW TO CITE THIS CHAPTER

de Lima, J. and Isaac, S. (with Rossi, V.). 2024.
Chapter 2: How to support students to develop skills that improve collaboration, including retrospective discussions. In 3T PLAY (Eds.), *Teaching Transversal Skills for Engineering Students: a practical playbook of activities with tangibles*, EPFL Press, Lausanne.
https://doi.org/10.55430/SJYVJ3TP24

3T PLAY



CHAPTER 3

How to support students giving each other constructive feedback, especially when it is difficult to hear

Generously funded by

The LEGO Foundation

EPFL LEARN Center for Learning Sciences

3T PLAY

CHAPTER 3

How to support students giving each other constructive feedback, especially when it is difficult to hear

CHAPTER INDEX

CONTRIBUTORS

- **Activity design + development:** Nicola Winzenried, Dr. Natascia Petringa, Dr. Yousef Jalali and Dr. Siara Isaac
- **Writing this chapter:** Dr. Siara Isaac and Dr. Joelyn de Lima
- **Graphic design:** Laura Persat

3T PLAY

CHAPTER 3

How to support students giving each other constructive feedback, especially when it is difficult to hear

ACTIVITY DESCRIPTION

Being able to deliver feedback to peers is a key management skill and something engineering students report finding difficult, due to the relational and emotional implications. This experiential activity provides students with emotional management strategies and a first, low-stakes opportunity to apply them when both giving feedback and responding to feedback received. This chapter provides the outline of an activity designed to teach the learning outcomes listed below, material to assist the facilitator to prepare, and the slides and handouts for teaching the activity.

LEARNING OUTCOMES

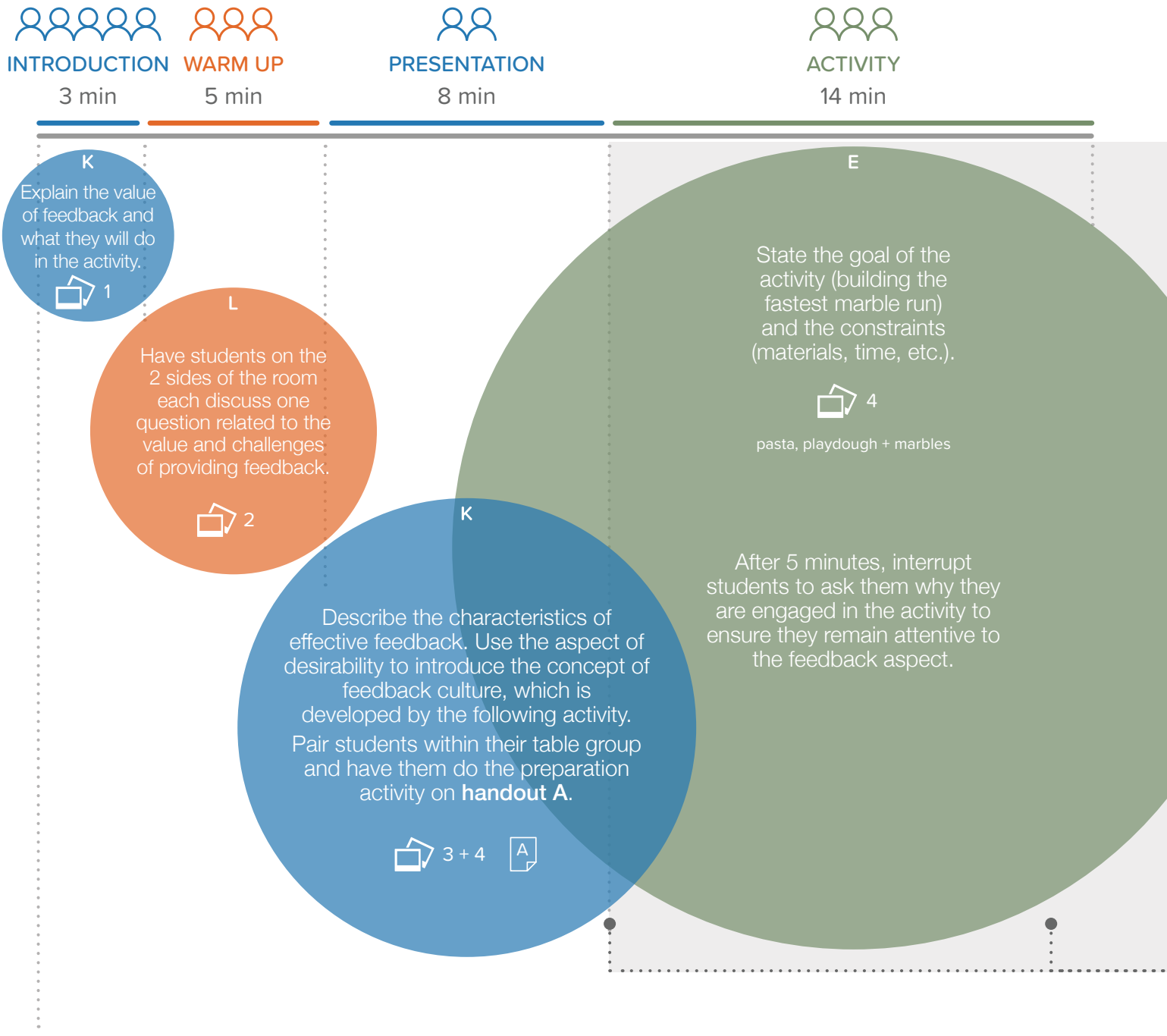
This 60-minute activity is designed for university-level engineering students.

It targets the development of the following skills

1. Formulating feedback to be “heard” by others by attending to their emotional response.
2. Managing your emotions when receiving and responding to feedback.

ACTIVITY 3

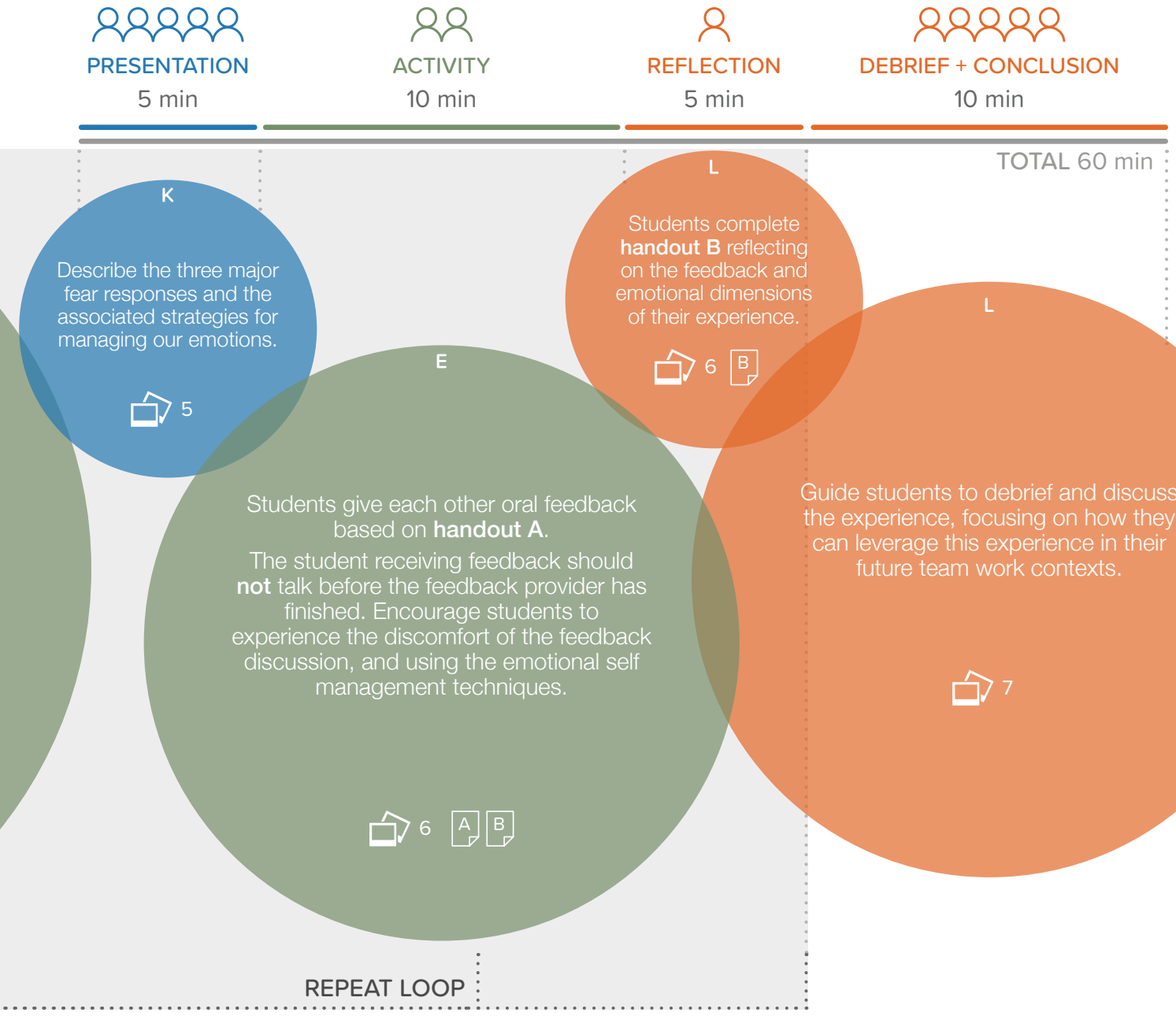
How to support students giving each other constructive feedback, especially when it is difficult to hear



PREPARATION

Set up the room with groups of 6 or 8 students. Place 1 marble, 100g spaghetti, a 150 cm length of string and 1 pot of playdough on each table.

3T PLAY



ALONE

PAIRS

SMALL GROUP

WHOLE GROUP

SLIDES

HANDOUT

K KNOWING
sharing knowledge and concepts that define the targeted skills

E EXPERIENCING
applying the concepts and tools in experiential learning

L LEARNING FROM EXPERIENCE
stepping back and reflecting about the activity enables students to transfer their skills

CONCEPTUAL AND PRACTICAL UNDERPINNINGS OF THE ACTIVITY

What skills will students develop in this activity?

Feedback is information obtained as the consequence of an action and can take different forms including positive behaviour, reinforcing feedback and negative deterrent feedback. Its objective is to be formative, meaning that the goal is to help the student improve unlike evaluations and assessments which are typically summative[1]. Feedback is an integral and powerful part of the learning process[2] and the effect of feedback on student achievement has been shown to be almost double the average found for educational interventions[3]. This effect can be either positive or negative, depending on the nature of the feedback and the student's ability to use the feedback productively[4]. Effective feedback practices are not common in higher education and students are often dissatisfied with the feedback they receive[5], finding it vague and insufficient to identify concrete steps towards improvement[6,7].

Feedback literacy

Therefore, in addition to providing students with feedback on their learning, it is relevant that they develop skills for giving, receiving, processing, and leveraging feedback. This group of skills is called "feedback literacy" and Carless & Boud's[8] proposed model for feedback literacy is shown in Figure 3.1. "Making judgements" may be the most familiar aspect in this figure, where we determine if the feedback is useful. This judgment is affected both by the person's "appreciation of feedback" and how they "manage the emotions" elicited. If a student's previous experiences with feedback have been useful, this appreciation can make them more receptive to feedback and therefore more likely to perceive subsequent feedback as useful. Similarly, a student's affective or emotional response will also influence how the student judges feedback as overwhelming positive emotions may cause a student to ignore important feedback.

Conversely, anxiety or a sense of distress can lead to rejection of the feedback as a coping strategy. However, negative emotional responses are lower when students value the feedback[9]. When these interactions are unanticipated and their influence on what actions the student will ultimately undertake is ignored, there will be a decrease in how much the feedback advances the desired outcome of assisting the student to improve.

Well developed feedback literacy reduces anxiety about feedback and contributes to a culture where feedback is considered a tool for growth, not criticism. Good feedback literacy reinforces an environment within a team or organisation that welcomes feedback and embraces its benefits whilst acknowledging and managing the emotions linked to the process. The result is that people are able to generate and share feedback, as well as to digest and apply the feedback they receive to achieve the goal of implementing improvements.

Emotional competencies

Engineering is often considered to be an objective and dispassionate discipline, with no room for subjective entities like emotions[10–13]. However, emotions play an important role in the various dimensions of engineering including sustainability, ethics, social responsibility and equity[14]. Further, emotional competencies play a crucial role in effective leadership[15], assisting with managing teams, handling difficult situations, and reducing stress[16]. Emotions are integral to collaboration work and therefore are ubiquitous in engineering work for people working in all roles[17]. Given the important role of emotional competencies during both university studies and professional work, more support should be provided to students in engineering programs[18]. While the term 'emotional intelligence' became popular as a way to emphasise the importance of these skills, it can give the counterproductive impression that emotional skills are inherent personality

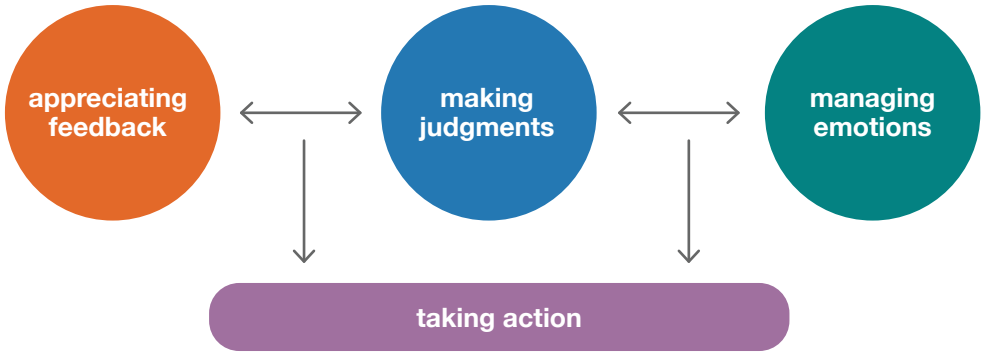


Figure 3.1 Feedback literacy models proposed by Carless and Boud (2018)

characteristics. This activity capitalises on the finding that emotional skills can be improved with training[18,19].

How to interest engineering students in learning these skills?

Beyond its relevance for their own learning, feedback literacy is important for engineering students because giving, receiving, and acting on feedback are important components of a professional engineer's role. It is a skill that is both valued by employers[20] and perceived as lacking in the engineering curriculum by engineering graduates[21].

Giving and receiving feedback helps engineers avoid the dreaded "feedback famine", where poor performance persists as a consequence of getting insufficient feedback. Timely and appropriate feedback allows them to become more self-aware, and by doing so maximise their potential to perform on the task and within the team. When the giver and receiver of the feedback have high feedback literacy skills, the feedback interaction can potentially improve satisfaction and motivation, and also enhance trust within the team. Thus, feedback can benefit both the giver and the receiver[22], and the team.

Students therefore should be trained to value the potential impact of feedback and to implement strategies to actively engage with it[2,23–28]. It is also important that students learn self-regulation with respect to the feedback they receive and use it to monitor their progress[29,30]. However, feedback discussions can also elicit emotions and concern about these emotions can influence how readily people give and receive feedback. While facilitating this activity for EPFL students, we have been told that avoiding potentially emotionally difficult conversations is a major reason why students hesitate to share feedback with their peers. Thus, attending to the emotional dimension of feedback should be integrated into feedback literacy training for engineers and managers. You can also consult [slides 3+5] for more information about how to do feedback well.

Finally, it is important for students to understand the value of emotional skills for engineering work. Emotions are fundamental to the leadership and collaboration skills that enable engineers to contribute more constructively. For instance, Boyatsis et al.[17] found that an engineer's emotional and social competencies, as observed by their peers, significantly predicted their effectiveness. Emotions also inform engineering thinking, particularly sustainability and ethics[14]. When we conceptualise emotional skills as a characteristic possessed by some people and not by others, we discourage students to adopt a growth mindset with respect to practising and improving their capacity to have

discussions with emotional dimensions. In this activity, students use the (sometimes difficult) experiences both giving and receiving feedback, when accompanied by relevant reflection, to develop and refine their emotional self management and feedback literary skills.

How does this activity help your students to develop these skills?

Project- and challenge-based activities provide engineering students with practical opportunities to use procedural skills and offer excellent opportunities to integrate transversal skills with disciplinary thinking. An important limitation is that students may find it difficult to perceive the skills as distinct from accomplishing the project tasks[31], a lack of visibility exacerbated when feedback and assessment activities do not include transversal skills. It has been conclusively documented that, for students to effectively develop transversal skills, they need instruction on the strategies and methods underpinning the skills and not just opportunities to practice them[32–34]. However, while there is no shortage of ways to make conceptual knowledge available to students (books, lectures, videos…), teachers often overlook this aspect of developing transversal skills[34,35]. In addition to conceptual knowledge and procedural skills, meta-cognitive and meta-emotional reflection is an important mechanism for learning from experience[36]. Meta-thinking also assists us to recognise patterns that support the transfer of skills between contexts and projects.

Our trident framework provides a practical structure for teaching transversal skills that addresses the issues identified above to ensure that students are really learning. Please see Chapter 1[37] of this playbook for an in-depth presentation of the framework.

The three aspects of the trident are

Knowing: the factual knowledge and concepts that underpin a skill. For instance, typical emotional reactions to threats.

Experiencing: focused, low-risk opportunities to practice the relevant skills while attending to the process, ideally with rapid feedback and a chance to iterate. For example, participating in an emotionally charged feedback discussion about a game (not a graded project) and then doing it a second time to immediately apply what was learned from the first round.

Learning from Experience: meta-cognitive and meta-emotional reflection about the experience of implementing conceptual knowledge and procedural skills. For example, recognising one's feelings during the feedback discussion and reflecting on why this experience was similar or different to previous feedback discussions.

This activity has been designed to include each of the aspects from our trident to ensure that students encounter activities that prompt the three types of thinking and develop a degree of proficiency in the targeted skills that allows students to apply them in their next project.

Let's return to the specific skills of feedback literacy targeted in this activity. As we can see from Figure 1, students make more effective use (taking action) of feedback when they appreciate the value of feedback and when they can manage the affective aspect of their own and others' emotions. So an effective learning activity for feedback literacy involves informing students about the value of feedback, creating an experiential opportunity to have a feedback discussion with an emotional dimension, and reflecting on the experience to support transfer. The 3T PLAY approach creates an experiential learning situation through the use of tangibles (here, marbles and pasta) that allows students to focus on the transversal skill in low-stakes, reduced cognitive load and rapid feedback conditions.

Knowing: [Slide 1] sets up the relevance of feedback literacy as skills for engineering students. [Slides 3+5] present some specific recommendations for good feedback practices and emotional self management.
The guidelines for structuring feedback

on [slide 3] are adapted from various sources[1,24,25,27,28]. [Slide 5] describes fight-flight-freeze[38] reactions to perceived threats to support students to be more aware of their own emotional responses.

Experiencing: [Slide 4] engages students in a constrained activity that creates some frustration (coordination challenges, insufficient time) and therefore serves to generate some potentially difficult-to-hear feedback to share in a feedback discussion. We have proposed an activity with pasta and playdough but this can be replaced with another challenging activity, including disciplinary activities already present in your course (i.e. synthesis of aspirin, group problem solving assignment, etc.).

[Handouts A+B] provide the instructions for students to practice the feedback discussion, including instructions to share at least one very negative point of feedback. Encourage students to use this relatively low-risk opportunity to get out of their comfort zone and do a little emotional self-management. A French translation of the slides and handouts can be accessed here https://doi.org/10.5281/zenodo.12811028. We have also created a version where Gravitrax® replaces the pasta and playdough https://doi.org/10.5281/zenodo.12802889.

Learning from Experience: The warm up [Slide 2] prompts students to review their previous experiences with feedback. [Handout B] and [slide 7] structure students' processing of the feedback they received and reflection on the emotional aspect of this experience to assist them to improve their next feedback opportunity.

Activity development and implementation

This activity was initially developed for management students at a Swiss technical university.

It was then refined and implemented several times for engineering students, professional engineers, UN staff, engineering teachers, teaching assistants, researchers, and pedagogical advisors across Switzerland. More than 500 people have experienced this workshop.

It has since been implemented in diverse contexts and for diverse audiences including:

Countries

Austria

Belgium

Canada

Kenya

Switzerland

United Kingdom

Conferences

QPES 2023 (Switzerland)

RCFE 2023 (Switzerland)

ICED 2024 (Kenya)

Audiences

Engineering students

Teaching assistants

STEM and engineering teachers

Professional engineers

Pedagogical advisors

Faculty developers

Researchers

United Nations staff

General public

HANDOUT A
PREPARING AND GIVING FEEDBACK

(Interview your PAIR before the group task) What skills or strengths does your pair expect to contribute to the group task?

1.

2.

(What do they expect to find difficult during the group task?

1.

2.

Generating feedback for your pair (after the group task)

What were your pair's strengths and contributions during the group task? Cite specific instances of how/when your pair contributed or made you feel that your contributions were appreciated. Include at least one really positive point.

•

•

How could your pair have improved their contributions or better supported your participation? Cite specific instances and be sure to find at least one really critical or negative point to help them improve.

•

•

For feedback to be useful and constructive, it should:

- **Not be an offload of emotion**: Develop awareness of your emotions - do you feel angry, frustrated, disrespected? What made you feel this way? How might others perceive the situation?
- **Be specific**: Provide observations or examples, not generalisations.
- **Occur at the right time**: Feedback should be given promptly but strong emotions or other constraints may make a delay more appropriate.
- **Be usable**: State what the person can do to implement your feedback, connecting to the objectives or strategies of the team / task.
- **Be desired**: Check when and how your peers want feedback to build an environment where feedback most effective and seen as an opportunity for growth.

HANDOUT B
RECEIVING FEEDBACK AND PERSONAL REFLECTION

RECEIVING FEEDBACK

What feedback did you receive from your pair? Note specific points, including at least 1 positive aspect and one negative aspect.

•

•

What were your emotions when RECEIVING feedback?

•

•

What emotion management techniques did you use?

•

•

What were your emotions when GIVING feedback?

•

•

What emotion management techniques did you use?

•

•

How does this experience compare to other times you have given or received feedback from teammates? What aspects of this experience could you use to improve the feedback culture in your next team?

•

•

Fear of feedback – managing emotions

FIGHT

Breathe.

Use active listening before reacting.

Try to understand the other's point of view.

Avoid "Yes but…"

FLEE

Breathe.

Remind yourself feedback is an opportunity to learn.

Ask for clarification + future oriented advice.

FREEZE

Breathe.

Move physically, head, eyes, hands or feet.

Notice your emotions.

Ask for time to reflect.

3T PLAY

Managing the emotional impact of feedback

Being able to give and receive feedback is important, especially when working across contexts and under pressure.

Feedback discussions can be emotionally charged, with the perceived challenges resulting in things being left unsaid or said things being ignored.

This session will help you improve your skills for

- constructing and delivering actionable feedback
- giving feedback to your colleagues without excessive emotional reactions
- receiving feedback from others without your emotions preventing you from really being able to “hear” it

3T PLAY

Warm Up

Please discuss your assigned question with your neighbours, writing down your ideas

On the left side of the room

- ★ What makes you feel reluctant or willing to provide feedback?

On the right side of the room

- ★ What happens when feedback isn't shared?

Debriefing – Groups take turns sharing one element from their discussion

3T PLAY

For feedback to be useful, it should:

Not be an offload of emotion: Develop awareness of your emotions - do you feel angry, frustrated, disrespected? What made you feel this way? How might others perceive the situation?

Be specific: Provide observations or examples, not generalisations.

Occur at the right time: Feedback should be given promptly unless strong emotions or other constraints make a delay more appropriate.

Be usable: State how the person can implement your feedback, connecting to the objectives or strategies of the team / task.

Be desired: Check when and how your peers want feedback to build an environment where feedback most effective and seen as an opportunity for growth.

3T PLAY

Activity Outline

1. Do the preparation activity on the top of HANDOUT A with your pair (groups of 2 people).

2. With your <u>all</u> tablemates, use the materials in the bag to build a spaghetti marble track
   - 15 minutes to complete your build
   - You can add materials but the marble can only touch pasta and playdough
   - Competition for the fastest marble track of 1.5m

3. Working alone, write down feedback for your pair on HANDOUT A

3T PLAY

Fear of feedback – managing emotions

FIGHT

Breathe.

Use active listening before reacting.

Try to understand the other's point of view.

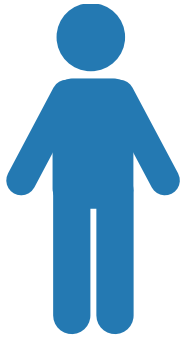
Avoid "Yes but…"

FLEE

Breathe.

Remind yourself feedback is an opportunity to learn.

Ask for clarification + future oriented advice.



FREEZE

Breathe.

Move physically, head, hands or feet.

Notice your emotions.

Ask for time to reflect.

3T PLAY

Doing feedback

1. Review what you have written on “Handout A” to align with good practices for constructing feedback.

2. In turns, share your feedback with your pair. Be sure to include at least one very positive point and one quite critical point. Remain attentive to your own emotions and your pair’s emotions.

3. Complete “Handout B” to reflect on your experience.

3T PLAY

Activity debrief – suggested questions

1. What will you do differently next time you have to provide feedback or you receive feedback?

2. What would you do differently if you were going to work with your pair for the next two years?

References

1. Jug, R., Jiang, X. "Sara", & Bean, S. M. (2018). Giving and Receiving Effective Feedback: A Review Article and How-To Guide. *Archives of Pathology & Laboratory Medicine, 143*(2), 244–250. https://doi.org/10.5858/arpa.2018-0058-RA

2. O'Donovan, B., Rust, C., & Price, M. (2016). A scholarly approach to solving the feedback dilemma in practice. *Assessment & Evaluation in Higher Education, 41*(6), 938–949. https://doi.org/10.1080/02602938.2015.1052774

3. Hattie, J. (2009). *Visible Learning: A Synthesis of Over 800 Meta-Analyses Relating to Achievement*. Routledge.

4. Hattie, J., & Timperley, H. (2007). The power of feedback. *Review of Educational Research, 77*(1), 81–112. https://doi.org/10.3102/003465430298487

5. Beaumont, C., O'Doherty, M., & Shannon, L. (2011). Reconceptualising assessment feedback: A key to improving student learning? *Studies in Higher Education, 36*(6), 671–687. https://doi.org/10.1080/03075071003731135

6. Higgins, R., Hartley, P., & Skelton, A. (2001). Getting the Message Across: The problem of communicating assessment feedback. *Teaching in Higher Education, 6*(2), 269–274. https://doi.org/10.1080/13562510120045230

7. Poulos, A., & Mahony, M. J. (2008). Effectiveness of feedback: The students' perspective. *Assessment & Evaluation in Higher Education, 33*(2), 143–154. https://doi.org/10.1080/02602930601127869

8. Carless, D., & Boud, D. (2018). The development of student feedback literacy: Enabling uptake of feedback. *Assessment & Evaluation in Higher Education, 43*(8), 1315–1325. https://doi.org/10.1080/02602938.2018.1463354

9. Harris, L. R., Brown, G. T. L., & Harnett, J. A. (2014). Understanding classroom feedback practices: A study of New Zealand student experiences, perceptions, and emotional responses. *Educational Assessment, Evaluation and Accountability, 26*(2), 107–133. https://doi.org/10.1007/s11092-013-9187-5

10. Cech, E. A. (2013). The (Mis)Framing of Social Justice: Why Ideologies of Depoliticization and Meritocracy Hinder Engineers' Ability to Think About Social Injustices. In J. Lucena (Ed.), *Engineering Education for Social Justice: Critical Explorations and Opportunities* (pp. 67–84). Springer Netherlands. https://doi.org/10.1007/978-94-007-6350-0_4

11. Lönngren, J., Adawi, T., & Berge, M. (2020). "I don't want to be influenced by emotions"—Engineering students' emotional positioning in discussions about wicked sustainability problems. *2020 IEEE Frontiers in Education Conference (FIE)*, 1–5. https://doi.org/10.1109/FIE44824.2020.9273946

12. Sinatra, G. M., Broughton, S. H., & Lombardi, D. (2014). Emotions in Science Education. In *International Handbook of Emotions in Education*. Routledge.

13. Zembylas, M. (2007). Theory and methodology in researching emotions in education. *International Journal of Research & Method in Education, 30*(1), 57–72. https://doi.org/10.1080/17437270701207785

14. Lönngren, J., Direito, I., Tormey, R., & Huff, J. L. (2023). Emotions in Engineering Education. In *International Handbook of Engineering Education Research*. Routledge.

15. George, J. M. (2000). Emotions and Leadership: The Role of Emotional Intelligence. *Human Relations, 53*(8), 1027–1055. https://doi.org/10.1177/0018726700538001

16. Haver, A., Akerjordet, K., & Furunes, T. (2013). Emotion Regulation and Its Implications for Leadership: An Integrative Review and Future Research Agenda. *Journal of Leadership & Organizational Studies, 20*(3), 287–303. https://doi.org/10.1177/1548051813485438

17. Boyatzis, R., Rochford, K., & Cavanagh, K. V. (2017). Emotional intelligence competencies in engineer's effectiveness and engagement. *Career Development International, 22*(1), 70–86. https://doi.org/10.1108/CDI-08-2016-0136

18. Stewart, M. F., Chisholm, C., & Harris, M. (2010). Engineering Student Learning and Emotional Competencies. *2010 IEEE Transforming Engineering Education: Creating Interdisciplinary Skills for Complex Global Environments*, 1–17. https://doi.org/10.1109/TEE.2010.5508871

19. Gendron, B., Kouremenou, E.-S., & Rusu, C. (2016). Emotional Capital Development, Positive Psychology and Mindful Teaching: Which Links? *International Journal of Emotional Education, 8*(1), 63–74. https://eric.ed.gov/?id=EJ1098792

20. Chhinzer, N., & Russo, A. (2017). An exploration of employer perceptions of graduate student employability. *Education + Training, 60*. https://doi.org/10.1108/ET-06-2016-0111

21. Kovacs, H., Capdevila, I., Lermigeaux-Sarrade, I. J. L., & Jermann, P. (2023). From University to Work: Alumni Viewpoints. *Proceedings of the CDIO 2023 Conference.* http://www.cdio.org/knowledge-library/documents/university-work-alumni-viewpoints

22. Ion, G., Sánchez Martí, A., & Agud Morell, I. (2019). Giving or receiving feedback: Which is more beneficial to students' learning? *Assessment & Evaluation in Higher Education, 44*(1), 124–138. https://doi.org/10.1080/02602938.2018.1484881

23. Harms, P. L., & Roebuck, D. B. (2010). Teaching the Art and Craft of Giving and Receiving Feedback. *Business Communication Quarterly, 73*(4), 413–431. https://doi.org/10.1177/1080569910385565

24. Kritek, P. A. (2015). Strategies for Effective Feedback. *Annals of the American Thoracic Society*, 12(4), 557–560. https://doi.org/10.1513/AnnalsATS.201411-524FR

25. Matua, G., Seshan, V., Akintola, A., & Thanka, A. (2014). Strategies for providing effective feedback during preceptorship: Perspectives from an Omani hospital. *Journal of Nursing Education and Practice, 4*, 24–31. https://doi.org/10.5430/jnep.v4n10p24

26. Price, M., Handley, K., Millar, J., & O'Donovan, B. (2010). Feedback: All that effort, but what is the effect? *Assessment & Evaluation in Higher Education, 35*(3), 277–289. https://doi.org/10.1080/02602930903541007

27. Rose, M. L., & Best, D. L. (2005). *Transforming Practice through Clinical Education, Professional Supervision and Mentoring*. Elsevier Health Sciences.

28. Shute, V. J. (2008). Focus on Formative Feedback. *Review of Educational Research, 78*(1), 153–189. https://doi.org/10.3102/0034654307313795

29. Evans, C. (2013). Making Sense of Assessment Feedback in Higher Education. *Review of Educational Research, 83*(1), 70–120. https://doi.org/10.3102/0034654312474350

30. Sadler, D. R. (1989). Formative assessment and the design of instructional systems. *Instructional Science, 18*(2), 119–144. https://doi.org/10.1007/BF00117714

31. Tormey, R., & Isaac, S. (2022). *Facilitating Experiential Learning in Higher Education Teaching and Supervising in Labs, Fieldwork, Studios, and Projects*. Routledge. https://doi.org/10.4324/9781003107606

32. Lehmann, M., Christensen, P., Du, X., & Thrane, M. (2008). Problem-oriented and project-based learning (POPBL) as an innovative learning strategy for sustainable development in engineering education. *European Journal of Engineering Education, 33*(3), 283–295. https://doi.org/10.1080/03043790802088566

33. Picard, C., Hardebolle, C., Tormey, R., & Schiffmann, J. (2022). Which professional skills do students learn in engineering team-based projects? *European Journal of Engineering Education, 47*(2), 314–332. https://doi.org/10.1080/03043797.2021.1920890

34. Sá, M. J., & Serpa, S. (2018). Transversal Competences: Their Importance and Learning Processes by Higher Education Students. *Education Sciences, 8*(3), Article 3. https://doi.org/10.3390/educsci8030126

35. Isaac, S., Petringa, N., Jalali, Y., Tormey, R., & Dehler Zufferey, J. (2023). Are Engineering Teachers Ready to Leverage the Power of Play to Teach Transversal Skills? *Proceedings of the SEFI 2023 Conference*. https://doi.org/10.21427/QP3D-B914

36. Steele, A. L. (2018). Developing Student Meta-Cognition in a Design Course. *Proceedings of the Canadian Engineering Education Association (CEEA)*. https://doi.org/10.24908/pceea.v0i0.13031

37. Jalali, Y., Alberink, B., Dehler Zufferey, J., and Mondada, F. (with Isaac, S., Petringa, N., Winzenried, N., and Tormey, R.). 2024. How to support students to develop skills for cultivating psychological safety in their teams. In 3T PLAY (Eds.), *Teaching Transversal Skills For Engineering Students: a practical playbook of activities with tangibles*, EPFL Press, Lausanne. https://doi.org/10.55430/SJYVJ3TP24

38. Maack, D. J., Buchanan, E., & Young, J. (2015). Development and Psychometric Investigation of an Inventory to Assess Fight, Flight, and Freeze Tendencies: The Fight, Flight, Freeze Questionnaire. *Cognitive Behaviour Therapy, 44*(2), 117–127 https://doi.org/10.1080/16506073.2014.972443

3T PLAY

LIST OF MATERIALS

- ◯ Slides to facilitate this activity
  (French version of the slides and handouts **https://doi.org/10.5281/zenodo.12811028**)
- ◯ 1x Handout A per student
- ◯ 1x Handout B per student
- ◯ For each team of 6 or 8 people**
  - ◯ 1 marble*
  - ◯ 100g spaghetti
  - ◯ 1 container of playdough
  - ◯ 150 cm length of string

** These materials can be substituted with another activity or material that allows teams to engage in a time-limited, high constraint activity. For instance, Gravitrax® can be used for the marble run. **https://doi.org/10.5281/zenodo.12802889**

* To see a video of example of how the tangibles are used, visit **http://go.epfl.ch/videoCh3**

MORE ABOUT 3T PLAY

To learn more about the 3T PLAY project, please visit **go.epfl.ch/3TPLAY**

To access more teaching materials, please visit **https://zenodo.org/communities/3tplay/records**

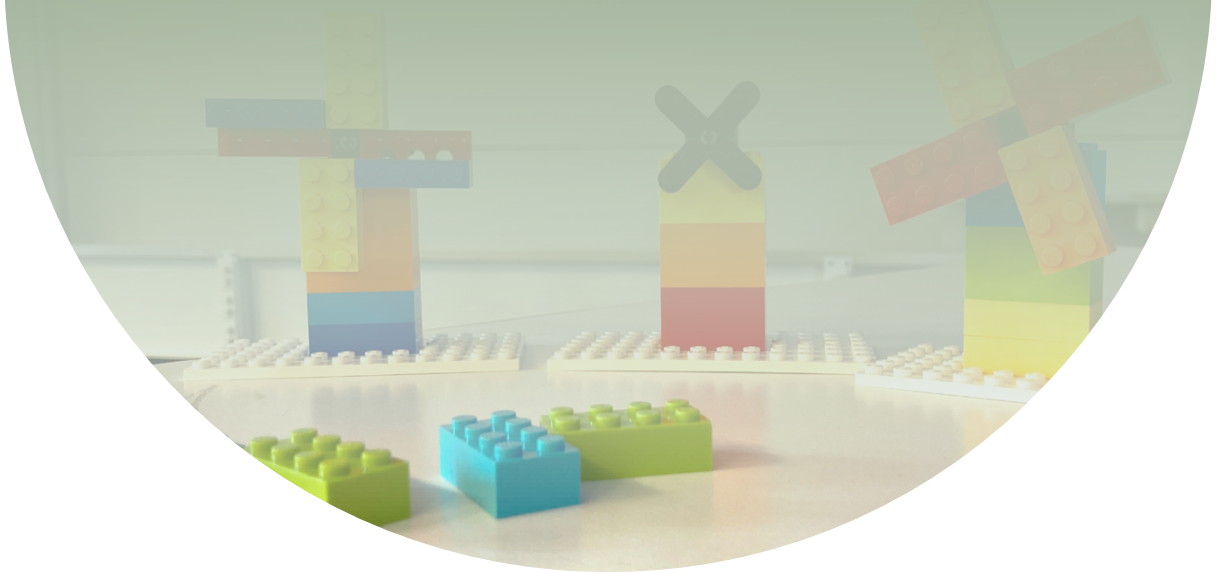
HOW TO CITE THIS CHAPTER

Isaac, S., and de Lima, J. (with Winzenried, N., Petringa, N., and Jalali, Y.). 2024. Chapter 3: How to support students giving each other feedback, especially when it is negative. In 3T PLAY (Eds.), *Teaching Transversal Skills For Engineering Students: a practical playbook of activities with tangibles*, EPFL Press, Lausanne.
https://doi.org/10.55430/SJYVJ3TP24

3T PLAY

CHAPTER 4

How to support students to develop skills that promote sustainability



Generously funded by

The LEGO Foundation

EPFL LEARN Center for Learning Sciences

3T PLAY

CHAPTER 4

How to support students to develop skills that promote sustainability

CHAPTER INDEX

CONTRIBUTORS

- **Activity design + development:** Dr. Siara Isaac and Valentina Rossi
- **Writing this chapter:** Dr Siara Isaac + Dr Joelyn de Lima
- **Photography:** Julie Clerget
- **Graphic design:** Laura Persat

3T PLAY

CHAPTER 4

How to support students to develop skills that promote sustainability

ACTIVITY DESCRIPTION

Sustainability should be integrated into everything we do, including engineering and student projects. This experiential activity uses the selection of materials for a wind turbine to engage participants in a contextualised negotiation of multiple facets of sustainability. Participants first assume one of 4 engineering roles to identify specific sustainability priorities based on their responsibilities and expertise. Next, they represent the perspective of their assigned role to optimise sustainability in the choice of materials. This chapter provides the outline of an activity designed to teach the learning outcomes listed below, material to assist the facilitator to prepare, and the slides and handouts for teaching the activity.

ACTIVITY OUTCOMES

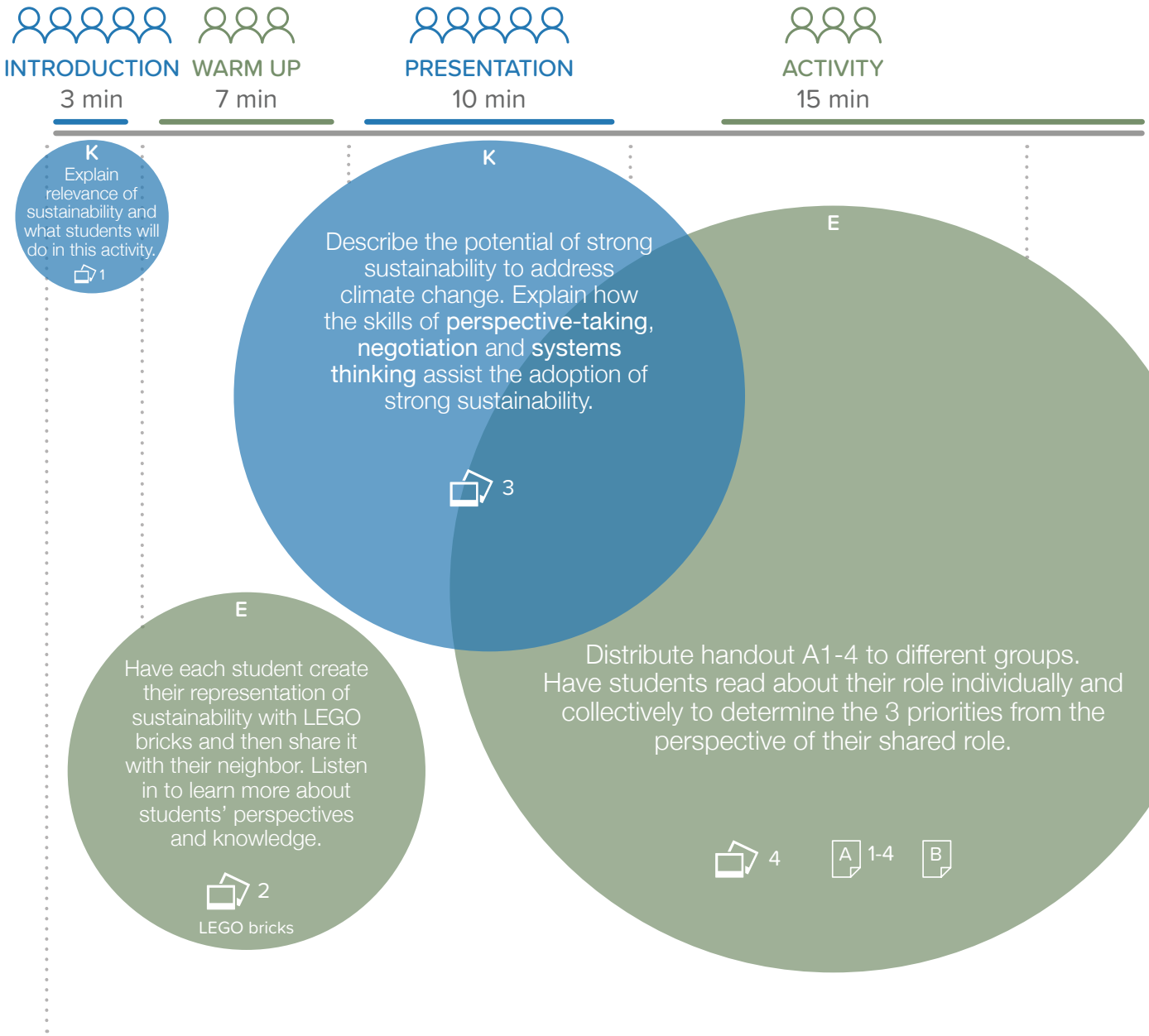
This 75-minute activity is designed for university-level engineering students.

It targets the development of the following skills

1. Perspective taking, applied to diverse stakeholders.
2. Systems thinking, applied to facets of sustainability.
3. Negotiation.

ACTIVITY

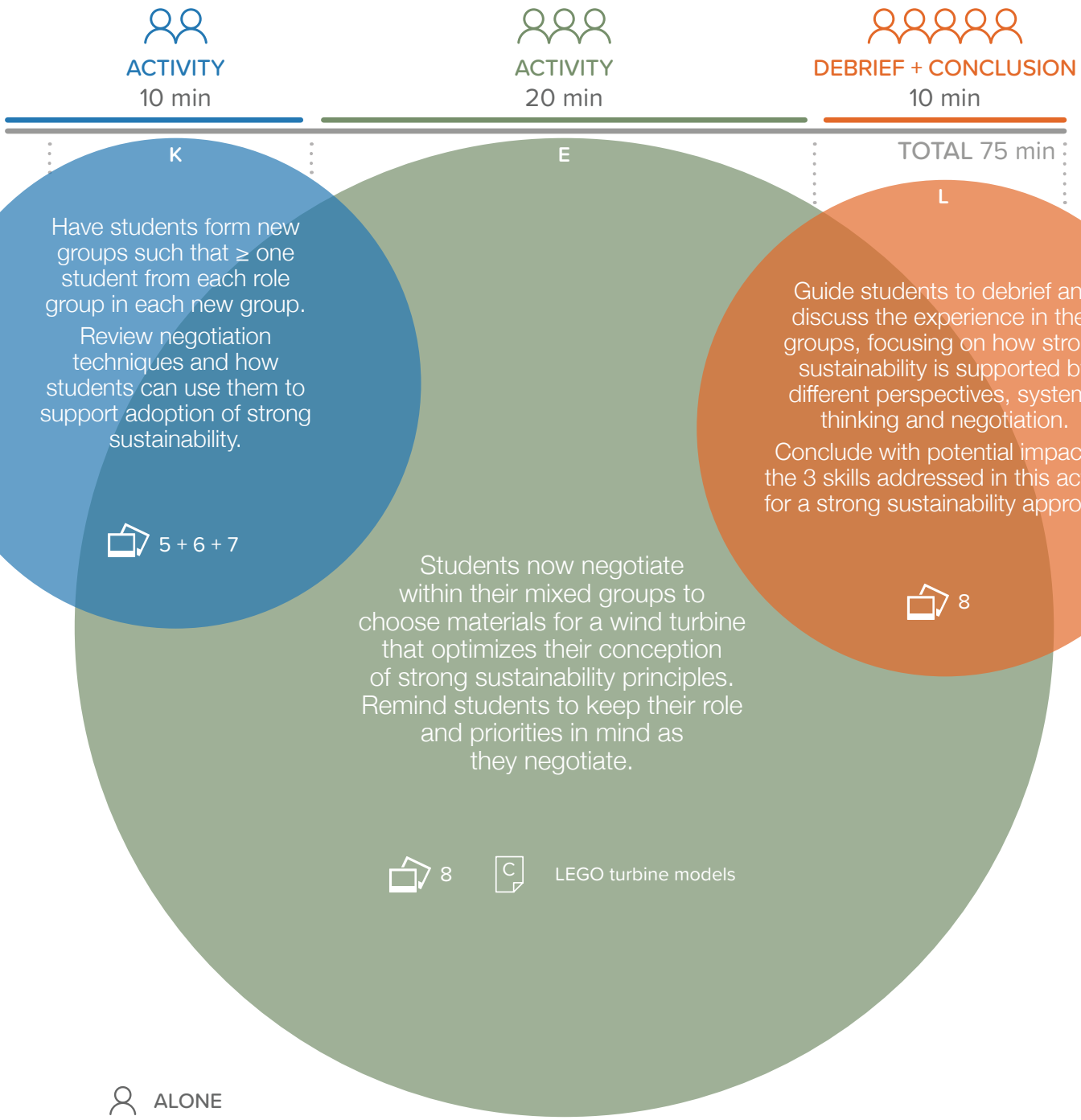
How to support students to develop skills that promote sustainability



PREPARATION

Set up the room to create groups of 4-6 students.
Each group should have some LEGO bricks.

This activity involves an information jigsaw.
When distributing the handouts ensure that the students in the same initial group get the same handout A (at least 4 groups to align with the 4 roles on handouts A1-4). In the next phase of the jigsaw, students form new groups such that there is at least one student from each of the 4 initial role groups.



ALONE
PAIRS
SMALL GROUP
WHOLE GROUP
SLIDES
HANDOUT

K KNOWING
sharing knowledge and concepts that define the targeted skills

E EXPERIENCING
applying the concepts and tools in experiential learning

L LEARNING FROM EXPERIENCE
stepping back and reflecting about the activity enables students to transfer their skills

CONCEPTUAL AND PRACTICAL UNDERPINNINGS OF THE ACTIVITY

What skills will students develop in this activity?

Sustainability is a topic of significant importance in higher education, but it is not itself a skill. Engineering students need to develop transversal skills to assist in making the products and processes they design more sustainable. UNESCO has identified several key competencies for sustainability, including systems thinking, collaboration, critical thinking, and integrated problem-solving[1]. Education has a central role in achieving the Sustainable Development Goals (SDGs)[2], as it is essential to developing the capacity needed to achieve the goals[1]. Sustainability is now generally understood to require a nested, holistic approach that integrates the dimensions of society, economy, and environment[3]. The concentric model on slide 3 is used in engineering curricula[4].

How engineers frame problems has a massive impact on the solutions envisaged. It influences the characteristics, approach, issues, and boundaries that ultimately guide problem solving activities. When engineers do not see ethics and sustainability as part of their responsibilities, they do not adequately incorporate these elements into their disciplinary thinking[5]. This activity focuses on three transversal skills relevant for sustainability: perspective taking, systems thinking and negotiation.

Perspective taking

Perspective taking involves temporarily adopting another person's point of view, essentially approaching empathy from a purposeful and relatively cognitive direction[6]. Thoroughly exploring different perspectives and constraints improves the quality of solutions[7] and Hess et al[8] found moderate correlations between engineering students' perspective-taking abilities and their ethical reasoning. Perspective taking influences how problems themselves are framed by designers and therefore the way the problem itself is formulated and solved[9,10]. Perspective taking has also been found to assist in negotiating between different points of view, including in business[11] and relationships[12]. This highlights the relevance for accommodating different stakeholders and facets of sustainability. Providing specific training on perspective taking is important for engineering students, as they have been found to have difficulty incorporating multiple stakeholder perspectives[13–15].

Systems thinking

Systems thinking is a way of reasoning which facilitates making inferences and predictions about a system based on a deep understanding of the components, interactions, and emergent dynamics within that system. Systems thinking skills are therefore valuable because they enable the efficient analysis and synthesis of information to gain a comprehensive understanding of complex phenomena[16]." This allows us to understand the intricacies of systems so that we may "better predict them and, ultimately, adjust their outcomes"[17]. Failing to consider context in a sufficiently broad and interconnected manner is a common issue for students and novice designers[13,15]. This relates to undergraduate students' lack of system thinking skills[18], especially related to sustainability[19].
Prior research on students' perceptions of systems thinking in engineering has shown that while they recognise the value of systems thinking, they do not perceive it as being a part of their instruction or assessment[20]. On a more positive note, gains have been documented in students' systems thinking skills after explicit and holistic instruction[19,21].

Negotiation

Since engineering projects usually have multiple stakeholders, engineers need to have the skills to negotiate between these diverse perspectives while simultaneously ensuring that they advocate for the stakeholders who cannot voice their opinion (e.g. the environment), and to optimise the resources at their disposal[22–25]. Negotiation is an important skill for all engineers, but especially so for those who seek to promote sustainability[26]. Prior research has shown that providing engineering students with an explicit negotiation support system led to improved negotiation outcomes[27], and that active learning strategies improve engineering students' self-efficacy with respect to negotiation skills[28,29].

How to interest engineering students in learning these skills?

The central role for engineers in addressing complex problems in a sustainable manner is evident[30]. However, engineering students report insufficient integration of skills related to sustainability in the curriculum[31]. Direct observations of design processes have found students overlook or under-value aspects of sustainability and ethics[5]. Encouragingly, we have found students welcome greater integration of sustainability in their engineering programmes[31], although what this would look like is not clear for some students.

So, for skills related to sustainability, it may be less a question of interesting students in learning the skills and more relevant to access their motivation for developing their skills by

- improving communication so students perceive opportunities to develop their skills[32,33]
- providing explicit instruction and scaffolding for students' skill development[34,35].

How does this activity help your students to develop these skills?

Project- and challenge-based activities provide engineering students with practical opportunities to use procedural skills and offer excellent opportunities to integrate transversal skills with disciplinary thinking. An important limitation is that students may find it difficult to perceive the skills as distinct from accomplishing the project tasks[36]. This lack of visibility is exacerbated when feedback and assessment activities do not include transversal skills. It has been conclusively documented that, for students to effectively develop transversal skills, they need instruction on the strategies and methods underpinning the skills and not just opportunities to practise them[35,37]. While there is no shortage of ways to make conceptual knowledge available to students (books, lectures, videos…), teachers often overlook this aspect of developing transversal skills[32]. In addition to conceptual knowledge and procedural skills, meta-cognitive and meta-emotional reflection is an important mechanism for learning from experience[38]. Meta-thinking also assists us to recognise patterns that support the transfer of skills between contexts and projects.

In a study with NASA engineers working on a design problem, two conditions that encouraged perspective taking were templated activities that focused participants' attention on stakeholders' points of view and framing or prompting from the facilitator to consider stakeholders[39]. We have integrated these two with the priority-setting component of this activity. In the same study, conditions that decreased perspective taking occurred when participants relied on their own experience or expertise, when they claimed specific identities or values ("since I am an engineer…") and when presenting to leadership versus presenting to their own teammates. Role-playing exercises and challenging cases have

been found to encourage engineering students to consider multiple stakeholders' perspectives[40]. Here again, we find coherence with the approach of our activity that creates an engaging, low-stakes environment outside students' own area of expertise to encourage and practice perspective taking.

Our trident framework provides a practical structure for teaching transversal skills that addresses the issues identified above. It helps ensure that students are developing their skills in meaningful ways that will support transfer to future contexts. Please see Chapter 1[41] of this book for an in-depth exploration of the how and why of teaching transversal skills to engineering students.

The three aspects of the trident are:

Knowing: the factual knowledge and concepts that underpin a skill. For instance, different persuasive strategies for negotiating.

Experiencing: focused, low-risk opportunities to practise the relevant skills while attending to the process, ideally with rapid feedback and a chance to iterate. For example, negotiating an outcome that incorporates disparate perspectives, and then engaging in a second negotiation to apply what was learned from the first round.

Learning from experience: meta-cognitive and meta-emotional reflection about the experience of implementing conceptual knowledge and procedural skills. For example, recognising the kinds of arguments and responses that were successful in persuading others to appreciate your perspective and reflecting on why this experience was similar or different to previous negotiations.

The activity in this chapter has been designed to include each of the aspects from our trident to ensure that students develop a degree of proficiency in the targeted skills that allow them to apply them in their next project. This activity uses LEGO bricks to provide a visual, concrete result around which students can discuss and negotiate. The wind turbine can be replaced with product that involves multiple dimensions of sustainability and various perspectives. This could be the geographic placement of data centres, the choice of protein in the school cafeteria menu or something else entirely.

Knowing [Slide 3] sets up the relevance of strong sustainability and perspective-taking for engineering students and seeks to connect to their current understanding. [Slides 6-7] present some specific recommendations for effective negotiation techniques and perspective-taking.

Experiencing: Students are first assigned to one of 4 engineering roles [slide 4] each concerned with a specific aspect of sustainability [Handout A]. Working with others assigned the same role, they read the case study and identify the top priorities from their perspective [Handout B]. Reforming into mixed groups that have one of each of the four types of engineer, [slide 8] participants negotiate the percentages of five materials in the design of an optimally sustainable wind turbine [Handout C]. We have proposed using LEGO bricks to create a visible record of the materials chosen. To improve the coherence with your context, students could design another product or assume different roles. LEGO bricks could be replaced with other coloured tangibles, pieces of coloured paper or a printed image that students shade with coloured pens.

Learning from experience [Slide 9] prompts students to process the experience both in terms of the negotiation strategies they used and were used by others, and to consider how they can leverage this experience in their next project.

HANDOUT A1
GEOLOGICAL ENGINEER

As a geological engineer your role is to assist your colleagues to create a proposal that respects sustainability in terms of the environmental and societal impacts of **resource extraction and transportation.**

When choosing materials to build the wind turbine, you should seek options that

- Reduce the environmental impact of extraction and transportation of materials to the construction site
- Improve the wellbeing of communities and workers at the extraction site

Here are some factors that might help you convince others to adopt your sustainability priorities in their decision making. Add other factors you deem important for the perspective of geological engineers

- Where do these materials come from?
- What are the working and living conditions for people at the extraction site?
- What is the environmental impact (i.e. water usage and contamination, deforestation, CO_2 production)?
- How much energy is consumed by transporting the material to Alpenblick?
- …
- …

Step 1. Working together with the other "geological engineers", define 3 priorities to guide the choice of sustainable materials for the wind turbine according to your role.

Priority 1	
Priority 2	
Priority 3	

HANDOUT A2
MECHANICAL ENGINEER

As a mechanical engineer, your role is to assist your colleagues to create a proposal that respects sustainability in terms of the effect on the **population, waste, noise and interaction with local animals around the Alpenblick installation site**.

When choosing materials to build the wind turbine, you should seek options that

- Improve the safety of workers and people living close to the construction site
- Reduce the environmental impact to the installation site

Here are some factors that might help you convince others to adopt your sustainability priorities in their decision making. Add other factors you deem important for the perspective of mechanical engineers.

- What effect will these materials have on the animals and plants at the installation site?
- What will happen if pieces of the wind turbine break off or decompose on the site?
- How will people and animals living close to the turbine be affected?
- How will these materials be disposed of at the end of the wind turbine's life?
- …
- …

Step 1. Working together with the other "mechanical engineers", define 3 priorities to guide the choice of sustainable materials for the wind turbine according to your role.

Priority 1	
Priority 2	
Priority 3	

HANDOUT A3
PRODUCTION MANAGER

As the engineer responsible for overseeing the production site, your primary responsibility is to the workers who will produce and construct the wind turbines. You know these people and do not want to expose them to health and safety issues. You are also concerned that if the materials are too expensive, you will struggle to pay fair wages to your employees. Or even that the design will not be selected by Alpenblick and the workers will lose their jobs.

When choosing materials to build the wind turbine, you should seek options that

- Respect corporate standards for ethics and safety of production process
- Ensure stable and fair employment conditions for your staff

Here are some factors that might help you convince others to adopt your sustainability priorities in their decision making. Add other factors you deem important for the perspective of production managers.

- Can the production workers handle these materials safely?
- What is the overall budget?
- Do our choices align with our company's stated values?
- …
- …

Step 1. Working together with the other "production managers", define 3 priorities to guide the choice of sustainable materials for the wind turbine according to your role.

Priority 1	
Priority 2	
Priority 3	

HANDOUT A4
PROJECT COORDINATOR

As the engineer responsible for overseeing the project coordination, your responsibility to ensure that the team creates a winning proposal. You should work to clarify objectives, ensure issues are examined from multiple perspectives and that everyone's contribution is taken into account in the decision-making process.

When choosing materials to build the wind turbine, you should seek options that

- Seek out and address concerns from all stakeholders, including the engineers from your company and the public in Alpenblick
- Ensure energy consumed producing and installing the turbines is coherent with your company's sustainability policy.

Here are some factors that might help you convince others to adopt your sustainability priorities in their decision making. Add other factors you deem important for the perspective of production managers.

- Is the team fully exploiting and valuing each person's contribution?
- Is the team using criteria-based decision making?
- Do your choices align with the company's stated values?
- …
- …

Step 1. Working together with the other "project coordinators", define 3 priorities to guide the choice of sustainable materials for the wind turbine according to your role.

Priority 1	
Priority 2	
Priority 3	

HANDOUT B
PROPERTIES OF MATERIALS

There are 5 materials, listed below, available for the construction of the wind turbines. Since your company is bidding to build 100 turbines, the choice of material will have an important impact on the price and sustainability profile of the turbines.

Block	Strength	Flexibility	Cost	Notes
YELLOW	+	+++	1€/kg	This beautiful organic material is sustainably produced from an Amazonian plant, however its recent popularity means local communities are no longer able to purchase it for traditional rituals.
GREEN	++	++	2€/kg	This material is produced in Asia from recycled waste collected in Europe. It breaks into pieces at the end of its lifetime.
RED	+++	+++	5€/kg	Manufacturing this material is energy intensive and requires highly skilled trades-people for the installation.
BLUE	++	+	2€/kg	This common material has a good lifetime, but its manufacturing process produces a toxic sludge side product. You only know this because a colleague used to work at the factory.
ORANGE	+++	+	1€/kg	This material has recently been banned in Norway for environmental reasons, although it appears unlikely that other countries will do the same.

HANDOUT C OPTIMISING WIND TURBINE PROTOTYPE FOR STRONG SUSTAINABILITY

In this group, you are each playing the role of a specific type of engineer. Each of you therefore bring certain priorities to optimising sustainablity. To make the choices more visible, the 5 brick colors represent 5 materials each with specific characteristics.

This is a role play, so you are welcome to create/add details to advance your thinking. The workshop facilitator can answer questions in the role of the mayor of Alpenblick.

Working together with the other "engineers", your group will select materials for the wind turbine that reflect your combined priorities for strong sustainability.

Step 1: Present yourself in your role (geological engineer, mechanical engineer, production manager and project coordinator) and tell your new teammates about the priorities for strong sustainability you set in the previous activity.

Step 2: Dissemble the LEGO bricks in your model and stack them on the outlines below. As you advance, you can replace these blocks with different colours and sizes, maintaining the equivalent of 10 "full sized" blocks in your model.

	yellow	green	red	blue	orange
Tower of wind turbine					
Blades of wind turbine					

Step 3: From the perspectives of your different roles, propose/discuss/debate how the relative merits of the different materials should be represented in terms of the % composition in the tower + turbine blades. See Handout B for these characteristics.

Step 4: When you have agreed on the final % composition of your wind turbine, reassemble the model with your chosen bricks.

3T PLAY

Developing skills that support sustainability

Sustainability should be integrated into everything we do, but how to do this is not always obvious.

This activity uses the context of a design project to explore how to include multiple facets of sustainability and negotiate apparently contradictory outcomes.

This session will help you improve your skills for

- **perspective-taking** and seeing what is important to others
- **systems thinking** that recognises complex interactions
- **negotiating skills** to incorporate multiple criteria and build consensus

3T PLAY

Warm Up

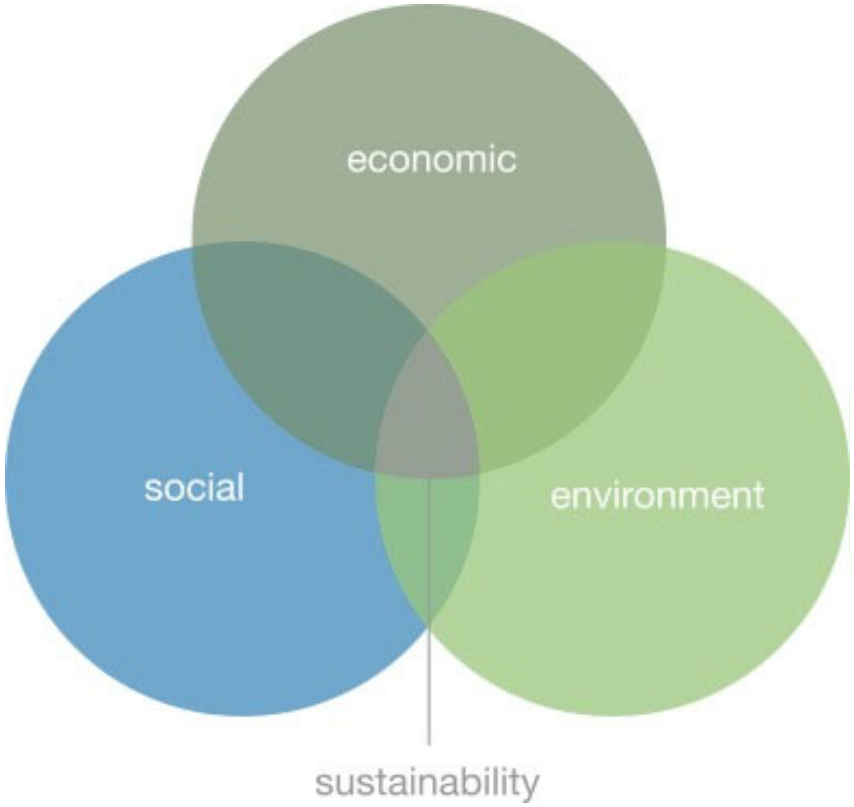
What does sustainability mean to you?

- ★ Grab 10 LEGO blocks of your choice
- ★ Create a representation of what sustainability means for you
- ★ Discuss with your neighbour

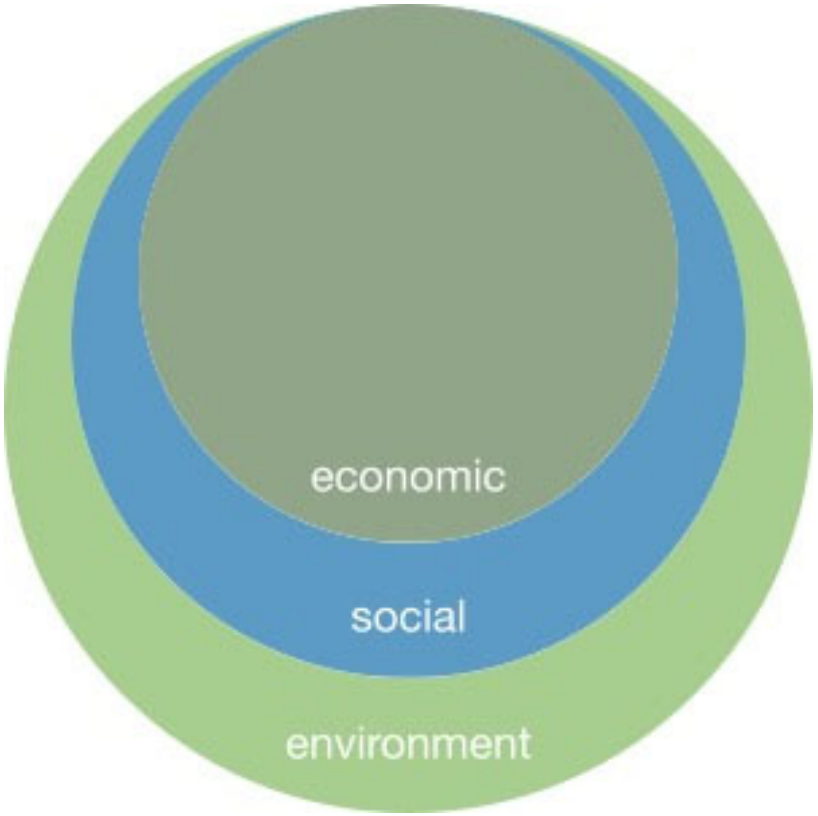
3T PLAY

All dimensions of sustainability are interconnected and codependent

weak sustainability



strong sustainability



adapted from Mebratu, 1998

3T PLAY

Activity Outline

Your engineering company is bidding for a wind turbine project in the region of Alpenblick. Residents are excited but have some concerns. To be accepted, your design must embody strong sustainability principles.

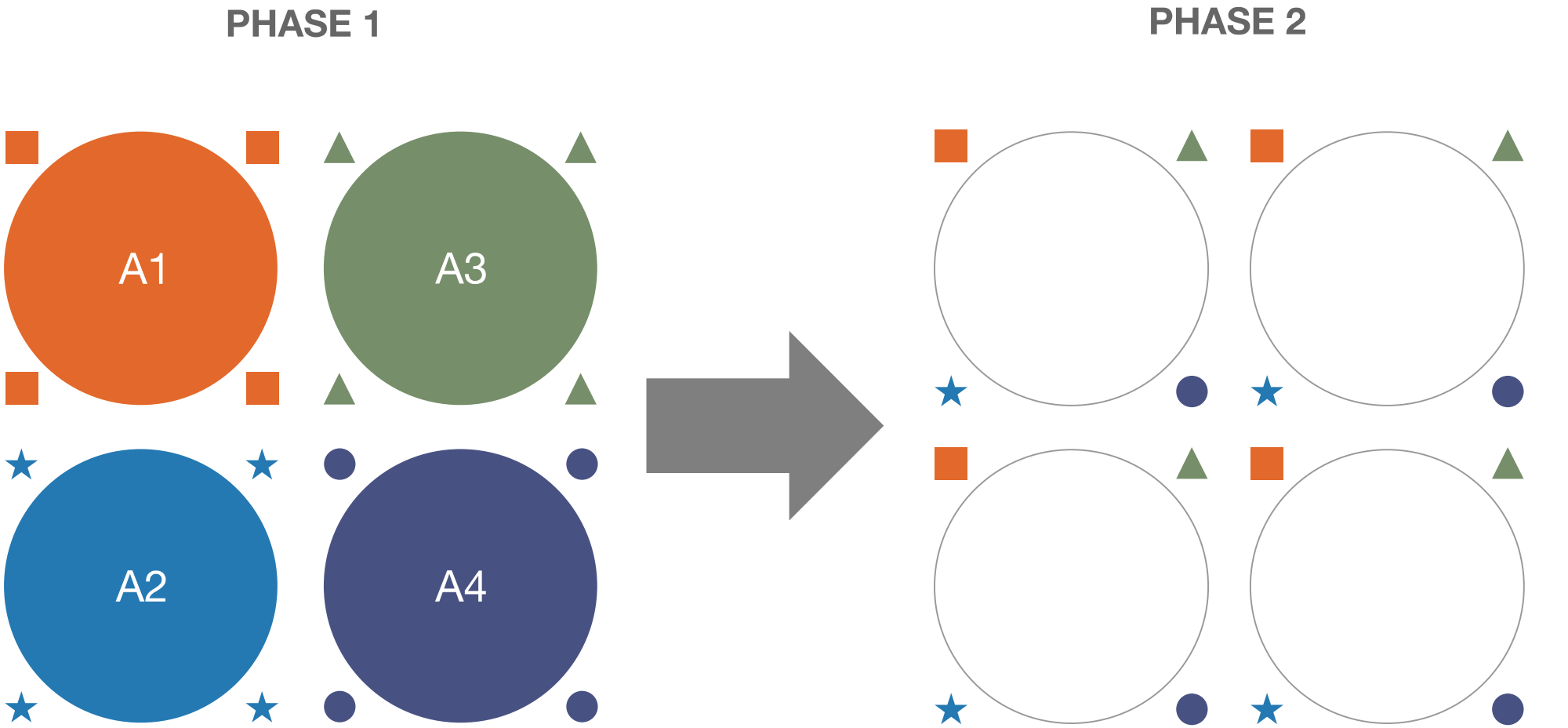
Your job is to bring your engineering skills and sustainability thinking into the proposed design. The choice of materials will have big socio-environmental and economic impacts as 100 wind turbines will be manufactured and installed.

1. Read attentively the description of your role on Handout A.

2. With the other people in your group, identify 3 priorities to guide the choice of materials for the wind turbines. Keep your role in mind.

3T PLAY

For the next phase, please rearrange your groups to create mixed groups



3T PLAY

Negotiation – a strategic discussion that resolves an issue in a way that ALL parties find acceptable

Principled negotiation involves exploring the deeper interests underlying stated positions to achieve better outcomes

1. focuses on interests rather than positions
2. generates a variety of options before settling on an agreement
3. seeks agreement based on explicit criteria

Lyons, Carl. *I win, you win: The essential guide to principled negotiation*. Bloomsbury Publishing, 2009.

3T PLAY

Getting others to see your perspective

LOGIC

- Facts: data, cause+effect
- Questions: get people to find the benefits themselves

"What are you worried will happen if we choose green?"

EMOTION

- Passion: stories that touch us
- Feelings: create a pleasant experience

"Imagine how we will feel visiting a dangerous work site"

GROUP

- Belonging: what others are (not) doing

"I've heard others are also avoiding this material"

EXCHANGE

- Reciprocity: *quid pro quo*
- Kindness: doing the right thing

"If we use blue, we could also…"

NATURE

- Rarity: uniqueness + opportunity
- Rules: norms + laws

"This is against our company policy"

Negotiation in groups

1. In this new group you will be working with other engineers to choose the materials for the wind turbine. The current prototype uses 5 colours of LEGO blocks to represent the materials described in Handout B.

2. Keeping your role in mind, negotiate the % of each material for the wind turbine to optimise for strong sustainability.

3. Make sure to write down the justification of your group decision.

Activity debrief sharing turbine prototypes

1. What different perspectives of how a project can embody sustainability did each role bring? What was the impact of this diversity on your discussions?

2. What priorities did you put forward in your project and why? Was it possible to separate out specific effects?

3. What strategies were effective for sharing perspectives and convincing others? How did the negotiations affect the final design?

4. In what ways are the prototypes different between teams? Is there a single best answer for strong sustainability?

Activity development and implementation

This activity was developed for engineering students at a Swiss technical university.

It was then refined and implemented several times for engineering students, engineering teachers, researchers, and pedagogical advisors at the same university. More than 350 people have experienced this workshop.

It has since been implemented in diverse contexts and for diverse audiences including:

Countries

Belgium

Canada

England

Greece

India

Mexico

Portugal

Switzerland

United Kingdom

Conferences

EDUCON 2024 (Greece)

PRME-North America 2024 (Canada)

PRME-UK 2024 (England)

ISCN 2024 (Switzerland)

SEFI 2024 (Switzerland)

Audiences

High school students

Engineering students

STEM and engineering teachers

Pedagogical advisors

Sustainability experts

Faculty developers

Researchers

References

1. The United Nations Educational, Scientific and Cultural Organization [UNESCO]. (2017). Education for Sustainable Development Goals: Learning objectives. UNESCO. https://doi.org/10.54675/CGBA9153

2. United Nations [UN]. (2015). Transforming our world: The 2030 Agenda for Sustainable Development. https://sdgs.un.org/2030agenda

3. Giddings, B., Hopwood, B., & O'Brien, G. (2002). Environment, economy and society: Fitting them together into sustainable development. Sustainable Development, 10(4), 187–196. https://doi.org/10.1002/sd.199

4. Thürer, M., Tomašević, I., Stevenson, M., Qu, T., & Huisingh, D. (2018). A systematic review of the literature on integrating sustainability into engineering curricula. Journal of Cleaner Production, 181, 608–617. https://doi.org/10.1016/j.jclepro.2017.12.130

5. Isaac, S., Kothiyal, A., Borsò-Tan, P., & Ford, B. A. (2023). Sustainability and Ethicality are Peripheral to Students' Software Design. International Journal of Engineering Education.

6. Surma-aho, A., Björklund, T., & Hölttä-Otto, K. (2022). User and stakeholder perspective taking in novice design teams. Design Science, 8, e24. https://doi.org/10.1017/dsj.2022.19

7. Cross, N. (2006). Designerly Ways of Knowing. Springer-Verlag. https://doi.org/10.1007/1-84628-301-9

8. Hess, J. L., Beever, J., Zoltowski, C. B., Kisselburgh, L., & Brightman, A. O. (2019). Enhancing engineering students' ethical reasoning: Situating reflexive principlism within the SIRA framework. Journal of Engineering Education, 108(1), 82–102. https://doi.org/10.1002/jee.20249

9. Beckman, S. L., & Barry, M. (2007). Innovation as a Learning Process: Embedding Design Thinking. California Management Review, 50(1), 25–56. https://doi.org/10.2307/41166415

10. Paton, B., & Dorst, K. (2011). Briefing and reframing: A situated practice. Design Studies, 32(6), 573–587. https://doi.org/10.1016/j.destud.2011.07.002

11. Galinsky, A. D., & Moskowitz, G. B. (2000). Perspective-taking: Decreasing stereotype expression, stereotype accessibility, and in-group favoritism. Journal of Personality and Social Psychology, 78(4), 708–724. https://doi.org/10.1037/0022-3514.78.4.708

12. Corcoran, K. O., & Mallinckrodt, B. (2000). Adult Attachment, Self-Efficacy, Perspective Taking, and Conflict Resolution. Journal of Counseling & Development, 78(4), 473–483. https://doi.org/10.1002/j.1556-6676.2000.tb01931.x

13. Björklund, T. A. (2013). Initial mental representations of design problems: Differences between experts and novices. Design Studies, 34(2), 135–160. https://doi.org/10.1016/j.destud.2012.08.005

14. Scott, J. B. (2008). The Practice of Usability: Teaching User Engagement Through Service-Learning. Technical Communication Quarterly, 17(4), 381–412. https://doi.org/10.1080/10572250802324929

15. Zoltowski, C. B., Oakes, W. C., & Cardella, M. E. (2012). Students' Ways of Experiencing Human-Centered Design. Journal of Engineering Education, 101(1), 28–59. https://doi.org/10.1002/j.2168-9830.2012.tb00040.x

16. Senge, P. (1990). The fifth discipline: The art and practice of learning. Doubleday.

17. Arnold, R. D., & Wade, J. P. (2015). A definition of systems thinking: A systems approach. Procedia Computer Science, 44(C), 669–678. https://doi.org/10.1016/j.procs.2015.03.050

18. Huang, S., Muci-Kuchler, K. H., Bedillion, M. D., Ellingsen, M. D., & Degen, C. M. (2015). Systems thinking skills of undergraduate engineering students. 2015 IEEE Frontiers in Education Conference (FIE), 1–5. https://doi.org/10.1109/FIE.2015.7344341

19. Hiller Connell, K. Y., Remington, S. M., & Armstrong, C. M. (2012). Assessing systems thinking skills in two undergraduate sustainability courses: A comparison of teaching strategies. Journal of Sustainability Education, 3. https://krex.k-state.edu/handle/2097/13783

20. Hadgraft, R. G., Carew, A. L., Therese, S. A., & Blundell, D. L. (2008). Teaching and Assessing Systems Thinking in Engineering. Research in Engineering Education Symposium.

21. Liu, S.-C. (2023). Examining undergraduate students' systems thinking competency through a problem scenario in the context of climate change education. Environmental Education Research, 29(12), 1780–1795. https://doi.org/10.1080/13504622.2022.2120187

22. Peña-Mora, F. (1998). A collaborative negotiation methodology for large scale civil engineering and architectural projects. In I. Smith (Ed.), Artificial Intelligence in Structural Engineering: Information Technology for Design, Collaboration, Maintenance, and Monitoring (pp. 271–294). Springer. https://doi.org/10.1007/BFb0030457

23. Seyff, N., Betz, S., Duboc, L., Venters, C., Becker, C., Chitchyan, R., Penzenstadler, B., & Nöbauer, M. (2018). Tailoring Requirements Negotiation to Sustainability. 2018 IEEE 26th International Requirements Engineering Conference (RE), 304–314. https://doi.org/10.1109/RE.2018.00038

24. Urbanavičiene, V., Kaklauskas, A., & Zavadskas, E. K. (2009). The conceptual model of construction and real estate negotiation. International Journal of Strategic Property Management, 13(1), 53–70. https://doi.org/10.3846/1648-715X.2009.13.53-70

25. Yates, J. K. (2011). The Art of Negotiation in Construction Contract Disputes. Journal of Legal Affairs and Dispute Resolution in Engineering and Construction, 3(3), 94–96. https://doi.org/10.1061/(ASCE)LA.1943-4170.0000060

26. Svanström, M., Lozano-García, F. J., & Rowe, D. (2008). Learning outcomes for sustainable development in higher education. International Journal of Sustainability in Higher Education, 9(3), 339–351. https://doi.org/10.1108/14676370810885925

27. Jin, Y., Geslin, M., & Lu, S. C.-Y. (2007). Impact of Argumentative Negotiation on Collaborative Engineering. CIRP Annals, 56(1), 181–184. https://doi.org/10.1016/j.cirp.2007.05.043

28. Nicola, S., Pinto, C., & Mendonça, J. (2018). The role of education on the acquisition of 21st century soft skills by Engineering students. 2018 3rd International Conference of the Portuguese Society for Engineering Education (CISPEE), 1–4. https://doi.org/10.1109/CISPEE.2018.8593495

29. Pujadas, P., & Pardo-Bosch, F. (2024). Propelling negotiation skills modules in construction engineering programs: Reflections and supporting tools for educators towards an enhanced effective training. Teaching and Teacher Education, 138, 104432. https://doi.org/10.1016/j.tate.2023.104432

30. Wilson, D. (2019). Exploring the Intersection between Engineering and Sustainability Education. Sustainability, 11(11), Article 11. https://doi.org/10.3390/su11113134

31. Isaac, S., de Lima, J., Jalali, Y., Rossi, V., Tormey, R., & Dehler Zufferey, J. (2024). *Exploring Engineering Students' Perception of Sustainability and Ethics in Their Curriculum Across Disciplines*. In 2024 IEEE Global Engineering Education Conference (EDUCON) (pp. 01-05). IEEE. https://doi.org/10.1109/EDUCON60312.2024.10578603

32. Isaac, S., Petringa, N., Jalali, Y., Tormey, R., & Dehler Zufferey, J. (2023). Are Engineering Teachers Ready to Leverage the Power of Play to Teach Transversal Skills? Proceedings of the SEFI 2023 Conference. https://doi.org/10.21427/QP3D-B914

33. Kovacs, H., Delisle, J., Mekhaiel, M., Dehler Zufferey, J., Tormey, R., & Vuilliomenet, P. (2020). Teaching Transversal Skills in the Engineering Curriculum: The Need to Raise the Temperature. Proceedings of the SEFI 2020 Conference.

34. Kovacs, H., Milosevic, T., & Niculescu, A. (2023). Planned, Taught, Learnt: Analysis of Transversal Skills Through Curriculum Using Portfolio. Proceedings of the SEFI 2023 Conference.

35. Picard, C., Hardebolle, C., Tormey, R., & Schiffmann, J. (2022). Which professional skills do students learn in engineering team-based projects? European Journal of Engineering Education, 47(2), 314–332. https://doi.org/10.1080/03043797.2021.1920890

36. Tormey, R., & Isaac, S. (2021). Facilitating Experiential Learning in Higher Education Teaching and Supervising in Labs, Fieldwork, Studios, and Projects. Routledge.

37. Lehmann, M., Christensen, P., Du, X., & Thrane, M. (2008). Problem-oriented and project-based learning (POPBL) as an innovative learning strategy for sustainable development in engineering education. European Journal of Engineering Education, 33(3), 283–295. https://doi.org/10.1080/03043790802088566

38. Steele, A. L. (2018). Developing Student Meta-Cognition in a Design Course. Proceedings of the Canadian Engineering Education Association (CEEA). https://doi.org/10.24908/pceea.v0i0.13031

39. Rieken, E. F., Bond, K. H., Best, R. M. M., Burleson, G. E., & Brubaker, E. R. (2023). A Spectrum of Stakeholder Perspective Taking in Early-Stage Design. 24th International Conference on Engineering Design, Bordeaux. https://ntrs.nasa.gov/citations/20220017482

40. Hess, J. L., Strobel, J., & Brightman, A. O. (2017). The Development of Empathic Perspective-Taking in an Engineering Ethics Course. Journal of Engineering Education, 106(4), 534–563. https://doi.org/10.1002/jee.20175

41. Isaac, S., de Lima, J., Jalali, Y., Rossi, V., Schmid, S., Tormey, R., and Dehler Zufferey, J. 2024. Chapter 1: How to develop engineering students' transversal skills. In 3T PLAY (Eds.), *Teaching Transversal Skills for Engineering Students: a practical playbook of activities with tangibles*, Centre for Learning Sciences EPFL, Lausanne. https://doi.org/10.5281/zenodo.13328581

3T PLAY

LIST OF MATERIALS

- ◯ Slides to facilitate this activity
  (French version of the slides and handouts **https://doi.org/10.5281/zenodo.13737378**)
- ◯ 1x Handout A per student (A1, A2, A3 or A4 in roughly equal number)
- ◯ 1x Handout B per group
- ◯ 1x Handout C per group
- ◯ LEGO bricks* for each team of 4-6 people†
  - ◯ A model wind turbine composed of 2 blocks each colour: red, green, blue, orange, and yellow
  - ◯ A selection of coloured blocks to allow participants to revise the material composition of their wind turbine.

* This tangible can be substituted with another material that provides students with a visible representation of their choices.

† To see a video example of how the tangibles are used, visit **go.epfl.ch/videoCh4**

MORE ABOUT 3T PLAY

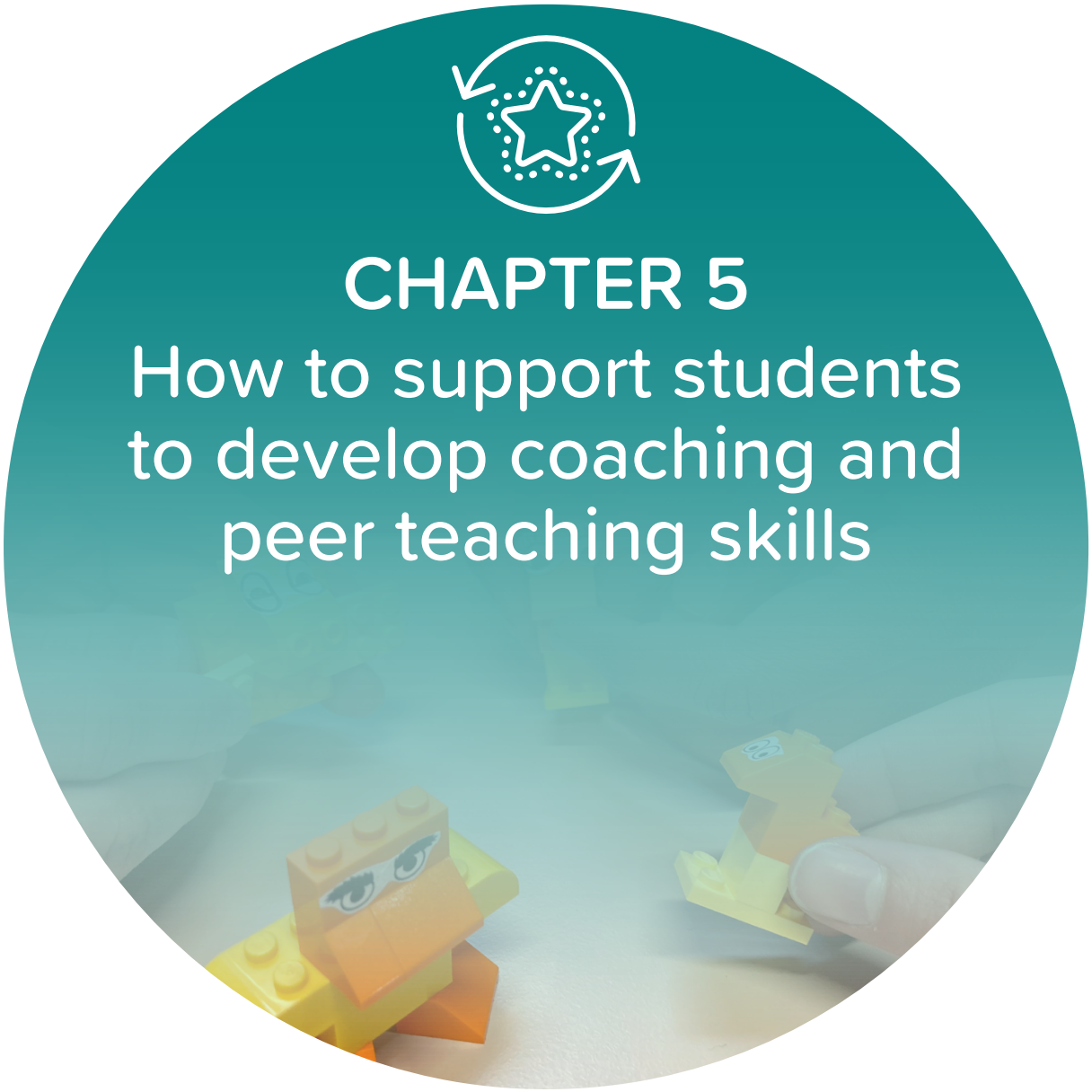
To learn more about the 3T PLAY project and access research output, please visit **go.epfl.ch/3TPLAY**

To access more teaching materials, please visit **https://zenodo.org/communities/3tplay/records**

HOW TO CITE THIS CHAPTER

Isaac, S., and de Lima, J. (with Rossi, V.). 2024.
Chapter 4: How to support students to develop skills that promote sustainability.
In 3T PLAY (Eds.), *Teaching Transversal Skills For Engineering Students: a practical playbook of activities with tangibles*, EPFL Press, Lausanne.
https://doi.org/10.55430/SJYVJ3TP24

3T PLAY



CHAPTER 5

How to support students to develop coaching and peer teaching skills

Generously funded by

The LEGO Foundation

EPFL LEARN Center for Learning Sciences

3T PLAY

CHAPTER 5

How to support students to develop coaching and peer teaching skills

CHAPTER INDEX

CONTRIBUTORS

- **Activity design + development:** Dr Siara Isaac, Dr Joelyn de Lima, and Dr Roland Tormey
- **Writing this chapter:** Dr Joelyn de Lima and Dr Siara Isaac
- **Graphic design:** Laura Persat

3T PLAY

CHAPTER 5

How to support students to develop coaching and peer teaching skills

ACTIVITY DESCRIPTION

Students learn more when they are actively engaged in the learning process. While hands-on activities, labs and projects are moments when students are active, the learning benefits can be amplified with coaching strategies. This activity will enable student peers and teaching assistants to implement 2 evidence-based strategies, **teaching with questions** and **giving process-level feedback**, to support students to develop relevant, transferable thinking skills. This chapter provides the outline of an activity designed to teach the learning outcomes listed below, material to assist the facilitator to prepare, and the slides and handouts for teaching the activity.

ACTIVITY OUTCOMES

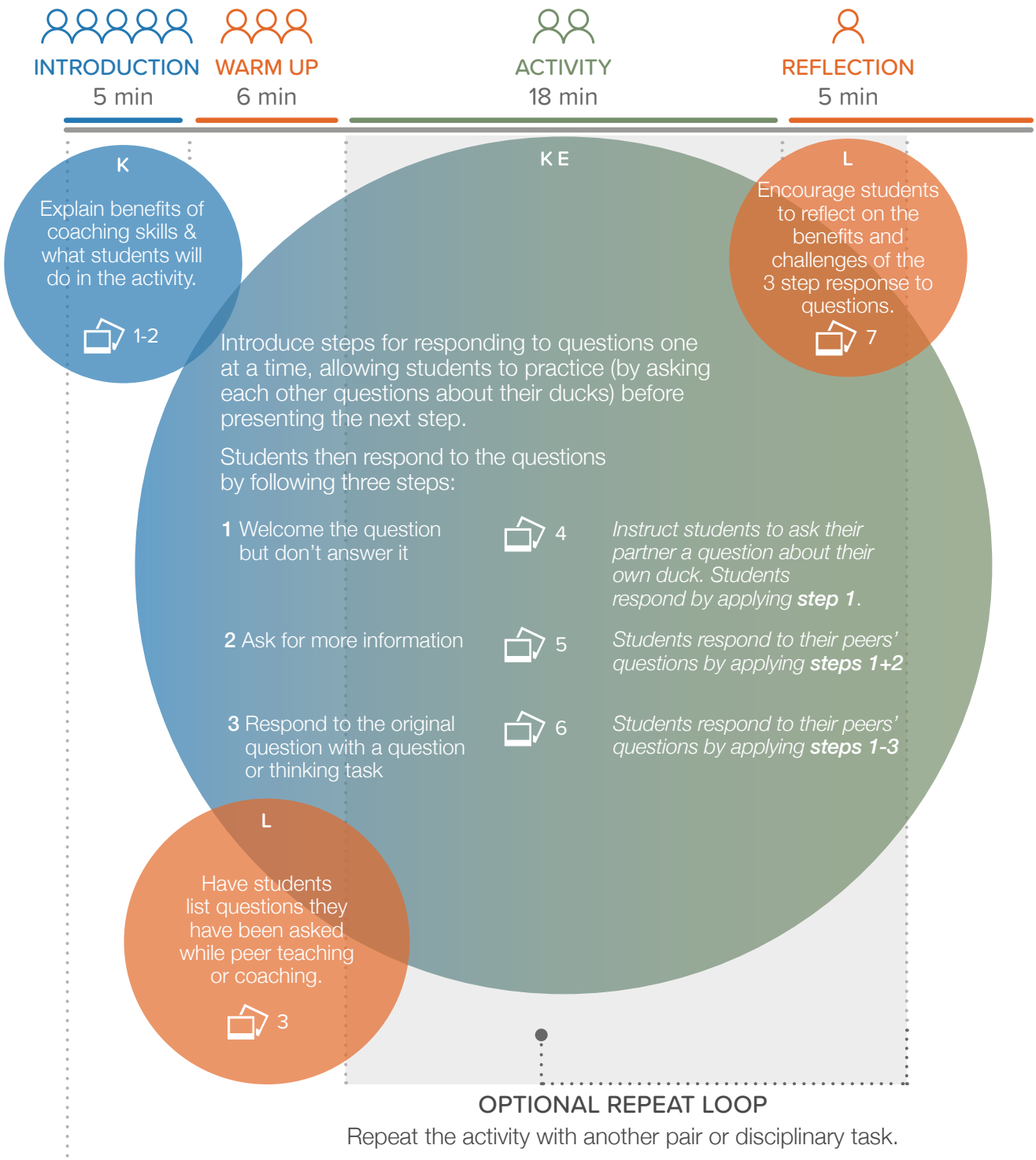
This 75-minute activity is designed for university-level engineering students or teaching assistants.

It targets the development of the following skills

1. Using questions to increase students' engagement and therefore their learning.
2. Providing process-level feedback to support the development of transferable thinking skills.

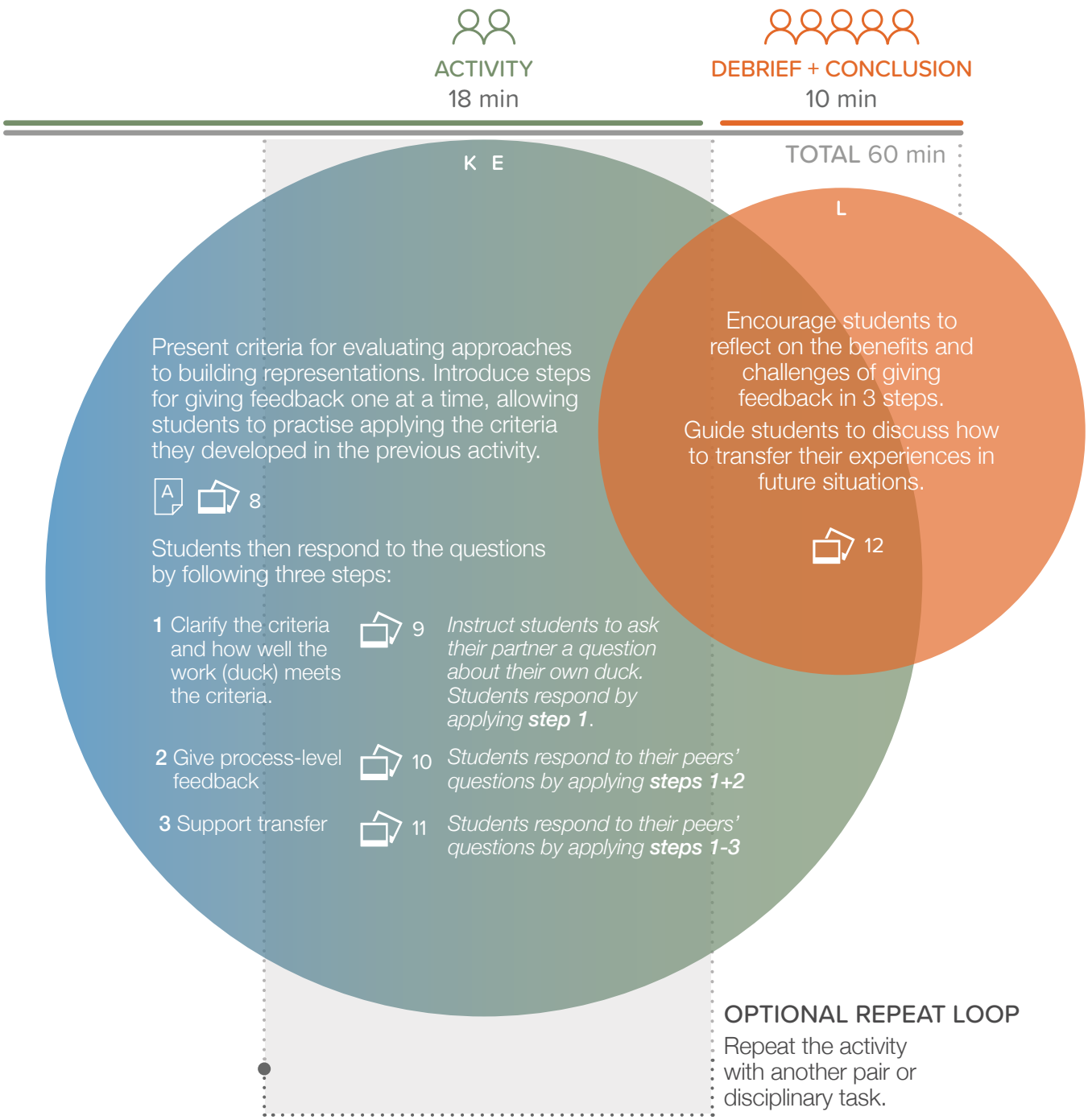
ACTIVITY

How to support students to develop coaching and peer teaching skills



PREPARATION

Set up the room to create groups of 4-6 students.
Get students to build a duck with 7 LEGO bricks while waiting to start.



ALONE
PAIRS
SMALL GROUP
WHOLE GROUP
SLIDES
HANDOUT

K KNOWING
sharing knowledge and concepts that define the targeted skills

E EXPERIENCING
applying the concepts and tools in experiential learning

L LEARNING FROM EXPERIENCE
stepping back and reflecting about the activity enables students to transfer their skills

CONCEPTUAL AND PRACTICAL UNDERPINNINGS OF THE ACTIVITY

What skills will students develop in this activity?

When students are actively engaged in the learning process they learn better[1]. In addition to improving academic performance, these student-centred pedagogies can also improve student engagement and attitudes towards learning[2], and decrease achievement gaps[3]; although this benefit only occurs when students experience intense cognitive engagement[4]. Practices for creating active learning are well-established in engineering[5], and a recent literature review of the effects of active learning in engineering showed that multiple studies documented positive learning outcomes not only on subject-related knowledge, but also on transversal skills[6].

Peer teaching has been shown to lead to learning gains that are comparable to faculty teaching[7], and for both the peer-teachers and the peer-students[8]. It can be leveraged to both amplify active learning pedagogies and support the desirable transfer of skills and perspectives between students in group work and projects. In Hattie's meta-analysis of pedagogical practices, peer teaching had one of the highest positive effects on student learning[9]. The same study also identified other practices with higher-than-average effect on student learning, and in this chapter we will focus on two such evidence-based strategies to enhance (peer) teaching[10,11].

Teaching with questions: Using questions to stimulate relevant thinking is a key tenet of coaching. While frequently used, not all questions support student learning and some actively hinder learning[12]. Although teachers frequently use questions that target lower cognitive levels[13], sometimes reserving the higher order questions for assessments[14], it is in fact questions targeting higher cognitive levels that facilitate learning[15]. Additionally, even in classes that use questioning, it is often the teacher posing the questions, and one student responding. The downside of this one-to-one interaction is that the rest of the students do not benefit. Lowering barriers to students being able to respond to questions (e.g. by allowing/requiring all students to respond), has been shown to lead to statistically significant improvements in academic performance and student engagement as well as students attitudes and behaviours in the class[16]. Having students generate thought provoking and intentional questions furthers their cognitive engagement while improving learning gains.

The activity in this chapter involves practising a flexible structure for formulating and responding to questions that get students to actively learn and develop thinking skills.

Feedback: Feedback is information given to the learner about their progress towards learning goals. Providing students with feedback is very effective for promoting student learning[17], with effect sizes almost double that of other pedagogical interventions[9]. Feedback has been shown to be most effective when it makes explicit references to the goals that students are expected to achieve, or the skills they are expected to master[9]. However students are often dissatisfied with feedback[18], particularly when they do not understand it or see how to use it to improve their performance[19,20]. Improving the feedback that students receive, both in the format and focus, has significant potential to increase learning and is the objective of this chapter. Other useful resources to help students constructively use the feedback they get includes skills for

managing the emotional aspects of giving and getting feedback from the activity in Chapter 3 of this book[21]. Additional resources related to structuring feedback including specific prompts that can be used to provide task level, process level and self-regulatory feedback can be found in Chapter 5 of *Facilitating Experiential Learning in Higher Education*[11], and Chapter 11 of *Visible Learning: The Sequel*[9].

The activity in this chapter involves a flexible structure for giving effective feedback that focuses on the thinking and reasoning process to support students' capacity to what they learn in different contexts.

How to interest engineering students in learning these skills?

While it is evident that peer teaching, teaching with questions, and providing feedback are very useful to enhance learning, they are also skills that engineering students will need as practising engineers. These skills will be particularly useful when they are expected to work in teams, onboard new colleagues, or in management roles where they are responsible for team capacity and skill building. Recent reviews of best practices in engineering education list both formative assessments (i.e. providing students with feedback) and questioning as two of the practices that enhance learning and the development of several other competencies such as self-directed learning, teamwork, problem solving, and analysis[22,23].

In engineering education, using systematic and intentional questions has been shown to develop critical thinking and problem solving skills[24]. Although they initially expressed discomfort with this methodology, engineering students appreciated it when they saw the improvements in their performance[25].
With respect to feedback, improvements in engineering students' performance have been documented when they were provided with individualised, structured, and constructive feedback[26,27].

How does this activity help your students to develop these skills?

Project- and challenge-based activities provide engineering students with practical opportunities to use procedural skills and offer excellent opportunities to integrate transversal skills with disciplinary thinking. An important limitation is that students may find it difficult to perceive the skills as distinct from accomplishing the project tasks[11], a lack of visibility exacerbated when feedback and assessment activities do not include transversal skills. It has been conclusively documented that, for students to effectively develop transversal skills, they need instruction on the strategies and methods underpinning the skills and not just opportunities to practise them[28,29]. However, while there is no shortage of ways to make conceptual knowledge available to students (books, lectures, videos…), teachers often overlook this aspect of developing transversal skills[30]. In addition to conceptual knowledge and procedural skills, meta-cognitive and meta-emotional reflection is an important mechanism for learning from experience[31]. Meta-thinking also assists us to recognise patterns that support the transfer of skills between contexts and projects.

The activity in this chapter has been designed to include each of the aspects from our trident to ensure that students develop a degree of proficiency in the targeted skills and allows them to apply the skills in their next project. Please see Chapter 1 of this book for an in-depth presentation of the framework.[32]

The three aspects of the trident are

Knowing: the factual knowledge and concepts that underpin a skill. For instance, the difference between task and process level feedback.

Experiencing: focused, low-risk opportunities to practise the relevant skills while attending to the process, ideally with rapid feedback and a chance to iterate. For example, practising responding to questions without answering them.

Learning from experience: meta-cognitive and meta-emotional reflection about the experience of implementing conceptual knowledge and procedural skills. For example, recognising the kinds of responses that were perceived as welcoming and prompted relevant process-level thinking.

A key element of our approach is the use of tangibles. This activity uses ducks made of LEGO bricks to provide a visual, concrete object to practice asking questions and giving feedback. The ducks can be replaced with other materials that allow students to make silly creations or a more serious disciplinary task.

Let's return to the specific skills of peer teaching using questioning and feedback that are targeted in this activity. For engineering students to effectively develop these skills, they need to both be convinced of the utility and relevance of questioning and feedback both for their current learning and future careers. Since students might be unfamiliar and uncomfortable with questioning and providing feedback, providing explicit scaffolding and instruction is important. For these skills, an effective learning activity will involve informing students about the benefits of active learning strategies such as questioning and providing feedback, having them practise these skills while providing them with well scaffolded and explicit instructions, and reflecting on their experience to support transfer.

When mapped on to the trident framework, this looks like:

Knowing: Set up the relevance of developing peer teaching skills and engaging in active learning for engineering students [slides 1+3]. Strategies for responding to questions [slides 4 - 6] and providing feedback [slides 9 - 11] are provided stepwise to minimise cognitive load.

Experiencing: Students apply the skills of questioning and giving feedback in 2 Experiencing phases. Each phase is scaffolded so students practise the skills just presented before advancing. First, students practise responding to questions by being welcoming of the question, asking for more information, and responding with a question or a thinking task [slides 4 - 6]. At the start of the second phase [slide 8, handout A], students create criteria to structure their feedback. Students then use the criteria to practise three steps of giving feedback by clarifying the goal, stating positive and negative points, and asking how the person can improve their own work [slides 9 - 11]. To support your students' capacity to transfer their developing skills into their coaching role, encourage them to use the language they usually use with their peers.

Learning from experience: Students are directed to reflect on their experience at three distinct points in this activity. In the warmup [slide 2], students recall and reflect on their prior experiences that are relevant to this activity. Students reflect on the benefits and challenges of teaching without telling [slide 7] and on the benefits and challenges of giving feedback [slide 12].

HANDOUT A
EVALUATING REPRESENTATIONS

Here are 3 criteria that can be used to characterise effective approaches for building representations with LEGO bricks (not necessarily of ducks)

REMEMBER: focus should be on the process of building representations in general.

Criteria that describe a good approach	Description
Application of mentioned criteria	Coherence of product (unmistakably a duck) with task assignment (i.e. 7 bricks)
Creative approach	Experimental and whimsical approach to representation that brings smiles
Attention to overall appearance	Attention to details humans often find attractive (uniform colour, symmetry…)

Coaching Skills Review

Using questions that encourage your peers to think & process information for themselves

1. Welcome questions.
2. Ask for more information.
3. Ask a question/give a thinking task.

Giving feedback that improves your peers' learning

1. Clarify what the criteria are, and how well the work (duck) meets the criteria.
2. Give process-feedback.
3. Support transfer

Debriefing

- Which aspect was most difficult for you?
- How can you self-assess your questioning and feedback skills?
- When and how will you apply these 2 coaching skills?

3T PLAY

Developing coaching and peer teaching skills

Students learn more when they are actively engaged in the learning process. These learning benefits can be amplified with effective coaching strategies.

This session will help you improve your skills for

- **Using questions** that encourage your peers to think & process information for themselves
- **Giving feedback** that improves your peers' learning

3T PLAY

Warm Up

When someone asks a question, it demonstrates some cognitive effort.

How you respond determines how much you will each learn.

★ In your role as a peer teacher or coach, what questions are you asked?

3T PLAY

Active learning increases students' learning outcomes

In addition to increasing learning, active pedagogies can also decrease achievement gaps.

This benefit only occurs when students experience intense cognitive engagement.

Some pedagogical practices have a higher-than-average effect on student learning – we will focus on two such practices today.

Freeman et al., 2014; Hattie, 2009; Theobald et al., 2020

3T PLAY

Don’t answer the question – welcome it

Context: When responding to questions, you may do more thinking than students.

Goal: Create a climate that encourages people to ask questions, while not immediately answering them.

Hints for welcoming questions: “Thank you for that question”, “I am glad you asked”, “That is an important question”, “This is a good thing to ask when doing this task”

★ **Your peer asks a question about their duck, using the warm up responses to formulate authentic questions.**

Task: Welcome the question. Don’t answer it!

3T PLAY

Understand where the question comes from

Context: *It is important to understand the motivation of a question and not to assume.*

Goal: Understand the question better and give yourself time to figure out a constructive response.

Hints for asking for more information: “Can you be more specific?”, “What have you done so far?” “Can you give me an example?”, “What caused you to ask this question?”

★ Your peer asks a question about their duck.

Task: Welcome the question. Ask for more information.

3T PLAY

Respond with a thinking task

Context: To learn, people need to process information.

Goal: Get people to think and process information for themselves, so they keep developing their own skills.

Hints for supporting learning: "How could you check your answer?", "Where could you find more information?"

★ **Your peer asks a question about their duck.**

Task: Welcome the question. Ask for more information.
Ask a question/give a thinking task.

3T PLAY

Let's take a moment to question ourselves

Welcome questions.

Ask for more information.

Ask a question/give a thinking task.

- What was the effect of responding in this way?
- Which step was the most difficult?
- How can you practice this skill?
- How can you self-assess your ability to respond to questions with questions?

3T PLAY

Evaluating Representations

Here are 3 criteria that can be used to characterise effective approaches for building representations with LEGO bricks (not necessarily of ducks)

Criteria that describe a good approach	Description
Application of mentioned criteria	Coherence of product (unmistakably a duck) with task assignment (i.e. 7 bricks)
Creative approach	Experimental and whimsical approach to representation that brings smiles
Attention to overall appearance	Attention to details humans often find attractive (uniform colour, symmetry…)

3T PLAY

What does excellent performance look like?

Context: Students don't deliver because they don't know what is required (even if they have been told).

Goal: Respond to a peer's work, clarify what excellent performance looks like.

Task: Clarify what the criteria are, and how well your peer's work (duck) meets the criteria.

- **The goal is…**
  The criteria are…..

  "It is important to deliver a product that matches the assignment. Here, you were told to use 7 bricks to build a duck."

- **How does the work meet the criteria? Positive and negative.**

  "Your duck is immediately identifiable as a duck but you used eight pieces."

3T PLAY

Helping students to develop their skills (not just solve this problem)

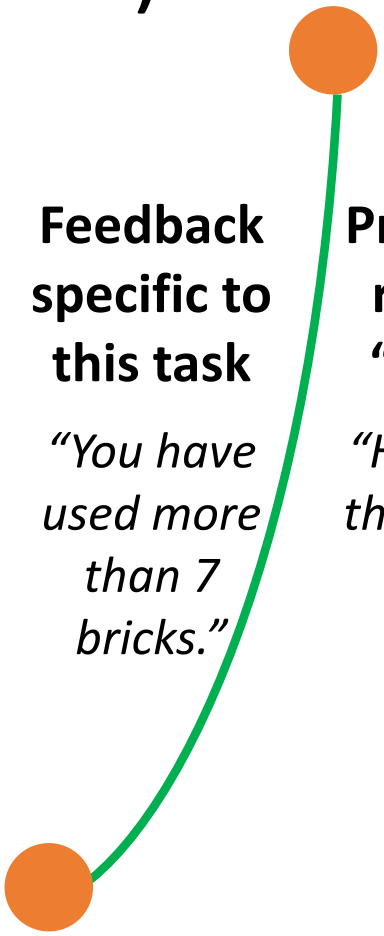
Context: Avoid task-focused and person-focused feedback; prioritise process-focused feedback.

Goal: Give the student feedback on how they are approaching the problem.

Task: Clarify the criteria and how well your peer's work (duck) meets the criteria.

Give process-focused feedback

"How did you … / how could you …."



Feedback specific to this task

"You have used more than 7 bricks."

Process feedback is reusable in other "tasks like these"

"How do you check to that you have met the criteria?"

3T PLAY

Helping students transfer their learning to the next problem

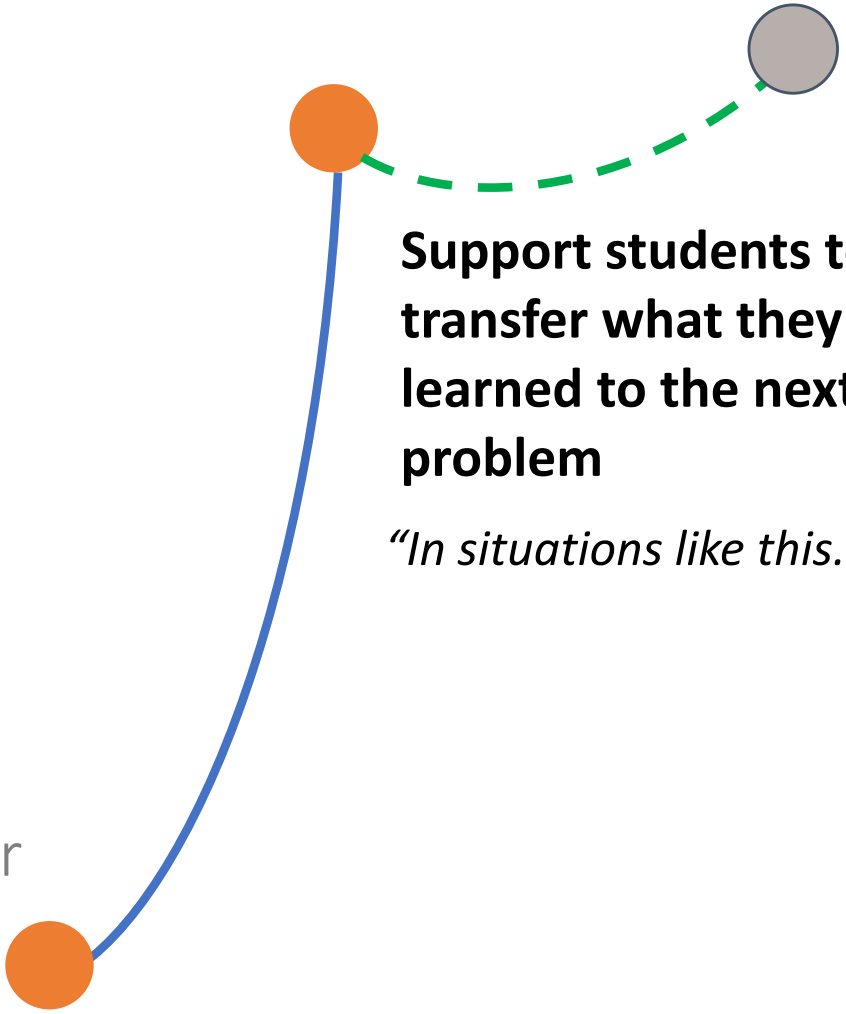
Context: It is difficult to transfer what we learn in one situation to future situations.

Goal: Help peers perceive the characteristics of this situation that made these skills relevant.

Task: Clarify the criteria and how well their work (duck) meets the criteria.

Give process-focused feedback.

Support transfer



Support students to transfer what they learned to the next problem

"In situations like this…"

3T PLAY

Let's take a moment to debrief and give ourselves some feedback

Clarify the relevant skills and their successful implementation
Give process-focused feedback
Ask a question that supports transfer

1. Which aspect was most difficult?
2. How can you improve your feedback skills?
3. How can you self-assess your ability to respond to provide useful feedback?
4. When and how will you apply these 2 coaching skills?
5. How will you track your progress?

Activity development and implementation

This activity was initially developed for student assistants at a Swiss technical university. The activity presented in this chapter is the result of many iterations with student and doctoral teaching assistants, as well as STEM teachers. More than 400 people have experienced this workshop.

It has since been implemented in diverse contexts and for diverse audiences including:

Countries

Croatia

Portugal

Tunisia

Kenya

Switzerland

Austria

Denmark

United Kingdom

Conferences

Rendez-vous-lehre 2023 (Switzerland)

CDIO 2024 (Tunisia)

MIPRO 2024 (Croatia)

Audiences

Engineering students

Student and doctoral assistants

STEM and engineering teachers

Pedagogical advisors

Faculty developers

Curriculum developers

Researchers

United Nations staff

References

1. Freeman, Scott., Eddy, S. L., McDonough, M., Smith, M. K., Okoroafor, N., Jordt, H., & Wenderoth, M. P. (2014). Active learning increases student performance in science, engineering, and mathematics. Proceedings of the National Academy of Sciences, 111(23), 8410–8415. https://doi.org/10.1073/pnas.1319030111

2. Armbruster, P., Patel, M., Johnson, E., & Weiss, M. (2009). Active Learning and Student-centered Pedagogy Improve Student Attitudes and Performance in Introductory Biology. CBE-Life Sciences Education, 8(3), 203–213. https://doi.org/10.1187/cbe.09-03-0025

3. Haak, D. C., HilleRisLambers, J., Pitre, E., & Freeman, S. (2011). Increased Structure and Active Learning Reduce the Achievement Gap in Introductory Biology. Science, 332(6034), 1213–1216.

4. Theobald, E. J., Hill, M. J., Tran, E., Agrawal, S., Arroyo, E. N., Behling, S., Chambwe, N., Cintrón, D. L., Cooper, J. D., Dunster, G., Grummer, J. A., Hennessey, K., Hsiao, J., Iranon, N., Jones, L., Jordt, H., Keller, M., Lacey, M. E., Littlefield, C. E., … Freeman, S. (2020). Active learning narrows achievement gaps for underrepresented students in undergraduate science, technology, engineering, and math. Proceedings of the National Academy of Sciences, 117(12), 6476–6483. https://doi.org/10.1073/pnas.1916903117

5. Lima, R. M., Andersson, P. H., & Saalman, E. (2017). Active Learning in Engineering Education: A (re)introduction. European Journal of Engineering Education, 42(1), 1–4. https://doi.org/10.1080/03043797.2016.1254161

6. Hartikainen, S., Rintala, H., Pylväs, L., & Nokelainen, P. (2019). The Concept of Active Learning and the Measurement of Learning Outcomes: A Review of Research in Engineering Higher Education. Education Sciences, 9(4), Article 4. https://doi.org/10.3390/educsci9040276

7. Rees, E. L., Quinn, P. J., Davies, B., & Fotheringham, V. (2016). How does peer teaching compare to faculty teaching? A systematic review and meta-analysis*. Medical Teacher, 38(8), 829–837.

https://doi.org/10.3109/0142159X.2015.1112888

8. Williams, B., & Fowler, J. (2014). Can Near-Peer Teaching Improve Academic Performance? International Journal of Higher Education, 3(4), 142–149. https://eric.ed.gov/?id=EJ1067552

9. Hattie, J. (2023). Visible Learning: The Sequel: A Synthesis of Over 2,100 Meta-Analyses Relating to Achievement. Routledge. https://doi.org/10.4324/9781003380542

10. Tormey, R., Hardebolle, C., & Isaac, S. (2020). The Teaching Toolkit: Design of a one-day pedagogical workshop for engineering graduate teaching assistants. European Journal of Engineering Education, 45(3), 378–392. https://doi.org/10.1080/03043797.2019.1584606

11. Tormey, R., & Isaac, S. (2022). Facilitating Experiential Learning in Higher Education Teaching and Supervising in Labs, Fieldwork, Studios, and Projects. Routledge.

12. Tofade, T., Elsner, J., & Haines, S. T. (2013). Best Practice Strategies for Effective Use of Questions as a Teaching Tool. American Journal of Pharmaceutical Education, 77(7). https://doi.org/10.5688/ajpe777155

13. Gaspard, C., & Gainsburg, J. (2020). Abandoning questions with unpredictable answers. Journal of Mathematics Teacher Education, 23(6), 555–577. https://doi.org/10.1007/s10857-019-09440-5

14. Lemons, P. P., & Lemons, J. D. (2013). Questions for Assessing Higher-Order Cognitive Skills: It's Not Just Bloom's. CBE—Life Sciences Education, 12(1), 47–58. https://doi.org/10.1187/cbe.12-03-0024

15. Redfield, D. L., & Rousseau, E. W. (1981). A Meta-Analysis of Experimental Research on Teacher Questioning Behavior. Review of Educational Research, 51(2), 237–245. https://doi.org/10.3102/00346543051002237

16. Randolph, J. J. (2007). Meta-Analysis of the Research on Response Cards: Effects on Test Achievement, Quiz Achievement, Participation, and Off-Task Behavior. Journal of Positive Behavior Interventions, 9(2), 113–128. https://doi.org/10.1177/10983007070090020201

17. O'Donovan, B., Rust, C., & Price, M. (2016). A scholarly approach to solving the feedback dilemma in practice. Assessment & Evaluation in Higher Education, 41(6), 938–949. https://doi.org/10.1080/02602938.2015.1052774

18. Beaumont, C., O'Doherty, M., & Shannon, L. (2011). Reconceptualising assessment feedback: A key to improving student learning? Studies in Higher Education, 36(6), 671–687. https://doi.org/10.1080/03075071003731135

19. Higgins, R., Hartley, P., & Skelton, A. (2001). Getting the Message Across: The problem of communicating assessment feedback. Teaching in Higher Education, 6(2), 269–274. https://doi.org/10.1080/13562510120045230

20. Poulos, A., & Mahony, M. J. (2008). Effectiveness of feedback: The students' perspective. Assessment & Evaluation in Higher Education, 33(2), 143–154. https://doi.org/10.1080/02602930601127869

21. Isaac, S., & de Lima, J. (2024). Chapter 3: How to support students' skills for giving constructive feedback, especially when it is difficult to hear. In Teaching Transversal Skills for Engineering Students—a playbook of practical activities with tangibles. EPFL. https://doi.org/10.5281/zenodo.10392344

22. Hernández-de-Menéndez, M., Vallejo Guevara, A., Tudón Martínez, J. C., Hernández Alcántara, D., & Morales-Menendez, R. (2019). Active learning in engineering education. A review of fundamentals, best practices and experiences. International Journal on Interactive Design and Manufacturing (IJIDeM), 13(3), 909–922. https://doi.org/10.1007/s12008-019-00557-8

23. Qadir, J., Taha, A.-E. M., Yau, K.-L. A., Ponciano, J., Hussain, S., Al-Fuqaha, A., & Imran, M. A. (2020, June 22). Leveraging the Force of Formative Assessment & Feedback for Effective Engineering Education [Conference Proceedings]. 2020 ASEE Annual Conference & Exposition. https://doi.org/10.18260/1-2--34923

https://doi.org/10.1080/03043790802088566

24. Golanbari, M., & Garlikov, R. (2008). Employing Socratic Pedagogy To Improve Engineering Students' Critical Reasoning Skills: Teaching By Asking Instead Of By Telling. 13.486.1-13.486.19. https://peer.asee.org/employing-socratic-pedagogy-to-improve-engineering-students-critical-reasoning-skills-teaching-by-asking-instead-of-by-telling

25. Shoop, B. L., & Ressler, E. K. (2011). Developing the critical thinking, creativity and innovation of undergraduate engineering students. International Journal of Engineering Education, 27(5), 1072–1080.

26. Das, D. K. (2023). Exploring the impact of feedback on student performance in undergraduate civil engineering. European Journal of Engineering Education, 48(6), 1148–1164. https://doi.org/10.1080/03043797.2023.2238188

27. Limniou, M., & Smith, M. (2014). The role of feedback in e-assessments for engineering education. Education and Information Technologies, 19(1), 209–225. https://doi.org/10.1007/s10639-012-9200-5

28. Lehmann, M., Christensen, P., Du, X., & Thrane, M. (2008). Problem-oriented and project-based learning (POPBL) as an innovative learning strategy for sustainable development in engineering education. European Journal of Engineering Education, 33(3), 283–295.

29. Picard, C., Hardebolle, C., Tormey, R., & Schiffmann, J. (2022). Which professional skills do students learn in engineering team-based projects? European Journal of Engineering Education, 47(2), 314–332. https://doi.org/10.1080/03043797.2021.1920890

30. Isaac, S., Petringa, N., Jalali, Y., Tormey, R., & Dehler Zufferey, J. (2023). Are Engineering Teachers Ready to Leverage the Power of Play to Teach Transversal Skills? Proceedings of the SEFI 2023 Conference. SEFI 2023. https://doi.org/10.21427/QP3D-B914

31. Steele, A. L. (2018). Developing Student Meta-Cognition in a Design Course. Proceedings of the Canadian Engineering Education Association (CEEA). https://doi.org/10.24908/pceea.v0i0.13031

32. Isaac, S., de Lima, J., Jalali, Y., Rossi, V., Schmid, S., Tormey, R., and Dehler Zufferey, J. 2024. Chapter 1: How to develop engineering students' transversal skills. In 3T PLAY (Eds.), Teaching Transversal Skills for Engineering Students: a practical playbook of activities with tangibles, Centre for Learning Sciences EPFL, Lausanne. https://doi.org/10.5281/zenodo.13328581

3T PLAY

LIST OF MATERIALS

- ◯ Slides to facilitate this activity
- ◯ 1x Handout A per student group
- ◯ Mixed selection of yellow and orange LEGO bricks* so each person can make a duck†

* This tangible can be substituted with another material that allows students to create a silly creation (playdough, coloured pencils and paper…)

† To see a video example of how the tangibles are used, visit **go.epfl.ch/videoCh5**

MORE ABOUT 3T PLAY

To learn more about the 3T PLAY project and access research output, please visit **go.epfl.ch/3TPLAY**

To access more teaching materials, please visit **https://zenodo.org/communities/3tplay/records**

HOW TO CITE THIS CHAPTER

de Lima, J., and Isaac, S. 2024.
Chapter 5: How to support students to develop coaching and peer teaching skills.
In 3T PLAY (Eds.), T*eaching Transversal Skills For Engineering Students: a practical playbook of activities with tangibles*, EPFL Press, Lausanne.

https://doi.org/10.55430/SJYVJ3TP24

3T PLAY

CHAPTER 6
How to support students to develop skills for planning and risk assessment

Generously funded by
The LEGO Foundation
EPFL LEARN Center for Learning Sciences

3T PLAY

CHAPTER 6

How to support students to develop skills for planning and risk assessment

CHAPTER INDEX

CONTRIBUTORS

- **Activity design + development:** Dr Siara Isaac, Julien Delisle and Dr Cécile Hardebolle
- **Writing this chapter:** Dr Siara Isaac, Dr Samuel Schmid, Dr Abasalt Khorasani, Dr Yousef Jalali
- **Graphic design:** Laura Persat
- **Photography:** Julie Clerget

3T PLAY

CHAPTER 6

How to support students to develop skills for planning and risk assessment

ACTIVITY DESCRIPTION

Engineering students encounter many team projects during their studies, yet rarely receive practical training on core project skills that they are expected to implement during their projects. This activity provides students with an experiential introduction to core project skills contextualised to demonstrate the both relevance and typical implementation challenges. This activity is an ideal initiation for a new team that will be completing a project together, assisting students to both be more effective in the project and to recognise the opportunity to develop relevant, transferable project skills. This chapter provides the outline of an activity designed to teach the skills listed below, material to assist the facilitator to prepare, and the slides and handouts for teaching the activity.

ACTIVITY OUTCOMES

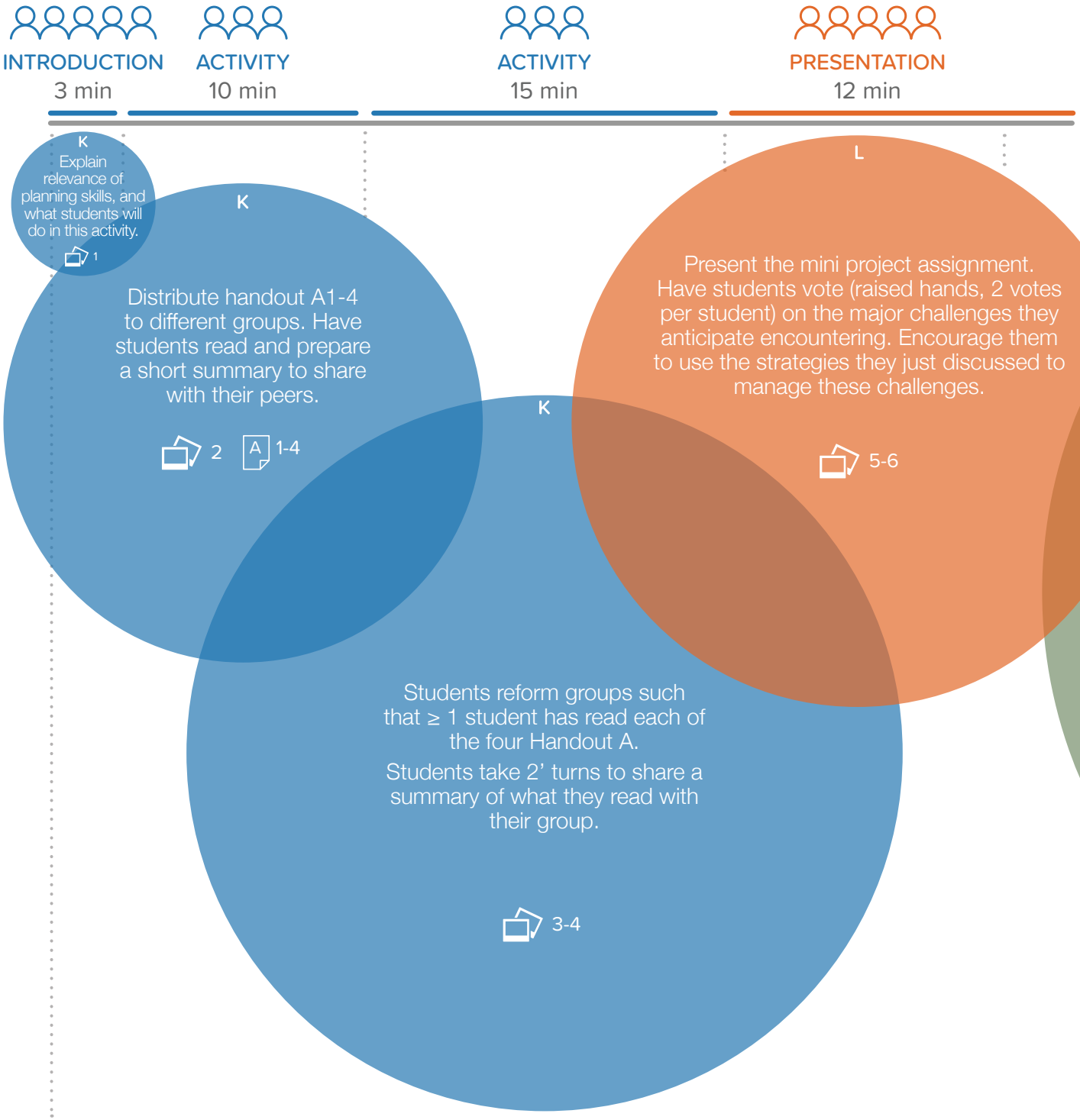
This 90-minute activity is designed for university-level engineering students.

It targets the development of the following skills

1. Risk assessment and planning for projects
2. Collaboration and decision making in teams

ACTIVITY

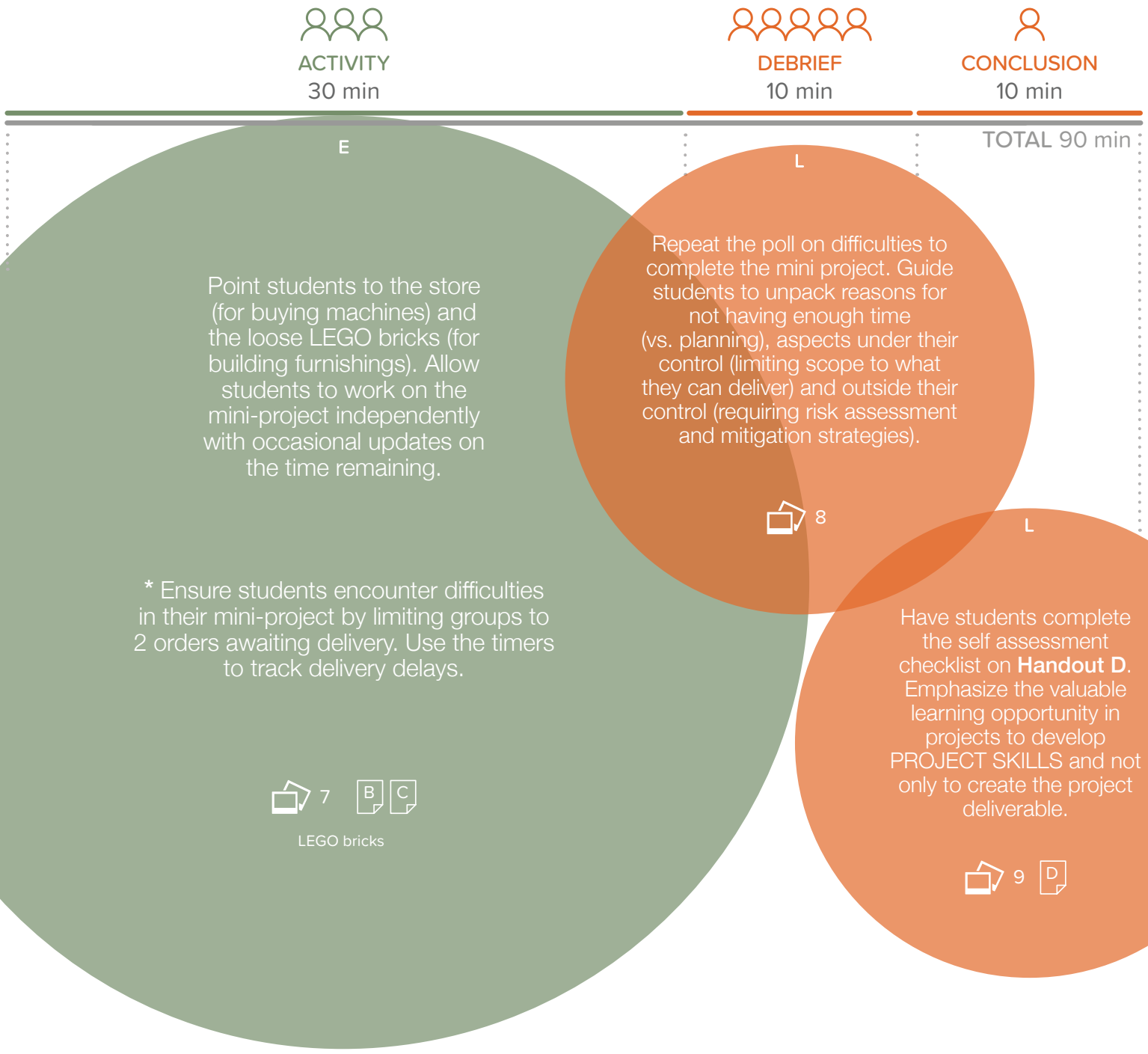
How to support students to develop skills for planning and risk assessment



PREPARATION

Set up the room to create 4+ groups of students.
Build the 'machines' in Handout B with LEGO bricks.

This activity involves an information jigsaw. When distributing handout A, ensure that the students in the same group all get the same handout (ie A1 or A2). In the next phase of the jigsaw, students form new groups such that there is ≥ 1 student who read A1, A2, A3 and A4 present in each group.



ALONE
PAIRS
SMALL GROUP
WHOLE GROUP
SLIDES
HANDOUT

K KNOWING
sharing knowledge and concepts that define the targeted skills

E EXPERIENCING
applying the concepts and tools in experiential learning

L LEARNING FROM EXPERIENCE
stepping back and reflecting about the activity enables students to transfer their skills

CONCEPTUAL AND PRACTICAL UNDERPINNINGS OF THE ACTIVITY

What skills will students develop in this activity?

Project planning and risk management are key project management skills that are widely used across industries. Project planning is the phase in project management where the specific steps required to complete a project are determined. This involves setting timelines, defining tasks within designated timeframes, and establishing key milestones. Risk assessment involves identifying potential *risks* - uncertain events that, if they occur, could impact the project's outcome. This process aims to anticipate and mitigate *issues* (realisation of uncertain events) to reduce their potential impact on the project[1]. Accreditation standards for engineering education programs underscore the significance of these transversal skills. Accrediting criteria from bodies such as ABET[2] and CTI[3] incorporate project planning and risk management. Moreover, the importance of these transversal skills in preparing graduates for the workforce has been explicitly emphasized by employers.[4]

Beyond enhancing engineering students' employability[5,6], teaching these skills also has educational benefits that contribute to their academic success.[7] Efficient project planning and risk assessment strategies are directly involved in the success of group work that students frequently encounter. Koolmanojwong & Boehm[7] found groups that rated themselves as more competent in risk management tended to achieve higher grades on their academic projects. This underscores the importance of incorporating comprehensive planning and proactive risk management into the educational program to enhance student performance and project outcomes. Student projects often encounter issues such as uneven commitment levels among team members, discrepancies in skill sets or inconsistencies in communication strategies.[8,9]

These challenges impact teamwork and lead to undesirable outcomes, like delayed completion, diminished project scope, substandard product quality, and the necessity for instructor intervention.[10] It is desirable that students encounter these authentic difficulties as they provide the necessary conditions for students to develop relevant project planning and risk assessment skills.[11] However, it's essential to assist students to not perceive these team-related problems as being mere barriers to the success of their current project and to recognize them as valuable learning opportunities.[12] Students whose contributions to their projects involved solving planning and risk management issues report higher learning gains on these topics than students who focus exclusively on technical aspects.[11]

Planning and project management

Student projects are inherently different from industry projects[7,9], so many established project management frameworks designed for industrial projects do not fully align with the academic context[13]. Learning opportunities for project management skills should, therefore, likely take a general approach. Student projects often have a short, inflexible deadline, few intermediate deliverables and start without clear roles. This provides students with opportunities to learn how to establish a plan, set intermediate objectives and determine how to work collaboratively[11]. A recurrent issue is that students plan their tasks at too general a level[11,14], with the result that students do not perceive delays sufficiently early and therefore do not update their plans. The result is often a mad rush to the final deadline and a final deliverable that may not be functional[15]. Since student projects are subject to tight deadlines[7], small deviations from the plan may end up being quite problematic. However, this does make students projects ideal for learning planning skills.

Risk assessment

Students' previous experiences likely enable them to identify some common risks in projects, although they may not use the term risks. For instance, students have probably encountered problems caused by team members with poor skills or low motivation.[8,9] They may be less aware of factors outside the team[7], such as access to resources (booking the 3D printer, shipping delays, etc.) or random incidents (illness, equipment maintenance, etc.). While each risk may result in only a small delay, the tight timeframe of student projects means that they can cause significant disruption.[7] Effective risk assessment in student projects must therefore include issues that appear to be minor, and mitigation strategies to reduce the potential problems caused when risk events do occur. For example, early testing high risk components or ordering materials in advance.[11]

How to interest engineering students in learning these skills?

Although students are aware of the importance of planning and risk management skills for their careers[16,17], they often find that these are not adequately integrated into their education.[18] Students frequently report dissatisfaction with their proficiency in these areas[19,20] and express a desire to further develop these skills. The discrepancy between students' desire to learn and the lack of support from the teaching staff can be explained by the assumption among educators that group work during studies is sufficient for students to acquire these transversal skills. However, effective skill acquisition requires explicit instruction[21], and explicit teaching consumes time that could be devoted to fundamental competencies, leading educators to be reluctant to dedicate adequate time to it.

Emphasising how risk assessment and project planning are key to producing a high quality project output will boost some students' engagement, while others will be more interested in the value for their employability. Additionally, teaching students about these transversal skills can reduce negative attitudes toward group work. For some students, the prospect of collaboration in a group setting is a major source of concern, primarily due to past negative experiences such as uneven contribution among team members and the challenge of coordinating work.[22,23] Teaching students how to implement risk assessment and project planning provides a clear framework and set of expectations for all team members, which helps distribute tasks evenly, clarify communication, and contribute to more positive group dynamics.

How does this activity help your students to develop these skills?

Project- and challenge-based activities create settings for engineering students to apply their transversal skills. However the potential for students to develop their transversal skills in such contexts are often diminished by a lack of explicit instruction on and scaffolding of transversal skills[21] and students' difficulty in perceiving the skills as distinct from project tasks and deliverables[24]. This activity creates a micro-experiential opportunity where students address a design task to practice essential projects skills in team settings and reflect on ways the brief experience relates to their experience handling engineering projects in educational and professional settings. In designing the activity, similar to the other activities in this handbook, we benefited from our trident framework as a practical structure for teaching transversal skills, highlighting conceptual underpinnings, procedural skills, and meta-cognitive and meta-emotional reflection. Please see Chapter 1[25] of this book for an in-depth presentation of the framework.

The three aspects of the trident are

Knowing: the factual knowledge and concepts that underpin a skill. For instance, the definition of risk assessment and key elements to consider when evaluating risk in a project.

Experiencing: focused, low-risk opportunities to practice the relevant skills while attending to the process, ideally with rapid feedback and a chance to iterate. For example, collaboratively delivering an ungraded product in a short timeframe.

Learning from experience: meta-cognitive and meta-emotional reflection about the experience of implementing conceptual knowledge and procedural skills. For example, reviewing how anticipated and unanticipated difficulties in a project were managed and what approaches would be more effective.

The activity in this chapter has been designed to include each of the aspects from our trident to ensure that students encounter activities that prompt the three types of thinking and develop a degree of proficiency in the targeted skills that allow them to apply them in their next project. This activity uses LEGO bricks in 2 ways: i) pre-built representations of the equipment that can be ordered (e.g., 3D printer, computer, or advanced toolbox) taking into account the limitation in the number and delay in shipping, and ii) a mixed selection of bricks for building furniture to complete the design. The nature of the task is open-ended, however students need to work as a group to produce a single design that respects the constraints. If sufficient LEGO baseplates are not available, groups can be given a paper equivalent (https://doi.org/10.5281/zenodo.12609232). The use of tangibles in this activity provides a visual, concrete project output around which students can encounter relevant project difficulties. The design task could be replaced with another complex task that creates opportunities for planning, collaboration and risk assessment.

The project skills of risk assessment, planning, collaboration and decision-making targeted in this activity respond to the growing emphasis on teamwork within educational and professional settings. Educators should help students to see the need and relevance of these skills for their careers. In what follows, we explain the details of the activity when mapped onto the trident framework:

Knowing: Students read the teamwork tips [slide 2; handouts A1,2,3,4] and prepare a summary to share [slides 3-4]. Note that students in each initial group receive the same handout. Then, new teams are formed so that there is at least one student who read each of the 4 handouts.

Experiencing: Students complete the mini-project assignment in teams, designing and equipping a scale mock-up of the ideal "makerspace" for engineering students [slide 7]. Creating the design together, delivery delays in orders, and budget constraints create a challenging experiential opportunity that introduces common project challenges related to planning, risk assessment, and collaborative decision-making. It can be helpful for teachers to remind students to apply concepts from the knowledge shared during the earlier phases of the activity and actively practice the targeted skills.

Learning from experience: Prior to starting the mini-project design task, students reflect on the challenges they expect to encounter [slide 6]. After the mini-project, students evaluate their result and process with the self-assessment checklist [Handout D] and reflect on the difficulties they encountered [slide 8]. Here, it is important to guide students to unpack reasons for not having enough time (vs. planning), aspects under their control (limiting scope to what they can deliver) and outside their control (requiring risk assessment and mitigation strategies).

HANDOUT A1
TEAMWORK TIPS FOR BETTER PROJECTS

The biggest challenge, and the biggest advantage, of teamwork is the people. It is complicated to work in a team but having a diverse set of people is also a key element of success. Diverse teams are more innovative, process information better and make better use of data (Rock & Grant, 2016). Diverse companies perform better on the stock market.

1. A Great Team is Clear about Its Mission

Everyone in a great team understands the overall mission of the team and is committed to attaining it. This sounds simple, but having the same idea of the mission can be difficult – and it is important as the mission structures all the various subtasks.

2. A Great Team Agrees on How to Work Together

People come to the team with different ideas and experiences, and therefore different expectations about how this team will work together. Getting started together as a team should involve explicitly agreeing to team habits. Below is a short list – so add any other questions you feel are relevant for your current context:

a. When will meetings be held? Where will be they held?

b. What should someone do if they will be absent or cannot meet a deadline?

c. How will a record of decisions be made? Where will it be kept?

d. How will the team make collective decisions?

3. A Great Team is Respectful and Intentional about Communication

Communication is a recurrent challenge between any 2 people who work together. When more people are involved, it becomes exponentially more complicated. Teams need to be intentional in ensuring that everyone receives the necessary information (having clear procedures for recording and disseminating information) and that the contributions of all team members are taken into account. Do people feel comfortable expressing their thoughts and opinions? Do people ask questions to increase their understanding of a proposed idea, before finding the flaws? Are some people being consistently interrupted? Informal communication is an area where unintentional bias (Banaji & Greenwald, 2016) may lead to the contributions of some team members being overlooked.

TASK: Prepare a summary to share with people have not read this page

-
-
-
-

"10 Tips for Better Teamwork", S. M. Heathfield, 2021. https://www.thebalancecareers.com/tips-for-better-teamwork-1919225
"Why Diverse Teams Are Smarter", D. Rock + H. Grant, 2016 https://hbr.org/2016/11/why-diverse-teams-are-smarter

HANDOUT A2
PLANNING TIPS FOR BETTER PROJECTS

While it is tempting to jump in and get started, complex final products and collaborative work require planning. And planning again. It is important to see project planning as an iterative process that needs to be reviewed and updated as the project progresses.

1. Know What Has to Be Done and By When

To determine what has to be done for what deadline, start on the macro scale and then zoom in. What is the final product (deliverable) and when must it be completed? Are there intermediate deliverables/deadlines? Now identify the subtasks. Once you have created your list of tasks, put them in chronological sequence. Perhaps task B cannot be done until task A is complete, but task C can be done at any time there is a gap in the schedule. Having a clear overview of the dependency of tasks is useful to keep an eye on progress and risks. Allow time for compiling, shipping, debugging, etc. to make sure you meet your deadlines.

2. Identify and Manage Risk

An exciting and innovative project will necessarily include some risk. Risky elements are those that have a narrow window of success – which may be due to technical difficulty, time limitations, adverse effects, or limited resources. For example, if you are building a device to protect an egg dropped from a height and only have 1 egg for testing.

The goal with risk management is to identify tricky spots early and take steps to avoid risks or to limit the potential impact. This is called assessment and mitigation. Strategies include tackling high-risk items early, seeking additional resources, and adapting the product. Like planning, risk management isn't something you do once and put away — your plan should be reviewed as your project and your understanding of the context progresses.

3. Addressing Problems and Conflicts

It can be tempting to ignore problems and hope that they will go away. And they might. But it is more likely that they will turn up again, probably right before a stressful deadline. Encountering problems and conflicts is a completely normal part of working together. Great teams do not have less conflict than other teams, but they are better at addressing it and moving forward.

TASK: Prepare a summary to share with people have not read this page

-
-
-
-

"10 Tips for Better Teamwork", S. M. Heathfield, 2021. https://www.thebalancecareers.com/tips-for-better-teamwork-1919225

"PMI/ESA project time management function". MacDonald. Project Management Quarterly, 14(1), 20–26. https://www.pmi.org/learning/library/time-management-project-functions-schedules-5723

HANDOUT A3
RESOURCE MANAGEMENT

Accomplishing your project will require certain investments (money, skills, ideas and time). None of these resources are endless and some will be in short supply.

1. Make Good Use of Team Members' Skills

An effective team sees each person as valuable. This means not just identifying their skills but also taking care to hear different perspectives when making decisions. Working together is also an opportunity to learn; consider people's personal development goals (rather than just what they are already good at) when assigning tasks.

What are the different skills that are required in your project? What skills do your team members already have, which will need to be acquired? Learning is a key objective for student projects - don't get so focused on the final product that you forget to develop your skills.

2. Make Good Use of Time

There are three big parts of managing time: the deadline, time available (ie total work hours across all team members) and the time required. You have the most control over this last one, so adjust the scale your project to fit within the constraints.

Make a list of the tasks and estimate how long each one will take. If this exceeds the time available, adapt early. Next, identify intermediate deadlines. Review your progress against the plan - identifying when you're falling behind and adapting early is key.

3. Manage Money and Inventory

In addition to money, other resources in this category may include tools (3D printer, NMR…) and materials (soldering flux, Agar medium…). It is useful to begin a project with a good map of the resources you will need and when they will be needed – while 4 3D printers might sound like ample capacity for the semester, in fact they are likely to be sitting idle for the first few weeks and then in very high demand as the deadline looms. Keeping on top of resources means maintaining a master list of everything that is needed and how much it costs, and then updating it as the project evolves and inventory is consumed.

TASK: Prepare a summary to share with people have not read this page

-
-
-
-

"10 Tips for Better Teamwork", S. M. Heathfield, 2021. https://www.thebalancecareers.com/tips-for-better-teamwork-1919225

"Task choice, group dynamics and learning goals: Understanding student activities in teams". Hirshfield & Chachra. 2015. IEEE Frontiers in Education Proceedings, pp. 1-5.

HANDOUT A4
ASSIGNED ROLES FOR BETTER PROJECTS

With "assigned roles", people focus their attention to a specific aspect of the project. These roles are independent of the individual tasks for the project. Let's take making breakfast as an example. The whole team will be involved in choosing the menu and cooking. However, while engaging in the discussion, the Timekeeper will make sure time isn't forgotten – can 20 pancakes be cooked before 8h? The Resource Manager has an eye on the 6 eggs –the team can't choose to make scrambled eggs and pancakes.

When everyone is responsible for everything, inefficient duplication and problematic omissions occur. Assigned roles help each person learn skills to contribute constructively.

Some Typical Roles

Manager or Facilitator

- Focuses team on task: "Let's do X now and complete this on time."
- Addresses team members by name and ensures that everyone is heard: "What do you think, (name)?"

Resource Manager

- Keeps on eye on the resources, particularly money and inventory: "We are running low on X, we should order more now."

Strategy Analyst

- Considers how the team is working and how it could improve
- Proposes ways to improve the group's work (multivoting, coffee break, conflict resolution…): "We have a few different ideas. Shall we make a list on the board?"

Recorder

- Records the important points, decisions, assigned tasks, etc.
- Notes who was present, absent
- Ensures records are made available: "This is an important conclusion. Wait a minute so I can write it down clearly."

Questioner

- Pushes back when decisions are made without considering other options, potential implications or potential areas of disagreement: "All the electrical engineers think this is a great idea. But what do the mechanical engineers think?"

Timekeeper

- Make sure team starts quickly and remains focused
- Keeps an eye on the clock and communicates about deadlines: "We have X minutes left." "We need to do the next question in 5 minutes or we will be late."

TASK: Prepare a summary to share with people have not read this page

-
-

"The POGIL Project". (2017). https://pogil.org

HANDOUT B
MINI-PROJECT ASSIGNMENT > DESIGN A MAKERSPACE

Create a design for a makerspace workshop for students in a robot competition.

Technical specifications

a. The workshop space should be at least 16 uL x 16 uL.
b. It must contain at least 5 machines ordered from the store.
c. There must be at least 1 door, centered on one wall.

uH unit of height
uL unit of length

Resources

a. Floor template and unrestricted access to LEGO blocks
b. Order sheet
c. Store to buy furniture and equipment according to the catalog

Budget: 80K is available to equip and furnish the space

Deliverables:

- A **scale LEGO model** with the machines/furniture placed appropriately
- **Handout C** – completed with design specifications and purchases

Catalog	Dimensions		Cost*	Location	Shipping
Machines	W x L (uL)	H (uL)			
CNC metal or wood	2x2	2	30k.-	EU	10min
3D printer plastic	1x1	1	10k.-	Asia	10min
3D printer powder	1x1	1	20k.-	EU	5min
Laser cutter	1x2	2	10k.-	Asia	10min
Injection molding plastic	2x2	2	40k.-	Canada	5min
Sewing machine	1x1	1	10k.-	Swiss	5min
Drill press	1x1	3	1500.-	Swiss	3min
Electronic drill	1x1	2	500.-	EU	5min
Work bench	1x2	3	1500.-	EU	5min
King size workbench	2x4	2	5000.-	USA	10min
Powerful computer	1x1	1	3000.-	Swiss	3min
Soldering machine	1x1	1	500.-	Swiss	3min
Advanced tool box	1x2	1	3000.-	EU	5min
Furniture	W x L (uL)	H (uL)			
Projector	1x1	1	3000.-	Local	
Screen uHD	0.5x4	4	2500.-	Local	
Table	3x2	2	500.-	Local	
Storage shelf	2x6	6	1500.-	Local	
Sofa	2x4	2	1500.-	Local	
White board	2x1	5	500.-	Local	
Coffee machine	1x1	1	300.-	Local	
Barista coffee machine	1x2	1	2000.-	Local	
Banner for the wall	4x0.5	2	200.-	Local	
Chairs	1x1uL	2	150.-	Local	

*Cost not including TVA 7% and border tax 15% for shipments coming from outside your region.

HANDOUT C
PROJECT DELIVERABLES

Write down 3+ **functional requirements** to guide your design of the space

- [ ]
- [ ]
- [ ]
- [ ]
- [ ]

Record your purchases in this table		quantity	price
1			
2			
3			
4			
5			
6			
7			
8			
9			
10			
11			
12			
13			
14			
15			
16			
17			
18			
		TOTAL	

HANDOUT D
LEARNING FROM EXPERIENCE

1. Use the checklist to evaluate the quality of your deliverables

Model	☐	≥ 5 machines or tools have been delivered and placed on the plans
	☐	Model delivered at least minimum viable product level (student teams can start work immediately)
	☐	Fixed elements (doors, windows, etc.) are shown, including at least one door big enough for the machines to be delivered
Requirements	☐	≥ 3 functional requirements are written on Handout C
	☐	Design created meets the requirements listed on Handout C
	☐	Several student teams can work simultaneously in the space
	☐	Clean and dirty equipment/tasks are separated
	☐	There is space for social / informal activities
Purchases	☐	All the equipment present on the plans is included in the budget, including VAT and border tax as appropriate
	☐	Money spent does not exceed the budget nor leave ≥ 3k
TOTAL	☐	/10

2. Use the checklist to evaluate the quality of your group processes

Planning	☐	We identified major deadlines to be met
	☐	We listed tasks to be done
	☐	We identified dependencies between tasks
	☐	We defined intermediate milestones to monitor our progress
	☐	We revised our planning when new information was available
Risk assessment	☐	We identified at least one major risk for the project
	☐	We identified measures to deal with the risks
	☐	We revised our risk analysis when new information was available
Resources	☐	We discussed the skills each team member brought to the project
	☐	We monitored the time available to complete our plan
	☐	We monitored the cost of the project
Teamwork	☐	We explicitly discussed how to make collective decisions
	☐	We took actions to ensure information circulated in the team
	☐	We paid attention to the atmosphere in our team
	☐	All team members were pretty much equally involved in the project
TOTAL	☐	/15

3. From this mini-project, I have learned…

4. On my next project, I intend to…

3T PLAY

Developing project skills

Projects are central to engineering, requiring us to integrate our technical skills in parallel to project skills.

This activity uses the design of a makerspace to create an experiential context to iterate and develop project skills to overcome key difficulties.

This session will help you improve your skills for

- **Risk assessment and planning** for projects
- **Collaboration and decision making** in teams

3T PLAY

Warm up

Read attentively the recommendations on **Handout A**.

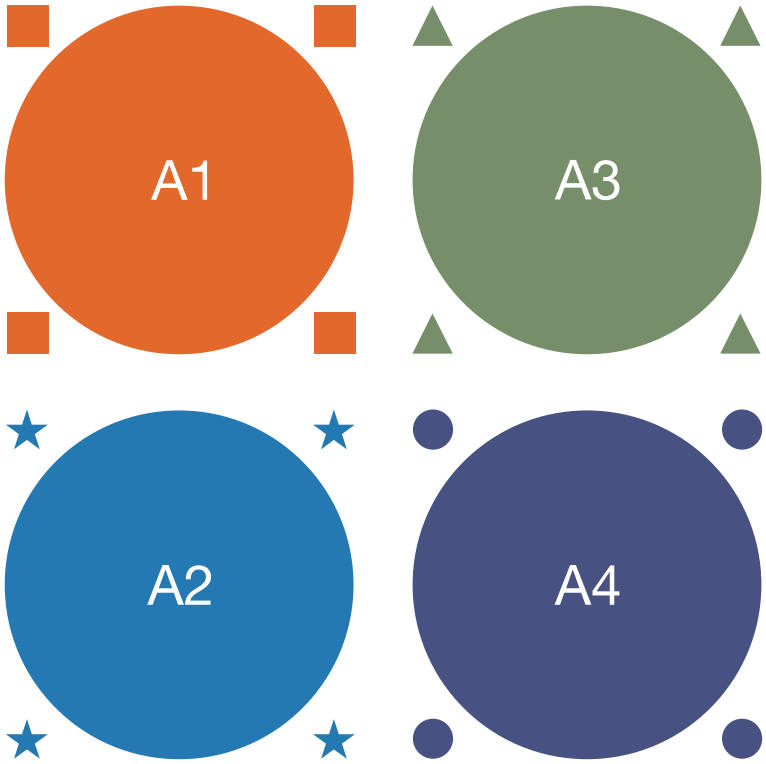
1. *Teamwork Tips*
2. *Planning Tips*
3. *Resource Management*
4. *Assigned Roles*

Then, discuss with your neighbours and prepare a summary of **2-3 key strategies** to share with someone who hasn't read the document.

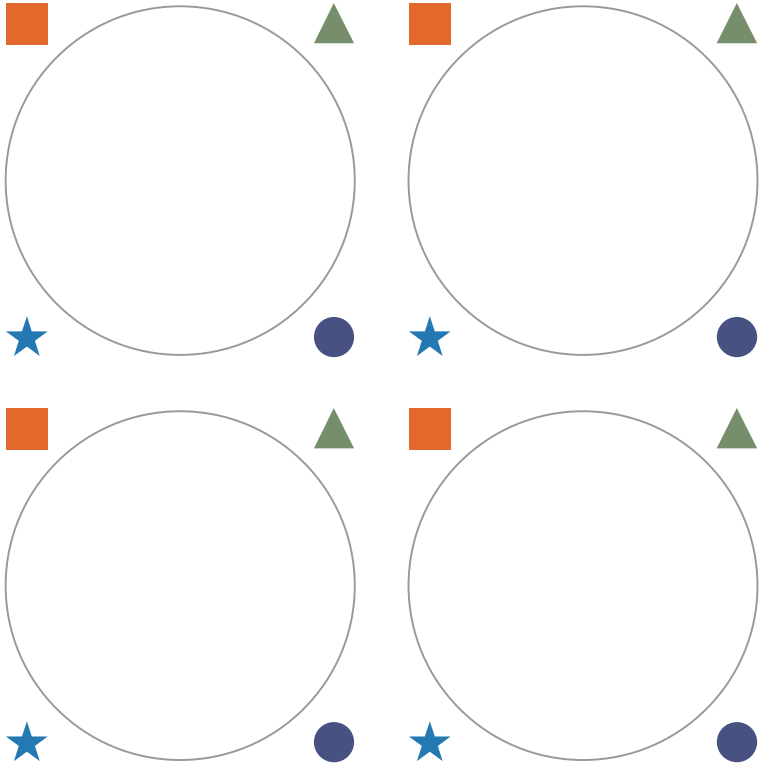
3T PLAY

For the next phase, please rearrange your groups to create mixed groups

PHASE 1



PHASE 2



3T PLAY

Team project skills debriefing

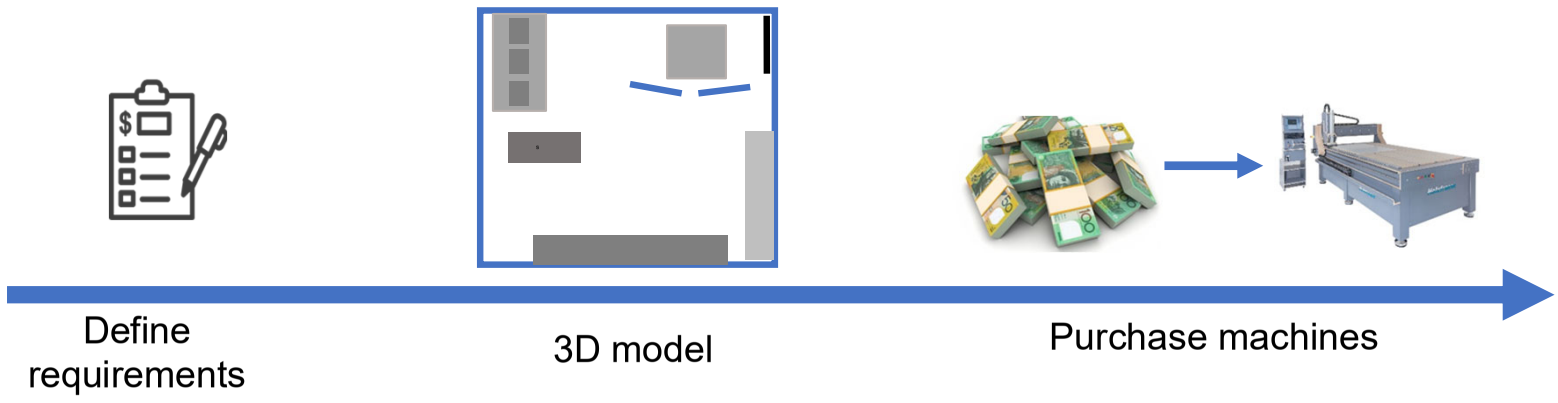
- **Share your key ideas summaries** of Handout A with your new team members
  - *Teamwork Tips*
  - *Planning Tips*
  - *Resource Management*
  - *Assigned Roles*
- **Distribute the assigned roles** within your group. Make this a learning experience by taking a different role than you usually take.

3T PLAY

Mini project assignment

You will design and equip a scale mock-up of the ideal "makerspace" for student teams to build highly innovative robots

- **Physical space** – represented by the LEGO board
- **Handout B – technical specifications and catalog of equipment**
- **Handout C – record design specification** and track purchases (80k)



3T PLAY

What do you expect to be TWO biggest challenges in this mini project?

2 votes per person

A. Unequal contributions from different people
B. Unpleasant team environment
C. Not enough time to do the project
D. Difficulty making decisions together
E. Information not flowing within the team
F. Managing the budget
G. Last minute changes creating other problems
H. Other

3T PLAY

Mini project deliverables – 30’ to work

You will design and equip a scale mock-up of the ideal “makerspace” for student teams to build highly innovative robots

- A **scale LEGO model** with the machines/furniture placed appropriately
- **Design specifications recorded** and purchases tracked on Handout C (budget 80k)

Note!

- **Machines ordered through the store**

Shipping delays, potential stock issues

- **Other items in the catalogue are built by you**

No shipping delays, help yourself to the LEGO pile

3T PLAY

What were the TWO biggest challenges in the mini project?

2 votes per person

A. Unequal contributions from different people
B. Unpleasant team environment
C. Not enough time to do the project
D. Difficulty making decisions together
E. Information not flowing within the team
F. Managing the budget
G. Last minute changes creating other problems
H. Other

Activity debrief - *learning from experience*

1. Complete the self-assessment on **Handout D** for
   - the DELIVERABLES your group produced
   - the PROCESSES your group practiced
2. How do your answers to Handout D relate the challenges identified in the pre and post quizzes?
3. In the context of this workshop, were the DELIVERABLES or the PROCESS more important…
   - in how your team worked together?
   - for learning the target skills and improving your next project?
   - demonstrating your project skills in a job interview?

Activity development and implementation

This activity was initially developed for engineering students involved in large scale interdisciplinary projects at a Swiss technical university. More than 400 students have participated, resulting in the robust activity presented in this chapter. It is also regularly facilitated for teaching assistants and engineering teachers involved in project work.

It has since been implemented in diverse contexts and for diverse audiences including:

Countries

Portugal

Denmark

United Kingdom

Switzerland

Conferences

QPES 2023 (Switzerland)

Audiences

Political science students

Social impact entrepreneurs

Engineering students

Student and doctoral assistants

STEM and engineering teachers

Researchers

References

1. Gluch, D. P. (1994). A Construct for Describing Software Development Risks. Technical Report CMU/SEI-94-TR-14. Software Engineering Institute, Carnegie Mellon University.

2. Accreditation Board for Engineering and Technology [ABET]. (2023). 'Criteria for Accrediting Engineering Programs, 2023 – 2024 | ABET'. 2023. https://www.abet.org/accreditation/accreditation-criteria/accreditation-policy-and-procedure-manual-appm-2023-2024/.

3. Commission des titres d'ingénieur [CTI]. (2023). 'The CTI's Major Criteria and Procedures – CTI – Commission Des Titres d'Ingénieur'. https://www.cti-commission.fr/en/fonds-documentaire.

4. Succi, C., & Canovi, M. (2019). Soft skills to enhance graduate employability: comparing students and employers' perceptions. Studies in Higher Education, 45(9), 1834–1847. https://doi.org/10.1080/03075079.2019.1585420

5. Kolmos, A, & Holgaard, J. E. Employability in Engineering Education: Are Engineering Students Ready for Work? (2019). In *The Engineering-Business Nexus: Symbiosis, Tension and Co-Evolution*, edited by S. H. Christensen, B. Delahousse, C. Didier, M. Meganck, and M. Murphy, 499–520. Philosophy of Engineering and Technology. Cham: Springer International Publishing. https://doi.org/10.1007/978-3-319-99636-3_22.

6. Winberg, C., M. Bramhall, D. Greenfield, P. Johnson, P. Rowlett, O. Lewis, J. Waldock, & Wolff, K. (2020). 'Developing Employability in Engineering Education: A Systematic Review of the Literature'. European Journal of Engineering Education 45 (2): 165–80. https://doi.org/10.1080/03043797.2018.1534086.

7. Koolmanojwong, S. & Boehm, B. (2013). A Look at Software Engineering Risks in a Team Project Course. In Proceedings of the 26th International Conference on Software Engineering Education and Training (CSEET'13). IEEE, 21–30. https://doi.org/10.1109/CSEET.2013.6595233

8. Licorish, S.A., Galster, M., Kapitsaki, G.M., & Tahir, A. (2022). Understanding Students' Software Development Projects: Effort, Performance, Satisfaction, Skills and Their Relation to the Adequacy of Outcomes Developed. J. Syst. Softw. 186, C. https://doi.org/10.1016/j.jss.2021.111156

9. Ahtee, T. & Poranen, T. (2009). Risks in Students' Software Projects. In Proceedings of the 22nd Conference on Software Engineering Education and Training (CSEET'09). ACM, NY, USA, 154–157. https://doi.org/10.1109/CSEET.2009.31

10. Kirk, D., Luxton-Reilly, A., & Tempero, E. (2022, February). Risks in student projects. In Proceedings of the 24th Australasian Computing Education Conference (pp. 143-152).

11. Vanhanen, J., Lehtinen, T. O. A., & Lassenius, C. (2018). Software engineering problems and their relationship to perceived learning and customer satisfaction on a software capstone project. *Journal of Systems and Software, 137*, 50–66. https://doi.org/10.1016/j.jss.2017.11.021

12. Kirk, D., Luxton-Reilly, A., & Tempero, E. (2023). Evaluating Student Risk Group Mitigation Strategies. IEEE Software.

13. Kirk, D., Luxton-Reilly, A., & Tempero, E. (2022, November). Refining a risk framework for student group projects. In Proceedings of the 22nd Koli Calling International Conference on Computing Education Research (pp. 1-11).

14. Carter, L. R., & Waite, W. M. (2000). Problem solving skills. *30th Annual Frontiers in Education Conference. Building on A Century of Progress in Engineering Education. Conference Proceedings (IEEE Cat. No.00CH37135), 2*, S1B/6-S1B10 vol.2. https://doi.org/10.1109/FIE.2000.896609

15. Moor, S. S., & Drake, B. D. (2001). Addressing Common Problems in Engineering Design Projects: A Project Management Approach. *Journal of Engineering Education, 90*(3), 389–395. https://doi.org/10.1002/j.2168-9830.2001.tb00618.x

16. Direito, I., Pereira, A., & Duarte, A. M. de O. (2012). Engineering Undergraduates' Perceptions of Soft Skills: Relations with Self-Efficacy and Learning Styles. Procedia - Social and Behavioral Sciences, 55, 843–851. https://doi.org/10.1016/j.sbspro.2012.09.571

17. Donald, W. E., Baruch, Y., & Ashleigh, M. (2019). The undergraduate self-perception of employability: Human capital, careers advice, and career ownership. Studies in Higher Education, 44(4), 599–614. https://doi.org/10.1080/03075079.2017.1387107

18. de Lima, J., Isaac, S., & Dehler Zufferey, J. (2024). Transversal Skills Priorities and Curricular Support as Experienced by Engineering Students on their Path to Becoming Responsible Engineers, in Proceedings of the 20th International CDIO conference.

19. Brunhaver, S. R., Korte, R. F., Barley, S. R., & Sheppard, S. D. (2018). Bridging the Gaps between Engineering Education and Practice. In R. B. Freeman & H. Salzman (Eds.), US Engineering in a Global Economy (pp. 129–163). University of Chicago Press. http://www.nber.org/chapters/c12687

20. Kovacs, H., Capdevila, I., Lermigeaux-Sarrade, I. J. L., & Jermann, P. (2023). From University to Work: Alumni Viewpoints. Proceedings of the CDIO 2023 Conference. CDIO 2023.

21. Picard, C., Hardebolle, C., Tormey, R., & Schiffmann, J. (2022). Which professional skills do students learn in engineering team based projects?. *European Journal of Engineering Education*, 47(2), 314-332.

22. Burdett, J. (2003). Making groups work: University students' perceptions. International Education Journal, 4(3), 177-191

23. Hall, D., & Buzwell, S. (2013). The problem of free-riding in group projects: Looking beyond social loafing as a reason for non-contribution. Active Learning in Higher Education, 14(1), 37-49.

24. Tormey, R., & Isaac, S. (with Hardebolle, C., & Le Duc, I.). (2022). *Facilitating experiential learning in higher education: Teaching and supervising in labs, fieldwork, studios, and projects*. Routledge.

25. Isaac, S., de Lima, J., Jalali, Y., Rossi, V., Schmid, S., Tormey, R., and Dehler Zufferey, J. 2024. Chapter 1: How to develop engineering students' transversal skills. In 3T PLAY (Eds.), *Teaching Transversal Skills for Engineering Students: a practical handbook of activities with tangibles*, Centre for Learning Sciences EPFL, Lausanne. https://doi.org/10.5281/zenodo.13328581

3T PLAY

LIST OF MATERIALS

- ◯ Slides to facilitate this activity
- ◯ 1x Handout A per student (A1, A2, A3 or A4 in roughly equal number)
- ◯ 1x Handout B per team*
- ◯ 1x Handout C per team*
- ◯ 1x Handout D per student
- ◯ Per team of 4-6 students†
  - ◯ 1 LEGO baseplate or paper equivalent (https://doi.org/10.5281/zenodo.12609232)
  - ◯ Assortment of classic LEGO bricks (150+ pieces per team)
  - ◯ 2 timers

* This design assignment can be substituted with another collaborative task where certain aspects are outside of students' control (i.e. access to materials).

† To see a video example of how the tangibles are used, visit **go.epfl.ch/videoCh6**

MORE ABOUT 3T PLAY

To learn more about the 3T PLAY project and access research output, please visit **go.epfl.ch/3TPLAY**

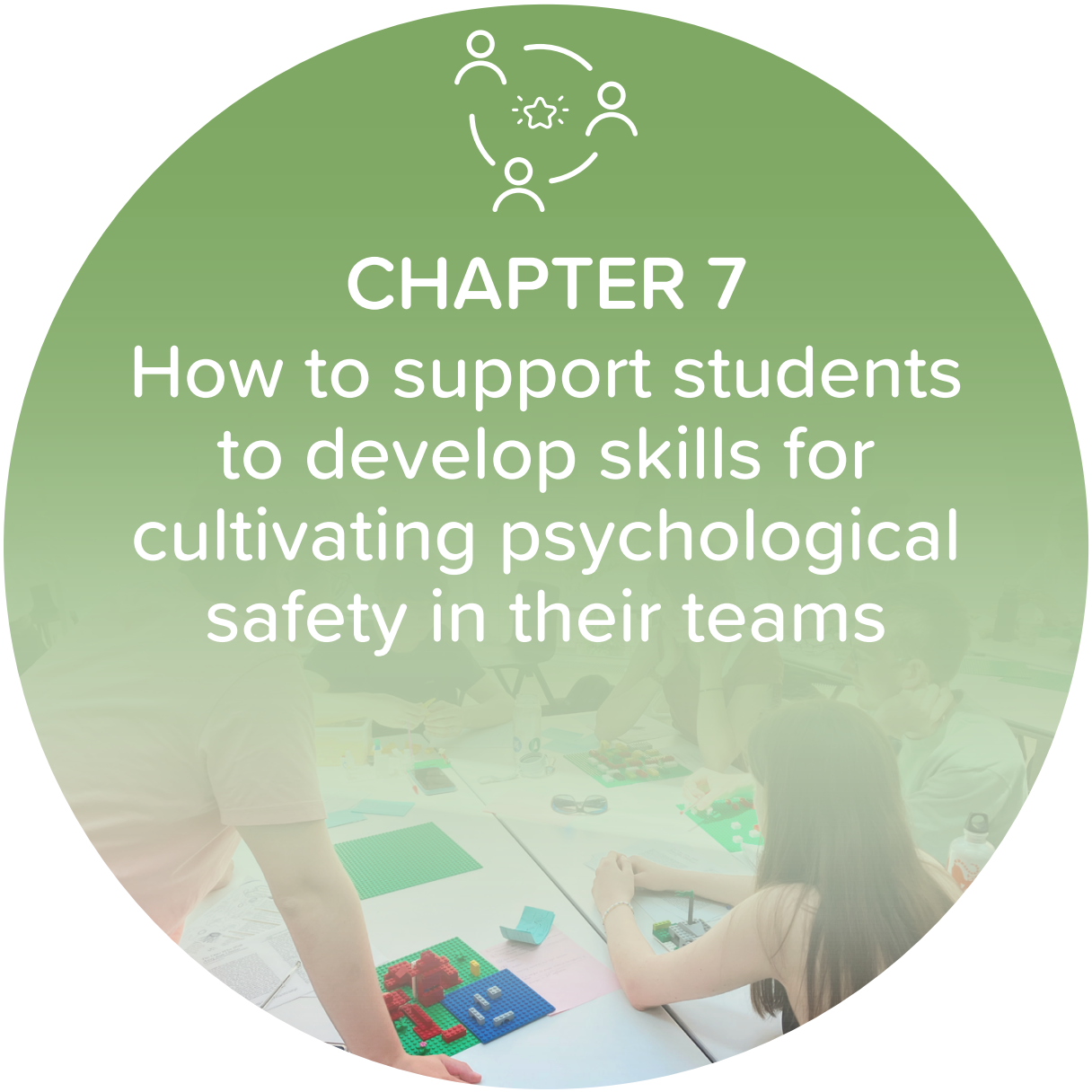
To access more teaching materials, please visit **https://zenodo.org/communities/3tplay/records**

HOW TO CITE THIS CHAPTER

Isaac, S., Schmid, S., Khorasani, A., and Jalali, Y. 2024. How to support students to develop risk assessment and planning skills. In 3T PLAY (Eds.), *Teaching Transversal Skills For Engineering Students: a practical playbook of activities with tangibles*, EPFL Press, Lausanne.

https://doi.org/10.55430/SJYVJ3TP24

3T PLAY



CHAPTER 7

How to support students to develop skills for cultivating psychological safety in their teams

Generously funded by

The LEGO Foundation

EPFL LEARN Center for Learning Sciences

3T PLAY

CHAPTER 7

How to support students to develop skills for cultivating psychological safety in their teams

CHAPTER INDEX

CONTRIBUTORS

- **Activity design + development:** Dr. Yousef Jalali, Beanta Alberink, Dr. Jessica Dehler Zufferey, Dr. Francesco Mondada, Dr. Siara Isaac, Dr. Natascia Petringa, Nicola Winzenried, and Dr. Roland Tormey
- **Writing this chapter:** Dr. Yousef Jalali, Beanta Alberink, Dr. Jessica Dehler Zufferey, and Dr. Francesco Mondada
- **Graphic design:** Laura Persat

3T PLAY

ACTIVITY 7

How to support students to cultivate psychological safety in their teams

ACTIVITY DESCRIPTION

The importance of psychological safety in teams has been demonstrated in different settings. Team performance improves when team climate allows team members to be their authentic selves, to ask questions and raise concerns comfortably. However, it is less clear how educators can support students to develop skills for cultivating psychological safety in their teams. Informed by the literature, this activity will help students to enhance their communication skills, more specifically skills for inquiry (asking questions) and listening, as the underlying foundation to create a psychologically safe team climate. Students will be introduced to conceptual foundations of conversational skills and will be given experiential opportunities to apply them in several exercises. This chapter provides the outline of an activity designed to teach the activity outcomes listed below, material to assist facilitators in preparing, and the slides and handouts for teaching the activity.

ACTIVITY OUTCOMES

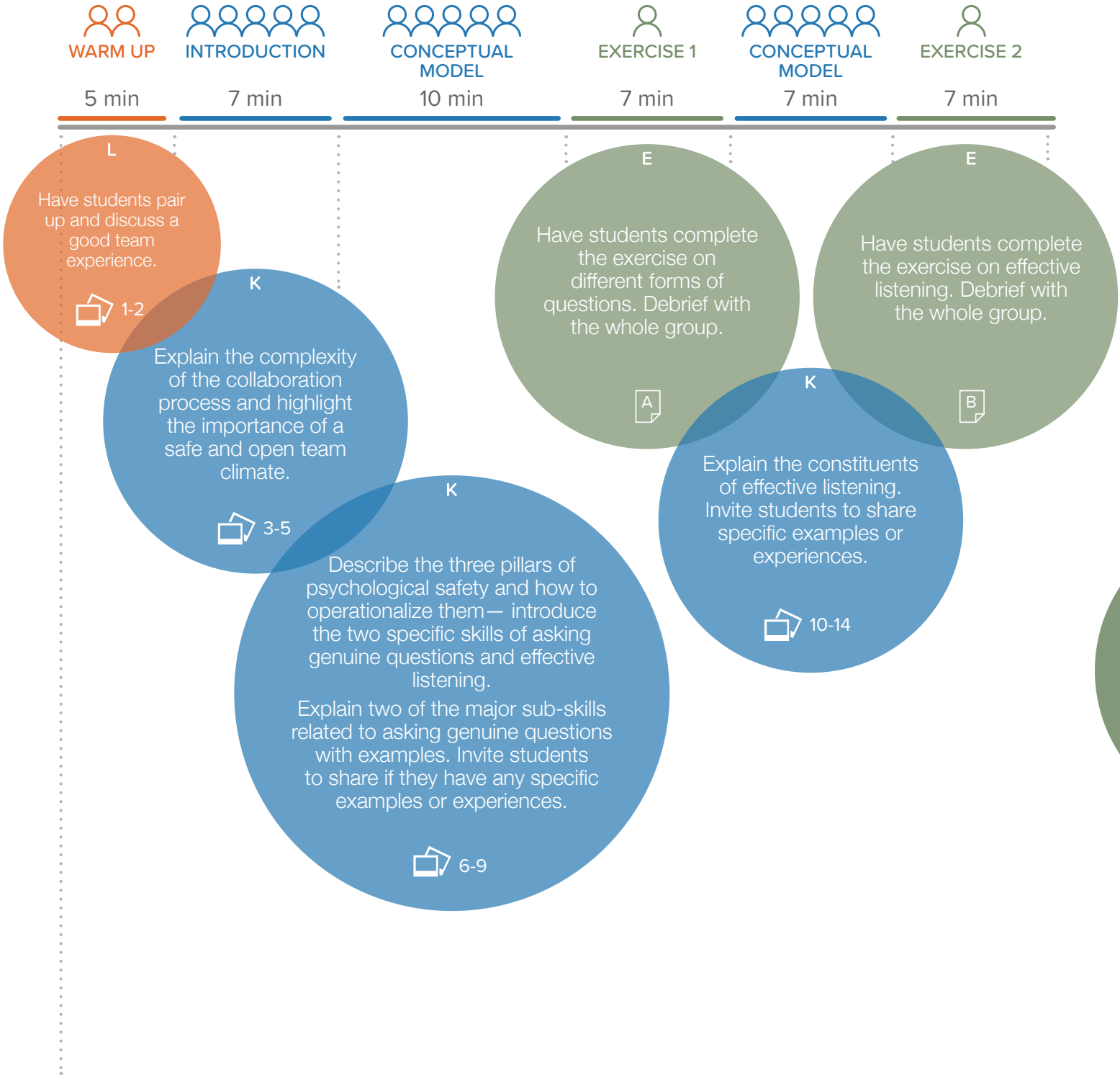
This 90-minute activity is designed for university-level engineering students. It targets the development of the following competencies for creating psychological safety in teams.

1. Inquiry and question-asking
2. Listening

3T PLAY

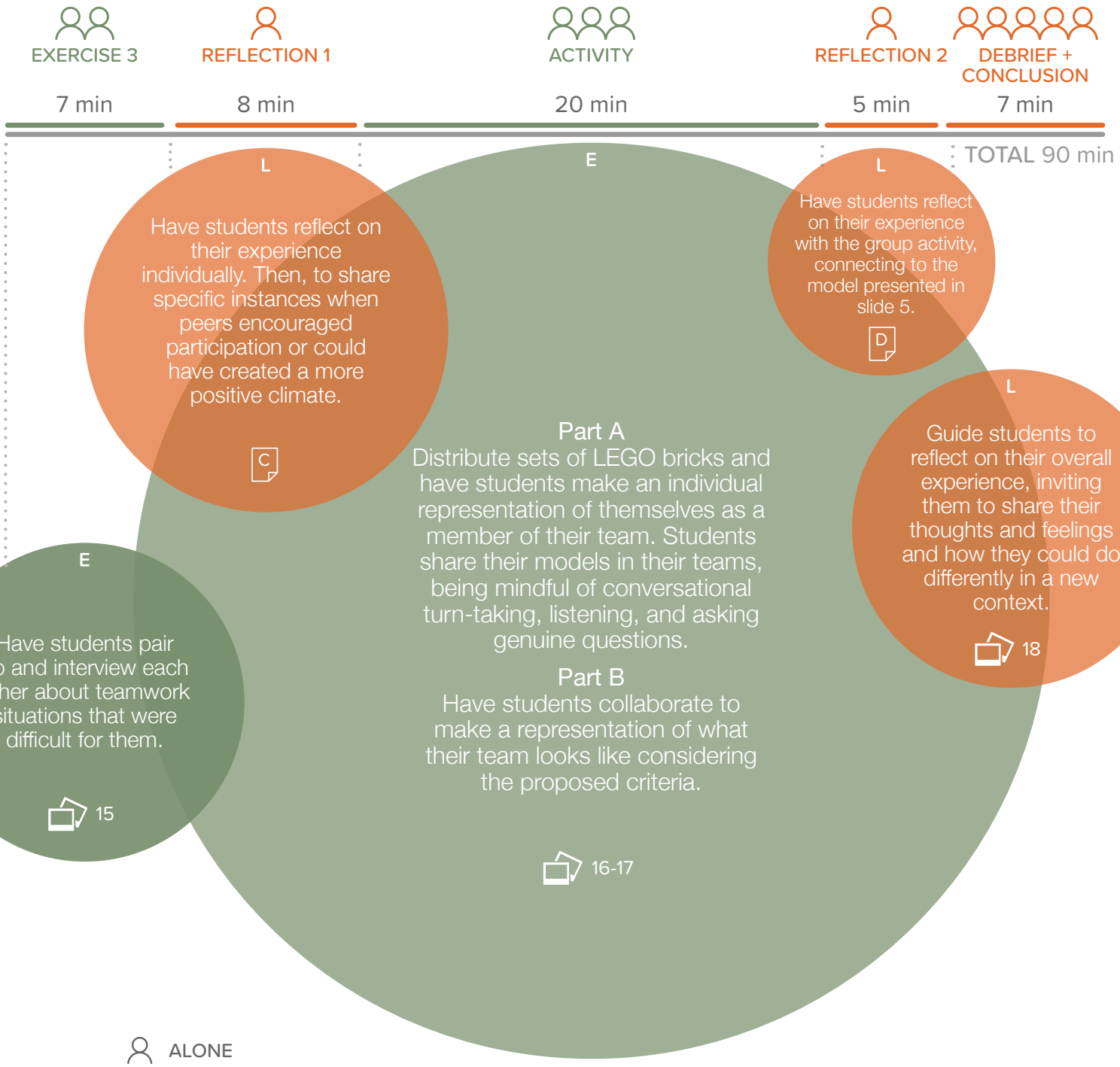
ACTIVITY

How to support students to cultivate psychological safety in their teams



PREPARATION

Set up the room for students to sit together with the members of their teams. While the activity assumes teams of 4 students at the formation stage, please adjust as needed for your context. Tangibles, LEGO bricks, are used to facilitate students' engagement and encourage authenticity and self-expression.



ALONE
PAIRS
SMALL GROUP
WHOLE GROUP
SLIDES
HANDOUT

K KNOWING
sharing knowledge and concepts that define the targeted skills

E EXPERIENCING
applying the concepts and tools in experiential learning

L LEARNING FROM EXPERIENCE
stepping back and reflecting about the activity enables students to transfer their skills

CONCEPTUAL AND PRACTICAL UNDERPINNINGS OF THE ACTIVITY

What skills will students develop in this activity?

Team psychological safety is a collective belief among team members that the team is safe for interpersonal risk-taking, where no one withholds their ideas, questions, and concerns, and there are more opportunities for giving and receiving feedback.[1,2] While there is consensus about the importance of psychological safety and its impact on team performance, there has been less attention to ways by which it can be operationalized in practice.[3] Prominent scholars, Amy Edmondson and William Kahn, uncovered essential components of a psychologically safe climate; for individuals to feel comfortable being themselves, to feel valued, and to believe that others have positive intentions, there should be a climate of trust and respect among people.[2,4] But what is underneath such a climate? In other words, in the context of student teams, what competencies would students need to create a "safe and open team climate"?—we use the two terms, psychological safety and safe and open team climate, interchangeably in this chapter. Granting the importance of quality of relationship in promoting psychological safety[5], microdynamics of interpersonal interactions, and more specifically, what we say and do during conversations would influence team climate. Building on the limited conceptual discussion of promoting psychological safety in teams[2,6-8], we used the term "skillful conversation" to highlight what members of a team should master to contribute to creating a safe and open team climate, and focusing on two essential interpersonal skills: inquiry and listening. While we present the two transversal skills separately in what follows, it is impossible to isolate one from another in conversations.

Inquiry

Asking for information is an effective way to encourage participation and empower others in any interpersonal setting. As Schein & Schein[7] argue we may miss opportunities to build personal relationship, characterized by openness and trust, simply due to failure to ask humbly with the right attitude. Schein & Schein coined the term *Humble Inquiry* as "the fine art of drawing someone out, of asking questions to which you do not already know the answer, of building a relationship based on curiosity and interest in another person".[7] Similarly, Van Quaquebeke and Felps used the term *Respectful Inquiry* as a multidimensional construct of "asking questions in an open way and subsequently listening attentively, which, in their interplay, signal the degree to which a person invites an addressee to (continue to) share his/her thoughts on a subject during a conversational episode."[9, p.7] To develop inquiry skills, students need to be aware of different ways of asking questions and recognize the difference between *telling* and *inquiry*. For instance, notice how using a question like "Didn't that make you angry?", instead of "How did that make you feel?", involves judgment and assumption that may close the door to a more genuine conversation. When one frames a question openly using the right tone, e.g., "Can you tell me more?" or "Can you tell me the whole story?", they minimize controlling and influencing the direction of the conversation, show their vulnerability, and demonstrate the importance of learning, which is radically different compared with when they ask confrontive questions.[7] In practice, students should see how framing open questions with an attitude of interest and curiosity, which demonstrates genuine interest in others and what they would say, helps people feel acknowledged and creates a safe climate to share and speak up.

Listening

Another essential component of genuine conversation is listening. To acknowledge and respect the presence of others, demonstrate care and concern for individuals and the relationship with them, and to understand them from their point of view effective listening is the key.[10,11] Different terms, with some overlapping dimensions, have been used in the literature to refer to listening skills, among them, active listening, empathetic listening, and active empathetic listening. Importantly, understanding speakers at a more human level with an appreciation of their experience and feelings has been highlighted in the conceptualization and measurement of effective listening.[12,13] In designing the activity, we borrowed from the listening framework demonstrated by DeVito[10] that includes the five-step process of receiving, understanding, remembering, evaluating, and responding to verbal (and/or nonverbal) messages. Note that asking questions is critical in both understanding what the speaker means and responding. Skills for improving listening at each stage should be introduced, and students should be given opportunities to practice effective listening. In introducing listening skills, educators can use examples reflecting on how different things could go wrong in conversations in teams (or interpersonal) settings; here are a few examples: getting distracted by the environment; jumping over and interrupting the speaker—perhaps because the listener has something interesting to say, or they make an assumption about the direction of conversation, or even worse they think what is said is of little worth of their time—; and tendency to fix/solve the speaker's problem without any efforts in seeing the problem from the speaker's point of view and appreciation of their feelings beyond what has been said. At a more fundamental level, genuine two-way interaction is about treating one another as a whole human being beyond characteristics and attributes;[14] that is why it is important to encourage students to be mindful of their assumptions and how they may conceive others. This, in turn, helps them to be attentive in conversations and develop a sense of appreciation for the speaker's effort and what is being said, whether they agree or not.

How to interest engineering students in learning these skills?

The ability to work effectively in teams is among widely recognized professional skills in engineering education,[15-17] in part due to the increasing demands of accreditation bodies, which is directly connected to the collaborative nature of engineering professional practice.[18,19] Working in teams requires specific competencies, some more context-driven for instance knowledge and skills pertaining task and its objectives, and other generic and transferrable to other settings, such as knowledge of teamwork skills or communication skills.[20] At a more macro-level, the primacy of psychological safety may need to be shared with students to highlight the relevance and meaningfulness of the activity. There is growing evidence documenting the influence of a safe and open team climate on team effectiveness and performance.[21-23] At a more micro-level, concerning specific skills, students should be given opportunities to see the relevance of inquiry and listening in promoting psychological safety. While implementing the activity outlined in this chapter in several settings at EPFL, we noticed how students naturally bring up components related to psychological safety when they are asked to reflect on their prior team experiences. The challenge is that many individuals take for granted that they possess skills in inquiry and effective listening. Building on students' experiences with teamwork, educators can demonstrate examples and incorporate exercises on how skillful conversation can contribute to flourishing individual and team capacity. In doing so, it is essential to employ active learning strategies, e.g., think-pair-share, and whole class discussion.

How does this activity help your students to develop these skills?

Although opportunities for teamwork within engineering curricula have been growing through various experiential activities, such as design projects, less attention has been paid to the conceptual underpinnings of collaboration and the need for explicit instruction for developing teamwork competencies. As highlighted in several exemplar reports and publications, there is a need for systematic instruction of teamwork skills and paying attention to the process of collaboration, in addition to outcomes.[18,24,25] Empirical studies have documented the benefits of explicit instruction of professional skills.[26] This activity has been designed to explicitly address communication competencies needed to build psychological safety, specifically at the earlier stages of the collaboration process, when trust and norms are developing within teams.[27] One of the things that could enhance the effectiveness of interventions centered around psychological safety is creating conditions for vulnerability and self-disclosure.[5] Incorporating components that encourage students to present their authentic selves, who they are, what their strengths or areas they would consider for improvement are in connection with a given task would be some strategies to promote authenticity and conversational disclosure. In terms of targeted transversal skills, we employed a trident framework[28] as a practical structure for teaching transversal skills—please see Chapter 1[29] of this book for an in-depth presentation of the framework.

The three aspects of the trident are:

Knowing: the factual knowledge and concepts that underpin a skill. For instance, different phases of effective listening.

Experiencing: focused, low-risk opportunities to practise the relevant skills while attending to the process, ideally with rapid feedback and a chance to iterate. For example, practicing asking open and genuine questions in an interview exercise.

Learning from experience: meta-cognitive and meta-emotional reflection about the experience of implementing conceptual knowledge and procedural skills. For example, reflecting on how and when students encouraged participation (or showed genuine interest).

An important element of this activity is the use of tangibles. We used tangibles, LEGO bricks, to create opportunities to practice skills and facilitate students' interaction through creation of concrete representation. Please see Chapter 1 for more details on the use of tangibles for creating micro-experiential activities. It is worth noting that our approach to using tangibles in this particular activity is methodologically akin to the core process of LEGO Serious Play (LSP), which facilitates building and sharing stories about the intangible world.[30] Specifically, we asked student to build and share individual models using LEGO bricks, and then, build shared models and stories.[30] The process creates a safe environment[31] that facilitates equality of participation and voices.[32-34] It is both playful and meaningful. It can create a context involving participants in the state of “flow” where they can be fully engaged and absorbed in the activity while following a purpose. We posit that the overall process and its essential underlying components of tangible activity align with the overall goal of cultivating psychological safety. In adapting the activity, educators should be clear about the purpose and communicate that the focus

is on meaning/stories (rather than models). It is also helpful to let students know that the use of LEGO bricks in visualizing and presenting ideas may remove barriers to self-expression and authentic voices,[32] and enhance safety in presenting challenging ideas,[33] otherwise hard to express. The process as a whole aligns with conceptualizations of psychological safety, where individuals should be their authentic selves without fear of negative consequences.[4]

Let's examine the details of the learning activity that addresses foundational skills in creating safe and open team climate, inquiry and effective listening. Notice how we started the activity with a reflective exercise by inviting students to think and discuss about a good team experience [slide 1]. This brief discussion is not only an effective warm-up, including when students just got to know their team members, but also helps educators to naturally make the connection with different aspects of the collaboration process [slide 2]. The illustration of the collaboration process on slide 2[35] is based on the conceptual frameworks on team effectiveness demonstrating the three core elements of inputs, processes, and outcomes,[27, 36, 37] which have been applied in different contexts. In what follows, we present the details of each phase, knowing, experiencing, and learning from experience, based on the order implemented.

Knowing: Students are introduced to the complexity of the collaboration process, the nature of their team project, and the importance of a safe and open team climate [slides 2-4]. To underline how psychological safety can be operationalized in team settings, students are introduced to the three pillars of psychological safety, framing the work as learning problem, acknowledging fallibility, and modeling curiosity[38] that will be attainable through skillful conversation [slides 5-6]. Focusing on inquiry skills, different forms of questions can be demonstrated by using examples. We encourage educators to invite students to share their examples/experiences [slides 7-9].

Experiencing: To help students imagine a challenging situation and apply what they have learned about the difference between telling and inquiry and ways to frame and pose questions, they are asked to complete the exercise I [Handout A]. Then, students are invited to share their insights with the whole group.

Knowing: Now focusing on effective listening, students are introduced to the major stages and elements of effective listening. Here again, students are invited to share if they have any specific examples or experiences [slides 10-14].

Experiencing: Students are asked to complete an exercise on effective listening in which they imagine how different responses are received by the speaker. They are encouraged to think about other potential responses and share their insights with the whole group [Handout B].

Experiencing: To bring the two skill sets together and create a more holistic and realistic practice situation, students are asked to pair up in their groups and interview each other about situations in which working in teams was difficult for them [slide 15]. Note that the theme again is team experience; students often have something to say about it; it is meaningful and personal. During the implementation, we did not give much time for preparation as this triggers a more authentic reflection. It is worth noting that teachers can choose other subjects for the interview, for instance, related to the definition and requirements of the team project.

Learning from experience: Students are invited to reflect individually on the interview experience, what went well and what could be improved [Handout C]. Then, they are invited to share specific instances in which their peers encouraged their participation or where they could do better to create a more positive climate.

Experiencing: Here is another opportunity for students to practice and be mindful of effective inquiry and listening in conversations. Students are first asked to build a model of themselves as a member of their groups using LEGO bricks and share the model with their team members [slide 16]. Then, they are asked to make a group representation of what their team looks like considering the proposed criteria [slide 17]. The activity enables students to visualize ideas, experiment through feedback and co-construction, and move towards building a shared vision about their team and task.[39] Meanwhile, it creates experiential opportunities for self-expression and practicing conversation skills.

Learning from experience: Students reflect on their experience with the group activity using LEGO bricks [Handout D]. Then, students reflect on their overall experience by answering the prompts; to be an effective exercise, a follow-up discussion should take place either in small groups (e.g., think-pair-share) or the whole class [slide 18].

Activity development and implementation

An initial version of this activity was designed and implemented in a graduate-level robotics course at a technical institution in Switzerland. The study evolved through discussions between two authors of this chapter where details of the course, observed challenges in teamwork, and potential interventions were explored. We later implemented the activity outlined in this chapter in a graduate-level management course focusing on transition and technology policy. It is worth noting that for both courses acquiring skills in effective teamwork was one of the major learning objectives. When asked to describe their experience working in teams after the interventions, most students shared positive impressions illustrating elements of supportive climate, perceived comfort, shared expectations, and motivation—a manuscript is currently under preparation. In total, more than 250 students have experienced this activity.

HANDOUT A
EXERCISE 1

A member of your team is not contributing as expected and is becoming less engaged in team meetings. You are not sure why. As a team member, you are worried about this.

What do you say in a one-on-one conversation?

What do you say in a team meeting?

On your own, think about different ways you could address the issue by:

I. Telling (without questions)

II. Asking a confrontive question

III. Asking a genuine question

Schein and Schein (2021)

HANDOUT B
EXERCISE 2

One of your classmates worked hard and prepared an outline for the term paper. Your professor asks them to change the topic and redo the entire outline. They are disappointed. In a meeting with several peers, they say, "I can't believe I have to redo this. I really worked hard on looking at the literature and drafting the outline, and now I have to do it all over again."

Based on what we have discussed on effective listening, how will each response be received by the person? Can you think of the main reasons?

A: "That's not so bad; I had to entirely redo it. That's normal."

B: "It is just a simple rewrite. No worries. I've heard several students changed their entire reports last semester."

C: "You have to rewrite the outline you've worked on for the past three weeks? You sound really frustrated."

Other potential responses?

DeVito (2022)

HANDOUT C
REFLECTION 1

How was it to do this exercise?

What have you done to create a genuine relationship with your peer?

When you reflect on what you have said and/or have done, what are the things that you did well?

When you reflect on what you have said and/or have done, what are the areas that you would like to work on?

What are the moments, interactions or comments that made you feel that you are valued and respected by your peer?

HANDOUT C
REFLECTION 1

What are the moments, interactions or comments that you think made your peer feel valued and respected?

Have a brief conversation with your peer and discuss how/when your peer showed genuine interest and encouraged your participation (at least one instance) and how/when they could better support your participation and foster a more positive climate (at least one instance).

HANDOUT D
REFLECTION 2

How was it to do this exercise? (How did it go?)

How did you show to the members of your team that you are open to questions, ideas, and feedback?

Can you remember what types of questions you asked?

How did you invite the others to share ideas and concerns?

How did you contribute to creating a safe environment?

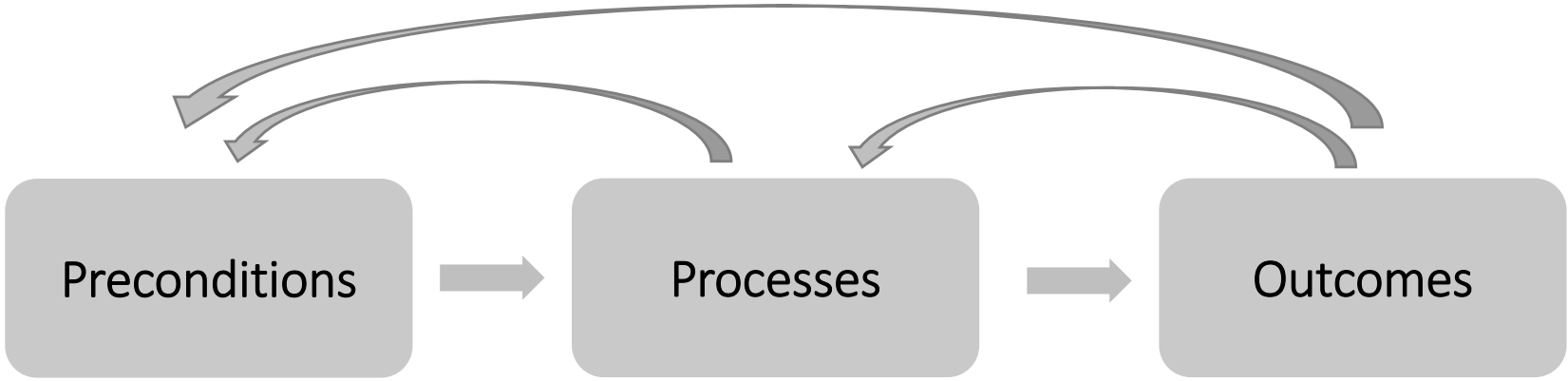
How did you demonstrate effective and thoughtful listening?

Teamwork and collaboration

Think about a **good team experience** you've had. What stands out about it? Pair up and discuss what you think made that experience good.

3T PLAY

Teamwork and collaboration



- Motivations and goals
- Surface-level diversity
- Deep-level diversity
- Prior interactions

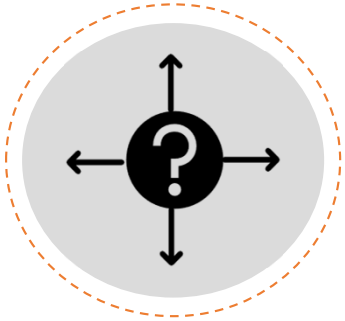
- Communication
- Coordination
- Decision making
- Dealing with conflict

- Team performance
- Satisfaction with membership

Ilgen et al. (2005); Jalali (2022); Marks et al. (2001)

3T PLAY

Your team project



Uncertainty

Interdependence

Potential for unsatisfactory performance

Or

Creativity and growth

3T PLAY

Increasing team effectiveness- Importance of a safe and open team climate

- Study of hundreds of Google's teams
- Intensive care teams in the United States and Canada
- Virtual project teams with different functions (e.g., engineering, IT, and management) in different industries
- …

With a safe and open team climate, people offer ideas, raise concerns, or ask questions; there are more opportunities for giving and receiving feedback, and overall team performance will improve.

Duhigg (2016); Gibson and Gibbs (2006); Nembhard and Edmondson (2006)

3T PLAY

Creating safe and open team climate

Framing your work as team learning

Acknowledging your vulnerability

Modeling curiosity

Through Skillful Conversation

Asking genuine questions

Effective listening

Edmondson (2014, 2018); Senge et al. (1994); Schein and Schein (2021)

3T PLAY

Skillful conversation-
A priority in creating safe and open team climate

Genuine two-way interactions

- Being speaker and listener
- Acknowledging the presence of the other person
- Demonstrating respect for the other person

3T PLAY

Skillful conversation- Asking genuine questions

- Using open questions (how, what, where, when, why)
- Being conscious when you switch between telling and different forms of questions

3T PLAY

Skillful conversation- Asking genuine questions

Using open questions

- "What other ideas could we generate?"
- "What might we be missing?"
- "Can you give me an example?"

"If I use this equation, do I get the right answer?"
vs.
"I'm looking to solve this problem, can you please help me with finding the proper equation?"

"Does this approach…"
vs.
"Which approach (do you think)…"

- Minimizing controlling, judging, or influencing
- Showing vulnerability
- Emphasizing learning

Edmondson (2018); Senge et al. (1994); Schein and Schein (2021)

3T PLAY

Skillful conversation- Asking genuine questions

Be conscious when you switch between telling and different forms of questions

"Here's what we will do.."

"What did you do?"
"Why didn't you say something about it?"

"Why do you suppose that happened?"
"Were they acting that way because they were scared?"

"How did that make you feel?"
"Didn't make you angry?"

"How were others reacting/feeling?"
"Were the others in the room surprised?"

"Can you tell me the whole story ….?"
"Can you give me an example?"

- Telling
- Diagnostic question
- Confrontive question
- Systemic question
- Genuine inquiry

Schein and Schein (2021)

Skillful conversation- Effective listening

- Focus your attention
- Understand what speaker means
- Organize and remember
- Evaluate the message
- Respond

Maintain your role as a listener
Don’t interrupt
Resist jumping in with evaluative, critical, or disparaging comment

Skillful conversation- Effective listening

- Focus your attention
- Understand what speaker means
- Organize and remember
- Evaluate the message
- Respond

See the speaker's message from speaker's point of view
Grasp both thought and emotions
Avoid assuming you understand what the speaker is going to say
Ask questions for clarification
Rephrase/paraphrase the speakers' ideas

Skillful conversation- Effective listening

- Focus your attention
- Understand what speaker means
- Organize and remember
- Evaluate the message
- Respond

Focus on central ideas
Rephrase and repeat names and key concepts

Skillful conversation- Effective listening

- Focus your attention
- Understand what speaker means
- Organize and remember
- Evaluate the message
- Respond

Resist evaluation until understanding the speaker's point of view

Skillful conversation- Effective listening

- Focus your attention
- Understand what speaker means
- Organize and remember
- Evaluate the message
- Respond

  Support the speaker; nodding, “I see”…
  Resist solving the person’s problems
  Avoid completing speaker’s thought or what you think speaker will say next

3T PLAY

Exercise III- Interviewing

Subject: Situations that working in teams were difficult for you, your experience, how you dealt with it.

Take 1-2 minutes to write down some ideas and think about introduction, the opening questions, and potential responses to the subject. Your role is **to learn and build relationships**.

Be mindful of **effective listening** and **asking open questions**.

a. Pair up and choose who will be the interviewer first

b. Interviewer introduces themselves, give an explanation of the purpose, and thank the interviewee.

c. Interviewer asks open questions and poses follow-up questions in response to what the interviewee says.

- Switch the roles

3T PLAY

Tangible activity- Part A

1. Using LEGO, build a representation of yourself as a member of this team. Please consider the following aspects.

- Areas of expertise and strengths
- Skills that you think need improvement
- What else can you offer to the group for creating a better team climate and improving team performance?

2. Share your LEGO model and engage in a brief discussion.

3T PLAY

Tangible activity- Part B

Create a group representation of what your team looks like. Build one model everyone agrees on which represents your team. What makes your team unique. Please address the following aspects.

- Team goals
- Provisional roles
- Safe and open environment for team learning, i.e., activities by which you share, refine, or combine task-relevant knowledge through interaction with one another.
- Potential risks and uncertainties you envision.

Debriefing

How did you feel during the activity?

What would you do differently in a new context? How would you do that?

What would you like to share with your peers based on this short experience?

References

1. Edmondson, A. (1999). Psychological safety and learning behavior in work teams. *Administrative science quarterly, 44*(2), 350-383.

2. Edmondson, A. C. (2018). *The Fearless Organization: Creating Psychological Safety in the Workplace for Learning, Innovation, and Growth.* John Wiley & Sons

3. Edmondson, A. C., & Bransby, D. P. (2023). *Psychological safety comes of age: Observed themes in an established literature. Annual Review of Organizational Psychology and Organizational Behavior,* 10, 55-78.

4. Kahn, W. A. (1990). Psychological conditions of personal engagement and disengagement at work. *Academy of Management Journal, 33*(4), 692-724.

5. Edmondson, A. C., & Lei, Z. (2014). Psychological safety: The history, renaissance, and future of an interpersonal construct. *Annual Review of Organizational Psychology and Organizational Behavior*, 1(1), 23-43.

6. Edmondson, A. C., & Besieux, T. (2021). Reflections: voice and silence in workplace conversations. *Journal of Change Management, 21*(3), 269-286.

7. Schein, E. H., & Schein, P. A. (2021). *Humble inquiry: The gentle art of asking instead of telling.* Berrett-Koehler Publishers.

8. Senge, P. M. (1994). *The Fifth Discipline Fieldbook: Strategies and Tools for Building a Learning Organization.* Crown Currency.

9. Van Quaquebeke, N., & Felps, W. (2018). Respectful inquiry: A motivational account of leading through asking questions and listening. *Academy of Management Review*, 43(1), 5-27.

10. DeVito, J. A. (2022). *The Interpersonal Communication Book*. 16th edition, Pearson.

11. Rogers, C. R., & Roethlisberger, F. J. (1991). Barriers and gateways to communication. *Harvard Business Review*, 69(6), 105-111.

12. Bodie, G. D. (2011). The Active-Empathic Listening Scale (AELS): Conceptualization and evidence of validity within the interpersonal domain. *Communication Quarterly*, 59(3), 277-295.

13. Drollinger, T., Comer, L. B., & Warrington, P. T. (2006). Development and validation of the active empathetic listening scale. *Psychology & Marketing*, 23(2), 161-180.

14. Buber, M. (1958). *I and Thou*. Trans. R.G. Smith, New York: Charles Scribner's Sons.

15. Crawley, E., Malmqvist, J., Ostlund, S., Brodeur, D., & Edstrom, K. (2007). Rethinking engineering education. *The CDIO approac*h, 302(2), 60-62.

16. Cruz, M. L., Saunders-Smits, G. N., & Groen, P. (2020). Evaluation of competency methods in engineering education: a systematic review. *European Journal of Engineering Education*, 45(5), 729-757.

17. Jalali, Y., Kovaks, H., Isaac, S., & Dehler Zufferey, J. (2022). Bringing Visibility to Transversal Skills in Engineering Education: Towards an Organizing Framework. *50th Annual Conference of the European Society or Engineering Education* (SEFI).

18. Borrego, M., Karlin, J., McNair, L. D., & Beddoes, K. (2013). Team effectiveness theory from industrial and organizational psychology applied to engineering student project teams: A research review. *Journal of Engineering Education*, 102(4), 472-512.

19. Trevelyan, J. (2019). Transitioning to engineering practice. *European Journal of Engineering Education*, 44(6), 821-837.

20. Cannon-Bowers, J. A., Tannenbaum, S. I., Salas, E., & Volpe, C. E. (1995). Defining competencies and establishing team training requirements. *Team effectiveness and decision making in organizations*, 333, 380.

21. Duhigg, C. (2016). What Google learned from its quest to build the perfect team. *The New York Times Magazine*, 26.

22. Nembhard, I. M., & Edmondson, A. C. (2006). Making it safe: The effects of leader inclusiveness and professional status on psychological safety and improvement efforts in health care teams. *Journal of Organizational Behavior: The International Journal of Industrial, Occupational and Organizational Psychology and Behavior, 27*(7), 941-966.

23. Gibson, C. B., & Gibbs, J. L. (2006). Unpacking the concept of virtuality: The effects of geographic dispersion, electronic dependence, dynamic structure, and national diversity on team innovation. *Administrative science quarterly*, 51(3), 451-495.

24. National Academies of Sciences, Engineering, and Medicine. (2017). *Supporting students' college success: The role of assessment of intrapersonal and interpersonal competencies.* National Academies Press.

25. National Research Council. (2012). *Education for life and work: Developing transferable knowledge and skills in the 21st century.* National Academies Press.

26. Picard, C., Hardebolle, C., Tormey, R., & Schiffmann, J. (2022). Which professional skills do students learn in engineering team-based projects? *European Journal of Engineering Education*, 47(2), 314-332.

27. Ilgen, D. R., Hollenbeck, J. R., Johnson, M., & Jundt, D. (2005). Teams in organizations: From input-process-output models to IMOI models. *Annual Review of Psychology*, 56, 517-543.

28. Isaac, S., Petringa, N., Jalali, Y., Tormey, R., & Dehler Zufferey, J. (2023). Are engineering teachers ready to leverage the power of play to teach transversal skills? 51st Annual Conference of the European Society for Engineering Education (SEFI), Dublin, Ireland, September 11-14.

29. Isaac, S., de Lima, J., Jalali, Y., Rossi, V., Schmid, S., Tormey, R., & Dehler Zufferey, J. (2024). Chapter 1: How to develop engineering students' transversal skills. In 3T PLAY (Eds.), *Teaching Transversal Skills for Engineering Students: a practical playbook of activities with tangibles*, Centre for Learning Sciences, EPFL, Lausanne. https://doi.org/10.5281/zenodo.13328581

30. Kristiansen, P., & Rasmussen, R. (2014). *Building a Better Business Using the Lego Serious Play Method*. John Wiley & Sons.

31. Dann, S. (2018). Facilitating co-creation experience in the classroom with Lego Serious Play. *Australasian Marketing Journal, 26*(2), 121-131.

32. McCusker, S. (2020). Everybody's monkey is important: LEGO® Serious Play® as a methodology for enabling equality of voice within diverse groups. *International Journal of Research & Method in Education, 43*(2), 146-162.

33. Schwabenland, C., & Kofinas, A. (2023). Ducks, elephants and sharks: Using LEGO® Serious Play® to surface the 'hidden curriculum'of equality, diversity and inclusion. *Management Learning, 54*(3), 318-337.

34. Zenk, L., Primus, D. J., & Sonnenburg, S. (2022). Alone but together: flow experience and its impact on creative output in LEGO® SERIOUS PLAY®. *European Journal of Innovation Management, 25*(6), 340-364.

35. Jalali, Y. (2022). What sustains inter-institutional collaborations? An exploratory study of research collaborations between faculty at HBCUs and PWIs. Unpublished doctoral dissertation, Virginia Tech.

36. Marks, M. A., Mathieu, J. E., & Zaccaro, S. J. (2001). A temporally based framework and taxonomy of team processes. *Academy of management review*, 26(3), 356-376.

37. Mathieu, J., Maynard, M. T., Rapp, T., & Gilson, L. (2008). Team effectiveness 1997-2007: A review of recent advancements and a glimpse into the future. *Journal of management*, 34(3), 410-476.38. Edmondson, A. (2014). Building a psychologically safe workplace. TEDx Talk, https://youtu.be/LhoLuui9gX8?si=SBssQCJygOr-WXQD1

39. Jalali, Y., Bürer, M. J., Petringa, N., & Zufferey, J. D. (2023). What Role Do Tangibles Play in Fostering Design Thinking Skills? An Exploratory Study. In 2023 *IEEE Frontiers in Education Conference* (FIE) (pp. 1-9). IEEE.

3T PLAY

LIST OF MATERIALS

- ◯ Slides to facilitate this activity
- ◯ 1x Handout A per student
- ◯ 1x Handout B per student
- ◯ 1x Handout C per student
- ◯ 1x Handout D per student
- ◯ Mixed selection of classic LEGO bricks, special elements, and minifigure parts, and one baseplate for each team to build their group representation

MORE ABOUT 3T PLAY

To learn more about the 3T PLAY project and access research output, please visit **go.epfl.ch/3TPLAY**

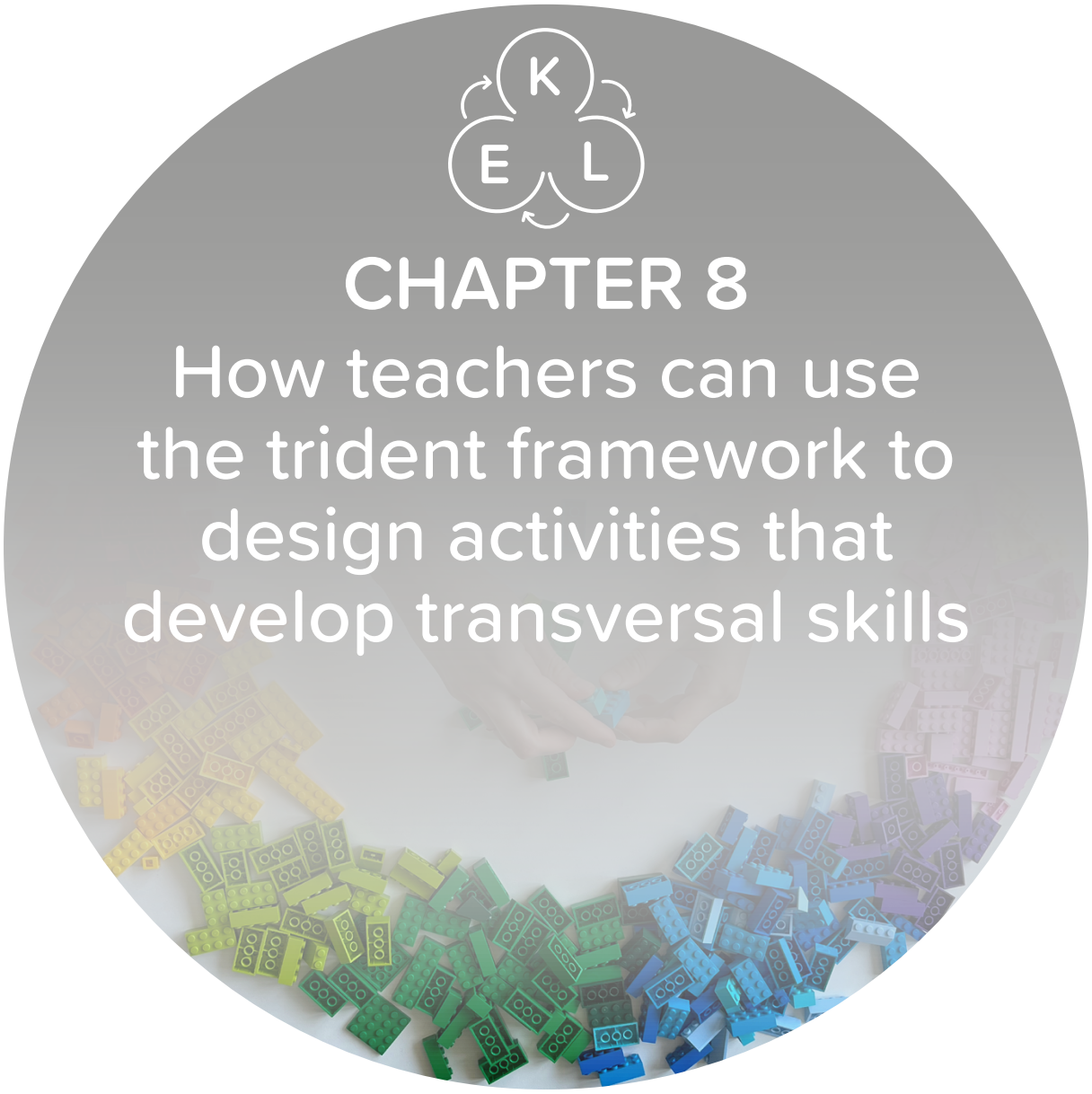
To access more teaching materials, please visit **https://zenodo.org/communities/3tplay/records**

HOW TO CITE THIS CHAPTER

Jalali, Y., Alberink, B., Dehler Zufferey, J., and Mondada, F. (with Isaac, S., Petringa, N., Winzenried, N., and Tormey, R.). 2024. How to support students to develop skills for cultivating psychological safety in their teams. In 3T PLAY (Eds.), *Teaching Transversal Skills For Engineering Students: a practical playbook of activities with tangibles*, EPFL Press, Lausanne.

https://doi.org/10.55430/SJYVJ3TP24

3T PLAY



CHAPTER 8

How teachers can use the trident framework to design activities that develop transversal skills

Generously funded by

The LEGO Foundation

EPFL LEARN Center for Learning Sciences

3T PLAY

CHAPTER 8

How teachers can use the 3T PLAY trident framework to design activities that develop transversal skills

CHAPTER INDEX

CONTRIBUTORS

- **Activity design + development:** Dr. Siara Isaac, Valentina Rossi, Dr. Yousef Jalali, and Dr. Joelyn de Lima
- **Writing this chapter:** Dr Siara Isaac and Dr Joelyn de Lima
- **Graphic design:** Laura Persat

CHAPTER 8

How teachers can use the 3T PLAY trident framework to design activities that develop transversal skills

ACTIVITY DESCRIPTION

This playbook contains several activities for teaching transversal skills.

However, your students might need to, or want to, develop skills that are not addressed in these activities. This chapter is designed for just such a situation. The activities in this chapter will guide you to identify relevant transversal skills and to design corresponding experiential learning activities. Explicit scaffolding using our trident framework will ensure that the activity you develop includes the three aspects essential for robust skill development: **Knowing, Experiencing** and **Learning from experience**.

The time necessary for this self-paced activity varies between people, however you should expect to invest 60 minutes to complete a first prototype of an activity.

ACTIVITY OUTCOMES

This chapter is designed for higher education teachers.

It assists them to

1. Identify relevant transversal skills for their students
2. Design a prototype of an activity based on the trident framework to develop students' level for these skills

CONCEPTUAL AND PRACTICAL UNDERPINNINGS OF THIS CHAPTER

Designing learning activities to develop engineering students' transversal skills

The importance of engineering students' transversal skills, and associated desire to improve, has been documented from students[1–4], employers[5–10], alumni[11,12] and engineering accreditation bodies[13–15].

Project activities provide engineering students with practical opportunities to use procedural skills and offer excellent opportunities to integrate transversal skills with disciplinary thinking. An important limitation is that students may find it difficult to perceive the skills as distinct from accomplishing the project tasks[16], a lack of visibility exacerbated when feedback and assessment activities do not include transversal skills[17]. It has been conclusively documented that, for students to effectively develop transversal skills, they need instruction on the strategies and methods underpinning the skills and not just opportunities to practise them[18,19]. However teachers rarely include explicit learning activities for these skills[20,21].

Previous work suggests that teachers would appreciate more practical support on how to incorporate opportunities for skill development in their courses[19,21,22]. This chapter provides a structured backward design process guide to implementing the 3T PLAY trident framework (Fig. 1) to design activities that develop transversal skills.

Backward Design Process

The worksheets in this chapter constitute a backward design approach[23] to creating a new activity using the 3T PLAY framework for teaching 1-2 transversal skills. It provides a step-wise guide to identifying desired outcomes, specifying how and when students should be able to implement the skill, and structuring the components to create a learning experience targeting the desired skill[24].

Briefly, the activities in this chapter follow the path below:

Identifying desired results - What skills do you want students to develop?

The backward design process starts with identifying the desired results. In the context of a 3T PLAY activity, this means identifying the skills that students will improve/develop as a result of participating in the new activity. This identification of relevant skills would ideally be jointly developed from priorities of the individual teacher and the context of their course, the program-level outcomes for graduate attributes defined for the degree program, and the needs/priorities of the students. It is, however, pertinent to keep the micro-scale of the 3T activities in mind. This means that the skills targeted should be quite specific and the intended improvement be realistic. For instance, 'communication skills' is too broad and specifying 'oral presentation skills' would better assist with structuring an effective activity. Similarly, it is unlikely that a 60-minute activity could feasibly increase first year students' skills to the level of 'deliver highly structured and engaging oral presentations'. In Worksheet A, you will be prompted to first identify and then refine a list of transversal skills relevant for your own context.

Determine evidence to show learning has occurred

Next, we consider how students' development of the skill can be observed. This requires articulating the knowledge about the skill students should acquire, typical difficulties in implementation that they should be able to overcome, and the situations they should recognise as relevant for implementing the skill. The activities in Worksheet A will guide you through this process.

Plan the learning experience

Finally, Worksheets B1 & B2 will guide you to sequence the elements you developed above to create an experiential activity that supports students to develop the target transversal skills.

The 3T PLAY trident framework for teaching transversal skills

Our trident framework (Fig. 8.1) provides a practical structure for teaching transversal skills that addresses the issues identified above to ensure that students are really learning. Please see Chapter 1[25] of this book for an in-depth presentation of the framework.

The three aspects of the trident are

Knowing: the factual knowledge and concepts that underpin a skill. The importance of providing conceptual knowledge related to transversal skills is often overlooked.

For instance, knowledge of different persuasive strategies.

Experiencing: focused, low-risk opportunities to practise the relevant skills while attending to the process, ideally with rapid feedback and a chance to iterate.

For example, negotiating to obtain a mutually acceptable solution that incorporates your own priorities and then doing it a second time to immediately apply what was learned from the first round.

Learning from experience: meta-cognitive and meta-emotional reflection about the experience of implementing conceptual knowledge and procedural skills. This is a key step in transfer, that is in students being able to apply or implement what they learn from this activity in future situations.

For example, reviewing the experience to identify the kinds of arguments that were successful in persuading others and reflecting on why this experience was similar or different to previous negotiations.

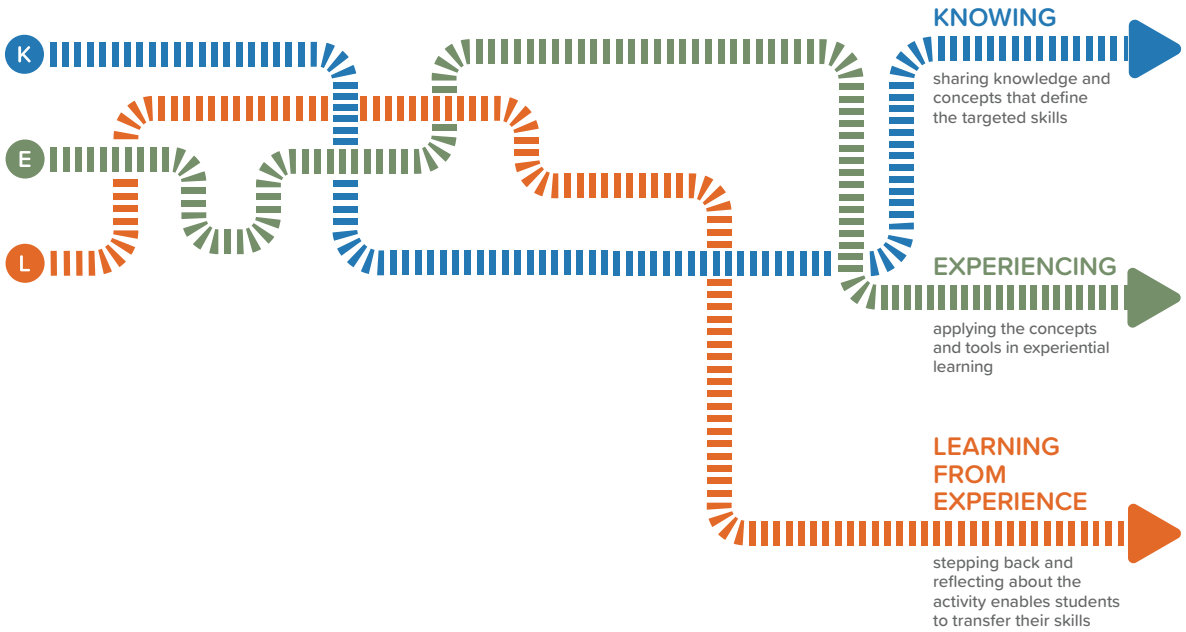


Figure 8.1: The 3T PLAY trident framework

Creating experiential learning activities

To reach our objective of supporting engineering students' to develop robust transversal skills, we need to provide them with opportunities to practice, to encounter authentic challenges, iterate, and reflect on their experiences. Experiential learning, where students actively apply their knowledge and skills in context, is ideally suited to the development of transversal skills. Please see Chapter 1[25] for a review of the conditions which support effective experiential learning, including clear learning objectives, deliberate practice, cognitive load, and addressing misconceptions.

Your activity should include each of the aspects from our trident to ensure that students encounter activities that prompt the three types of thinking and develop a degree of proficiency in the targeted skills that allows them to apply them in their next project. Before you get started designing your own activity, we recommend that you look back over the previous chapters of this playbook to identify some typical activities for each aspect of the trident: **Knowing, Experiencing** and **Learning from experience**.

Designing an activity is a creative process - creativity is fostered by a playful approach, collaboration and a bit of silliness. So you will make better progress with these worksheets if you start with a good mood and allow your thinking to make connections. Co-designing an activity with a small group of colleagues is helpful to stimulate creativity. A backward design process is rarely linear. Looping back to revise previous steps is normal and even encouraged to make your activity more consistent and focused.

In the next pages of this chapter, you will find:

- instructions to start creating an activity using the 3T PLAY framework for teaching transversal skills (Worksheet A).
- guidance for designing the temporal structure of your activity (Worksheets B1 & B2).

Additional resources in this chapter include support for articulating specific and relevant transversal skills (Appendix 1) and a completed example of Worksheet A (Appendix 2). We conclude with a section on piloting and revising your activity.

Let's get started!

ACTIVITY DESIGN WORKSHEET A

Please allow 40+ minutes for this worksheet.

The steps below will assist you to design an experiential learning activity that targets the development of students' transversal skills. You will be guided through a backward design process, so Worksheet A starts with you defining the learning objective and then considering how to enable your students to accomplish the learning objective.

Design processes are typically non-linear, so allow yourself to bounce forward and backward. In Worksheets B1 & B2, you will put your ideas and design elements into a timeline to create a coherent activity.

STEP 1. Identify the transversal skills that your activity will assist students to develop.

a

On a piece of scrap paper, make a list of 4-6 skills that your students should develop during your course. If you need a little inspiration, see the list of transversal skills in Table 8.2 in Appendix 1.

b

Use this checklist to remove or reformulate non-skills. For additional guidance, see Table 8.1 in Appendix 1.

- Is it a skill, involving know-how (and not just knowledge)?
- Is it a skill students can develop (and not a personality characteristic)?
- Is it formulated to point to a specific skill (and not a category of skills)?

c

Review your list to

- remove skills that are implemented differently depending on the discipline. Test this by adding 'in discipline' - for instance 'critical thinking in water infrastructure' requires different approaches than 'critical thinking in electrical circuits'
- highlight skills that are used in multiple contexts, important for your course, under-developed in the curriculum or required by professionals

d

Review the priorities indicated by your highlighting and choose 1-2 'target skills' on which to focus. **Write these below.**

Skill 1	Skill 2

ACTIVITY DESIGN WORKSHEET A

STEP 2. Identify academic and/or future professional situations that require the students to implement each of the target skills. You may, or may not, want to consult the worked example in Appendix 2.

a

When do students use this skill? And professionals? Make a list of 2-3 situations for each target skill.

Situations for skill 1	Situations for skill 2
1	1
2	2
3	3

b

Which obstacles and difficulties do students encounter when they implement the skills? Make a list of 2-3 difficulties for each skill.

Difficulties about skill 1	Difficulties about skill 2
1	1
2	2
3	3

c

Based on your responses above, choose the one skill that you will prioritise in the development of your activity. Highlight your choice in 1d.

ACTIVITY DESIGN WORKSHEET A
LEARNING FROM EXPERIENCE

STEP 3. What do you want students to take away from the activity? Asking this question is fundamental to backward design, where you identify the desired result and then work backwards to determine how to help students accomplish this result.

To clarify what students should learn, imagine one of your students has a job interview and the interviewer says, "Tell me about a time when you need to implement [skill] and how you went about it." The interviewer is likely looking for (1) a description of a situation that required this skill, (2) a personal account of using a specific strategy related to this skill and (ideally) (3) some insight or personal growth arising from their experience.

In this step of the activity design, you will create reflective questions to help students digest their experiences, enabling them to recognise situations that require the target skills, to structure how they implement the skills, and to evaluate the effectiveness of the implementation. These questions are essential to students' capacity to transfer what they learn in this activity to their coursework and beyond. Transfer is supported when students think about why the skills were needed, how they were implemented, and potential similarities or differences with 'real' contexts.

a

What are the key signs that students can use to identify situations in which the target skill should be implemented?

b

For students to learn from their experience, they need to perceive the relevant parts of the experience and how it connects to the target skill. What would enable students to evaluate how well they and their peers implemented the skills?

ACTIVITY DESIGN WORKSHEET A
LEARNING FROM EXPERIENCE

c

Your responses above should represent the **Learning from experience** that your students need to achieve to be able to transfer (implement the skill in future situations) their learning to their next challenge. Reformulate your response to 3a+b as questions directed to students, and write them in the **Learning from experience** box*

LEARNING FROM EXPERIENCE

* In Worksheet B2, you will transfer elements from the coloured boxes to the activity template. It may, therefore, be more convenient to affix sticky notes in the coloured boxes and write on the sticky notes.

ACTIVITY DESIGN WORKSHEET A
EXPERIENCING

STEP 4. This step is about creating an experiential activity to allow students to implement the transversal skill in a low-stakes environment. It should generate a context for students to implement the target skill (review your response 2a) and experience common difficulties (see 2b). We have found this step requires creativity and several iterations. If you are having difficulty getting started, we recommend adapting an activity already used in this playbook to refocus on the development of your target skill.

For example,

creating a product requires organisational and problem solving skills.	See Chapter 2 (https://doi.org/10.5281/zenodo.13328621) and Chapter 6 (https://doi.org/10.5281/zenodo.11263642).
working in teams requires development of collaborative and emotional management skills.	See Chapter 3 (https://doi.org/10.5281/zenodo.10392344) and Chapter 4 (https://doi.org/10.5281/zenodo.10731771).
using an object to generate interactions.	See Chapter 5 (https://doi.org/10.5281/zenodo.10931765) and Chapter 7 (https://doi.org/10.5281/zenodo.11192095).

In the **Experiencing** box*, write a brief description of a learning activity where students can practice the target skill and encounter relevant difficulties. Consider including the following details:

- What tasks will students attempt to complete? What constraints will ensure they encounter authentic difficulties?
- How much time will they have? What materials will they have available?
- Will they work alone, in pairs, small teams or as a class?

EXPERIENCING

ACTIVITY DESIGN WORKSHEET A
KNOWING

STEP 5. This step is about identifying existing knowledge, frameworks, and tools that can help students implement and develop your targeted skill. You may need to do some research - for many transversal skills, the 'tools' that students should learn to use are mental tools or approaches, which can make them difficult to perceive.

a

What advice do you give students when they encounter the difficulties listed in Step 2b? What actions do you propose they take?

b

What strategies, models or concepts informed your advice in Step 5a? Write some key words in **Knowing** box* - later, these can guide your research into models, strategies or concepts to provide a robust underpinning for students.

KNOWING

ACTIVITY DESIGN WORKSHEET A

STEP 6. Review your responses in Step 2 and compare them to how you have developed Steps 4 and 5.

- Will students receive guidance or information about how to implement the target skill before they experience it?
- What elements of the activity generate experiences that allow students to reflect on the target skill? Will students see the relevance for future scenarios?
- Will the activity be engaging (even fun) yet challenging?

You may want to revise or edit several aspects of your activity. Separate elements that occur at different times by using a separate sticky note for each. If you are making a lot of changes, starting again with a blank version of the worksheet might facilitate your thinking.

ACTIVITY DESIGN WORKSHEET B1

Worksheets B1 & B2 will help you in transforming your ideas from Worksheet A into a temporal outline for facilitating the activity. We recommend having your responses from the coloured boxes on separate sticky notes or small papers.

STEP 7. Position the 3 aspects of **Knowing** and **Learning from experience**, and **Experiencing** to create the activity outline on Worksheet B2.

a Place the **Experiencing** sticky note(s) in any central circle on Worksheet B2.

b In general, students should have access to **Knowing** elements before **Experiencing** to enable them to apply it and practice the relevant skills. Remember the goal is to create authentic experiences, where students already have the information yet still encounter implementation challenges. Place the **Knowing** sticky notes on circles before or after **Experiencing** depending on your objectives.

c Learning from experience about the current activity should likely occur after **Experiencing**. If **Learning from experience** is about how students can transfer the skill (implement in future situations), place the sticky note near the conclusion. For **Learning from experience** activities that leverage students' previous experiences, consider placing this sticky note as a pre-**Experiencing** warm up activity to assist students to see the value of this activity.

STEP 8. Creating an introduction and conclusion for the session.

a Creating a positive, low-stakes environment and having students see the skill as relevant is important. Use your notes from Steps 1 + 2 to create an introduction and/or warm up that includes a direct statement of the skill students will develop.

b Support students' consolidation of learning with a conclusion that restates the target skill and assists them to pivot to future situations where they will apply them. If there are additional blank spaces on Worksheet B2, eliminate or ignore them.

STEP 9. Clarifying the time, mode and resources for the activities.

a Determine an overall length for your activity, keeping in mind contextual constraints. Record the time allocated for each moment of the activity at the top of the template.

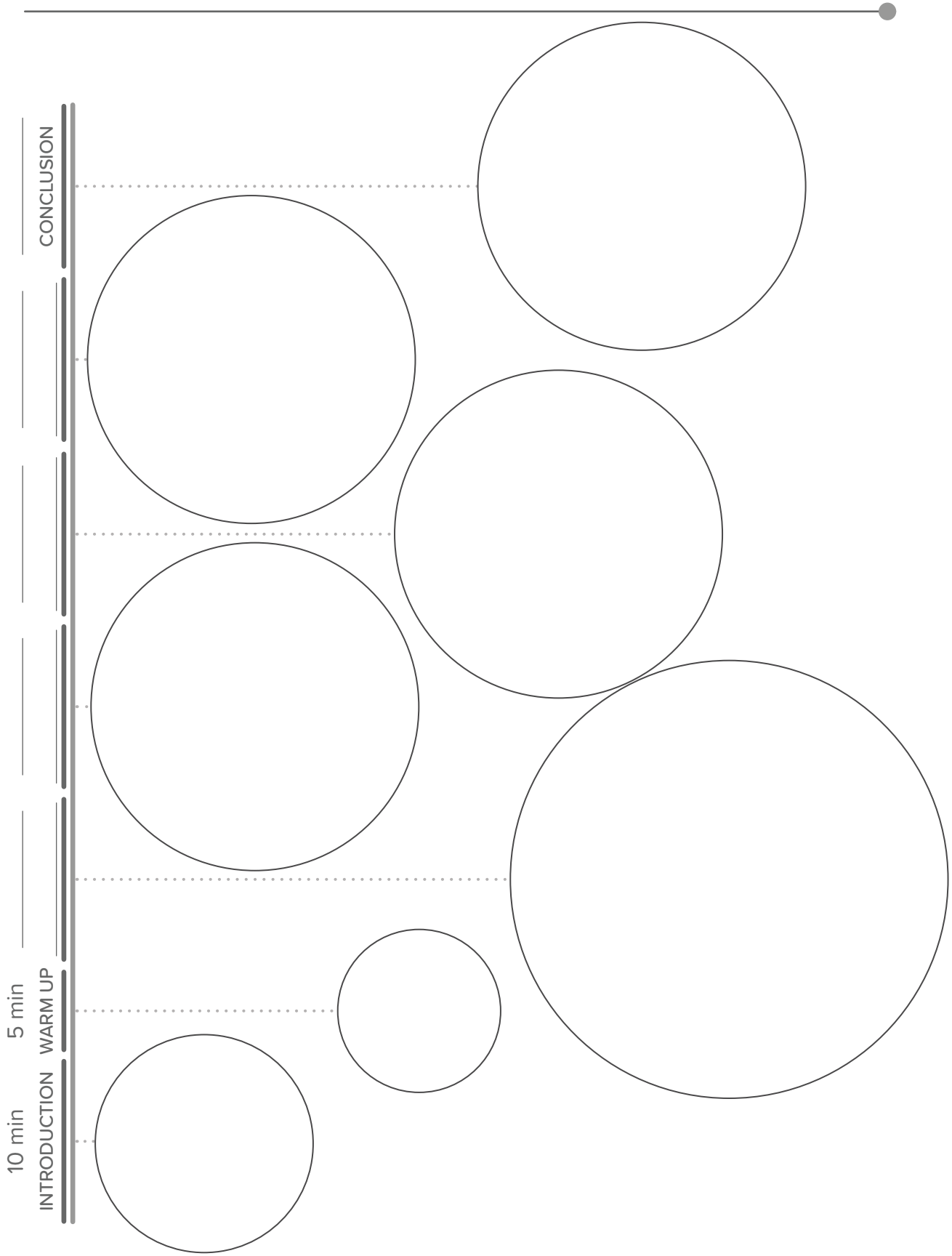
b The trident framework requires that students encounter **Knowing**, **Experiencing** and **Learning from experience** activities. Consider the cumulative amount of time allocated for each of these elements. Does this fit with your learning objectives? Should some activities be shortened or lengthened?

c For each moment on the template, indicate if the class is all together, working alone, in pairs or small groups. This is also a good time to indicate when slides, handouts or other materials will be used.

STEP 10. OPTIONAL: In Step 1c, you identified some high priority skills for your students. Considering how your activity has developed, you may want to integrate the development of a second skill. If yes, you should repeat Steps 2-4 for this second skill as it is essential for students to receive adequate structure for **Knowing** and **Learning from experience**, as simply **experiencing** is insufficient for robust skill development.

Congratulations - you now have a first prototype of your activity! You likely need to do some research to prepare the resources related to **Knowing** and to develop the student-facing materials such as hand-outs and slides. For recommendations for piloting and revising your activity, see the final section of this chapter.

ACTIVITY DESIGN WORKSHEET B2



PILOTING, FACILITATING AND REVISING YOUR ACTIVITY

Once you have a draft of your activity, and before implementing it with students, it is advisable to pilot it. A pilot is a small-scale preliminary implementation of your activity design. The main purpose is to test the activity before teaching it in your class and get feedback (from multiple perspectives) that is useful for considering revisions of your activity.

Piloting the activity

Audience: Invite a diverse audience to participate in your pilot. This could include students from the target course, students who have already taken that course, your peers, pedagogical advisors, etc.

Preparation: Plan to conduct the activity as you would do with students. Pay attention to the facilities in the room and the materials needed to ensure that your pilot participants get an authentic experience rather than having to imagine what they would do in a particular scenario.

Time: In Worksheets B1 & B2 you prepared the temporal outline. When piloting the activity try to stay as close to this plan as possible, while making a note of discrepancies in the time allotted for each step. Be sure to reserve time at the end to get feedback from your pilot participants.

Intentional feedback: A key benefit of piloting the activity is to get feedback from multiple perspectives. Consider how to make it easier for your pilot participants to give you useful and relevant feedback. This can be an open discussion or questionnaire, but prompting your participants with specific questions will likely produce more actionable ideas. Some questions you could use are:

- Did you receive sufficient information/ knowledge related to this skill?
- What additional knowledge about this skill would have been useful?
- Did you have sufficient opportunities to practice the skill?
- Did the reflection activities/prompts help you think of how you could use this skill in other contexts?
- Was the time allotted to the various steps of this activity appropriate?
- Were the instructions clear and explicit throughout the activity?
- Were there any inconsistencies in the approach or flow of the activity?
- Do you have any feedback that can be used to improve this activity?

Facilitating students' learning during experiential activities

Experiential learning activities may require teachers to adopt different teaching strategies from those they rely on more traditional settings. Effective teaching will likely involve alternating between facilitation strategies that support students to be immersed in the activity, refining their own processes for resolving difficulties, and strategies to prompt students to step back and perceive connections across contexts. Page 15 in Chapter 1[25] provides some practical facilitation advice.

Reflecting on the pilot implementation

In his book "Becoming a critically reflective teacher" Stephen Brookfield[26] suggests using four different perspectives to get a holistic view of your teaching. Here, we propose using his four "lenses" to reflect on the pilot implementation of your activity:

You the teacher: Your critical self reflection is a powerful and important source of insight into the activity. What were your experiences when teaching the activity? What assumptions did you make when designing the activity, and how did these assumptions play out during implementation?

Your students: Understanding how your students have experienced the activity is important when reflecting on its effectiveness. Did they interpret your words/actions in the way you intended? Did something inconsequential to you seem very important to them, or vice versa? Were there any differences in the experiences of students with different backgrounds?

Your peers: Your peers may share your learning goals or have encountered similar challenges. Asking them to provide an additional viewpoint can bring to light issues – and solutions – that escape your gaze. They can also help you perceive and evaluate your assumptions.

Pedagogical theory and best practices: This is the broadest perspective that you can take. Consulting the educational literature will allow you to evaluate your pedagogical choices in light of evidence-based practices. It will provide insights into why you might be facing certain difficulties, and what strategies you could use to overcome them. Additionally, it can help you identify which issues you can tackle easily, and which are systemic and/or beyond your control. A first step towards accessing this perspective could be to ask a pedagogical advisor to participate in the pilot.

Revising the activity

After piloting and reflecting on the activity, it is time to revise the activity. At this stage it is important to ensure that your focus remains on ensuring students' learning meets the activity outcomes.

While multiple rounds of piloting can help further refine the activity, that is not always possible. In the absence of secondary pilots, you could discuss your intended changes with some of the participants in your first pilot implementation.

When you teach the activity with your students, consider getting additional feedback from your students, and then further revising it based on that feedback and your experience. If you will be teaching it to different audiences, consider tailoring it based on the needs and prior skills levels of the respective students.

SUPPORT FOR ARTICULATING SPECIFIC AND RELEVANT TRANSVERSAL SKILLS (APPENDIX 1)

The 'transversal' denomination for transversal skills indicates that these skills can be used in a wide variety of situations. While not limited to specific disciplinary or contexts, how transversal skills are applied can differ significantly and it is therefore important to create contextualised, experiential learning opportunities for students to develop these skills. While these skills were often called "soft skills", this term has fallen out of favour because it implies these skills are easy or peripheral, rather than really important.

In Table 8.1 below, we provide a couple examples of skills that are not transversal skills to assist with developing a clear, shared definition of these key skills.

Table 8.1: Examples of knowledge, disciplinary skills and personal characteristics

Non-transversal and non-specific skills	Explanation
How electron microscopes produce images of samples	This is knowledge and not a skill. A quick test to identity knowledge is that is a theoretical or practical understanding, whereas skill is the ability to use knowledge effectively in context.
Performing electron microscopy on a sample of cellulose	This is a skill but it is more disciplinary or technical than transversal.
Self-discipline	This is a characteristic that describes a person's tendency to implement several skills, such as time management and planning. It is not in itself a skill.
Teamwork	This is a whole category of skills. Help students to develop their skills by articulating what specific teamwork skills they will practice (collaborative decision making, conflict resolution, chairing a meeting…)

Listed in Table 8.2 are some transversal skills that are useful for engineering students and professionals. It is not exhaustive, so please do consider additional skills for your teaching. It may be helpful to consult a reference list of transversal skills from your institution or professional body for further inspiration.

Table 8.2: Non-exhaustive list of transversal skills relevant to engineering students and professionals**

Communication skills	Organisational skills	Enterprise skills
Giving oral presentations	Setting objectives	Working with other professionals
Writing reports	Managing time	Determining relevant societal issues
Using additional languages (spoken, written)	Choosing appropriate methodology	Applying relevant ethical, legal, and safety goals
Listening actively	Creating + recreating plans	
Communicating effectively and appropriately across cultures	Defining + redefining priorities	
Interdisciplinary communication	Delegating tasks	
	Assessing risks and recognising long-term consequences	
	Monitoring progress and implementation	

Interpersonal skills	Intrapersonal skills	Strategic & innovative thinking skills
Collaborating	Being aware of own internal processes (biological, emotional, cognitive) and apply regulation	Identifying and defining problems
Taking the perspective of others	Self assessment	Generating alternative actions to be undertaken in a specific situation
Managing conflict	Planning learning goals and monitoring own progress	Generating multiple good solutions, taking into account the desired outcomes, available resources and circumstances
Providing appropriate feedback to others	Managing priorities	Critically analysing actions for their contribution to achieve specific goals
Interpreting the emotional states of other people	Adapting own actions when necessary to achieve a desired outcome or to fit with the situation	Creating new strategies when existing strategies are insufficient
Applying negotiation techniques to build consensus and achieve desired outcomes	Accepting feedback from other people, analyse own behaviour according to it and change behaviour if necessary	
Adjusting behaviour and communication techniques to other people		

** This list has been compiled from internal Swiss Federal Institute of Technology Lausanne (EPFL) materials and other sources, including the CDIO syllabus[27] and the Inner Development Goals[28].

COMPLETED EXAMPLE OF WORKSHEET A (APPENDIX 2)

KNOWING

SKILLS (STEP 1)

- making decisions in a team
- conflict resolution ****do this one

SITUATIONS (STEP 2)

- final week before project deadline
- finding roles in new team

DIFFICULTIES (STEP 2)

- lots of talking but no progress
- having to let go of your own ideas
- managing emotions of self and others

- Creative and productive value of disagreement in a team
- Disagreement as a normal part of working together
- Process for conflict resolution (give steps)
- Emotional self management strategies

LEARNING FROM EXPERIENCE

STEP 3

- Was the conflict resolution process necessary for your team? why or why not?
- Which steps of conflict resolution process were more difficult for you and for your team?
- How did you feel during the difficult steps and what strategies did you use to manage your emotions?
- Have you previously experienced a situation when a similar process would have been useful?

WARM-UP (STEP 8)

- How do you usually deal with conflict?
- What makes you more willing to address conflict?

EXPERIENCING

STEP 4

"Following complicated instructions" promise **big, exciting** reward for best team. Task for each team should be in 2 parts and require two of the same essential LEGO bricks. However materials provided to the team have only 1 such brick. Have students work on their part long enough to be invested before they discover the missing piece and have to do the conflict resolution process.

Chapter development and implementation

This chapter was developed for engineering teachers at a Swiss technical university. It was then refined and implemented several times for engineering teachers, researchers, and pedagogical advisors at the same university. More than 175 people have used this template to develop their own activities.

It has since been implemented in diverse contexts and for diverse audiences including:

Countries

Austria

Belgium

Canada

Denmark

United Kingdom

United States of America

Ireland

Portugal

Switzerland

Audiences

STEM and engineering teachers

Researchers

Doctoral students and postdocs

Curriculum developers

References

1. Direito, I., Pereira, A., & Duarte, A. M. de O. (2012). Engineering Undergraduates' Perceptions of Soft Skills: Relations with Self-Efficacy and Learning Styles. *Procedia - Social and Behavioral Sciences, 55,* 843–851. https://doi.org/10.1016/j.sbspro.2012.09.571

2. Direito, I., Pereira, A., & De Oliveira Duarte, A. M. (2014). The Development of Skills in the ICT Sector: Analysis of Engineering Students' Perceptions about Transversal Skills. *International Journal of Engineering Education, 30*, 1556–1561.

3. Donald, W. E., Baruch, Y., & Ashleigh, M. (2019). The undergraduate self-perception of employability: Human capital, careers advice, and career ownership. *Studies in Higher Education, 44*(4), 599–614. https://doi.org/10.1080/03075079.2017.1387107

4. Lermigeaux-Sarrade, I., Kovacs, H., & Capdevila, I. (2021). Students' Perceptions of Master Programmes: Ready for Work in 2021? *Proceedings of the 49th Annual Conference (SEFI 2021)*. https://infoscience.epfl.ch/record/290641?ln=en

5. Busteed, B. (2014, February 25). *Higher Education's Work Preparation Paradox.* Gallup.Com. https://news.gallup.com/opinion/gallup/173249/higher-education-work-preparation-paradox.aspx

6. Craps, S., Pinxten, M., Knipprath, H., & Langie, G. (2022). Different roles, different demands. A competency-based professional roles model for early career engineers, validated in industry and higher education. *European Journal of Engineering Education, 47*(1), 144–163. https://doi.org/10.1080/03043797.2021.1889468

7. Hirudayaraj, M., Baker, R., Baker, F., & Eastman, M. (2021). Soft Skills for Entry-Level Engineers: What Employers Want. *Education Sciences, 11(*10), Article 10. https://doi.org/10.3390/educsci11100641

8. Patacsil, F., & Tablatin, C. L. S. (2017). Exploring the importance of soft and hard skills as perceived by IT internship students and industry: A gap analysis. *Journal of Technology and Science Education, 7*(3), Article 3. https://doi.org/10.3926/jotse.271

9. Robles, M. M. (2012). Executive Perceptions of the Top 10 Soft Skills Needed in Today's Workplace. *Business Communication Quarterly, 75*(4), 453–465. https://doi.org/10.1177/1080569912460400

10. Succi, C., & Canovi, M. (2020). Soft skills to enhance graduate employability: Comparing students and employers' perceptions. *Studies in Higher Education, 45*(9), 1834–1847. https://doi.org/10.1080/03075079.2019.1585420

11. Brunhaver, S. R., Korte, R. F., Barley, S. R., & Sheppard, S. D. (2018). Bridging the Gaps between Engineering Education and Practice. In R. B. Freeman & H. Salzman (Eds.), *US Engineering in a Global Economy* (pp. 129–163). University of Chicago Press. http://www.nber.org/chapters/c12687

12. Kovacs, H., Capdevila, I., Lermigeaux-Sarrade, I. J. L., & Jermann, P. (2023). From University to Work: Alumni Viewpoints. *Proceedings of the CDIO 2023 Conference.*

13. Accreditation Board for Engineering and Technology [ABET]. (2023). *Criteria for Accrediting Engineering Programs, 2023 – 2024 | ABET*. https://www.abet.org/accreditation/accreditation-criteria/accreditation-policy-and-procedure-manual-appm-2023-2024/

14. Commission des titres d'ingénieur [CTI]. (2023). *The CTI's Major Criteria and Procedures – CTI– Commission des Titres d'Ingénieur.* https://www.cti-commission.fr/en/fonds-documentaire

15. European Network for Accreditation of Engineering Education [ENAEE]. (2023). EUR-ACE® Framework Standards and Guidelines. *ENAEE.* https://www.enaee.eu/eur-ace-system/standards-and-guidelines/

16. Tormey, R., & Isaac, S. (2022). *Facilitating Experiential Learning in Higher Education Teaching and Supervising in Labs, Fieldwork, Studios, and Projects.* Routledge.

17. de Lima, J., Isaac, S., & Zufferey, J. D. (2024). Distinctly Human—Students' Perception of Transversal Skills in Engineering Curriculum. *Proceedings of the 20th International CDIO Conference.*

18. Lehmann, M., Christensen, P., Du, X., & Thrane, M. (2008). Problem-oriented and project-based learning (POPBL) as an innovative learning strategy for sustainable development in engineering education. *European Journal of Engineering Education, 33*(3), 283–295. https://doi.org/10.1080/03043790802088566

19. Picard, C., Hardebolle, C., Tormey, R., & Schiffmann, J. (2022). Which professional skills do students learn in engineering team-based projects? *European Journal of Engineering Education, 47*(2), 314–332. https://doi.org/10.1080/03043797.2021.1920890

20. Doktor, L. (2024). *Academics' Perspectives on Transversal Skills: A Case Study in the New Engineering Programme at the Norwegian Military Academy. Proceedings of the SEFI 2024 Conference.*

21. Isaac, S., Petringa, N., Jalali, Y., Tormey, R., & Dehler Zufferey, J. (2023). Are Engineering Teachers Ready to Leverage the Power of Play to Teach Transversal Skills? *Proceedings of the SEFI 2023 Conference.* https://doi.org/10.21427/QP3D-B914

22. Kovacs, H., Milosevic, T., & Niculescu, A. (2023). Planned, Taught, Learnt: Analysis of Transversal Skills Through Curriculum Using Portfolio. *SEFI 2023 Proceedings.* https://doi.org/10.21427/R0JP-8277

23. Wiggins, G. P., & McTighe, J. (2005). *Understanding by Design*. Association for Supervision and Curriculum Development.

24. Mertz, P. S., & Neiles, K. Y. (2020). Scaffolding Career Skills into the Undergraduate Curriculum Utilizing a Backward Design Approach. In *Integrating Professional Skills into Undergraduate Chemistry Curricula* (Vol. 1365, pp. 43–55). American Chemical Society. https://doi.org/10.1021/bk-2020-1365.ch004

25. Isaac, S., de Lima, J., Jalali, Y., Rossi, V., Schmid, S., Tormey, R., and Dehler Zufferey, J. (2024). Chapter 1: How to develop engineering students' transversal skills. In 3T PLAY (Eds.), *Teaching Transversal Skills for Engineering Students: a practical playbook of activities with tangibles*, Centre for Learning Sciences EPFL, Lausanne. https://doi.org/10.5281/zenodo.13328581

26. Brookfield, S. D. (1995). *Becoming a Critically Reflective Teacher. Jossey-Bass Higher and Adult Education Series.* Jossey-Bass, Inc. https://eric.ed.gov/?id=ed387073

27. Crawley, E. F., Malmqvist, J., Lucas, W. A., & Brodeur, D. R. (2011). The CDIO Syllabus v2.0. An Updated Statement of Goals for Engineering Education. In M. Vigild (Ed.), *Proceedings of the 7th International CDIO Conference.* https://api.semanticscholar.org/CorpusID:110610803

28. IDG Foundation. (2021). *Framework – Inner Development Goals.* https://innerdevelopmentgoals.org/framework/

3T PLAY

LIST OF MATERIALS

While the only essential item to get started designing your activity is a way to record your ideas, it may be convenient to have

- ◯ Sticky notes
- ◯ A highlighter
- ◯ Orange, blue and green pens

MORE ABOUT 3T PLAY

To learn more about the 3T PLAY project and to access more materials, please visit go.epfl.ch/3TPLAY

To access more teaching materials or to share the activity you have created, please visit:
https://zenodo.org/communities/3tplay/records

HOW TO CITE THIS CHAPTER

Isaac, S., and de Lima, J. (with Rossi, V., Jalali, Y.). 2024.
Chapter 8: How teachers can use the trident framework to design activities that develop transversal skills. In 3T PLAY (Eds.), *Teaching Transversal Skills For Engineering Students: a practical playbook of activities with tangibles*, EPFL Press, Lausanne.
https://doi.org/10.5281/zenodo.10992806