

# Integrating stakeholders in project-based transdisciplinary teaching and learning – the case of ‘Tackling Environmental Problems’

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## Abstract

In this reflection on a teaching practice, we present how we implement project-based transdisciplinary teaching and learning in the Bachelor of Environmental Science (hereafter BSc) course ‘Tackling Environmental Problems’ (‘Umweltproblemlösen’ in German, abbreviated as UPL hereafter) at ETH Zurich. First, we focus on the question of how stakeholders are involved in transdisciplinary higher education courses. Then, we present which stakeholders we involve in UPL and which roles they take. A (non-exhaustive) literature review of transdisciplinary courses in other institutions has shown that it is often not explicitly described which stakeholders, and especially in which roles, they are involved in a project-based transdisciplinary course. In UPL, we distinguish between stakeholders at the course level of the case study and stakeholders at the project level who are approached by the students for development of their sustainability projects. Finally, we discuss why we integrate stakeholders in our course and link this to the development of transdisciplinary competences. We conclude with a reflection on the challenges and opportunities of the stakeholders, lecturers and students, as well as experiences, reflections, and feedback from eight years of running this course.

## Introduction

For many environmental issues, students who enter the Bachelor of Environmental Sciences at ETH Zurich might be convinced that 1) the problems are clearly defined, 2) the solutions ready to be implemented, and 3) the missing link is (political) will. Our goal is to fundamentally challenge these assumptions. To do so, we use the concept of wicked problems as the starting point in our course ‘Tackling Environmental Problems’ (UPL). According to Rittel and Webber (1973), wicked problems lack a clear definition and have multiple reasons. Therefore consequently, they do not offer a unique solution, but rather multiple solutions. In contrast, the way a problem is described already defines the space of possible solutions. Furthermore, the problem may appear differently to various stakeholders involved, some may not see a problem at all, whereas for others an action is required immediately.

We let students experience the diverse perceptions of wicked problems by including stakeholders from diverse societal sectors throughout our course. We involve relevant stakeholders from early on in identifying and framing specific problems, as experts for local knowledge during problem analysis and when students develop and test solutions. Students thus experience the wickedness of problems through their own interactions with stakeholders from a specific case area.

At the beginning of their studies, students often encounter disciplinary foundations. It is crucial for them to understand from the outset that today’s complex challenges cannot be solved by a single discipline alone. Instead, they require the collaboration of multiple disciplines, as well as knowledge and perspectives from practical experience.

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UPL is a first-year course in the Bachelor of Environmental Sciences at ETH Zurich. According to the study guide, *'we equip the students with the ability to tackle today's environmental problems at local, regional, and global levels. The students will learn to analyse environmentally relevant issues using scientific methods, develop solutions, and evaluate them'* (translated from Departement Umweltnaturwissenschaften, 2024, p. ii). 'Tackling Environmental Problems' aims to bridge the gap between science and practice while fostering transdisciplinary competences among students. These include for instance method-specific competences like problem solving and imagining solutions and their consequences, social competences like communication and teamwork as well as personal competences like systems thinking and reflection. Through a project-based and self-organised teaching format, students are confronted with real-world problems and learn how they can contribute to their solutions.

This manuscript addresses the question of which stakeholders and how they are involved in transdisciplinary higher education courses. First, we describe general reasons for involving stakeholders in transdisciplinary courses. We provide examples of other courses and institutions as well. Then we outline why we involve stakeholders in our course. We are convinced that by directly applying learned methods in a real-world context and with directly affected stakeholders, students are much more likely to acquire new competencies than if they were to learn them purely theoretically. To cover different perspectives and local knowledge, we involved stakeholders who performed different roles. Depending on the course phase, we lecturers work with an advisory group as well as practical experts. Additionally, students independently contact other societal stakeholders relevant to their respective projects. We explain how collaboration and exchange with stakeholders helps students to develop transdisciplinary competences. Finally, we discuss the challenges and opportunities that arise in this process for stakeholders, lecturers and students.

Our work is based on a non-exhaustive overview review of the literature, previous work and our experiences, reflections and feedback from eight years of running this course.

## Stakeholders in transdisciplinary courses

The involvement of stakeholders is a core feature of transdisciplinary research and teaching. They can be involved to fulfil many objectives and principles (Schmidt et al., 2020). In UPL, we mainly focus on the principles 'Improvement of the quality of research' (in our case teaching), and 'Stimulating processes of social learning to better understand and solve the problem' (Schmidt et al., 2020, p.3). The stakeholders offer the diversity of perspectives of those who are concerned by the wicked problem.

The transdisciplinary research process explicitly connects the realm of science with the realm of practice (see Figure 1). *'The transdisciplinary process consists of the stages of framing the problem, analyzing the problem, and exploring the project's impact'* (Pohl et al., 2017, p. 44). Stakeholder groups from society (Figure 2) are integrated either in the realm of science (academia) or practice (administration, business, and civil society). In our manuscript, we have further assigned the stakeholders to the course level or project level. We will discuss this in more detail later.

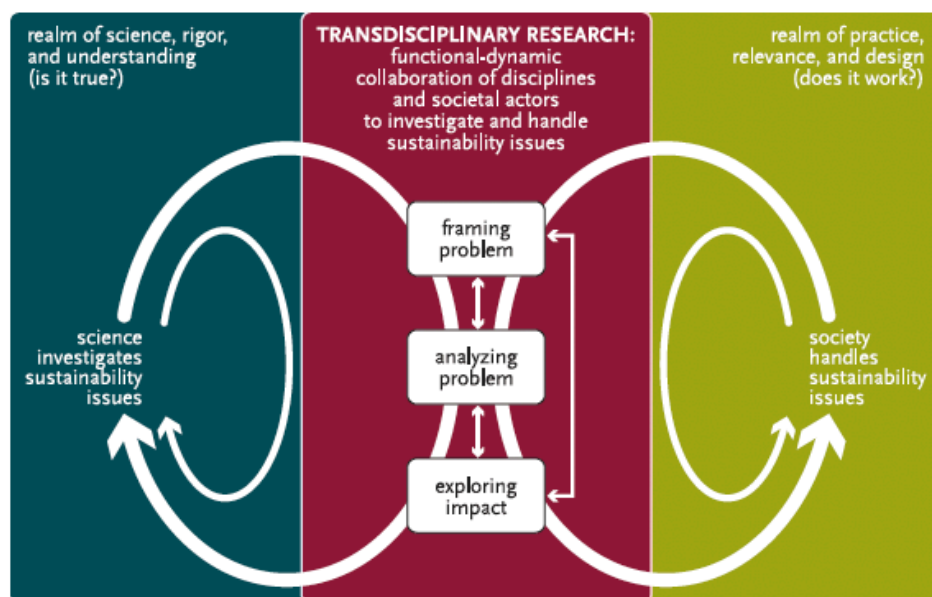


Figure 1: The transdisciplinary research process - Join Problem Framing and Solving between the realm of science and the realm of society as described in Pohl et al., 2017, p. 44.

In our course, we distinguish between four types of stakeholders as described in Figure 2. We have a main partner, an advisory group, practical experts and societal stakeholders. It will be further described below when they appear in the UPL process and what their roles are.

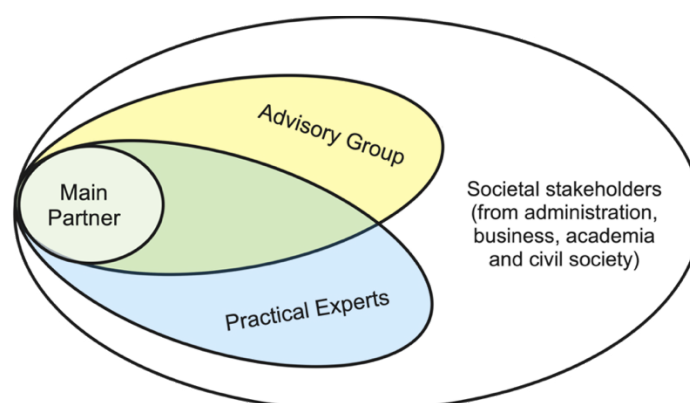


Figure 2: The different types of stakeholders of the BSc course 'Tackling Environmental Problems'.

In our short (and non-exhaustive) review (see Figure 2), we discover that stakeholders are mainly integrated as 'practitioners' in other programmes. This means that the details of the stakeholder engagement are not usually described. There is no or very little distinction between 1) the different types of stakeholders, 2) when they are involved and in which part of the transdisciplinary process, and 3) the role they perform. As explained in our programme, we have four different types of stakeholders who perform different roles at different stages of the transdisciplinary research process.

Name of the Programme	Type Stakeholder	Roles	Institutions	Source
Bachelor of Creative Intelligence and Innovation (BCII)	Industry Partners	<ul style="list-style-type: none"> <li>- Challenges Provider (co-creation)</li> <li>- Transfer of knowledge and Perspectives</li> </ul>	University of Technology, Sydney	Baumber, 2022

Bachelor of Technology and Innovation (BTi)	Industry Partners	<ul style="list-style-type: none"> <li>- Challenges Provider (co-creation)</li> <li>- Transfer of knowledge and Perspectives</li> </ul>	University of Technology, Sydney	Baumber, 2022
Diploma in Innovation (DiplInn)	Industry Partners	<ul style="list-style-type: none"> <li>- Challenges Provider (co-creation)</li> <li>- Transfer of knowledge and Perspectives</li> </ul>	University of Technology, Sydney	Baumber, 2022
'The sustainable development indicator exercise (SDIE)', graduate-level seminar	Not specified	- Co-creation	University of Geneva	Balsiger, 2015
'Transformative Innovation Lab', MSc learning course developed and tested at 2 German universities	Local Practice Partners	- Not specified	Not mentioned	Bernert et al., 2022
the 'Sustainability Challenge', a learning environment for Td learning and teaching	Society	<ul style="list-style-type: none"> <li>- Co-creation</li> <li>- Transfer of knowledge and Perspectives</li> </ul>	4 Universities of Vienna (Regional Centre of Expertise on Education for Sustainable Development, which includes City of Vienna, UN EP and others)	Biberhofer & Rammel, 2017
'Transacademic case study'	Community Partners	- Not specified	School of Sustainability at Arizona State University	Brundiers et al., 2010
Certificate Program 'el Mundo - ESD in university level teacher education'	Not specified	- Collaboration	Ludwig-Maximilians-University Munich	Hoiß, 2020
Undergraduate course 'Wicked Problems of Sustainability'	Society	<ul style="list-style-type: none"> <li>- Co-creation</li> <li>- Transfer of knowledge and Perspectives</li> <li>- Feedback</li> </ul>	Grand Valley State University, USA	Lake et al., 2016
'the NYC office of Public Imagination', studio course, Transdisciplinary design MFA Program	Society	- Co-creation	Parsons School of Design, USA	Penin et al., 2015

ETH Certificate of Advanced Studies in Climate Innovation	Society	<ul style="list-style-type: none"> <li>- Challenges Provider (co-creation)</li> <li>- Transfer of knowledge and Perspectives</li> <li>- Consultation and Feedback</li> </ul>	ETH Zurich	Rapo et al., 2024
'Leuphana Semester with opening week', for all first year students	Not specified	- Not specified	Leuphana University Lüneburg	Adomßent, 2022
'Complementary Studies', selected by 2 <sup>nd</sup> to 3 <sup>rd</sup> year students	Not specified	- Not specified	Leuphana University Lüneburg	Adomßent, 2022

*Table 1: Transdisciplinary Learning Formats offered at different institutions including types and roles of stakeholder involved (when available). The roles reported are described in Figure 3 (Transfer of Knowledge and Perspectives, Co-Creation, Coaching & Feedback, Consultation, Grading).*

## The course 'Tackling Environmental Problems'

In UPL, we wish students to experience the process of problem solving by means of a concrete case study. The obligatory course is for first semester students in the Bachelor of Environmental Sciences and lasts a whole year. Around 120 students attend the course. Every year we work on a different sustainability topic in Switzerland, e.g. sustainable water management in the Upper Engadine, regional development in the Jurapark Aargau, or a climate-positive canton of Uri (cp. Pohl et al., 2018; Pohl et al., 2020; USYS-TdLab, 2024). This sustainability topic represents the case study under investigation.

The first semester (UPL I) is about analysing the situation and the case topic. Each case study is divided into five to six sub-analyses. For instance, for the case study Uri, which we worked on in 2023/2024, the aim was to explore how mobility, agriculture, energy, consumption or tourism contribute to a climate positive canton. Four student groups of five to seven members deal with one of the sub-analyses. They carry out a literature search, a stakeholder analysis and gain insights as part of an excursion.

The synthesis week takes place after the first semester. The student groups are reshuffled so that one student from each sub-analysis is represented in a new group. The purpose of the synthesis week is to bring together all the knowledge from the first semester and to make the students experience how it is to be an expert. During this block week, students familiarise themselves with our problem-solving approach – a combination of systems thinking and design thinking (Pohl et al., 2020). They learn to identify stakeholder needs, formulate problems and develop solutions that also have an impact in the overall system.

In the second semester (UPL II), the students independently apply the methods learnt during the synthesis week in sustainability projects they develop themselves. They draw a rich picture, formulate an insight and problem statements, develop a qualitative system model, develop measures, prototype them (Pohl et al., 2020) and present their projects at a public final event, the 'market of measures'. The students follow an iterative process, where the contact with and feedback of stakeholders presents an important part to further develop their projects. If they wish, they can realise their projects in an optional third semester (UPL III).

We follow ETH's approach to project-based education (cp. PBLabs, 2024). The practice-oriented project approach, where students work in self-organised groups, is an integral component of our course. Particularly in UPL II and UPL III, project work is emphasised. Students learn the methodological and transferable competences we aim to foster through direct application. We, as lecturers and our tutors, act as coaches and support students in their learning processes. When grading groups, we also grade this process and the reflection on it.

### **Why we integrate stakeholders**

UPL aims to bridge the gap between science and practice while fostering transdisciplinary competencies among students. Through a self-organised teaching format, students are confronted with real-world problems and learn how they can contribute to their solutions. In competence-oriented teaching, the focus is not only on imparting knowledge (primarily case-specific, local, and context-related knowledge in our case) but also on developing skills and attitudes. This is achieved through a project-based iterative process of application, practice, and experimentation. In UPL, failure is explicitly allowed and encouraged, if students reflected upon and use it as a learning opportunity for future applications. The emphasis is strongly on 'learning by doing'.

The development of competences in our course is based on the ETH competence framework, which distinguishes between four competence domains: subject-specific competences, method-specific competences, social competences and personal competences (ETH Zurich, 2023). However, this framework does not encompass all the competences we aim to promote in transdisciplinary teaching (see Pearce et al., 2018). Therefore, we have supplemented it as shown in Table 2.

Regarding subject-specific competences, we are not only interested in whether students understand and can apply specific concepts, but also in their ability to apply these concepts in diverse real-world contexts. Among the method-specific competences, problem solving is central to our degree program. In UPL, we also emphasize problem framing, which involves collaboration with others. Consequently, we have included this aspect. Holistic and future-oriented problem solving is also important to us. As this is not covered in the ETH competence framework, we have added the competence 'Imagining solutions and their consequences'. We identify two areas within the social competence of 'communication': firstly, communicating one's own values, and secondly, communicating with stakeholders. In the ETH competence framework, systems thinking is categorized under 'critical thinking'. Given its importance to us, we list it as a separate competence.

In the following Table 2, we describe how the involvement of and exchange with stakeholders supports students in developing these competences.

The competences 'Framing and solving complex problems with others', 'Imagining solutions and their consequences' as well as 'Communicating with others in different contexts' apply to UPL II only, while the others are embedded both in UPL I and UPL II.

Competence domains	Competences in UPL	Supported by interaction with stakeholders	Phase of the research process
Subject-specific competences	Applying concepts in the real world	The application of concepts and methods in the real world requires an exchange with stakeholders. Through their experience, build-on local and practical knowledge, they can judge what works and what not. Students realise how important the knowledge of the local context is. There is no one right solution to wicked problems.	Analysing the problem (Exploring impact)
Method-specific competences	Framing and solving complex problems with others	By talking to stakeholders, students learn about the different needs of the people concerned. Through these different perspectives on an insight, they recognise why a problem can be wicked. Students ask stakeholders for feedback on their initial drafts of solutions and, as the project progresses, more concretely on their prototypes of measures. This feedback from the stakeholders enables the students to recognise whether their measures really contribute to solving a real problem and fulfil the needs of the stakeholders. It helps them to make their ideas implementable. While stakeholders usually have a rather passive role in the development of measures, they are key partners in the facultative project implementation.	Framing the problem Analysing the problem Exploring impact
	Imagining solutions and their consequences	Through the exchange with stakeholders, students can find out whether their skills in developing effective solutions and recognising their potential impacts on the system are also practically applicable.	(Exploring impact)
Social competences	Communicating your own values and communicating with others in different contexts	The worldview of stakeholders can often be diverse. This can help students to question and reflect on their own values. They learn to communicate with different people (from science, practice, administration, business, etc.) at an equal footing and in 'their' respective language.	(Framing the problem) (Analysing the problem)

	Cooperation and teamwork	During UPL, students always work in groups. They reflect on their group collaboration and their work process in a weekly learning journal (with short entries or videos). They define their group ideal, reflect on their individual roles and strengths within the group. They learn to evaluate each other and give constructive feedback. Students develop this competence above all in exchange with their own group. When students develop their projects in UPL II in close collaboration with stakeholders, this level is added once again.	Framing the problem Analysing the problem Exploring impact
Personal competences	Critical thinking	Students develop the ability to distinguish scientific facts from the personal opinions of stakeholders. They must take both into consideration and synthesise different sources in order to develop implementable measures. They must critically evaluate which measures make sense, also with regard to systemic impacts.	(Framing the problem) (Analysing the problem) (Exploring impact)
	Systems thinking	Through the exchange with stakeholders, but also through working in a group, students get to know different points of view. This can help them to reflect on their own views and recognise where their strengths and weaknesses lie. They learn to listen to other people and better understand and accept their perspectives and behaviour.	(Framing the problem) (Exploring impact)

Table 2: Competences in UPL and how the interaction with stakeholders supports their development.

## Which stakeholders we integrate and how

The involvement of stakeholders in different phases of the transdisciplinary process and with different roles is a core element of our course. We distinguish between two levels: the course level and the project level. With reference to Figure 3, the course level (left) is therefore about the respective sustainability case study as such, while the project level (right) concerns the individual student group projects. The figure links these two levels with the transdisciplinary research process in the centre. In the following, we explain how this works in detail.

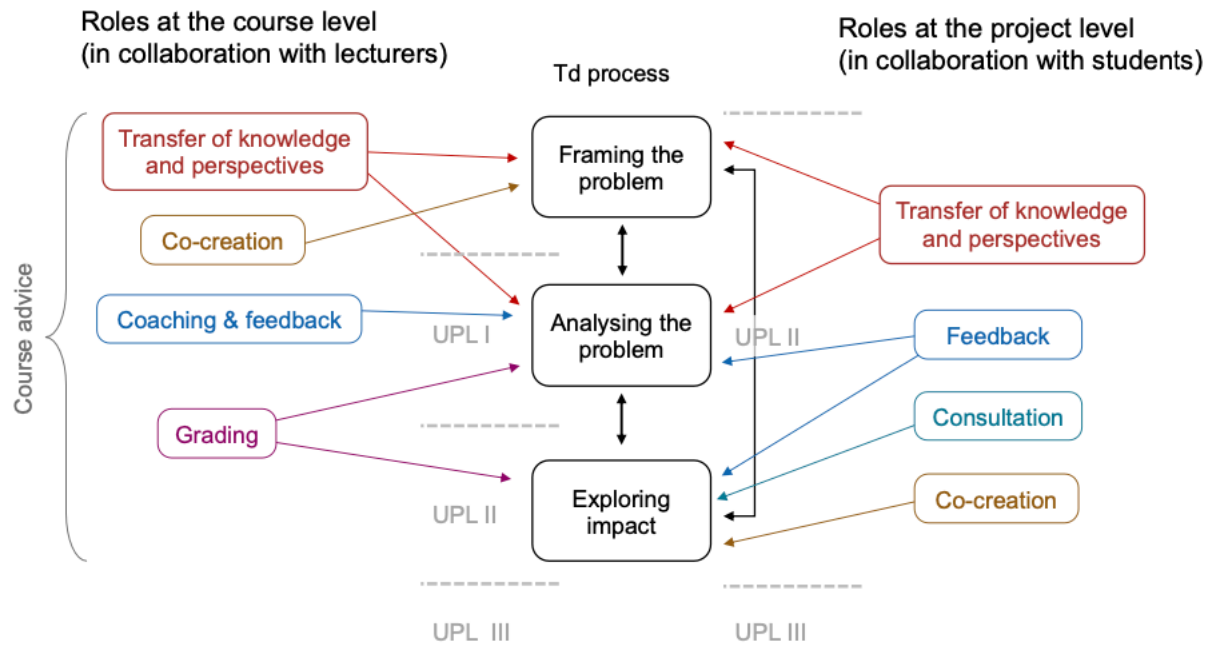


Figure 3: The roles of stakeholders in 'Tackling Environmental Problems' (UPL) in the transdisciplinary research process (own figure based on Pohl et al., 2017, p. 44).

## Stakeholders' roles at the course level

Every year, we work with an advisory group. Half a year before the first semester starts, we identify a topic as well as a main partner from a Swiss region. This can be a community mayor, a head of a cantonal office, an employee of a research institution or a company. Together with them, we consider an initial draft of the case topic and which other people we can ask to join our advisory group. Besides the main partner, the group consists of stakeholders of the course (lecturers and two representatives each of the students and tutors) and stakeholders of the respective case (representing administration, business, academia and civil society). We always choose stakeholders from these four areas as we believe they represent important areas of society and come with different perceptions of, and interest in, the topic. In order to make well-founded decisions on the case topic and the sub-analyses, it is important for us to incorporate these perspectives right from the beginning. Two representatives of the lecturers, tutors and students complete the advisory group. They ensure that the learning objectives and framework conditions of the course are guaranteed. The tutors and students also make sure that, for example, questions are understandable for future students and tasks are distributed.

In Figure 3, the roles of the course level on the left-hand side relate to the involvement of the advisory group and practical experts. The advisory group has an important role in 'framing the problem'. Together with them we lecturers determine (and co-create) the respective case topic. In this way, we want to ensure that we work on a topic that is of regional relevance and that their different perspectives are considered right from the beginning. The advisory group also proposes the sub-analyses and practical experts to accompany them. This all happens before the start of the first semester. Then during the course (UPL I and UPL II), the stakeholders of the case support the course, are available to the students as a source of information and

provide feedback. At the end of the course, they are also involved in grading the student projects, thus assessing 'the impact' of the projects. Over the course of a year and a half, we meet five times.

Besides the advisory group there are further practical experts for each of the sub-analyses in the first semester (UPL I). We contact them on the recommendation of the advisory group. These are, for example, a farmer, forest ranger or representatives of regional, communal or cantonal offices, energy providers or companies. They contribute their specific regional expertise to the formulation of the sub-analyses and respective research questions. Furthermore, they give a short introductory lecture for the students on their sub-analysis topic, meet once with their four student groups for a feedback discussion and read and assess the student reports at the end of the semester. Thus, they are less concerned with a joint problem framing but more with transferring case knowledge and providing feedback in order to support students in 'analysing the problem'.

At the course level, i.e. the stakeholders of the respective case study of the advisory group and practical experts, we work with a total of eight to ten stakeholders.

### **Stakeholders' roles at the project level**

In addition to the official stakeholders of the course (case study), who are approached by us lecturers, the students have the task of contacting further stakeholders independently. This takes place during the second semester, when they work on their projects.

At project level, the entire transdisciplinary process takes place in UPL II. In order to 'frame the problem', students approach local stakeholders, ask about their knowledge, challenges and individual perspectives. While 'analysing the problem', they conduct research, ask for further information and seek feedback on their assumptions. 'Exploring impact' refers to the development of proposed solutions and specific measures that are ready for implementation. The students build prototypes of these measures, which they test with stakeholders and obtain feedback on. In addition, some groups also involve stakeholders in an in-depth consultation process and develop and co-create the measures together. The roles of stakeholders are therefore diverse – they contribute local knowledge and needs, provide hands-on feedback, but can also become partners in the implementation of the student projects. In the course of a case study, students contact about 150-200 different stakeholders.

### **Challenges and opportunities**

After eight years of teaching experience in this course, we can report on a variety of challenges and opportunities. These challenges and opportunities are based on our observations and feedback from the advisory group, as well as from the students. During our final meeting with the advisory group, we inquire about their expectations, experiences and challenges. We gather information from the students through their weekly learning journal entries, where they reflect on their work process, as well as through their individual reflection reports at the end of each semester. Finally, we collect information through the responses during oral exams where the students apply and reflect on what they have learned. Tabl summarises the key challenges and opportunities for stakeholders, lecturers and students in our course, which we address in more detail below.

	Challenges	Opportunities
<b>Stakeholders</b> (incl. members of the advisory group and practical experts)	<ul style="list-style-type: none"> <li>- Resources (time commitment).</li> <li>- Organising their professional life with course dates and activities.</li> <li>- Possible lack of experience in grading students' work.</li> </ul>	<ul style="list-style-type: none"> <li>- Sharing their local knowledge with students.</li> <li>- Their concerns will be heard.</li> <li>- Gaining new and fresh perspectives from students for problems and possible solutions.</li> <li>- Networking opportunities with other stakeholders and lecturers.</li> </ul>
<b>Students</b>	<ul style="list-style-type: none"> <li>- Identifying relevant stakeholders and establish contacts with them.</li> <li>- Coordination of stakeholder contacts.</li> <li>- Understanding and being able to assess the needs of stakeholders in the overall system.</li> <li>- Dealing with diverse perspectives and sometimes contradictory information.</li> </ul>	<ul style="list-style-type: none"> <li>- Being forced to get out of the university bubble.</li> <li>- Gaining a more comprehensive understanding of specific local sustainability issues.</li> <li>- Experimenting and learning by doing.</li> <li>- Being able to implement their project ideas.</li> </ul>
<b>Lecturers</b>	<ul style="list-style-type: none"> <li>- Resources (high time commitment).</li> <li>- Finding a new case topic and new motivated stakeholders every year.</li> <li>- Coordinating between lecturers, tutors, students and stakeholders.</li> </ul>	<ul style="list-style-type: none"> <li>- Being forced to get out of the university bubble.</li> <li>- Gaining a more comprehensive understanding of specific local sustainability issues.</li> <li>- Having the possibility to realise our transdisciplinary learning objectives.</li> <li>- Networking with regional stakeholders.</li> </ul>

Table 3: Overview of challenges and opportunities of integrating stakeholders.

For stakeholders, a challenge is how they can organize themselves professionally to align with our course dates. The members of the advisory group and the practical experts are also involved in the grading. Initially, this responsibility can be quite daunting, and it is difficult for them to estimate the performance level expected from first-semester students. However, with the help of clear assessment criteria and our advice, this has never actually been a problem. Especially when comparing multiple groups they evaluate, they can accurately assess their performances. However, we also adjust their grades, in case they are much lower or higher than the grades given by other stakeholders. Though we never change how they grade the groups relative to each other. The adjustment is to avoid students feeling unfairly treated. The students' inquiries can also be challenging for stakeholders – whether due to the sheer quantity or because they are too general or too detailed.

The greatest challenge for students is in UPL II to first identify the relevant stakeholders, understand their needs, relate these to the overall system of their project and then establish successful contact with them. When they succeed in this, receive helpful responses, and encounter interest and support, it shows them that they have identified a real demand. This helps them to make their project more concrete and often provides significant motivation. On the other hand, it is incredibly frustrating when they do not receive any feedback. However, this is a translation of working with real-world case studies. Students must learn how to formulate their inquiries in a way so that they receive responses that are helpful to them. As all students together can easily contact 200 stakeholders during their project development in the second semester and we want to avoid one stakeholder being contacted by ten different students (and possibly being overwhelmed as a result), the students must coordinate their

contacts. One student is responsible for one stakeholder at a time and forwards enquiries from other student groups to him or her collectively. However, this also means that students are not completely free in their requests, have to coordinate well and take other groups into consideration. This can certainly delay their own process. The contacts are entered transparently in a table.

In addition, students are confronted with contradictory information and opinions. For example, they might get different feedback on their work from lecturers and practical experts, as they have different requirements or prioritise certain aspects differently despite having the same assessment criteria. Students also sometimes find information in the literature that does not match the statements of stakeholders. Or stakeholders have contradictory opinions about their projects - some think it's great, some perhaps unnecessary.

Even if students are given a comprehensive assignment for each semester, it is a challenge for them to imagine the end product. Dealing with this uncertainty and learning how to cope with it is a challenge for many.

For us lecturers, the high time commitment is a challenge. Each year, we develop a new case topic in collaboration with a new main partner, a new advisory group and new practical experts. This process starts practically with the question of whom we can contact for collaboration and usually requires several emails and phone calls to convince people to participate in our course. The total time commitment is approximately 50 hours for the advisory group and 35 hours for the practical experts. Although we often encounter interest, the time commitment, which we communicate transparently from the beginning, should not be underestimated. Subsequently, it takes time to build trust and a shared understanding of the course's objectives. Dates and tasks need to be communicated and coordinated. Meetings always take place in the respective case region to show our interest in the topic and the stakeholders. This is well appreciated. As our course involves many different aspects (such as introductory lectures, delivery of milestones, feedback to student groups, optional workshops, an excursion or final events) and groups of people (stakeholders, lecturer's team, tutors and students), coordination and a consistent flow of information between them should not be underestimated. One of our lecturers is responsible for this.

In addition to the challenges, there are also various opportunities. Many stakeholders enjoy sharing their knowledge with young students. They appreciate it when their concerns are taken seriously and met with interest. Many are also happy to participate in our excursion, where they can introduce students to their expertise and everyday life. They value the fresh perspective students bring to problems, the diverse ideas for solutions, and especially when measures are implemented. Another aspect is the opportunity for networking. Even though many stakeholders often already know each other, the course and student projects continually create new contacts or provide the chance to discuss controversial views in a neutral context. Contacts with stakeholders are also of interest to lecturers. For example, a further research project for a real-world lab emerged from the collaboration in the advisory group (Department of Environmental Systems Science, 2022).

The exchange with stakeholders enables both students and lecturers to gain a deeper and more comprehensive understanding of specific sustainability issues. We step out of our higher education bubble and learn about diverse regions and what concerns the people there. Students can experiment with applying their theoretical and methodological knowledge in a real-world context and understand what it takes to solve wicked problems. While many courses end with the development of solutions, students here have the opportunity to implement their measures in an optional third semester. Even if only around 10% do this, the offer is important and was introduced at the request of former students. This course gives us lecturers the opportunity to apply our didactic principles and transdisciplinary learning objectives. We contribute to opening up the universities and taking up concerns from society. In addition, networking with local stakeholders is a valuable side effect.

## Conclusions

Dealing with wicked problems in the real world requires an iterative and participative approach of practicing and experimenting. With this teaching practice, we aim to contribute to the current literature by clarifying the roles and involvement of stakeholders. We do this by illustrating the exact process of how, why and which stakeholders we involve in our transdisciplinary teaching and learning process. When we compare the roles of stakeholder in UPL (see Figure 3) with the other teaching and learning formats described in Table 1, we can see that the roles they take on are more diverse in UPL. The international examples from the literature illustrate that the two main roles of the stakeholders are 'transfer of knowledge' and 'co-creation'. In many cases, stakeholders are referred to as partners with whom the content is co-created. Not all authors elaborate on the roles of the stakeholders in their respective programs. In the examples of the University of Technology in Sydney (Baumber, 2022), the co-creation role is also described as a challenge provider. This does not occur in UPL, as the identification of challenges is part of the students' task at the project level (see Figure 3). What is also rarely addressed is the role at the project level of giving students feedback, supporting them in their project development, or actively contributing to finding solutions. No example addresses the involvement of stakeholders in grading at the course level, which is the case in both semesters at UPL.

However, we see differences not only in the roles but also in the types of stakeholders involved and how exactly they are described. For example, industry partners or society are mostly mentioned in the international examples (see Table 1). In UPL, we differentiate between our main partner, the advisory group, practical experts, and further societal stakeholders (see Figure 2). They come from administration, business, academia and civil society to reflect different perspectives in society.

We are convinced that the exchange with stakeholders and their local knowledge, expertise and experience is necessary to promote the development of transdisciplinary competences among students. It is important to us that 1) not only the students familiarise themselves with concepts and methods, but 2) that they also apply them in the real world. This is made possible by working on hands-on projects. Setbacks are also part of this learning experience. Dealing constructively with failures and how they can learn from them so to develop their project further is an ability that will also be relevant in later professional life. UPL is all about learning by doing.

Students learn, among other things, how to deal with conflicting views and integrate different perspectives, critical and systemic thinking, self-organised group work and continuous reflection on their own role and the work process. We think that the tasks students need to fulfil and develop over the span of the course should be more robust as they accommodate diverse perspectives. Additionally, the integration of a various set of stakeholders ensures a higher likelihood of implementing the projects developed by the BSc students at a later stage. All parties involved show a higher ownership of the process and outcomes.

In our view, the following success factors are central to the involvement of stakeholders in our course:

- Project-based work in a real-world context.
- Clear and transparent communication about their time commitment and what they can expect.
- Honest interest in the local situation of the stakeholders and joint agreement on topics and research questions.
- Meetings of the advisory group and the final event for the students always take place in the case region. This seems trivial, but for many stakeholders it makes a difference that we lecturers (and students) are travelling to them.

## Bibliography

- Adomßent, M. (2022). Taking interDISCIPLINARITY and transdisciplinarity to eye level with scientific disciplines. In B. V. Baptista & J. T. Klein, *Institutionalizing Interdisciplinarity and Transdisciplinarity* (1st ed., pp. 27–42). Routledge.  
<https://doi.org/10.4324/9781003129424-4>.
- Balsiger, J. (2015). Transdisciplinarity in the class room? Simulating the co-production of sustainability knowledge. *Futures*, 65, 185–194.  
<https://doi.org/10.1016/j.futures.2014.08.005>.
- Baumber, A. (2022). Transforming sustainability education through transdisciplinary practice. *Environment, Development and Sustainability*, 24. <https://doi.org/10.1007/s10668-021-01731-3>.
- Bernert, P., Wanner, M., Fischer, N., & Barth, M. (2022). Design principles for advancing higher education sustainability learning through transformative research. *Environment, Development and Sustainability*. <https://doi.org/10.1007/s10668-022-02801-w>.
- Biberhofer, P., & Rammel, C. (2017). Transdisciplinary learning and teaching as answers to urban sustainability challenges. *International Journal of Sustainability in Higher Education*, 18(1), 63–83. <https://doi.org/10.1108/IJSHE-04-2015-0078>.
- Brundiers, K., Wiek, A., & Redman, C. L. (2010). Real-world learning opportunities in sustainability: From classroom into the real world. *International Journal of Sustainability in Higher Education*, 11(4), 308–324. <https://doi.org/10.1108/14676371011077540>.
- Departement Umweltwissenschaften. (2024). Wegleitung Bachelor-Studiengang Umweltwissenschaften 2024/2025. Departement Umweltwissenschaften, ETH Zürich. [https://ethz.ch/content/dam/ethz/special-interest/usys/departement/documents/studium/umweltnaturwissenschaften/bachelor/bsc-umnw-wegleitung%20\(1\).pdf](https://ethz.ch/content/dam/ethz/special-interest/usys/departement/documents/studium/umweltnaturwissenschaften/bachelor/bsc-umnw-wegleitung%20(1).pdf).
- Department of Environmental Systems Science. (2022). The Jurapark Aargau as Real-world Lab for Sustainable Development. <https://usys.ethz.ch/en/research/joint-initiatives/Jurapark-Aargau.html>.
- ETH Zurich. (2023). Competence Framework. <https://ethz.ch/content/dam/ethz/main/eth-zurich/organisation/stab-rektor/eth-talent/eth-competenceframework-fulltext-en.pdf>.
- Hoiß, C. (2020). Transdisciplinary Collaboration in ESD Teacher Education Programs. *Revista de Fomento Social*, 177–197. <https://doi.org/10.32418/rfs.2020.297.4015>.
- Lake, D., Fernando, H., & Eardley, D. (2016). The social lab classroom: Wrestling with—and learning from— sustainability challenges. *Sustainability: Science, Practice and Policy*, 12(1), 76–87. <https://doi.org/10.1080/15487733.2016.11908155>.
- PBLabs. (2024). What is Project-Based Education? <https://ethz.ch/en/the-eth-zurich/education/pblabs/what-is-pbe-.html>.
- Pearce, B., Adler, C., Senn, L., Krütli, P., Stauffacher, M., & Pohl, C. (2018). Making the Link Between Transdisciplinary Learning and Research. In D. Fam, L. Neuhauser, & P. Gibbs (Eds.), *Transdisciplinary Theory, Practice and Education* (pp. 167–183). Springer International Publishing. [https://doi.org/10.1007/978-3-319-93743-4\\_12](https://doi.org/10.1007/978-3-319-93743-4_12).
- Penin, L., Staszowski, E., & Brown, S. (2015). Teaching the Next Generation of Transdisciplinary Thinkers and Practitioners of Design-Based Public and Social Innovation. *Design and Culture*, 7(3), 441–450.  
<https://doi.org/10.1080/17547075.2015.1105564>.
- Pohl, C., Krütli, P., & Stauffacher, M. (2017). Ten Reflective Steps for Rendering Research Societally Relevant. *GAIA - Ecological Perspectives for Science and Society*, 26(1), 43–51. <https://doi.org/10.14512/gaia.26.1.10>.

- Pohl, C., Krütli, P., & Stauffacher, M. (2018). Teaching Transdisciplinarity Appropriately for Students' Education Level. *GAIA - Ecological Perspectives for Science and Society*, 27(2), 250–252. <https://doi.org/10.14512/gaia.27.2.14>.
- Pohl, C. E., Pearce, B., Mader, M., Senn, L., & Krütli, P. (2020). Integrating systems and design thinking in transdisciplinary case studies. *GAIA - Ecological Perspectives for Science and Society*, 29(4), 258–266. <https://doi.org/10.14512/GAIA.29.4.11>.
- Rapo, C. B., Gruber, N., Bresch, D. N., & Krütli, P. (2024, November 4). The Climate Innovation programme at ETH Zurich. Review of 2 years of transformative learning, roles of peers and career perspectives. In Preps. ITD Conference 2024, Utrecht, the Netherlands.
- Rittel, Horst W. J., & Webber, Melvin M. (1973). Dilemmas in a General Theory of Planning. *Policy Sciences*, 4(2), 155–169.
- Schmidt, L., Falk, T., Siegmund-Schultze, M., & Spangenberg, J. H. (2020). The Objectives of Stakeholder Involvement in Transdisciplinary Research. A Conceptual Framework for a Reflective and Reflexive Practise. *Ecological Economics*, 176, 106751. <https://doi.org/10.1016/j.ecolecon.2020.106751>.
- USYS-TdLab. (2024). Umweltproblemlösen. Retrieved 9 September 2024, from <https://upltdlab.ethz.ch>.

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