Developing Interpersonal Competence Through Project-based Sustainability Courses – Material from a Comparative Study

Theres Konrad, Arnim Wiek, Matthias Barth

Working Papers in Higher Education for Sustainable Development Series

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Editorial

Working Papers in Higher Education for Sustainable Development is a series dedicated to publishing recent insights and discussions from ongoing research projects in the field of Higher Education for Sustainable Development. One major goal is to make detailed case descriptions, notes on methods, research designs, and related information available in a transparent fashion; such information usually exceeds the scope of journal articles. Fellow researchers, scholars, and practitioners are invited to comment, discuss, and contribute their thoughts and experiences. This working papers series is published by the joint Center for Global Sustainability and Cultural Transformation (CGSC), a transatlantic academic collaboration between Leuphana University of Lüneburg and Arizona State University.

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Abstract

English
As part of the *Educating Future Change Agents* project, one case study investigated three project-based sustainability courses regarding the link between learning outcomes, i.e. *what* students learn in such courses, and processes, i.e. *how* they learn, as well as the enabling or hindering learning environment. This working paper provides detailed case descriptions of the three project-based sustainability courses at (1) Leuphana University of Lüneburg (Germany) and Arizona State University (USA), (2) the Swiss Federal Institute of Technology (Switzerland), and (3) the Polytechnic University of Catalonia (Spain). It captures contextual conditions, learning environment, teaching and learning formats, and student cohorts of the courses to increase transparency of the research and provide context for the empirical results.

Key words: key competence development, project-based learning sustainability courses, teaching and learning processes and environments, case study, sustainability higher education

Deutsch
Im Rahmen des Projekts *Educating Future Change Agents* untersuchte eine Fallstudie drei projektbasierte Nachhaltigkeitskurse hinsichtlich des Zusammenhangs zwischen Lernergebnissen, d.h. *was* die Studierenden in solchen Kursen lernen, und Lernprozessen, d.h. *wie* sie lernen, sowie der fördernden oder hemmenden Lernumgebungen. Dieses Arbeitspapier enthält detaillierte Fallbeschreibungen der drei projektbasierten Nachhaltigkeitskurse an (1) der Leuphana Universität Lüneburg (Deutschland) und der Arizona State University (USA), (2) der Eidgenössisch Technische Hochschule (Schweiz) und der Polytechnischen Universität von Katalonien (Spanien). Es erfasst die Kontextbedingungen, Lernumgebung, Lehr- und Lernformate, sowie Studierendenkohorten der Kurse, um die Transparenz der Forschung zu erhöhen und die empirischen Ergebnisse zu kontextualisieren.

Keywords: Entwicklung von Schlüsselkompetenzen, projektbasierte Nachhaltigkeitskurse, Lernprozesse, Lernumgebungen, Fallstudie, Nachhaltigkeit in der Hochschulbildung

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1. Introduction

1.1 The Educating Future Change Agents Project

The *Educating Future Change Agents* (EFCA) project produced empirical insights on how higher education can support students' development of key competencies in sustainability. The project was conducted 2016-2020 as a joint research project between Leuphana University of Lüneburg, Germany and Arizona State University, Tempe, Arizona, USA. The project was structured into five studies, which conducted in-depth research on course, curriculum, and institutional levels. The specific cases were selected to capture a high degree of similarity and difference within and across cases and to represent the field of sustainability education, namely, education of sustainability professionals, teachers, and entrepreneurs.
All studies were grounded in a shared analytical framework that informed both data collection and analysis. Based on this framework, each study adopted its own suite of research methods appropriate for the respective research questions, while still coordinating and sharing insights on methods among the studies. Each study produced a set of results specific to the specific case(s) and contexts. In the final phase of the project, results from the individual studies were synthesized to offer general insights for researchers, educators, and administrators in the field of sustainability education.
Results of the EFCA project have been published and can be found on ResearchGate: https://www.researchgate.net/project/Educating-Future-Change-Agents. This working paper series provides additional background material to facilitate deeper understanding of the research. The working papers offer thorough case documentation and in-depth information on instruments and analytical steps.

1.2 The Comparative Case Study on Project-based Sustainability Courses

Focusing on the course-level of the EFCA project, this working paper covers research on three project-based sustainability courses at (1) Leuphana University of Lüneburg and Arizona State University (ASU), (2) the Swiss Federal Institute of Technology (ETH), and (3) the Polytechnic University of Catalonia (UPC). The study addressed the question of *how students develop interpersonal competence, as a key competence in sustainability, in project-based sustainability courses*.
The courses at Leuphana/ASU, ETH, and UPC were selected to compare and contrast pioneering courses to derive specific as well as generalizable insights. The three cases display variance in terms of learning objectives, teaching and learning approach, and context. A comparative study allows for more generalizable insights compared to single case studies (Barth and Thomas, 2012). To enhance transparency, reliability, and understanding of the findings, detailed insights into case specifics are presented here (Yin, 1984).
This working paper describes each case, i.e. course, along the same structure, including learning objectives, teaching and learning approach, course outline (sequence of activities), and participating student cohort. The working paper concludes with a comparative table that highlights similarities, differences, and methods applied across cases. The findings of this case study are published in three scientific journal articles (Konrad *et al.*, 2020; Konrad *et al.*, 2021; Konrad *et al.*, in review).

1.3 Acknowledgements

We acknowledge support from the EFCA research team. Special thanks go to all course participants, i.e. students, instructors, tutors, stakeholders, and participating faculty. The authors acknowledge funding from the Lower Saxony Ministry of Science and Culture and Volkswagen Foundation for the grant “Educating Future Change Agents – Higher Education as a Motor of the Sustainability Transformation” (A115235) through the program “Science for Sustainable Development”.

2. Description of Cases

2.1 The Global Sustainability Research (GSR) Course (Case 1)

The Global Sustainability Research (GSR) course is a joint endeavor between Arizona State University and Leuphana University of Lüneburg within the international dual-degree master program Global Sustainability Science (GSS). It is formally embedded in the joint Center for Global Sustainability and Cultural Transformation (CGSC)[1], launched in 2015. The GSR course is a mandatory project-based course that is structured into multiple parts and spans over three semesters.

Context of the case study

To provide context to this case study, we briefly summarize relevant aspects of the German and U.S. higher education systems.

In the 2000s, most German universities adopted the suggested changes of the Bologna Declaration and replaced Diploma or Magister degrees with bachelor/undergraduate and master/graduate degrees. The European Credit Transfer and Accumulation System (ECTS) was introduced as part of an agreement to simplify the transfer of courses and degrees among universities in Europe. One credit in the ECTS is the equivalent of 25-30 hours, with an academic year consisting of 60 ECTS credits, or 1,500-1,800 hours of work. Enrollment at a university in Germany is subject to completed university preparatory school and exam (Abitur) or equivalent. Most universities in Germany are public and study fees are generally less than 500€/semester (360€/semester at Leuphana). Most graduate students at German universities are full-time students. Leuphana had 10,000 students enrolled in year 2018-2019, 1,000 of whom study sustainability graduate and undergraduate programs[2].

Most universities in the U.S. follow a credit system in which one Credit Point (CP) corresponds to one hour of instructional time per week, plus two hours of student work, translating 1 CP into 3 hours total time per week. A typical course is 3 CP and graduate students pursue 4 courses per semester, i.e., 12 CP. Enrollment in a graduate program requires a certificate of completed secondary school (or similar). In some cases, a Graduate Requirement Exam (GRE) is required and/or a university-specific entry exam. As of fall term 2021, the GRE will no longer be required at ASU. Tuition varies significantly across and within universities. For Arizona residents, for instance, graduate study fees at ASU's School of Sustainability are more than $12,000 per year. Students cover tuition through scholarships, student loans, working for the university, e.g. as teaching or research assistants, or other work. ASU is the largest public university in the U.S. with more than 75,000 students and more than 7,000 full-time master students (fall 2019). The School of Sustainability has more than 500 undergraduate students and more than 70 graduate students enrolled in master programs (fall 2019)[3].

The international, dual-degree Master's Program *Global Sustainability Science* (GSS) was jointly developed by ASU and Leuphana (see Birdman *et al.*, 2020). As a dual-degree program, workload is higher compared to single-degree master programs. Students attend

[1] https://global.asu.edu/center-global-sustainability-and-cultural-transformation [13.05.20]
[2] https://www.leuphana.de/en/university/history/sustainability/faculty-of-sustainability.html [28.07.20]
[3] https://sustainability.asu.edu [28.07.20]

mandatory and elective courses as well as the project-based GSR course (Fig. 1). The GSS program includes for all students a mandatory semester abroad (Semester 2 or 3 respectively) and concludes with a master thesis in semester four at the respective home university.

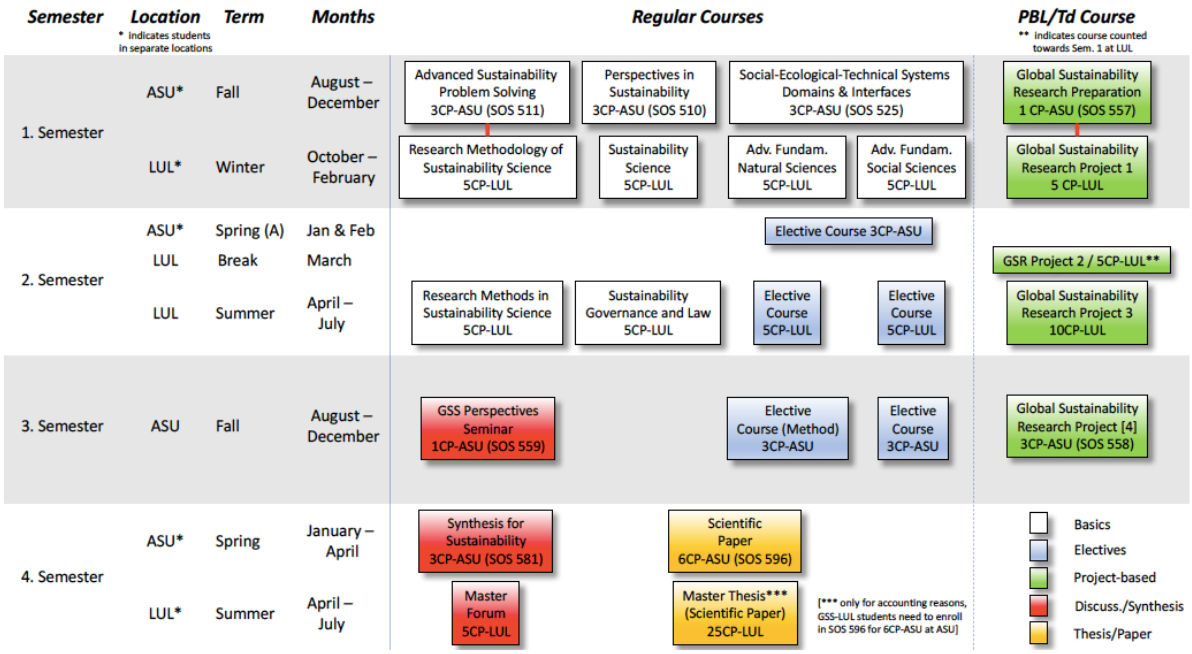

Figure 1: Overview of the Global Sustainability Science (GSS) program

General features of the Global Sustainability Research (GSR) course

The GSR course spans three semesters (Semester 1-3) and takes place in both locations. It starts in semester one at the respective home university, continues at Leuphana in semester two, and concludes at ASU in semester three (Fig. 1). Students receive intercultural, collaborative, as well as professional training in the GSR course. After first virtual encounters during semester one, students collaborate in person in the GSR course during semesters two and three.

The GSR course consists of 10 + 10 + 5 ECTS (Leuphana) or 1 + 3 + 3 CP (ASU). For semester 3 at ASU, for instance, this translates into a workload of 180 working hours, including 45 contact/coaching hours, over 15 weeks (August-December). Per week this refers to 12 working hours, including 3 contact/coaching hours.

The design of the GSR course builds upon an international sustainability education pilot project (Wiek *et al.*, 2013; Caniglia *et al.*, 2018) and various project-based learning collaborations between ASU and Leuphana (Wiek *et al.*, 2014; Withycombe Keeler *et al.*, 2016). It has been formed over several years and utilizes project-based, experiential, and professional learning pedagogies (Brundiers and Wiek, 2013; Wiek *et al.*, 2013; Wiek *et al.*, 2014; Caniglia *et al.*, 2016; Caniglia *et al.*, 2018). The general features of the course are summarized in Table 1.

Table 1: General features of the GSR course

Course title	Global Sustainability Research
Duration	3 semesters
Structure	Semester 1 – at respective home university (ASU or Leuphana) Semester 2 – all at Leuphana (April-July) Semester 3 – all at ASU (August-December) [case study focus]
Students	10-20 GSS students (open to select graduate students from other master programs)
learning objectives	Theoretical, methodical, and professional skills for transformational research in sustainability
assessment	1. Project deliverables 2. Teamwork 3. Stakeholder engagement 4. Project report

Learning objectives

The main objective of the GSR course is that students learn to conduct a transformational sustainability research project within a frame of reference and thereby develop key competencies in sustainability (Wiek *et al.*, 2011; Caniglia *et al.*, 2017). Students are expected and supported to collaborate in mixed teams from both universities and engage stakeholders in the project. Developing professional skills in sustainability (Brundiers and Wiek, 2017) is an integral learning objective of the GSR course.

Specific features of the GSR course 2016-17

The GSR project course 2016-17 was linked to ongoing research projects and focused on local food economy solutions. The goal was to conceptualize and pilot a so-called “Mobile Solution Studio”, i.e., a flexible facility that uses data, visuals, narratives, etc. in various engagement activities (during semester 3 at ASU) to enable and empower decision makers and other stakeholders to implement sustainability solutions (Lang *et al.*, 2016; Lang *et al.*, 2017). The guiding research question was: *How can a mobile solution studio foster capacity for implementing sustainability solutions in general, and local food economy solutions in particular, in Lüneburg and Tempe?* This case study focuses on semester three (Tab. 2) of the GSR course for comparability with the other two (one-semester) courses (ETH, UPC).

Table 2: Specific features of the GSR course 2016-2017, semester 3

Students	12 GSS students
assessment	1. Delivery of (i) an interactive capacity-building process template, (ii) data-based descriptions of sustainable food business and economy solutions, (iii) a functional capacity-building tool (3 teams)

2. Active participation in teamwork and coaching
3. Facilitation of one or more stakeholder engagement sessions, in which the aforementioned components were integrated, applied, and tested
4. Project report

Pedagogical approach of the GSR course 2016-17

Over 15 weeks students met twice per week for 1,5 hours each. Class time was used for interactive, collaborative working and input sessions by instructors, external guest speakers, and supporting faculty. The course followed a sequenced scaffolding approach:

(1) A facilitation training prepared students for their first stakeholder event.
(2) Students participated in the event (Withycombe Keeler *et al.*, 2018) as table or room observers, and/or receptionists. Students were able to observe good practices of impactful stakeholder engagement, for which they were debriefed afterwards in class.
(3) Students co-facilitated a public engagement event (at "First Friday" in Phoenix) together with instructors. This was debriefed afterwards in class, too.
(4) Students worked in teams (4 students each) on project deliverables, (i) an interactive capacity-building process template, (ii) data-based descriptions of sustainable food business and economy solutions, and (iii) a functional capacity-building tool (Tab. 2). In-class presentations and team coaching accompanied this phase.
(5) Run-throughs, dry-runs, and revisions of deliverables, including facilitation practice, prepared students for the main stakeholder capacity-building event.
(6) Students co-facilitated the main capacity-building event, which provided students with opportunities to perform as facilitators, note takers, (solution) experts, receptionists, and overall event manager. The event was followed by instructor debriefings, report writing, and a reflective focus group (with an external researcher).

Table 3: Sequences of activities in the GSR course 2016-17, semester 3 at ASU

Session	Focus Areas
00	Pre-course: Facilitation Training, **Event #1** with City of Tempe staff in Tempe
01	**Course introduction**: course objectives, structure, time line, etc.
02	Familiarizing / Planning of deliverables / Preparation Event #2
03	Familiarizing / Planning of deliverables / Preparation Event #2 **Event #2** with public in Phoenix
04	**Working on deliverables**, teamwork and coaching sessions
05	Working on deliverables
06	Working on deliverables + **integration**
07	Working on deliverables + integration
08	Run-Throughs
09	Refining deliverables & integration
10	Refining deliverables & integration
11	Refining deliverables & integration

12	Dry-Run(s)
13	**Event #3** with food economy stakeholders in Tempe
14	Processing data, preparing report
15	Processing data, preparing report
16	Synthesis, report writing, and reflections

The teaching and learning approach was based on two pillars: First, tailored support for student teams provided by three instructors plus a professional skills advisor, available for consultation and responsible for review, mediation, etc. Second, several local project partners, most notably the Sustainability Director of the City of Tempe, and about 30 local food economy stakeholders were involved in research and project activities providing professional resources and real-world application context. A series of stakeholder engagement events provided opportunities for observation and practice experience with increasing task difficulty (from observation to note-taking to facilitation).
The teaching and learning approach can be described as guiding and supportive, i.e., instructors giving direction and coaching project teams along the process. All students entered semester 3 with prior initial training on conflict mediation and intercultural collaboration (semester 2).

Participants
The GSR course cohort (2016-2017) consisted of 12 students from four countries (USA, Mexico, Germany, South Africa) – 7 female and 5 male students between 25 and 35 years in age with academic backgrounds ranging from political science to natural science and tourism studies. The majority of students brought relevant experiences from previous work, volunteering, and/or international travel to the course.

2.2 The transdisciplinary Case Study (tdCS) course (Case 2)

The transdisciplinary Case Study (tdCS) course is available to all master students of the Swiss Federal Institute of Technology (ETH) Zurich, Switzerland. Particularly, students pursuing a master´s program within the *Department of Environmental Systems Science* (D-USYS) are encouraged to apply. The tdCS course is formally embedded within the Transdisciplinary Laboratory (TdLab), launched in 2013 and situated within the Institute of Environmental Decisions (IED)[4]. The tdCS case study is an elective one-semester course and consists of two phases: the Zurich phase (entire semester) and the following field phase (three weeks).

Context of the case study

To provide context to this case study, we briefly summarize relevant aspects of the Swiss higher education system.

In 1999, Switzerland signed the Bologna Declaration, which led to a comprehensive reform of academic degree programs at all higher education institutions in Switzerland, including the shift to the two-tier study system, i.e. bachelor and master. The European Credit Transfer and Accumulation System (ECTS) was introduced as part of an agreement to simplify the transfer of courses and degrees among universities in Europe. One credit in the ECTS is the equivalent of 25-30 hours, with an academic year consisting of 60 ECTS credits, or 1,500-1,800 hours of work.

Enrollment at a Swiss university is subject to completed university preparatory school and exam or equivalent (Baccalaureate or a Federal Vocational Baccalaureate). Both public and private universities claim student fees. The average tuition fees at public universities ranged from 400 to 3,700 EUR/year for a bachelor or master program (1,200 EUR at ETH) in 2019. ETH had more than 22,000 students enrolled, 7,000 of whom in master programs in 2019.

The international master course “transdisciplinary Case Study” (tdCS) builds upon more than 10 years of transdisciplinary, project-based sustainability education (Krütli *et al.*, 2018b; Stauffacher *et al.*, 2006).

General features of the transdisciplinary Case Study (tdCS) course

The tdCS course typically takes place in the second semester, every other year with focus on the Seychelles. Students train intercultural, collaborative, as well as professional competencies. After first virtual encounters with bachelor students of the University of the Seychelles, students collaborate in person during the field phase on the Seychelles. The tdCS course consists of 7 ECTS. Over 14 weeks (February-May) students meet weekly (Wednesday afternoons) for four hour sessions, with two hours additional homework/preparation time. The field phase lasts for 15 working days (8 working hours/day). With two additional validation workshop days this adds up to 220 hours for the full course. The general features of the course are summarized in Table 4.

[4] https://ied.ethz.ch/about.html [20.03.20]

Table 4: General features of the tdCS course

Course title	Transdisciplinary Case Study
Duration	1 semester + field phase
Structure	Zurich phase: 14 weeks with 4 hours weekly sessions + 2 days: workshop in April with stakeholders from the Seychelles for joint project framing Seychelles phase: 3 weeks
Students	Max. 25, ideal 20 [cohort 2018: 19 students]
learning objectives	Understand a case in its context; apply transdisciplinary methods, skills and knowledge in the real world; manage research activities independently; work in inter-disciplinary and -cultural teams; and adapt to foreign social, economic, cultural and political settings
assessment	Continuous self-assessment of competence development: First, at the course start (self-assessment); then course assessment around mid-semester, end-of-semester, and end-of-field phase, including a 30 minutes instructors-student-conversation with individual feedback

Learning objectives

The main objective of the tdCS is that students develop an understanding of "a case and its context from a variety of perspectives, and to extract multiple ways of framing, analysing and developing potential solutions for the problem at hand."[5] Students learn to define relevant research questions for a (wicked) sustainability problem; select and apply tools and methods to collect, analyze, and interpret data to answer research questions; apply transdisciplinary methods and overall knowledge in the real world; independently manage research activities; work in an interdisciplinary and intercultural team; collaborate with stakeholders; and adapt to foreign social, economic, cultural and political settings[6]. Students are expected to collaborate in mixed teams from both universities and engage stakeholders during their respective project. Developing professional skills in sustainability is therefore a potential learning outcome of the tdCS course.

Specific features of the tdCS course 2018

The tdCS course 2018 had focused on waste management in small island developing states. The goal was to build upon the first tdCS on the Seychelles (2016) and advance insights and solutions for sustainable waste management. Focus areas were waste collection and sorting, feasibility of recycling, hazardous waste flow, anaerobic digestion, incineration, financial mechanisms and implementation of plans (Krütli *et al.*, 2018a). Each of the project teams developed their own research question and design.

[5] https://tdlab.usys.ethz.ch/teaching/tdcs.html [20.03.2020]
[6] https://tdlab.usys.ethz.ch/teaching/tdcs.html [20.03.2020]

Pedagogical approach of the tdCS course

During the semester, students meet weekly for four hours in the TdLab. Similar to the flipped classroom model, students do some preparation outside of class, so that class time can be used for interactive, collaborative working sessions. The design of the course can be described as follows:

(1) An introduction to the case study and a first virtual encounter of collaboration partners at the University of the Seychelles (UniSey) prepares the ground for further collaboration. The focus lies on research project orientation with desk research (reading) and preparation of research ideas, including preliminary research questions (week 1 to 7).

(2) In week 8, local stakeholders from the Seychelles (e.g. representatives from ministries and the private sector) take part in a validation and framing workshop at ETH. Joint problem framing through constructive feedback and project hand-over from instructors to students take place, beginning with students guiding through the pre-prepared workshop-agenda. Team building is finalized. Field visits off-campus complement these workshop days.

(3) Research plans are adapted according to the validation workshop and the fieldwork is being prepared (weeks 10-14).

(4) The field phase on the Seychelles (three weeks) takes place, structured into data collection (week 1), data collection and data analysis (week 2), and data reporting, i.e. report writing[7] and dissemination of results (week 3).

Table 5: Sequences of activities in the tdCS course (Zurich phase)

Session	Focus Areas
01	**Introduction** topic, methodology, case area
02	Introduction topic, methodology, case area + **Case understanding** (readings, presentations by ETH experts); **Teaming up/collaboration with students from UniSey**
03	Case understanding (readings, presentations by ETH experts); **System (module related) analysis & contextualization**; Teaming up/collaboration with students from UniSey
04	Case understanding (readings, presentations by ETH experts); System (module related) analysis & contextualization; Teaming up/collaboration with students from UniSey
05	Case understanding (readings, presentations by ETH experts); **Develop research question; Outline research plans**; System (module related) analysis & contextualization; Collaboration with students from UniSey
06	Case understanding (readings, presentations by ETH experts); Develop research question; Outline research plans; System (module related) analysis & contextualization; Collaboration with students from UniSey

[7] https://ethz.ch/content/dam/ethz/special-interest/usys/tdlab/docs/csproducts/cs18-report.pdf

07	**Develop research question; Outline research plans**; System (module related) analysis & contextualization; Collaboration with students from UniSey
08	Develop research question; Outline research plans; System (module related) analysis & contextualization; **Planning fieldwork (stakeholder contacts, methods, etc.)**; Collaboration with students from UniSey **2 extra days for validation workshop** [project hand-over to students; final team building, field visits off-campus]
09	**Outline research plans**; System (module related) analysis & contextualization; Planning fieldwork (stakeholder contacts, methods, etc.); Collaboration with students from UniSey
10	System (module related) analysis & contextualization; Planning fieldwork (stakeholder contacts, methods, etc.); Collaboration with students from UniSey
11-13	Continued
14	Planning fieldwork (stakeholder contacts, methods, etc.); Teaming up/collaboration with students from UniSey; Final preparation of fieldwork activities

Student team support (coaching) is offered by one instructor plus one alumnus tutor during the Zurich phase. For the Seychelles phase, a second alumnus tutor is available for consultation. Additionally, several academic experts (on the topical focus of waste), and local undergraduate students from the University of the Seychelles, as well as faculty and local stakeholders are involved in research and project activities providing professional resources and real-world application context. Further, an advisory board of local experts from the Seychelles provides regular feedback during the field phase after students´ presentations of research progress. Depending on the student project students need to engage with the local population (e.g. household surveys) or facilitate workshops (e.g. with people from the ministry). Results are presented in a public event, organized by the instructor. Students get familiarized and then facilitate and lead the project. The teaching and learning approach of the tdCS at ETH is described in Stauffacher *et al.* (2006).

Participants

The 2018 cohort consisted of 19 students, from eight countries (Switzerland, Germany, Netherlands, Italy, South Africa, Lebanon, Colombia, Japan). There were 10 female and 9 male students between 22 and 32 years in age. The majority of students brought relevant experiences of either previous work, volunteer and/or travel to the course. Seven students each from two master programs (*Environmental Science* and *Environmental Engineering*) participated in the tdCS 2018, as well as four students from the *Agricultural Sciences* program and one student from the program *Area Development and Infrastructure*.

2.3 The Action Research Workshop (ARW) course (Case 3)

The Action Research Workshop (ARW) course[8] is offered at the *Polytechnic University of Catalonia* (UPC) Barcelona, Spain, within their Master's degree in *Sustainability Science and Technology*[9]. The ARW course is a mandatory one-semester project-based course that is structured into several phases (following the Action Research cycles).

Context of the case study

To provide context to this case study, we briefly summarize relevant aspects of the higher education system in Spain.

In 1999, Spain signed the Bologna Declaration, which led to the introduction of the European Credit Transfer System (ECTS), and to changes of various aspects of teaching and learning practices. The European Credit Transfer and Accumulation System (ECTS) was introduced as part of an agreement to simplify the transfer of courses and degrees among universities in Europe. One credit in the ECTS is the equivalent of 25-30 hours, with an academic year consisting of 60 ECTS credits, or 1,500-1,800 hours of work.

Enrollment at a university in Spain is subject to completed university preparatory school and the associated exam (Bachillerato). Most universities in Spain are public, and constrained by greater regulation and stricter control mechanisms than private universities despite operation within the same legal framework (i.e. being assigned the same main tasks, namely, teaching, research and knowledge transfer) (de la Torre García, Eva M., 2018). Average tuition fees at public universities range from 2,000 – 3,500 EUR (2,200 EUR / year for a master´s degree at UPC) in 2019. UPC has almost 28,000 students enrolled, with 6,000 bachelor and master students, as well as 500 doctoral students graduating[10]. The international Master's Program *Sustainability Science and Technology* is described in Segalàs and Tejedor (2016).

General features of the Action Research Workshop (ARW) course

The ARW course takes place in the second semester. It is a mandatory five credit (ECTS) unit offered during spring term (February to June). This translates into a total study time of 125 hours. Key characteristics are project-oriented research-based teaching and learning in collaboration with real world partners who the students engage with over the length of the entire semester. Project work starts by identifying a stakeholder need, linking academia and praxis. The course is offered in English and each year between 1-5 exchange students join the course, increasing its heterogeneity (Erasmus students but also students from outside Europe, particularly Latin America). As stakeholders are not necessarily fluent in English, this often requires adaptations, e.g. in terms of the project defense (e.g. presentations in Spanish; reports written in English).

The design of the ARW course builds upon several years of research and practice (Segalàs and Tejedor, 2016; Tejedor *et al.*, 2019). The general features of the course are summarized in Tab. 6.

[8] https://www.upc.edu/content/master/guiadocent/pdf/ing/480042 [16.04.2020]
[9] https://www.upc.edu/en/masters/sustainability-science-and-technology [16.04.2020]
[10] https://www.upc.edu/en/the-upc/the-institution [05.08.20]

Table 6: General features of the ARW course

Course title	Action Research Workshop on Sustainability Science and Technologies (referred to as Action Research Workshop course)
Duration	1 semester
Structure	15 weeks with 3 hours weekly sessions + team specific arrangements with external project partners
Students	15 students (cohort 2018)
learning objectives	Theoretical, methodical, and professional skills for sustainability research and practice
assessment	1. Comprehensive Action Research project report (assessed by instructors) 2. Client 'report' (this can e.g. be a policy brief). Project providers decide on the concrete deliverable, i.e. it can also be a video (assessed by the project providers/clients; assessment rubrics provided to them); [Deliverables 1 and 2 together make 80% of the grade] 3. Final project defense [10%, clients involved] **4.** Individual Course Assignments (e.g. Concept maps, backcasting, and post-Emotional-Intelligence-Reflection-assignment; 10%]

Learning objectives

The main objective of the ARW course is that students learn how to "apply their knowledge and ability to solve problems in new or unfamiliar environments within broader (or multidisciplinary) contexts"[11] related to their field of study. Further, students shall be able to describe, solve, "prevent and / or alleviate the problems and dysfunctions associated with the processes of development of environmental socio-economic systems with their own approaches to science and technologies of sustainability."[12] Teamwork, i.e. being "able to work in an interdisciplinary team, whether as a member or as a leader, with the aim of contributing to projects pragmatically and responsibly and making commitments in view of the resources that are available"[13], is another learning objective. At the end of the course, students ought to be aware of and critically analyze "the organisations, strategies, local, national, European and International policies on sustainability and sustainable social development."[14] Students will further have an understanding of sustainable development in the long-term and the role technology plays in it. Further learning objectives include skills in foresight, forecasting, backcasting and scenario analysis[15]. Students are expected to collaborate in teams and with external project providers, further developing professional skills in sustainability.

Specific features of the ARW course 2018

The topical foci of the ARW 2018 ranged from energy to food to housing and built upon previous work of the project providers, some of which participate annually in the ARW project course. Students worked in five teams (three of which participated in this research) of three

[11] https://www.upc.edu/content/master/guiadocent/pdf/ing/480042 [17.04.20]
[12] Ibid.
[13] Ibid.
[14] Ibid.
[15] Ibid.

students each. In contrast to the other two case studies, there was no overarching research question across individual student projects. One team focused on food waste and how it can be minimized by collaborating with food suppliers, supporting people in need. Another one worked on energy infrastructure and policies, analyzing national consumption and creating maps of grassroots initiatives. The third team worked closely with an energy sovereignty organization, partaking, for instance, in a Delphi process.

Pedagogical approach of the ARW course

Over 15 weeks students meet weekly for three hours in a room organized on campus by the instructor(s). Class sessions are usually used for input, e.g. on different participatory research methods, feedback on project progress presentations, to which external project partners are invited (see table below). At the beginning and at the end of the course students get a self-assessment rubric to foster their self-reflection. The last session is further used to ask for general feedback and reflections about the course and learning informally (short conversation). Additionally, students are asked to assemble their comments, criticisms, and contributions in a short document. The course is composed of three phases:

(1) *Project constitution and problem framing*. Team building activities (including a personality test to support group formation), and presentation of project proposals by external project providers, i.e. stakeholders, lead to project choice by students. Introduction to Action Research Methodology, initial research on problem and stakeholders supports the framing of problem and project (weeks 1-4).

(2) *Project design and integration strategy*. Defining a workable research question, developing project design and integration strategy, i.e. students working on their intervention plan presentation to stakeholders, instructors, and peers for feedback and validation. Inputs on backcasting and concept maps. Emotional Intelligence session (week 9): Experiencing and reflecting interactive theater pedagogies to learn about own and others´ behavior in a group context (purposefully placed mid semester once students have already encountered collaboration-related difficulties)[16]. Working sessions and selected input (weeks 5-11).

(3) *Revision of the generated new knowledge. Contributions to societal and scientific progress*. Finalizing analysis and present and discuss findings with invited stakeholders (project partners). Reviewing work. Final presentation, i.e. project defense, in front of stakeholders, instructor(s), peers.

Table 7: Sequences of activities in the UPC course (following three phases)

Session	Focus Areas
01	Introduction Input: Action Research Theory Individual & group task: do and discuss personality test
02	Beginning of phase 1- Project constitution and problem framing Teambuilding after presentation by project managers (external project partners present)
03	Problem Framing

[16] The Emotional Intelligence session was further described in Segalàs and Tejedor ((2016)).

	Input: Action Research Methodology Group task: Cycle 1 - Research question definition and planning Outcome: Grouping + Project selection
04	Problem Framing Input: Action Research Tools: Inquiry Group task: Gather data on the problem and stakeholder
05	Beginning of phase 2 – Project design and integration strategy Research Question Input: Action Research Tools: Backcasting Group task: Define research question Individual task: Backcasting exercise
06	Research Question Presentation of Research question and discussion (**external project partners invited**) Input: Action Research Tools: Concept maps Group task: Framing research question Individual task: Concept maps exercise Outcome: Result of phase 1: Research question
07	Project design and integration strategy Working session Group task: Cycle 2 - Intervention Planning
08	Project design and integration strategy Presentation of intervention planning and discussion (**external project partners invited**) Group task: Reframe intervention planning Outcome: Plan for cycle 2
09	Project design and integration strategy Emotional intelligence Group task: Apply intervention planning Individual task: Engage with own feelings
10	Project design and integration strategy Input: Action Research Tools: Complexity Group task: Apply intervention planning
11	Project design and integration strategy Working Session (external project partners invited) Group task: Apply intervention planning
12	Beginning of phase 3 – Revision of the generated new knowledge. Contributions to societal and scientific progress Working Session Group task: Analysis of results
13	Presentation of results and discussion (external project partners invited)

	Group task: Cycle 3 – Evaluation Outcome: Results of phase 2
14	Working Session Group task: Evaluation of interaction
15	Project Defense (external project partners present) Group task: Celebrate Outcome: Project report - project outcomes and presentation

The teaching and learning approach is based on the following pillars: First, tailored input from one main instructor and supporting faculty, leading sessions based on their expertise. Second, local project providers share their expertise too, while providing professional resources and real-world application context. Further, student teams are supported by formative feedback through regular in-class presentations with external project partners as well. Moreover, as student teams work on different projects these presentations allow to get insights into peer group´s team and project work. ARW students usually meet on individually scheduled times outside of class for course / project work. Due to close collaboration with external project partners, depending on the respective project, students further participate at their organizations´ meetings and gatherings, fieldtrips, etc. The primary experiential teaching and learning approach is service-learning also referred to as “community-based learning” (McIlrath *et al.*, 2016, p. 5) which enables learning in action for society, through the planning and implementation of projects that respond to real needs (Tejedor *et al.*, 2019). The teaching and learning approach has further been described by Tejedor *et al.* (2019).

Participants

The 2018 cohort consisted of 15 students, from four countries (Spain, Colombia, Chile, Germany). There were 8 female and 7 male participants between 21 and 33 years in age. The majority of students worked part-time in addition to their full-time study program.

3. Case Comparison

The three project-based sustainability courses at Leuphana/ASU, ETH, and UPC show various differences and similarities (Tab. 10). Differences include: The GSR course at Leuphana/ASU extends over three semesters with one semester for all students at their respective partner university; it is also still fairly new (compared to the other ones) and thus undergoes more changes than the other two. The tdCS course at ETH has a short culminating field phase abroad (Seychelles). The ARW course at UPC is based on *immediate* collaboration with stakeholders. In general, though, all courses follow the same three aims: similar learning objectives (teaching component), solutions to sustainability problems (solution component), and stakeholder engagement (transdisciplinary component). In all courses, students work in small teams in a problem-based and solution-oriented way. The tdCS and the GSR course also require synthesis among individual project groups due to working within the same overarching research project (waste management and local food economies respectively). While many students brought either prior work, travel, and/or volunteer experience to the course, most students of the UPC case study also worked simultaneously to their studies. The need for evidence-supported insights on innovative teaching and learning formats was highlighted by students' unfamiliarity with project-based learning. Table 8 und Table 9 summarize how and what data was collected. Findings are presented in Konrad *et al.* (2020), Konrad *et al.* (2021), and Konrad *et al.* (in review).

Table 8: Methods applied across cases to allow for comparison (Konrad et al., 2021)

Methods	Specific Applications	Covered Aspects
Observations	Class sessions (2-4 hours) Student team meetings (1,5-3 hours) Instructor team meetings (0,5-1 hour) Stakeholder meetings (2 hours) Stakeholder engagement events (2-7 hours) Cultural context (continuous)	External researcher's perspective on: Teaching and learning processes Teaching and learning environment Students´ dispositions and performances Institutional and cultural contexts → informed further data collection
Interviews	Individual students Individual instructors Individual stakeholders Group interviews (0,5-1,5 hours)	Emic perspectives on: Teaching and learning processes Teaching and learning environment Students´ dispositions and performances → informed further data collection
Focus groups	Individual teams (1 hour) Across teams (1 hour)	Students´ reflections on: Teaching and learning processes Teaching and learning environment Teaching and learning outcomes → concluded data collection
Photovoice	Process tracking of teams´ learning processes, in- and outside of class (continuous)	Students´ emic perspectives on: Teaching and learning processes Teaching and learning environment Teaching and learning outcomes

	Collective reflection session (combined with focus group)	→ concluded data collection → provided opportunity for reflection

Table 9: Total data set

Case	Observations	Interviews	Focus Groups	Photovoice
GSR	55	23	2	3/3 groups; 22 photos
tdCS	11	14	2	1 group; 23 photos
ARW	3	8	2	3/5 groups; 23 photos
Total	69	45	6	7/9 groups; 68 photos

Case selection was informed by Brundiers and Wiek's (2013, p. 1731) process model of project-based learning courses with the following criteria:

1. Faculty establishes stakeholder networks to draw upon and collaborate with during their project-based learning courses.
2. Courses start with a phase of orientation (including reading up on relevant literature) before, at different stages of the courses, project framing takes place.
3. Courses move beyond problem analysis and work hands-on in solution-oriented research either in collaboration with or engaging stakeholders.
4. Courses engage students individually but particularly in team working activities, with coaching support.
5. Faculty, faculty support (e.g. tutors, experts), students and externals coordinate their efforts through a project management structure.
6. Course aims at simultaneously fulfilling learning objectives (teaching component), providing solutions to the problem at hand (solution component), and taking care of the needs of specific stakeholders (transdisciplinary component).

Table 10: Basic features of the three project-based sustainability courses (Konrad et al.,2021)

University	Arizona State University (ASU), USA & Leuphana University of Lüneburg, Germany	Swiss Federal Institute of Technology (ETH) Zurich, Switzerland	Polytechnic University of Catalonia (UPC) Barcelona, Spain
Program (2 years, 4 semesters/ terms)	Double-degree international master program: *Global Sustainability Science*	4 different master programs [10 different majors]	Master program: Sustainability Science and Technology
Course	Global Sustainability Research (GSR)	Transdisciplinary Case Study (tdCS)	Action Research Workshop (ARW)
Mandatory	Yes	No	Yes
Course duration	3 semesters (study focus: semester 3)	1 semester + field phase (3 weeks)	1 semester
Course location	Germany & Arizona	Switzerland & Seychelles	Spain

Pedagogy of place	On- and off-campus	On- and off-campus	On- and off-campus
ECTS	10+10+5	7	5
# of students	12 (2016-2017)	19 (2018)	15 (2018)
# of student groups	3 + 1	7	5
Project topic	Food economy	Waste management	Energy; Food; Housing
Stakeholder engagement	3 major events; City staff, public, food economy entrepreneurs	Continuous with peak phase; NGOs, government, businesses, citizens	Ranging from few check-ins to continuous; NGOs, members, supermarkets
# of instructors	1 (lead) + 3 [in semester 3]	1 (lead) + 1	1 (lead) + 1
# of tutors	0	ETH: 1; Seychelles: 2	0 (occasionally 1)
Expert support	City sustainability officer	Scientific experts and advisory board (local ministry, NGO and business representatives)	Faculty members, project providers

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