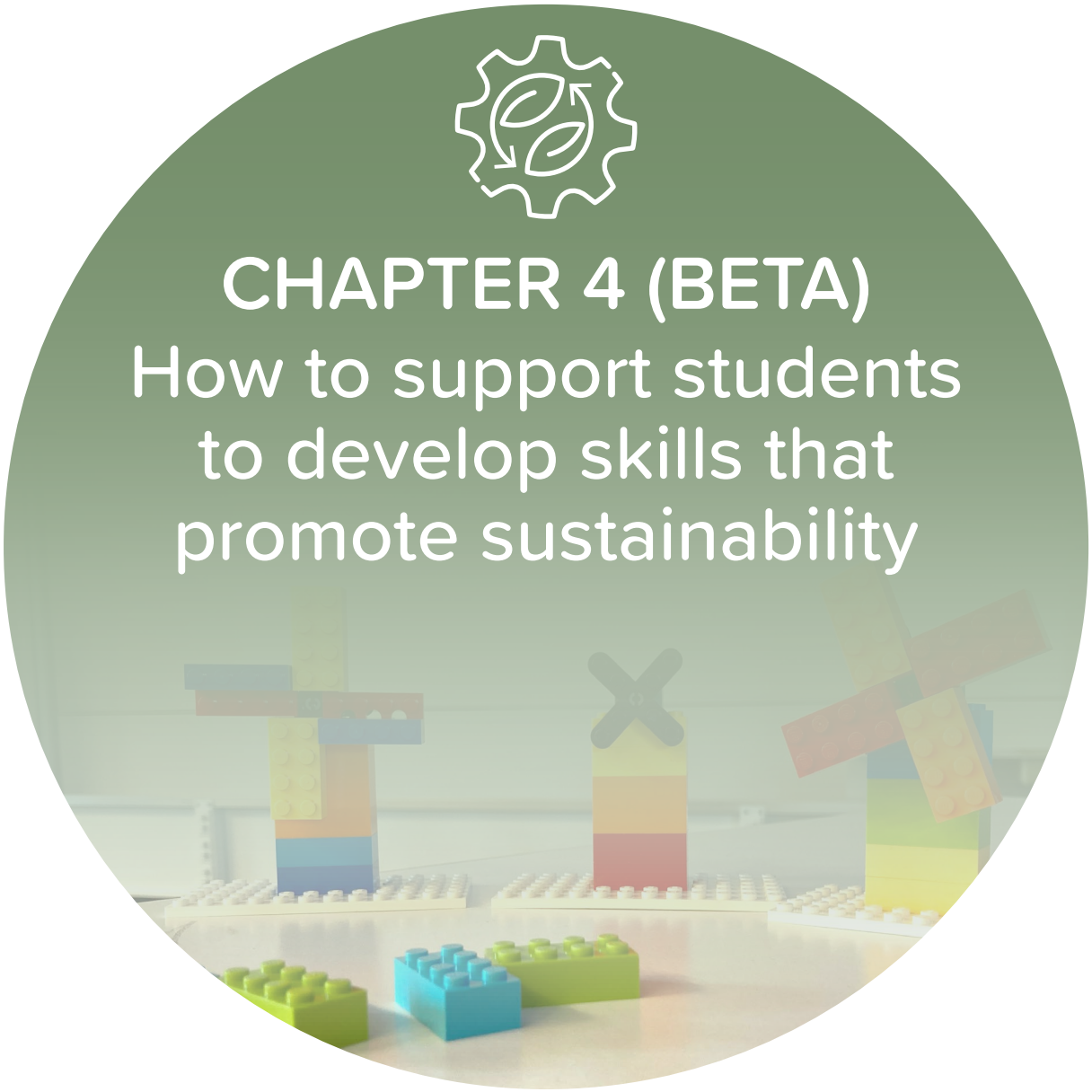
3T PLAY

CHAPTER 4 (BETA)

How to support students to develop skills that promote sustainability



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CHAPTER 4

How to support students to develop skills that promote sustainability

CHAPTER INDEX

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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 design. 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

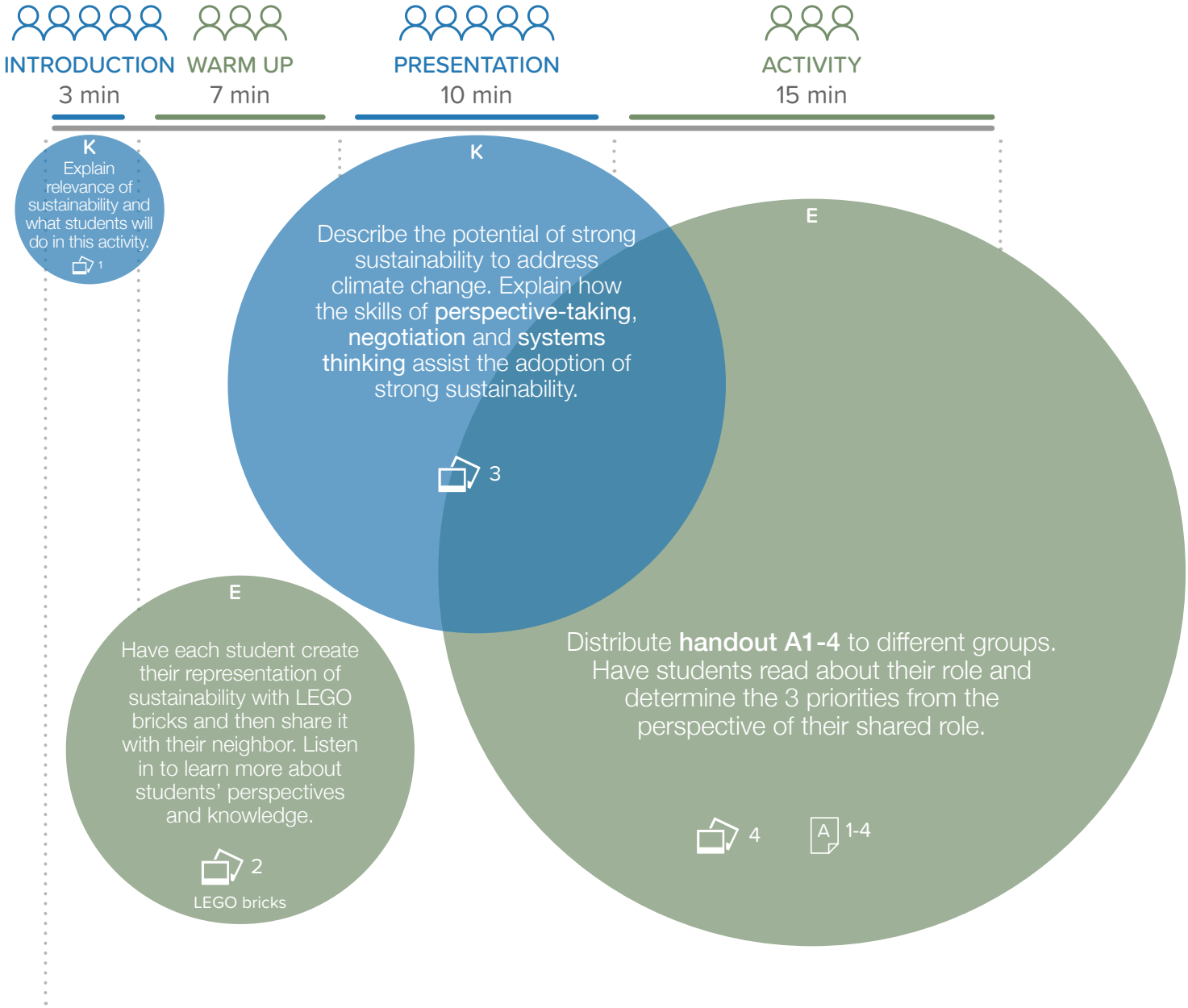
This 75-minute activity is designed for university-level engineering students.

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



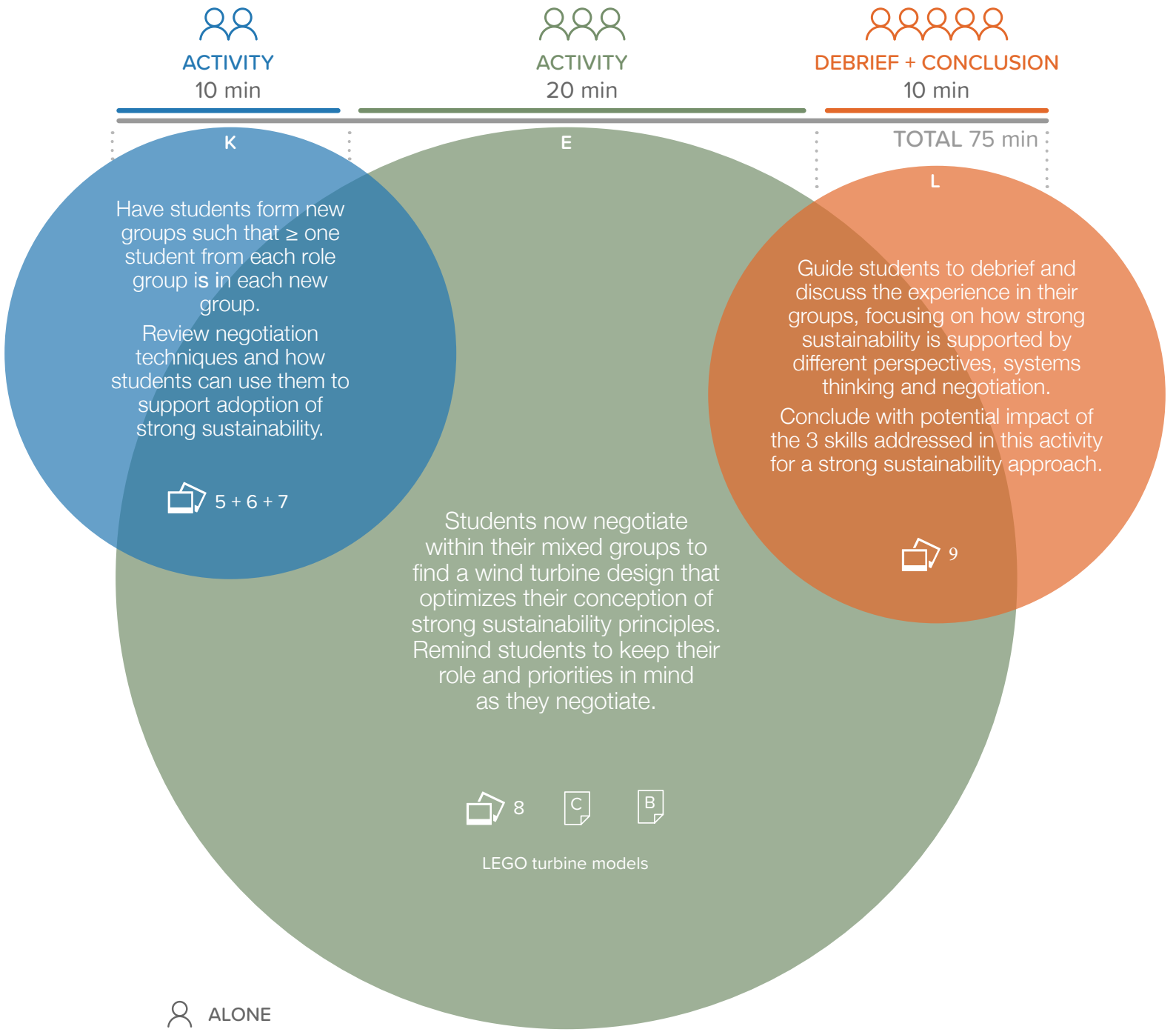
PREPARATION

Set up the room to create groups of 4 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.

ACTIVITY

How to support students to develop skills that promote sustainability



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]. 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 romantic 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 Chapters 1 and 2 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:

Conceptual knowledge: 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. They are designed to ensure that students are prompted to engage in these three types of thinking and develop a degree of proficiency in the targeted skills that allows them to apply them in their next project.

For engineering students to effectively integrate sustainability into the products and systems they design and maintain, we need them to consider multiple facets of sustainability and to convince other people about the value and feasibility of sustainabile choices. For these skills, an effective learning activity will involve informing students about perspective-taking and negotiation strategies. They will need to explore sustainability from multiple perspectives while negotiating with other concerned stakeholders, and reflecting on their experience to support transfer.

Here is a mapping of this activity onto the trident framework:

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] presents 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 their materials choices. 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

3T PLAY

As a geological engineer your role is to assist your colleagues to make decisions that respect 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 Switzerland?
- …
- …

Step 1. Working together with the other "geological engineers", define **3 top priorities** to guide the decision-making in the design of 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 make decisions that respect sustainability in terms of the effect on the **population, waste, noise and interaction with local animals around the installation site**.

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

- Improve the safety of workers or 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 top priorities** to guide the decision-making in the design of 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 Felicity and 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 top priorities** to guide the decision-making in the design of the wind turbine according to your role.

Priority 1	
Priority 2	
Priority 3	

HANDOUT A4 Project coordinator

3T PLAY

As the engineer responsible for overseeing the project coordination, your responsibility to ensure that the team makes responsible decisions. 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 decisions and total 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 our choices align with our company's stated values?
- …
- …

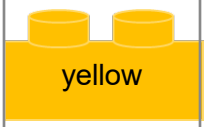
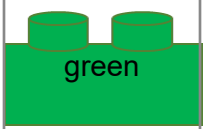
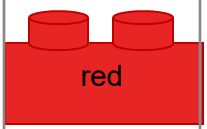
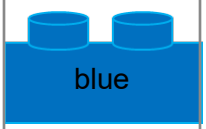
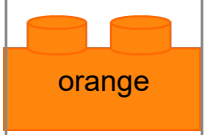
Step 1. Working together with the other "project coordinators", define **3 top priorities** to guide the decision-making in the design of the wind turbine according to your role.

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 the contract is for 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
	+	+++	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.
	++	++	2€/kg	This material is produced in Asia from recycled waste collected in Europe. It breaks into pieces at the end of its lifetime.
	+++	+++	5€/kg	Manufacturing this material is energy intensive and requires highly skilled tradespeople for the installation.
	++	+	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.
	+++	+	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

3T PLAY

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

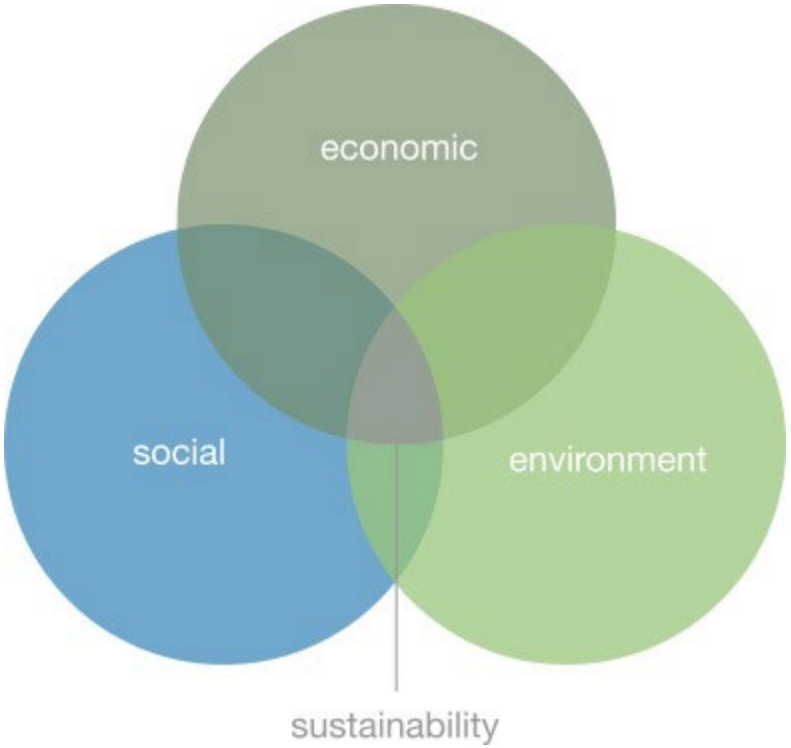
What does sustainability mean to you?

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

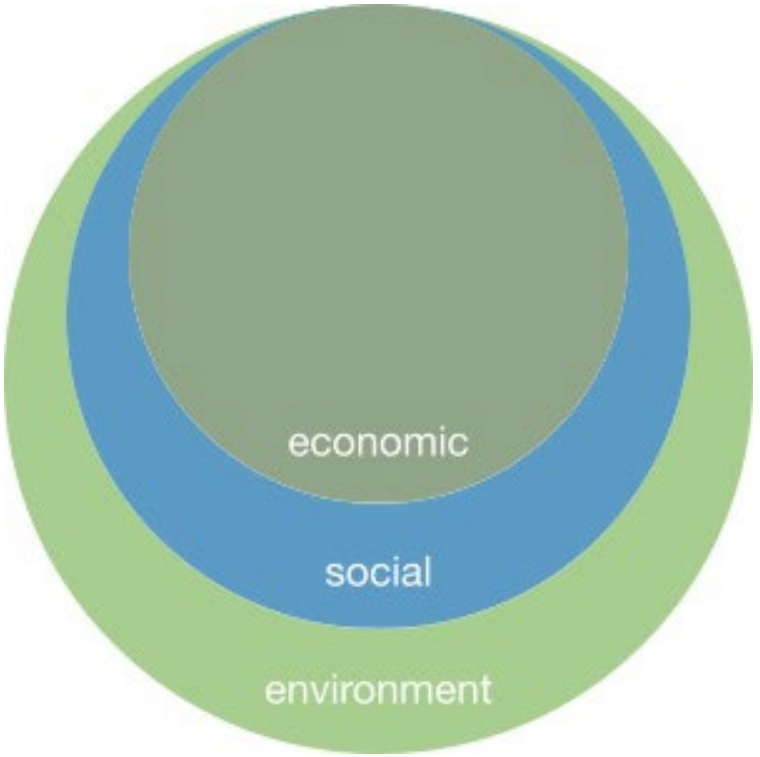
3T PLAY

All dimensions of sustainability are interconnected and codependent

weak sustainability



strong sustainability



adapted from Mebratu, 1998

3T PLAY

Activity Outline

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

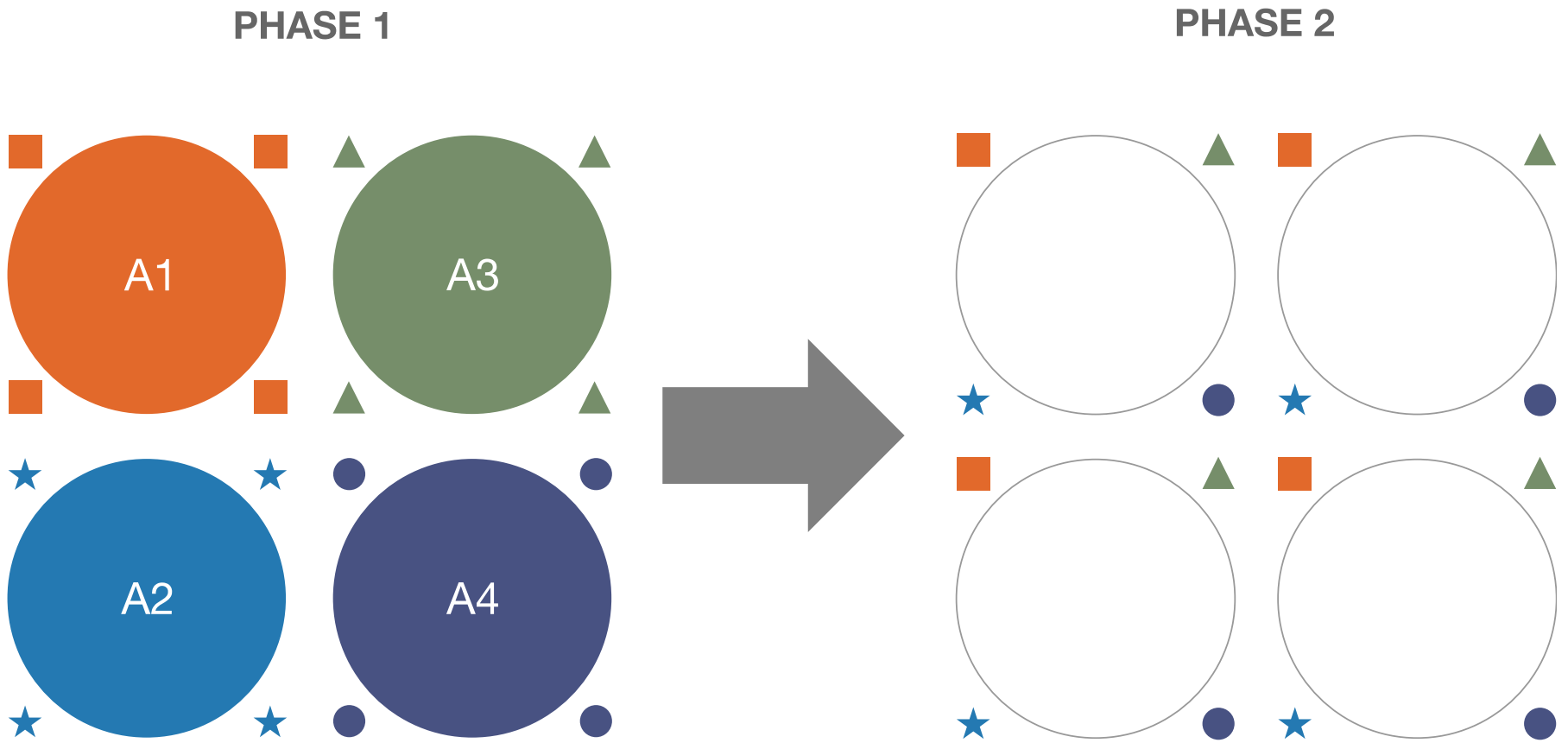
Your job is to bring your engineering skills and sustainability thinking into the proposed design. The choice of materials will have big socio-environmental and economic impacts as 100 wind turbines will be manufactured and installed.

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

2. With the other people in your group, identify 3 priorities to guide decision-making in the wind turbine project. 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. insists that the agreement be based on objective 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"

3T PLAY

Negotiation in groups

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

2. Keep 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.

3T PLAY

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. How did you balance different sustainability concerns with engineering concerns?

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

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

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

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. (Eds.). (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., & Zufferey, J. D. (2024). Exploring disciplinary differences in engineering students' perception of sustainability and ethics in their curriculum. Submitted to EDUCON2024.

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. SEFI 2023. 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. SEFI 48th Annual Conference: Engaging Engineering Education. Proceedings. SEFI 48th Annual Conference: Engaging Engineering Education.

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

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

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 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 black
  - ◯ 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.

MORE ABOUT 3T PLAY

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

We would love to hear your ideas about this activity! Please visit **go.epfl.ch/3Tfeedback**

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