Framing project-based education at ETH Zurich

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Abstract

Universities today walk a complex line between delivering education that is more than just professional training, whilst ensuring that graduates are equipped adequately to navigate post-study employment. One approach to this challenge is to focus on competencies as a way to frame and capture learning that goes beyond classic subject-specific knowledge. This paper explores the potential of project-based education (PBE) as a pedagogic approach relevant for institutions interested in fostering transferable competencies, using the example of ETH Zurich. After introducing the history of PBE, this paper proposes a definition of PBE for ETH Zurich. It discusses the operationalisation of the definition, using guiding questions and sharing examples of PBE that already take place at ETH Zurich. Finally, the paper concludes with a set of implications of PBE for ETH Zurich and more broadly for higher education institutions.

Introduction

Universities are at the forefront of educating and training the researchers and professionals of tomorrow. In a rapidly changing world, graduates must develop the ability to learn and adapt swiftly. Universities play a crucial role in equipping them with knowledge, skills, attitudes while fostering lifelong, critical and reflective learning (Harvey, 2000). Universities today walk a complex line between delivering education that is more than just professional training, whilst ensuring that graduates are equipped adequately to navigate post-study employment (Collini, 2012; La Cara, 2023a). This balancing act is often understood through the lens of 'missions': the different, sometimes contradictory aims and expectations of higher education (HE) institutions can be broadly captured under Mission 1 ('doing research'), Mission 2 ('doing teaching'), and Mission 3 ('adding value to society') (Berghaeuser & Hoelscher, 2020; Etzkowitz & Leydesdorff, 2000).

Teaching, the core of Mission 2, forms a point of connection between the other missions. Universities are in the unique position of selecting and shaping their future employees – the training of future scholars and scientists is intrinsic to the purpose of a university. The way universities teach today influences the abilities of those students that go on into research to plan, undertake and communicate the research of tomorrow – the Mission 1 of universities (Collini, 2012). Universities are also organisations embedded in a broader social context, deeply bound to it via material resources (e.g. funding), and government rules and regulations (Berghaeuser & Hoelscher, 2020). The expectations of universities have grown as society has changed towards a 'Knowledge Society', and modern governments and society expect universities to have a higher contribution through innovation, spin-outs, and by promoting life-long learning suited to a changing work context (Enders & De Boer, 2009). Teaching thus bridges both the need for excellent researchers and the need of society for graduates who are capable of supporting the modern workplace and knowledge society.

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Careful consideration of how teaching is done is therefore a crucial activity for universities wishing to navigate these complex, contradictory relationships and requirements. Curricula (the foundation of study/degree programmes) are one of the most important 'products' that a university offers and are profoundly shaped by the specific knowledge field of the academics that deliver the curricula (Barnett et al., 2001). At the same time, since the 1980s there has been a shift in the production and application of academic knowledge, from 'is it true?' to 'what use is it?' (Barnett et al., 2001; Lyotard et al., 1984). This focus on 'use value' has driven changes in curricula, with a move towards including 'competencies' in addition to subject-specific knowledge within curricula (Barnett et al., 2001). Examples of this emphasis on competencies can be observed in medicine (e.g. in the US (Powell & Carraccio, 2018)), chemistry (e.g. in Brazil (Franco et al., 2023)), engineering (e.g. in Russia (Lunev et al., 2013)) and many other. Examples dating back to the mid-1970s (e.g. agricultural science (Mather et al., 1977)), indicate that this approach has been around for a long time.

Competencies can be defined as the combination of knowledge (information developed or learned through experience and study), skills (acquired through repeated application of knowledge or ability) and behaviours (observable reaction of an individual to a certain situation) that are directly related to successful performance (National Institutes of Health, n.d.; United Nations, 2010). Competencies are defined as *knowledge* (what knowledge students acquire in a course, e.g. facts and concepts), *skills* (what the students can do after a course, e.g. procedures and strategies), and *attitudes* (the values or beliefs students can develop in a course) (La Cara et al., 2023b). Someone who is competent is consistently capable of using their body of knowledge, skills and attitude to successfully undertake tasks beyond what was covered within their education programme (Vitello et al., 2021).

Because universities are required to train their future staff to be able to do research (Mission 1) as well as contribute well-educated future employees to a society that is changing and increasingly in need of knowledge workers (Mission 3), competencies have the potential to serve both purposes. Transferable competencies[2] are a cross-cutting set of skills, knowledge and attitudes that support students to apply subject-specific knowledge during their studies (La Cara, 2023a) and across a lifetime (European Union, n.d.). Examples of transferable competencies include: problem-solving and decision-making, working in teams and collaborating, project and self-management, communicating and negotiating, critical and creative thinking, and technology and information literacy amongst others. Fostering these competencies is increasingly seen as an essential requirement of advanced degrees and must be given in context i.e. cannot be separated from subject-specific competencies (La Cara et al., 2023a).

Higher education institutions are challenged today in how they teach to ensure that transferable competencies in addition to subject-specific competencies can be developed. This paper investigates the potential for a specific pedagogic approach, project-based education (PBE), as a way to frame and strengthen the acquisition of transferable competencies within the student body using the example of ETH Zurich. This paper defines and operationalizes PBE, building on the existing ETH Competence Framework (La Cara, 2023a) to illustrate what project-based education is and how it fosters students' transferable competencies.

A brief history of PBE at ETH Zurich

Today's project-based education can trace its roots back to the post-Enlightenment European art and architecture Academies. The Académie des Beaux-Arts[3] established in 1648 in Paris developed a teaching style where students learned from a Master with the aim of imitating his[4] approach on developing an architecture project in a real-world context. Each student would

[2] Transferable competencies are also known as transversal skills or 21st century skills. Depending on the context, they typically combine social and personal competencies as well as method-specific competencies.
[3] and later in 1863 renamed into École des Beaux-Arts
[4] Women were admitted beginning in 1897.

choose an ‘atelier’ run by his desired master which he would stay with until the end of his studies. Each atelier was characterized by the small number of students and hence, greater attention by the teacher. In this group, students would work individually on their six design projects which they completed over a period of five weeks to three months (Chafee, 1977). Based on the public competition system in practice, students would defend their thesis design project in a lengthy oral examination in front of a prominent jury (Salama, 2015). Ever since, architectural education has been strongly based on this pedagogical model of design teaching in the design class (also referred to as studio or atelier). Typical characteristics of design teaching such as 1) navigating a complex and open-ended problem while tackling heterogeneous issues, 2) expressing design proposals in various media, 3) passing through multiple and rapid iterations within semester length projects, and 4) earning frequent critique in both formal and informal set-ups are typical features of the culture in architecture studio teaching (Kuhn, 2001).

This project-based learning approach was established at ETH Zurich[5] from its foundation in 1854 to boost technical education in the newly formed Swiss Confederation. On October 15, 1855, Gottfried Semper founded the Bauschule[6] as one of six departments at the Polytechnikum (the original name of ETH Zurich). As a proven Baukünstler and theorist, he reformed the tightly organized structure of polytechnic teaching for his discipline. Drawing on his experiences as a professor at the École des Beaux-Arts in Dresden from 1834 to 1854, he translated its model of project-based education to his own in Zurich (Tschanz, 2015). Through this, he would prepare his students for their later work in practice. Since the founding of the Architecture school, the model of architecture education at ETH Zurich, especially the design studios, has remained basically the same.

Project-based education globally found its verbal expression, recognition in education science and application within other disciplines beyond architecture later in the early 20th century. In 1918, an essay was published by the American pedagogue William H. Kilpatrick (1918), entitled ‘The Project Method’ (Kilpatrick, 1918), which caught the attention of US educators and drew focus onto the importance of student engagement in learning, a key element of project-based education today (Larmer et al., 2015). This contrasted with dominant assumptions at the time about how learning occurred. Until about the 1950s, the dominant theory of learning, called ‘Instructionism’, assumed that knowledge was deposited into the heads of students by teachers or lecturers through lecturing and demonstration. It emphasised factual learning and rote memorisation (Sawyer, 2022).

However, since at least the 1900s, educators in polytechnical education had proposed alternatives to this theory, and as education science and observations of learning have become a field of research, it has become evident that students (indeed, all learners) construct their knowledge through experience – the so-called ‘Constructivist’ theory of learning (Sawyer, 2022). By the 1960s, many educators were pushing back on Instructionist-informed education approaches, with authors like the Brazilian educator and philosopher Paulo Freire (1970) advocating for active and participatory didactic approaches. He wrote about ‘problem-posing education’ – the foundations to develop transferable competencies (Freire, 1970). Higher education institutions established in the 1970s, like McMaster University, Roskilde University and Aalborg University, began to test new approaches to higher education emphasising smallgroup, self-directed and problem-based education (Servant-Miklos, 2019).

At ETH Zurich, students demanded reform of how teaching was delivered in the 1970s. A new curriculum was designed for advanced students, the Projektorientierter Studiengang (POST). This moved away from traditional frontal teaching and towards more active student participation and real-world connection. This was co-designed with lecturers and students and hosted in the Abteilung für Naturwissenschaft (Department of Natural Sciences, today called

[5] ETH Zurich is a federal university in Switzerland; https://ethz.ch/en.html
[6] In 1899, the Bauschule was renamed Architekturschule, and in 1924, it became the Department of Architecture.

Department for Environmental Systems Science, or D-USYS). POST was a radical departure from typical ETH Zurich teaching at that time. It completely rethought the content and form of study with an emphasis on interdisciplinarity across teaching, research and didactics. Its intention was to give students an understanding of research through teaching (Gugerli, 2005). POST was discontinued after 15 years for a variety of reasons (Gugerli, 2005), although its essence lives on in the teaching at D-USYS within specific modules like the year-long Umweltproblemlösen (solving environmental problems) bachelor's course (Pohl et al., 2020).

In 2022, ETH Zurich decided to build anew on its background in project-based education, and its strong tradition of preparing students of careers in research and industry. It established PBLabs (Project-based Labs) to promote and enable project-based education across the institution and encourage more competence-oriented teaching and especially to foster transferable competencies. PBLabs supports lecturers in developing and implementing project-based formats and helps students acquire specific transferable competencies, such as coaching and facilitation skills.

ETH Zurich's definition and approach to PBE

Terminology around PBE in practice and in academic literature can be confusing for practitioners (Servant-Miklos, 2020). There are many terms in use around this style of teaching, including: problem-based education (Denayer et al., 2003), problem-based learning (Winning & Townsend, 2007), practice-based education (Mann et al., 2020), challenge-based learning 'CBL' (Sukackė et al., 2022), case study learning (Savery, 2006), project-oriented studies (Lee et al., 2014), inquiry-based learning (Larmer et al., 2015), project-based learning and problem-based learning (De Graaff & Kolmos, 2003; Krajcik & Blumenfeld, 2006; V. Servant-Miklos, 2020, V. F. C. Servant-Miklos, 2019). This broad range of terms encompass the following key aspects: active teaching styles or learning techniques (strongly focused on engaging students directly in the learning process), mixed educational approaches, a commitment to interdisciplinarity, the promotion of self-directed learning, encompassing group work and a focus on the real-world connection.

Higher education institutions like ETH Zurich, because of different disciplines and teaching methodologies, require a shared understanding of and language for pedagogical approaches. ETH Zurich spans 16 departments, over 70 bachelor's and master's programs, and various continuing education formats, so selecting a broad yet precise term is crucial. PBLabs therefore made dedicated effort to develop a practical, institution-wide definition to ensure clarity and consistency in how project-based education is implemented at ETH Zurich. The definition was based on a literature review and multiple discussions with members of ETH Zurich (including educational developers, members of the of the Unit for Teaching and Learning, and lecturers).

The term 'Project-Based Education' (PBE) was chosen because it accommodates the wide range of courses incorporating project elements, allowing for flexibility in interpretation while maintaining conceptual coherence. Furthermore, the term 'education' emphasizes the integral relationship between teaching and learning, reinforcing that project-based formats are not just about active learning (the foundations to develop transferable competencies) but also structured educational design. The following section presents a detailed definition of project-based education at ETH Zurich, outlining its key features.

Definition:
Project-Based Education (PBE) is a pedagogic approach that uses project work to foster subject-specific and transferable competencies, as well as independent learning. Students typically work in teams, sometimes with a guide/coach, and are given a challenge situated in a practice-based context. Through independent inquiry and research (both individually and as part of a group), as well as with a variety of inputs (such as lectures and expert visits), students develop problem statements and solutions that are presented at the end of the course.

Key Features: Under the term 'project-based', we recognise that there are many varieties of projects and many methods that can be applied within projects. Across this diversity, however, there are some core principles (see Figure 1):

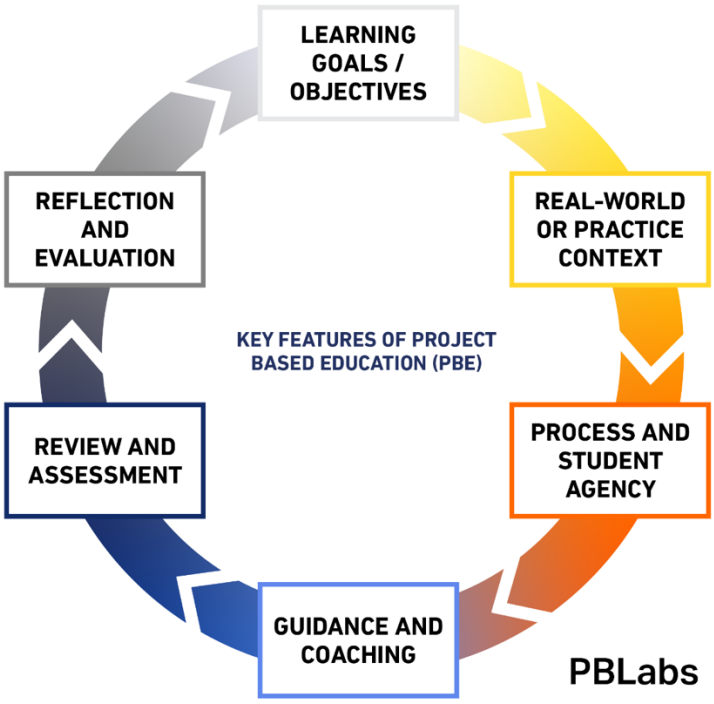

Figure 1: The key features of project-based education (PBE).

Learning objectives

The project is central to the course's curriculum, i.e. students learn a substantial part of the content through the project. Lecturers design learning objectives that clearly connect the content of the course to the subject-specific and transferable competencies that students are expected to develop during the course.

Real-world or practice context

The lecturer(s) situate the project in a relevant, practice-based context, often with connection to practitioners or communities outside the academic context (e.g. as project partners, experts or reviewers). Students navigate a complex and open-ended problem while considering manifold perspectives in their solution-finding process.

Process and student agency

The project offers students a degree of freedom in the definition of a problem/situation, the project process and/or the development of the outcomes of the project. Students pass through multiple and rapid (design/development) iterations. The project promotes independent inquiry and exploration and through this stimulates agency and piques curiosity.

Guidance and coaching

Students often collaborate in (interdisciplinary) groups. Coaches moderate the team process. The lecturers facilitate the learning process by providing guidance and prompting the groups or individuals to find solutions independently. Experts may be invited to provide subject-matter insights, feedback and reviews. Depending on the project size and structure, the roles of the lecturer, coach, and expert may be fulfilled by multiple individuals or the same person.

Review and assessment

Students undertake formative assessments throughout the project and produce a final result that is typically presented to peers and (ideally) external stakeholders from the practice context. Assessments are graded such that both subject-specific and transferable (including method-specific) competencies are assessed. Often, assignments are tailored to the real-world context, such that students use a variety of media to visualize their project as well as process.

Reflection and evaluation

The lecturers design and deliver the project in a way that students are encouraged to reflect on their own learning journey and can understand how both subject-specific and transferable competencies are fostered through the project.

Operationalising the approach

Project-based education is a practice that must be tried out, reflected upon and improved – much like any sort of teaching. In the following section, the above definition and core principles are reconfigured to encourage and support readers to engage with them, and particularly to promote the inclusion of PBE elements into existing teaching practice as well as pedagogical concepts such as Constructive Alignment (Biggs, 1996).

Understanding how the core principles relate to each other is a fundamental aspect of designing a good PBE experience. Whilst the different elements interact across the circle in Figure 1, when designing a PBE format typically the elements are planned in the order shown: First, the main learning objectives of the class and a real-world context needs to be agreed on. Then, more detailed elements such as coaching, assessment, or reflection can follow in the planning process. In this way, Figure 1 aligns with the course design process captured by which forms an excellent introduction to course design for those with little experience.

The cyclical nature of the principles is also important. Most classes at ETH Zurich are part of a curriculum and offered multiple times, providing opportunities to test, gain experience, collect feedback, refine and implement again. In PBE, the overall format may be reasonably consistent although the real-world or practice context or external partners may change.
The PBE cycle can be easily integrated with the Constructive Alignment approach (Biggs, 1996). This pedagogical concept suggests that learning objectives, learning experience and assessment need to be carefully aligned with each other.

As Figure 2 shows, this maps neatly onto the PBE core principles: This suggests that assessment should be heavily informed by the learning objectives to make sure that what is tested is in fact producing the desired learning. At the same time, assessment should reflect/support the student learning experience including the real-world context, the learning process, the guidance and coaching that they receive, and the space for reflection.

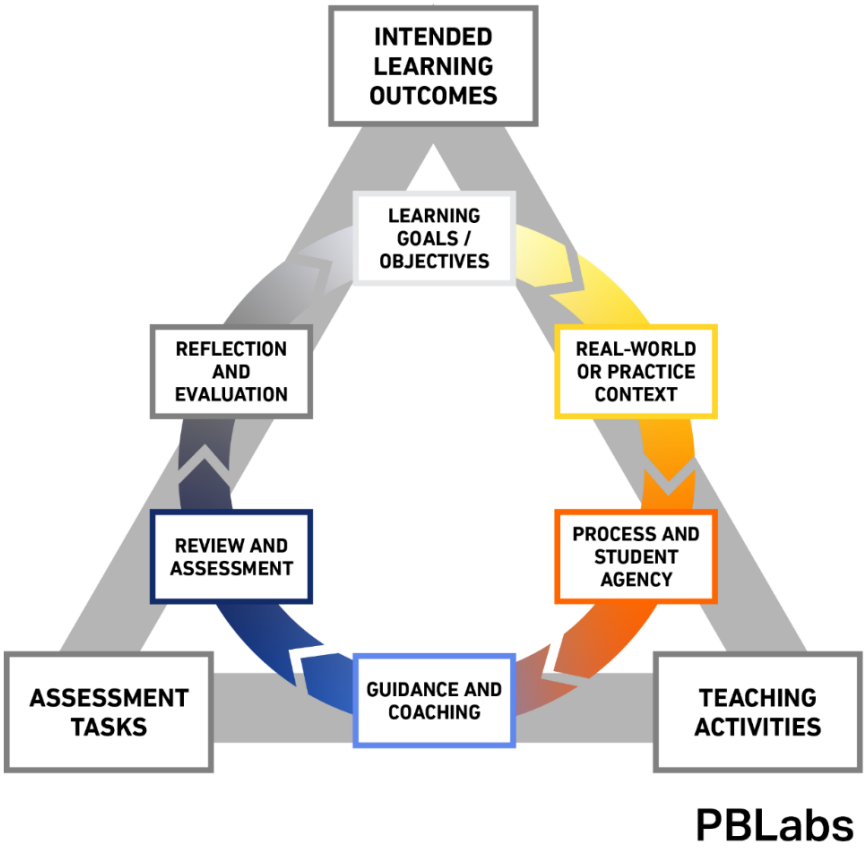

Figure 2: Key features of PBE mapped against the concept of Constructive Alignment. Teaching and learning activities are included the real-world or practice context, the process and student agency as well as the guidance and coaching.

Guiding questions for implementing PBE at ETH Zurich

To support the operationalization of the definition of PBE, the following 'guiding questions' are offered. These questions are intended to help those involved in designing and delivering a module to think carefully about how to engage with the different aspects of PBE. It is important to note that there is no one-size-fits-all approach to designing PBE formats. The guiding questions, and examples in this paper aim to serve as inspiration for those interested in introducing PBE elements to classes. As with any teaching, but perhaps especially when committing to project-based formats which often involve external guests, site visits, etc., it is important to take resources into account at an early stage in the design process. Thus, we also include additional guiding questions for anyone designing a class. These are not considered in the examples listed below but should be a central part of any course design discussion.

Learning goals/objectives	▪ What are the main subject-specific knowledge and transferable competencies that students should learn through this project?[7]
Real-world or practice relevance/ context	▪ How is the project embedded into the curriculum? ▪ What is the connection to a real-world or practice/industry context? ▪ Which challenge or situation can students address through the project?

[7] See more on how to write competence-based learning objectives here: https://ethz.ch/content/dam/ethz/main/eth-zurich/education/lehrentwicklung/files_EN/Vorlage_LernzieleFormulierenEn.pdf

Process and student agency	▪ What options do students have in the design and delivery of the project? ▪ How does the project support students to work independently and develop their own learning journey?
Guidance and coaching	▪ What support is offered to students and when throughout the project? ▪ Who gives this support, and what preparation or training do they need?
Review and assessment	▪ How do students present their work to an audience which could include peers, faculty and external members from the real-world/practice context? ▪ How is formative assessment used? ▪ How are assessments designed to assess the subject-specific and transferable competencies mentioned in the learning objectives?
Reflection and evaluation	▪ How can students explain how the project fostered their transferable and subject-specific competencies? ▪ What space can be given within the project to reflection and feedback on the project journey, the results and teamwork?
Resources	▪ Who needs to be involved to deliver the core content? ▪ What locations or teaching spaces will be needed for this project? ▪ What is the budget for the project's delivery?

Table 1: Guiding Questions for Designing Project-Based Formats.

Examples of PBE in action at ETH Zurich

Example 1 – Entrepreneurship: This course is notable for the very large class size, and the strong connection to the tech sector.

Example 2 – River Restoration: This class fosters an autonomous learning experience that highlights the complexity of river restoration. Lecturers act as experts to be consulted.

Example 3 – NADEL Interdisciplinary MAS project: This course works closely with external organisations who provide a challenge. This gives students a strong motivation to work hard as they have a public presentation to the organisations at the end.

Course information	**Module title:** Entrepreneurship **Lecturer responsible for the project:** Prof. Bart Clarysse **Further involved person/s:** ▪ Business Coaches: 3 ▪ Teaching Assistants: 3-4 (incl. one responsible for coordination) **Department:** D-MTEC; Chair of Entrepreneurship **Credits:** 3 ECTS **Class size:** up to 120 students from Bachelor to PhD
Learning goals/objectives	After this course, students will be able to understand: ▪ How technologies develop from science to commercial products

	▪ What kind of entrepreneurial opportunities emerge from this cycle ▪ How assumptions are tested in the market and evolve into business plans ▪ What the importance of founding teams is and how they are fit together ▪ How to raise money from various sources ▪ How to develop a business case ▪ How to negotiate and structure a funding deal *Transferable competencies (selected):* problem-solving, cooperation and teamwork, project management, customer orientation, creative thinking
Real-world or practice relevance/context	*Driving question:* How can we develop a business idea into a viable business plan and pitch it to an expert jury? *Practice context:* During the course, teams will create a business plan. In 2024, the best plan (voted by a panel of external experts) will go to compete in the Innova Europe Business Plan competition.
Process and student agency	*Length/format of module:* ▪ 14 weeks ▪ 6 lecture inputs ▪ 5 coaching sessions (timed to be after the lectures) ▪ Pitching to external jury members *Student agency in the project:* ▪ Students can bring their own business idea or select an idea to join via a marketplace where other student ideas have been shared. ▪ All students go through a self-assessment process designed to tell them what sort of team member they are, using tools like Kolb's Learning Style Questionnaire. ▪ Based on this, they form teams of 5-6 people who have complementary team styles.
Guidance and coaching	▪ Coaching sessions offer groups feedback and direction based on their deliverables.
Review and assessment	▪ 5 project deliverables that encourage students to form a team, identify a problem and solution, explore markets and prototype their ideas (10%) ▪ Public pitch – Dragon's Den style (20%) ▪ Business plan (20%) ▪ End-of-semester exam (50%)
Reflection and evaluation	▪ Feedback on assignments and grade can be requested at any time

Table 2: Entrepreneurship Course.

Course information	**Module title:** River Restoration **Lecturer responsible for the project: Dr. Volker Weitbrecht** **Further involved person/s:** ▪ Lecturers/experts: 4 ▪ Admin support and team management: 4 **Department:** D-BAUG; Laboratory of Hydraulics, Hydrology and Glaciology (VAW) **Credits:** 3 ECTS **Class size:** Max. 40 students, MSc level
Learning goals/objectives	After this course, students will be able to: ▪ Describe the most important relations in river morphodynamics[8] and their impact on the ecosystem of riverscapes ▪ Elaborate solutions within river restoration, dealing with the different societal expectations towards riverscapes. ▪ Deal with personal, social and technical obstacles in the planning of a river restoration project. *Transferable competences (selected):* analytical competencies, project management, creative thinking, cooperation and teamwork, communication
Real-world or practice relevance/context	*Driving question:* How can we revitalise a river section and restore near natural processes to increase habitat quality and biodiversity? *Practice context:* In 2023 and 2024 the case study area is a 1.7km stretch of the Töss River, Canton Zürich.
Process and student agency	*Length/format of module:* ▪ Expert inputs from lecturers ▪ A role play exercise ▪ Self-guided fieldtrip to the study site and field trip to a completed restoration project ▪ Coaching sessions with lecturers (3 in total) ▪ Presentation session in a market-place format *Student agency in the project:* ▪ Students can select from several focus topics they would like to work on. ▪ The project work is very self-guided: students have to discuss and agree which possible topics to work on, which questions to answer and what the report will contain. They are supported by a grading rubric and coaching to ensure that their decisions will meet the expectations of the lecturers (e.g. to avoid missing out a vital section due to lack of knowledge).
Guidance and coaching	▪ Coaching sessions from lecturers for each of the focus topics. ▪ Optional coaching and feedback sessions from Teaching Assistants are regularly offered during the semester during regular office hour slots. ▪ Optional expert opinions from lecturers can also be requested.

[8] The process by which channel form affects the dynamics of water movement and hence the evolution of channel form

Review and assessment	▪ Project report (50%) ▪ Project presentation in the form of an elaborated situation map (not Powerpoint) (25%) ▪ Peer review of another group's report (25%) ▪ Bonus grade for active participation (+0.25 on final grade)
Reflection and evaluation	▪ Self-reflections on the role-play exercise and field trips in the form of a voice note ▪ Feedback on the class is solicited via an online collaborative tool

Table 3: River Restoration.

Course information	**Module title:** ETH NADEL MAS Interdisciplinary Sustainable Development Challenge **Lecturers responsible for the project:** Jasmine Neve **Further involved person/s:** 4 lecturers/coaches **Department:** D-GESS; NADEL Centre for Development and Cooperation **Credits:** 4 ECTS **Class size:** 24 students, continuing education level (Masters in Advanced Science, MAS)
Learning goals/objectives	After this course, students will be able to: ▪ Systematically analyse specific sustainable development challenges, & design possible solutions, taking into account scientific evidence, user perspectives; and the complexity of the tackled sustainable development challenge (including the social, environmental, economic system in which it occurs). ▪ Apply tools to prompt creativity, innovation and complex problem solving, including design thinking, systems thinking. ▪ Build collaborative relationships with others from diverse disciplines and exchange feedback and ideas constructively. *Transferable competencies (selected):* problem solving, cooperation and teamwork, communication, creative thinking
Real-world or practice relevance/context	*Driving question:* How can we address sustainable development challenges that are complex, interdisciplinary and intercultural in nature? *Practice context:* 8 international cooperation partner organisations present 8 sustainable development challenges they are facing.
Process and student agency	*Length/format of module:* ▪ 14 weeks (1 semester) ▪ 5 classroom sessions with lectures and group work ▪ 1 pitching event with partner organisations ▪ Approximately 20 hours group work outside the classroom ▪ Approximately 35 hours of individual work (reading, research, writing) *Student agency in the project:* ▪ Students form interdisciplinary groups based on their industry background

	▪ Student groups can select the challenge they want to work on. Challenges are provided by the partner organisations
Guidance and coaching	▪ All groups have a supervisor from NADEL who provides feedback at two interim deadlines during the semester on the draft problem analysis and the proposed solutions. ▪ Peer feedback is encouraged throughout. ▪ Three exchanges with the project partners are organised during the project.
Review and assessment	▪ Concept note (including academic literature review) (65%) ▪ Pitch (20%) ▪ Active participation (15%)
Reflection and evaluation	▪ Two reflection rounds were organised to help students address issues that they encountered.

Table 4: NADEL Interdisciplinary MAS Challenge.

Conclusions and implications for higher education

This paper has outlined the historical development of project-based education – both broadly and within ETH Zurich. Rooted in long-standing traditions of higher education, PBE can be framed as a highly relevant approach for university teaching, helping connect the three missions of a university. Based on the history and examples presented here, several key implications for delivering project-based education within ETH Zurich can be identified. These implications will also be relevant to other higher education institutions when they foster PBE.

First, the potential for PBE to foster transferable competencies is an important aspect to consider when thinking about curriculum design. If students in a curriculum have several PBE courses at different points, there may be specific competencies that are fostered across several courses, for example project-management or collaboration. At a curriculum-level it could be helpful to coordinate how these competencies are covered in different courses, to avoid repetition of basic information or methods - a 'stacking' of competence-based content. Similarly, PBE courses often benefit from the content taught earlier on in a curriculum – students may already know methods or knowledge that they can use for a project. However, when the learning transfer is not sufficiently clear, students may not realise that they can use that prior knowledge – a missed opportunity, requiring more content-heavy input from the PBE lecturer that may be repetitive for some students. Close alignment by lecturers of content-focused and project-focused courses across a curriculum can strengthen the overall learning experience and have been documented elsewhere (e.g. Habbal et al., 2024).

Secondly, designing PBE courses opens up opportunities for building up interdisciplinarity in teaching. Real-world contexts, problems and challenges often need students to delve into many different aspects of a topic, encouraging them to connect knowledge from different areas. When classes have diverse student groups this can explicitly encourage interdisciplinary exchange – for example, the NADEL course outlined above (example 3) asks students to build teams of peers from different sectors for the project, to strengthen creative thinking and solution finding. In complex contexts, or where interdisciplinarity is an explicit goal of a course, students may need to put more time into learning new methods, gathering background knowledge or incorporating diverse perspectives compared to a more subject-specific course, and projects can benefit from larger courses with more credit points to provide sufficient time for exploration.

Thirdly, and given the above points, it seems likely that implementing PBE will foster communication and exchange between lecturers, and ultimately that 'communities of practice' (Wenger-Trayner et al., 2022) – a group of people informally bound together by shared

expertise and passion for a joint enterprise – will develop within and across departments to share their experiences, strategies and classroom techniques without necessarily teaching together. Indeed, Oliveira discusses the essential role of community in ensuring that efforts to create PBE curricula are maintained as staff members leave and HE strategies change (Oliveira, 2023), and ETH Zurich already has communities of practice within some departments (e.g. Bondar et al., 2024).

Fourthly, the topic of classroom or teaching spaces is also important. PBE often requires multiple classroom set ups – for example plenary lectures, poster sessions, group spaces, design studios and more. The examples in this paper range from lectures to field trips, coaching sessions, idea 'market places', and pitching events. As PBE becomes more important within an institution, the teaching spaces needed will change from traditional raked lecture theatres to more flexible, open spaces capable of hosting diverse classroom formats. If PBE work involves the creation of physical objects or prototypes, then there may be additional need for workshops and lab spaces that are used in new ways to classic teaching labs where multiple classes are accommodated on a regular basis. PBE is therefore likely to require greater efficiency in sharing and reuse of tools, resources and spaces across departments. This is an important consideration at a time when the scarcity of resources is a problem within institutions as well as in wider society.

Fifthly, PBE challenges traditional perceptions of university teaching. In primary and secondary education, the shift has been described as 'from the sage on the stage to the guide on the side' (Larmer et al., 2015). Engaging with and learning from the expertise and deep knowledge of university lecturers is one of the great opportunities for students in higher education. While PBE emphasizes student agency and increased responsibility, it does not mean that the profound knowledge base of university lecturers and researchers are no longer needed. On the contrary, their deep knowledge of their subject, the methods used to advance it, and its contribution to the wider world and its problems remains essential. PBE is different from the traditional lecture-based approach that has long dominated higher education, but builds upon it. The examples in this paper, each involving 3-4 additional academics or professionals, suggest that even in small classes, multiple experts are essential for a comprehensive teaching experience. Given their changing role, lecturers will need to have and use their own competencies in coaching, team-management and project planning to guide, advise and support students in PBE formats.

Finally, at institutions with large student cohorts (like ETH Zurich where classes can have 400+ students), attaining good student to lecturer ratios will require the appointment of teaching assistants able to support project-based courses. ETH Zurich has long offered training in coaching skills for teaching but is now developing a more structured approach to train teaching assistants in coaching skills, to enable them to support and co-deliver PBE courses as 'student coaches'.

Universities are complex places, subject to contradictory missions (Berghaeuser & Hoelscher, 2020; Etzkowitz & Leydesdorff, 2000). Teaching, one of the three core missions of universities, is the connection point between the other two (doing research and adding value to society). The way teaching is designed and delivered is critical if current students and future members of society are to acquire the various competencies (both subject-specific as well as transferable) that they will need to navigate a rapidly changing world and its increasingly knowledge-based economy (Collini, 2012; Harvey, 2000; La Cara, 2023a). Project-based education provides a useful frame for discussions about what students need to learn and how this can be taught. The adoption of PBE will encourage learning environments to align with the real-world context most graduates will end up in. PBE will bring changes in how curricula are designed and will support lecturers and TAs to reimagine their roles to meet the changing world. These changes will help the higher education sector stay relevant.

Bibliography

Barnett, R., Parry, G., & Coate, K. (2001). Conceptualising Curriculum Change. *Teaching in Higher Education*, 6(4), 435–449. https://doi.org/10.1080/13562510120078009.

Berghaeuser, H. & Hoelscher, M. (2020). Reinventing the third mission of higher education in Germany: political frameworks and universities' reactions. Tertiary Education and Management, 26(1), 57–76. https://doi.org/10.1007/S11233-019-09030-3/FIGURES/3.

Biggs, J. (1996). Enhancing teaching through constructive alignment. *Higher Education*, 32(3), 347–364. https://doi.org/10.1007/BF00138871/METRICS.

Bondar, V., Nuber, J., Zeyen, M., Schiltz, G., Kirch, K., & Dissertori, G. (2024). Supporting Teaching Assistants in a Community of Practice. *Journal of Physics: Conference Series*, 2750(1), 012046. https://doi.org/10.1088/1742-6596/2750/1/012046.

Chafee, Richard. (1977). The teaching of architecture at the École des Beaux-Arts. In A. Drexler (Ed.), The architecture of the École des Beaux-Arts (pp. 61–109). Museum of Modern Art ; Distributed by MIT Press. https://books.google.com/books/about/The_Architecture_of_the_Ecole_Des_Beaux.html?hl=de&id=csPDugEACAAJ.

Collini, S. (2012). What are Universities For? The Penguin Group, UK. https://books.google.ch/books?hl=de&lr=&id=_k3pZxmPSVUC&oi=fnd&pg=PT12&dq=Colini,+S.+(2012).+What+are+universities+for%3F+The+Penguin+Group,+UK.&ots=OAwfTWZelV&sig=WbZDOPJg2p72LSZIroecHrIkzxo&redir_esc=y#v=onepage&q=Colini%2C%20S.%20(2012).%20What%20are%20universities%20for%3F%20The%20Penguin%20Group%2C%20UK.&f=false.

De Graaff, E. & Kolmos, A. (2003). Characteristics of Problem-Based Learning. *International Journal of Engineering Education*, 19 (5), 657662.

Denayer, I., Thaels, K., Vander Sloten, J., & Gobin, R. (2003). Teaching a structured approach to the design process for undergraduate engineering students by problem-based education. *European Journal of Engineering Education*, 28(2), 203–214. https://doi.org/10.1080/0304379031000079031.

Enders, J. & De Boer, H. (2009). The Mission Impossible of the European University: Institutional Confusion and Institutional Diversity. In A. Amaral, G. Neave, C. Musselin, & P. Maassen (Eds.), *Higher Education Dynamics* (Vol. 26, pp. 159–178). Springer, Dordrecht. https://doi.org/10.1007/978-1-4020-9505-4_7.

Etzkowitz, H. & Leydesdorff, L. (2000). The dynamics of innovation: from National Systems and ‘‘Mode 2’’ to a Triple Helix of university-industry-government relations. In Research Policy (Vol. 29). www.elsevier.nlrlocatereconbase.

European Union. (n.d.). Defining ‘Skill’ and ‘Competence.’ EU Science Hub. Retrieved February 24, 2025, from https://joint-research-centre.ec.europa.eu/scientific-activities-z/skills-and-competences/defining-skill-and-competence_en.

Franco, L. F. M., da Costa, A. C., de Almeida Neto, A. F., Moraes, Â. M., Tambourgi, E. B., Miranda, E. A., de Castilho, G. J., Doubek, G., Dangelo, J. V. H., Fregolente, L. V., Lona, L. M. F., de La Torre, L. G., Alvarez, L. A., da Costa, M. C., Martinez, P. F. M., Ceriani, R., Zemp, R. J., Vieira, R. P., Maciel Filho, R., … Suppino, R. S. (2023). A competency-based chemical engineering curriculum at the University of Campinas in Brazil. *Education for Chemical Engineers*, 44, 21–34. https://doi.org/10.1016/J.ECE.2023.04.001.

Freire, P. (1970). Pedagogy of the oppressed. In Toward a sociology of education (pp. 374–386). Routledge. https://api.taylorfrancis.com/content/chapters/edit/download?identifierName=doi&identifierValue=10.4324/9780429339530-34&type=chapterpdf.

Gille, F. (2020). What works in course development? A practice guide. *ETH Learning and Teaching Journal*, 2(1), 103–114. https://doi.org/10.16906/LT-ETH.V2I1.68.

Gugerli, D. (2005). ETHistory - POST. https://www.ethistory.ethz.ch/besichtigungen/touren/vitrinen/forschungspfade/vitrine23/index.html.

Habbal, F., Kolmos, A., Hadgraft, R. G., Holgaard, J. E., & Reda, K. (2024). Reshaping Engineering Education. In Reshaping Engineering Education. Springer Nature Singapore. https://doi.org/10.1007/978-981-99-5873-3/COVER.

Harvey, L. (2000). New realities: The relationship between higher education and employment. *Tertiary Education & Management*, 6(1), 3–17. https://doi.org/10.1080/13583883.2000.9967007.

Kilpatrick, W. H. (1918). The Project Method. Teachers College Record, XIX(4). https://www.education-uk.org/documents/kilpatrick1918/index.html.

Krajcik, J. & Blumenfeld, P. (2006). 19. Project-Based Learning. In The Cambridge handbook of the learning sciences (pp. 317–333). https://scholar.google.com/scholar?hl=de&as_sdt=0%2C5&q=Krajcik%2C+J.%2C+Shin%2C+N.+%282022%29.+Project-based+learning.+In%3A+The+Cambridge+Handbook+of+the+Learning+

Sciences%2C+3rd+Edn.+Ed%3A+R.+K.+Sawyer.+Cambridge+University+Press%2C+UK.&btnG=#d=gs_cit&t=1740412948500&u=%2Fscholar%3Fq%3Dinfo%3AoDoH3HYH68J%3Ascholar.google.com%2F%26output%3Dcite%26scirp%3D0%26hl%3Dde.

Kuhn, S. (2001). Learning from the Architecture Studio: Implications for Project-Based Pedagogy. *International Journal of Engineering Education*, 17 4-5, 349–352.

La Cara, B., Gemünden, M., & Koch-Kiennast, B. (2023a). Fostering social and personal competencies in higher education: The ETH Competence Framework case. *ETH Learning and Teaching Journal*, 4(1), 105–118. https://doi.org/10.16906/LT-ETH.V4I1.223.

La Cara, B., Gemünden, M., & Volk, B. (2023b). Competencies in eDoz Manual. https://ethz.ch/content/dam/ethz/main/eth-zurich/organisation/stab-rektor/eth-talent-restricted/2023.09.04_Manual_Competencies%20in%20eDoz_v5.pdf.

Larmer, J., Mergendoller, J., & Boss, S. (2015). Setting the standard for project based learning. Ascd, USA.

Lee, J. S., Blackwell, S., Drake, J., & Moran, K. A. (2014). Taking a Leap of Faith: Redefining Teaching and Learning in Higher Education Through Project-Based Learning. *Interdisciplinary Journal of Problem-Based Learning*, 8(2). https://doi.org/10.7771/1541-5015.1426.

Lunev, A., Petrova, I., & Zaripova, V. (2013). Competency-based models of learning for engineers: a comparison. *European Journal of Engineering Education*, 38(5), 543–555. https://doi.org/10.1080/03043797.2013.824410.

Lyotard, J.-F., Bennington, G., & Massumi, B. (1984). The Postmodern Condition: A Report on Knowledge. *Poetics Today*, 5(4), 886. https://doi.org/10.2307/1772278.

Mann, L., Chang, R., Chandrasekaran, S., Coddington, A., Daniel, S., Cook, E., Crossin, E., Cosson, B., Turner, J., Mazzurco, A., Dohaney, J., O'Hanlon, T., Pickering, J., Walker, S., Maclean, F., & Smith, T. D. (2020). From problem-based learning to practice-based education: a framework for shaping future engineers. *European Journal of Engineering Education*, 46(1), 27–47. https://doi.org/10.1080/03043797.2019.1708867.

Mather, L. L., Davis, J. T., Brannon, R. H., Bordeaux, A. F., & Beck, R. L. (1977). Developing a Competency-Based Curriculum in Agricultural Economics. *American Journal of Agricultural Economics*, 59(4), 760–765. https://doi.org/10.2307/1239409.

National Institutes of Health, O. of H. R. (n.d.). What are competencies? Retrieved February 24, 2025, from https://hr.nih.gov/about/faq/working-nih/competencies/what-are-competencies.

Oliveira, J. M. N. de. (2023). Reflecting on 21 years of running full PBL programs. *Frontiers in Education*, 8, 1033764. https://doi.org/10.3389/FEDUC.2023.1033764/BIBTEX.

Pohl, C., 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.

Powell, D. E., & Carraccio, C. (2018). Toward Competency-Based Medical Education. *New England Journal of Medicine*, 378(1), 1–3. https://doi.org/10.1056/nejmp1712474.

Salama, A. M. (2015). Spatial Design Education New Directions for Pedagogy in Architecture and Beyond. Ashgate.

Savery, J. R. (2006). Overview of Problem-based Learning: Definitions and Distinctions. *Interdisciplinary Journal of Problem-Based Learning*, 1(1), 9–20. https://doi.org/10.7771/1541-5015.1002.

Sawyer, R. K. (2022). An introduction to the learning sciences. In The Cambridge handbook of the learning sciences (pp. 1–24). https://doi.org/10.1017/9781108888295.002.

Servant-Miklos, V. (2020). Problem-oriented project work and problem-based learning: 'Mind the gap!' *Interdisciplinary Journal of Problem-Based Learning*, 14(1), 1–17. https://doi.org/10.14434/ijpbl.v14i1.28596.

Servant-Miklos, V. F. C. (2019). Problem solving skills versus knowledge acquisition: the historical dispute that split problem-based learning into two camps. *Advances in Health Sciences Education*, 24(3), 619–635. https://doi.org/10.1007/s10459-018-9835-0.

Sukackė, V., Guerra, A. O. P. de C., Ellinger, D., Carlos, V., Petronienė, S., Gaižiūnienė, L., Blanch, S., Marbà-Tallada, A., & Brose, A. (2022). Towards Active Evidence-Based Learning in Engineering Education: A Systematic Literature Review of PBL, PjBL, and CBL. *Sustainability* 2022, Vol. 14, Page 13955, 14(21), 13955. https://doi.org/10.3390/SU142113955.

Tschanz, M. (2015). Die Bauschule am Eidgenössischen Polytechnikum in Zürich: Architekturlehre zur Zeit von Gottfried Semper (1855-1871). Gta-Verlag. https://doi.org/10.3929/ETHZ-A-010050178.

United Nations. (2010). UN Competency Development.

Vitello, S., Greatorex, J., & Shaw, S. (2021). What is competence? A shared interpretation of competence to support teaching, learning and assessment Research Report. https://www.cambridge.org/.

Wenger-Trayner, E., Wenger-Trayner, B., Reid, P., & Bruderlein, C. (2022). Communities of practice within and across organizations: A guidebook. Social Learning Lab.

Winning, T. & Townsend, G. (2007). Problem-based learning in dental education: What's the evidence for and against... and is it worth the effort? *Australian Dental Journal*, 52(1), 2–9. https://doi.org/10.1111/j.1834-7819.2007.tb00458.x.

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