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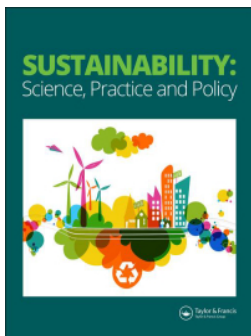
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Connecting curricula and competence through student learning journeys

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ABSTRACT

This research examines the connection between higher education curricula for sustainable development and student development of key competencies for sustainability. The authors conducted a comparative case study that followed ten students from three graduate sustainability programs. Through a combination of student-generated and contextual data, we created a set of learning journeys. These journeys showed that activities which foster reflection, interaction, and real-world connections are especially critical for competence development as part of the whole curriculum. What and how students found most useful depended on individual disposition and we identified four general categories based on prior experience, attitude to learning, and individual goals. Barriers to competency development were frustration, feelings of helplessness, and being unable to link competence to concrete activities or concepts. These barriers could be mitigated through peer interaction and mentorship, environmental support such as spaces for collaboration, and instructor scaffolding. Because no single course can fit the needs of each student, we recommend that beneficial components in the form of courses that support the above-mentioned activities be part of purposeful curriculum design.

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Higher education; sustainability education; education for sustainable development; competence development; curriculum



Introduction

Reaching a desirable and sustainable future requires the transformation of higher education curricula (UNESCO 2014). Universities especially play a role as a driver for sustainability transition by fostering knowledge, expanding capacity, and shaping attitudes and perspectives (Cortese 2003; Jickling and Wals 2008; Leal Filho, Salvia, et al. 2021). Worldwide, the number of universities offering sustainability-oriented courses or curricula has been growing, as has research in this area (Salovaara, Soini, and Pietikäinen 2020; Weiss and Barth 2019). These developments bring forward the need for evidence-based insights on best practice in curriculum design and delivery for sustainable and sustainability-oriented education. Doing so necessitates an understanding of the goals and parameters of success.

One approach has been to reorient learning goals to sustainability competencies (Barth et al. 2007; UNESCO 2016, 2017). Currently, the most frequently cited competence framework is that by Wiek, Withycombe, and Redman (2011) which suggests five key competencies for sustainability:

systems-thinking competence, futures-thinking competence, values thinking-competence, strategic-thinking competence, and interpersonal competence. They synthesized this framework based on a literature review and then Wiek et al. (2015) further operationalized it into learning objectives for use in competence-oriented teaching. These key competencies in sustainability are differentiated from general academic competencies—for example critical thinking and self-regulated learning—in that they subsume the competencies necessary for every academic program within the greater scope of sustainability orientation (Wiek, Withycombe, and Redman 2011). However, competence-oriented teaching and assessment often challenges common university practices such as lecture-based instruction and closed-answer exams (Lozano et al. 2017, 2019).

If students are to develop competencies for sustainability, the teaching activities and assessments need to also align with this goal (Biggs 1996; Caniglia et al. 2016). Common suggestions for competence-fostering courses prioritize student-centered, active learning practices (Lozano et al. 2017). For example, methods that foster reflection and holistic

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growth such as transformative learning (Mezirow 1997; Sipos, Battisti, and Grimm 2008) and experience-based learning (Caniglia et al. 2016; Kolb and Kolb 2012) have shown potential (Backman et al. 2019; Caniglia et al. 2016; Cörvers et al. 2016; Wals and Schwarzin 2012). This is also the case regarding real-world embedding through problem-based and project-based learning (Cörvers et al. 2016) and, more recently, real-world labs (Lake, Fernando, and Eardley 2016; Schöpke et al. 2018). These pedagogies engage students in activities intended to trigger self-reflection and comparison with their assumed realities through dialogic interaction as described by Mezirow (transformative learning) and Kolb and Kolb (experience-based learning) and elaborated in the Global Classroom case study by Caniglia et al. (see above), and by engaging students in complex activities solving real-world challenges through collaborative project work as discussed in the above-mentioned reports and the following selection of case studies: Ceulemans and Severijns (2019); Konrad, Wiek, and Barth (2021); Kricsfalusy, George, and Reed (2018). Such practices share a focus on self-regulated problem solving and collaborative learning. Still, the expectation of student success without instructional content support has drawn legitimate critique (Kirschner, Sweller, and Clark 2006).

Currently, the majority of praxis-oriented research has investigated individual courses or methods. The narrow focus has created the problem of not seeing the forest for the trees. If competencies are an embodied set of knowledge, skills, and attitudes and *knowing* itself is a sum of the whole of a student's experiences and learning as proposed (Kolb and Kolb 2017; Lave 2009; Mezirow 1997; Sipos, Battisti, and Grimm 2008; Wenger 2009), then it is reasonable to believe that it is not the individual class, but the whole curriculum and surrounding experiences which shape a student's competence development. Initial differences between students in different programs have been observed (Remington-Doucette and Musgrove 2015). It has also been recognized how over a semester, the composition of classes and student schedules can support or impede the process of reflection and learning (Birdman, Redman, and Lang 2021). Longitudinal studies have shown that specific pedagogical interventions such as project-based learning have a positive influence on student self-assessed competence (Kolmos, Holgaard, and Clausen 2021; Servant-Miklos, Holgaard, and Kolmos 2021). However, the link between macro (curriculum) and micro (individual courses) needs strengthening. Given the interiority of competence itself, a qualitative investigation of curricula and the associated

components from student perspectives would add value and depth to multiple areas of sustainability education studies (Backman et al. 2019).¹

This research investigates the following question: What connections exist between experienced sustainability curricula and student self-perception of competence?

Design and methods

To address this question, we conducted a comparative case study following students in three different, but otherwise comparable, sustainability study programs. The triangulation of curricula, competence, and student experience required a mixture of open exploration and structured comparison using a multifaceted approach. These procedures will be described in the following subsection with the research design, and then we will turn our attention to outlining the cases followed by a discussion of data collection and analysis.

Research design

To create a structure which allowed for comparison of rich data, we developed a comparative case-study design with multiple levels of analysis (Yin 2009, 41–54). Information on the macro-level (program structure, institutional context) frames the contexts in which the micro-level (activities, assignments, interaction) take place. Here, specifically, the macro-level encompasses data on the three programs that we investigated and the micro-level is provided by individual students whose journeys were recorded (see Figure 1).

Data collection and analysis were built off the work of Barth (2015), through which we identified potential key variables for sustainability competence development (Redman et al. 2019). Our goal was to create a frame which was broadly applicable with

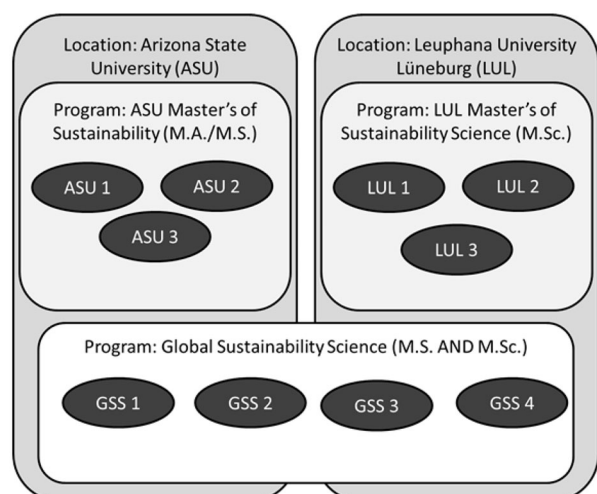


Figure 1. Case overview.

room for specificity through elaboration. The frame captures (1) a change in competence level, which is linked to (2) an individual-learning process that happens (3) (partly) in a specific teaching and learning environment which is set in (4) a unique context of a study program at a specific university and perceived and shaped by (5) participants with unique experiences and attitudes.

Case description: programs and participants

The programs that we selected were Leuphana University Lüneburg's Sustainability Science M.Sc., Arizona State University's (ASU) Sustainability M.S./M.A. program, and the joint Leuphana/ASU Global Sustainability Science (GSS) dual degree program M.Sc. & M.S. We selected these programs due to specific, intentional overlaps in curricular design.² All three of them include foundations of sustainability, natural and social sciences, and a focus on a solution orientation and transdisciplinary project work (see Table 1). The GSS program takes place at and shares courses with both universities. The students are from Leuphana and ASU and all of them spend their second semester at Leuphana and the third semester at ASU. The curricular and contextual overlap of the GSS program with the other programs enhances cross-case analysis. Key differences between the three programs were:

- The ASU M.S./M.A includes a first semester of required, collaboratively designed courses.
- The Leuphana M.Sc. requires a two-semester transdisciplinary research project
- The GSS program requires a two-semester international transdisciplinary research project.

This study followed the cohort of students starting the three respective programs in Fall 2017 and data collection occurred from August 2017 through August 2019. Student enrollment in 2017 was as follows: Leuphana (38 students), ASU (7 students), and GSS (11 students).

Table 1. Curriculum overview.

| | All programs | ASU specific | Leuphana specific | GSS specific |
|------------|---|---|--|--|
| Semester 1 | Sustainability foundations | Graduate-skills course | Complementary studies* | Key-competence based research-methods course |
| Semester 2 | Research methods Natural sciences Social sciences Project-based learning | Graduate-skills course Projects are single semester | Complementary studies Project spans two semesters | Introduction to teamwork Project is international and spans two semesters, starting at Leuphana |
| Semester 3 | Specialization of previous topics Project-based learning | Graduate-skills course Projects are single semester | Complementary studies (Continued project) | (Continued project now at ASU) GSS specific graduate skills course |
| Semester 4 | | Thesis/graduate forum (all programs) Thesis semester (all programs) Any required credits not yet completed (all programs) | | |

*Complementary studies are short courses on a broad variety of topics at the instructor's discretion, and which are open to all graduate study programs.

All three programs begin with an introduction to sustainability with student-centered activities, reflective exercises, and a set of readings which are similar across the three programs, including the key competencies by Wiek, Withycombe, and Redman (2011). Each of them requires students to complete courses in research methodology, social sciences, and natural sciences. All offer praxis-oriented and transdisciplinary opportunities and feature cross-enrollment that requires students to take courses of personal interest that are not exclusive to their sustainability programs.

We recruited study participants through a combination of targeted- and self-selection. Criteria included, when possible, at least one representative per cohort from each of the following backgrounds: natural sciences, social sciences, and business/finance (Remington-Doucette and Musgrove 2015). We conducted voluntary semi-structured interviews during Weeks 3–6 of the first semester with students from each program ($n = 23$) to gather initial data on backgrounds, motivations, and personal goals for each program and to gain familiarity with the members of each program. We also informed students about this study in more detail during these interviews and identified participants who expressed a willingness to participate in the full duration of the project. We ultimately selected eleven students: three from the ASU Master's degree program, three from the Leuphana Master's degree program, and five from the GSS. Due to inability to obtain a visa for study in the United States, one student left the GSS program, resulting in ten participants in total (see Figure 1).

Data collection

Primary data on student activities and competence were collected through repeated individual reflective interviews at the beginnings of the second, third, and fourth semesters with a fourth and final interview at the conclusion of the fourth semester. All interviews were conducted in person or via Skype,

lasted 25–40 minutes, and were recorded and transcribed for analysis. These reflective interviews consisted of a competence self-assessment (see [Supplementary Material A](#)) asking students to rate their theoretical and practical competence on a nine-point scale divided into beginner (1–3), intermediate (4–6), and expert (7–9) to both fit the Wiek et al. (2015) model and to give students an external benchmark for assessment (Boekaerts 1991). In addition to ratings, the survey asked them to provide examples from the previous semester of when, where, and how they used this competence with the goal of capturing student knowledge, skills, and attitudes (Wiek et al. 2015). The self-assessment served the purposes of assisting student reflection and memory in preparation for the interview (Creswell 2012) and was used as a frame for the subsequent discussion. The final interview held after the conclusion of the fourth semester asked students to rate their overall change in competence (decreased, no change, some increase, large increase) and prompted them to give examples of how they know this change occurred (see [Supplementary Material B](#)). This interview occurred following the thesis defense for the ASU and GSS students. All Leuphana students chose to extend their thesis deadlines beyond the end of the fourth semester. One student was unable to participate in the third self-assessment and interview due to fieldwork and one student declined to participate in the final self-assessment but consented to the final interview.

We collected further information about the learning environment and activities through real-time observation, instructor interviews, and analysis of

course syllabi/descriptions and assignments. Observations included all required courses during the first semester (minimum six observations per course) followed by observations based on student recommendations (see [Table 2](#)). We gathered institutional and contextual information from official university websites and publications, program descriptions, and interviews with program developers and coordinators.

Analysis

We analyzed all student self-assessments and reflective interviews using the qualitative analysis software package MAXQDA. All interviews were first summarized for content and initial interviews were used for organizing students into descriptive typologies (Lofland and Lofland 1984). We analyzed the reflective interviews and self-assessments using a combination of deductive coding and constant comparison (Berg 2010; Creswell 2007; Schreier 2012). Deductive categories based on the research variables were applied to selected data samples and these samples were then re-examined by two independent researchers for validation. Further coding resulted in a set of inductive codes followed by a second validation with a separate researcher. We organized these inductive codes within the existing categories ([Figure 2](#)).

Observations, student-focus groups, and instructor interviews were used to add context to the student interviews and to create a more nuanced description of the context, teaching and learning environment, and learning process. Additional

Table 2. Data overview.

| Student-centered data | N | Description | Variable(s) |
|---|-----|---|-------------|
| <i>Instrument</i> | | | |
| Initial interviews | 10 | Fourteen-question semi-structured interview. Voice recorded and transcribed. One per student in Semester 1. | 4 |
| Student self-assessments | 29* | Ten-question form using numerical rating (1–9) and open descriptions. One per student at the beginning of Semesters 2, 3, and 4. | 1, 2, 3, 4 |
| Student reflective interviews | 29* | Semi-structured interviews using student self-assessment as a frame. 25–45 minutes, voice recorded, and transcribed. One per student per semester. One per student at the beginning of Semesters 2, 3, and 4. | 1, 2, 3, 4 |
| Student revised (final) self-assessments | 9** | Five-question form using “decreased,” “no change,” “small increase,” and “large increase” and open descriptions. One per student at conclusion of Semester 4. | 1, 2, 3, 4 |
| Student revised (final) reflective interviews | 10 | Semi-structured interviews using revised self-assessment as a frame. 25–45 min, voice recorded, transcribed. One per student at conclusion of Semester 4. | 1, 2, 3, 4 |
| <i>Contextual data</i> | | | |
| Instructor interviews | 21 | Semi-structured interviews 25–45 minutes, voice recorded, transcribed. | 2, 3, 5 |
| Curricular support interviews | 5 | Semi-structured interviews with hand-written notes | 2, 5 |
| Observation | 152 | Semi-regular observation of all required classes and courses recommended by participants. Unstructured, real-time field notes. | 2, 3, 4, 5 |
| Document analysis | 75 | Official program descriptions and all available course descriptions/syllabi of all program-related courses taken by participants. | 2, 5 |
| Focus groups | 13 | Semi-structured focus groups. 60 minutes, voice recorded, transcribed. Conducted at each semester conclusion, minimum of one per program, 2–10 participants per focus group. | 2, 3, 4 |

Notes. Variables refer to 1 = change in competence level, 2 = learning process, 3 = teaching and learning environment, 4 = participants, and 5 = context

*One student was unavailable for an interview after Semester 2 due to field work.

**One student declined the final self-assessment.

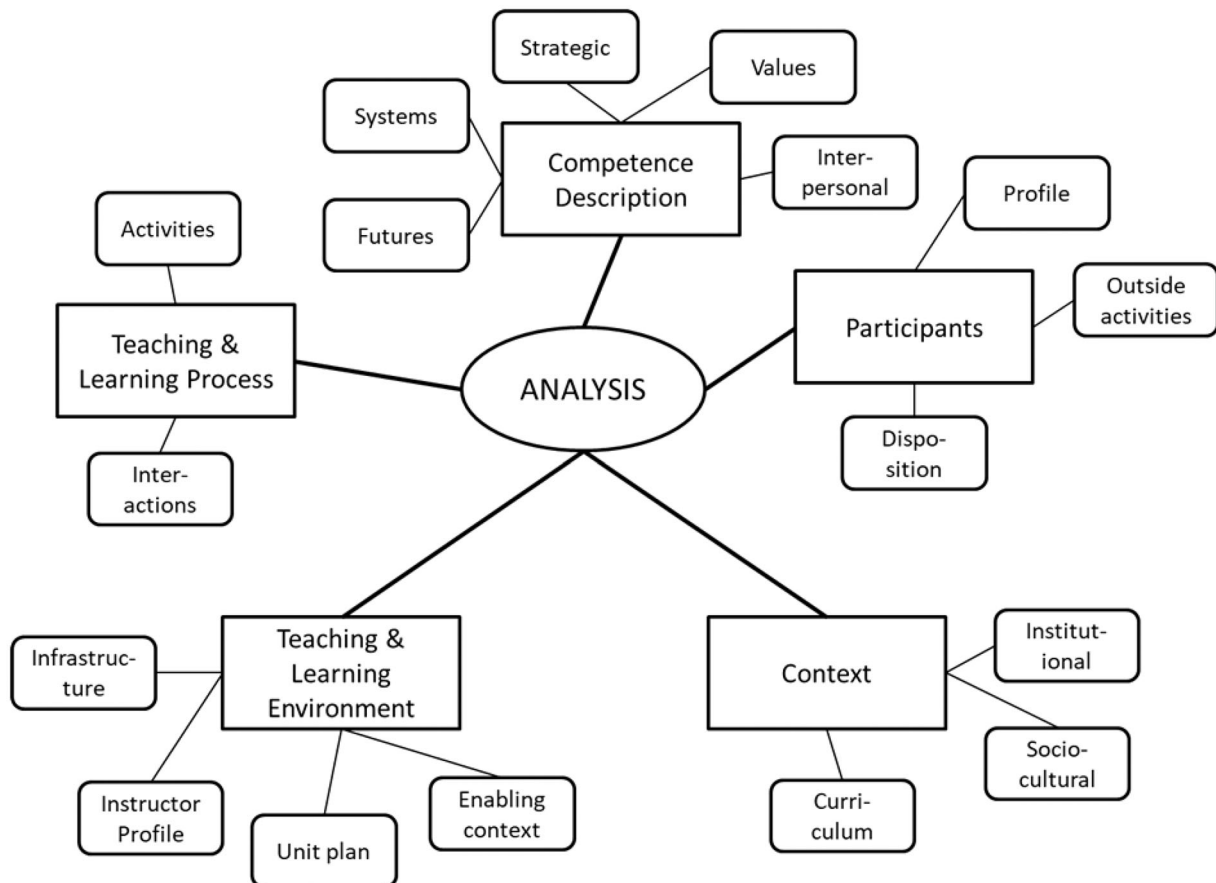


Figure 2. Deductive categories.

Table 3. Self-assessment results overview.

| Student | Systems | Futures | Values | Strategic | Interpersonal |
|---------|----------------|----------------|----------------|----------------|----------------|
| ASU_1 | Large Increase | Small Increase | Small Increase | No Change | Small Increase |
| ASU_2 | Large Increase | Small Increase | Small Increase | No Change | Small Increase |
| ASU_3 | Small Increase | Decrease | Large Increase | Small Increase | Decrease |
| GSS_1 | Large Increase | Small Increase | Large Increase | Large Increase | Small Increase |
| GSS_2 | Large Increase | Small Increase | Large Increase | Large Increase | Large Increase |
| GSS_3 | Small Increase | Small Increase | Small Increase | Small Increase | Decrease |
| GSS_4 | Small Increase | No Change | Small Increase | Small Increase | Small Increase |
| LUL_1 | Small Increase | Small Increase | Small Increase | No Change | Small Increase |
| LUL_2 | N/A* | N/A* | N/A* | N/A* | N/A* |
| LUL_3 | Small Increase | Small Increase | No Change | Small Increase | Small Increase |

*Student chose not to fill out the final self-assessment but participated in the interview.

contextual information from document analysis and program-support interviews resulted in descriptive program profiles.

Results

This section reviews the self-reported competence changes in the students embedded within their learning journeys. It does so according to the frame used for data collection and analysis, starting with change in competence. We then discuss the teaching and learning environment and then the contextual factors. Finally, participant profiles are considered to bring the individual student's relationship with the curriculum back into focus. The order of the frame has been changed for narrative purposes.

Change in self-reported competence

All participants reported overall increases in at least three key sustainability competencies in the final interview (see Table 3). Most students also reported an overall numerical increase in competence (see Supplementary Material C) and systems-thinking competence showed the most consistent concluding outcome with all reporting students attributing either a large or small increase in competence. Strategic competence was the least consistent, with five students reporting either large or small increases and four reporting no change. Two students reported decreases in competence: Student ASU_3 reported a reduction in futures thinking and interpersonal competence and student GSS_2 indicated a decrease in interpersonal competence in

praxis, despite feeling that theoretical understanding had increased. This specification was made despite the division between practical and theoretical being absent from the final self-assessment.

As anticipated, some student self-reported competence levels fluctuated over the four semesters in ways not observably linked to their academic performance. All students actively addressed the subjective nature of the self-assessments, discussed the justification for their self-assigned competence rating, and engaged in meta-reflection in each interview. Meta-reflection showing acknowledgment of the subjectivity of self-assessment was marked with statements such as, “Yeah, that’s probably how I’m feeling today” and “I said decrease because I’m like, this is how I feel right now.” Some meta-reflection was more targeted. For example, one student observed, “Maybe the systems-thinking and the values-thinking is now more developed, because to be honest, before coming here the systems-thinking for me was ... maybe I used it without knowing it sometimes. But now I’m really aware of that.” This is an example of a student remarking on how the addition of competence vocabulary has changed their self-perception. Meta-reflection also included insight on the students’ emotional state, which was exemplified by student expressions of frustration or failure while describing lack of competence development, and less consistently pride and success when describing increased competence. Overall, these statements provided insight on the internal processes involved in their self-assessments.

Teaching and learning environment and process

Observation found the three programs to be similarly designed and to offer curricular content that addressed all competencies either explicitly through inclusion of competencies in the course description/syllabus or activities or implicitly through inclusion of competence-related concepts and activities each semester. The activities observed and/or described by students were also comparable. Differences were that ASU required more individual homework, the GSS specific and Leuphana courses required more group homework, and ASU courses included more discussion in the group convenings during in the first semester. These differences were noticeable in that the ASU students tended to cite individual homework as influential more often than the Leuphana students. All activity types were identified as competence-development drivers at least once by at least one student in each program. Student-centered activities with a high level of interaction either with others (project work, in-class tasks, group work) or reflective interaction (individual

homework, thesis work) were most frequently listed.³ Project work was especially discussed by the Leuphana and GSS students, whose projects spanned multiple semesters (see Table 4 and Supplementary Material D). Collaborative activities, and especially those with a real-world connection such as project work, were most frequently associated with practical competence development. Theoretical competence development was more mixed, and here students also more frequently listed individual tasks and instructor interaction.

Curricular design

Curricular build between the three programs differed on some points. The ASU first semester consisted of all required courses, with following semesters nearly completely open to student selection. The first semester also included an experience-based learning element intended to increase student capacity for dealing with complex problems with multiple perspectives and developing key competencies. These activities were embedded in a collaboratively-designed curriculum with assignments and readings intended to overlap between courses. This resulted in ASU students first expressing insecurity about their competence due in part to a (reported) lack of diversity in the first semester followed by reported increasing sustainability identity and self-confidence in subsequent interviews after coming in contact with students from other faculties. Students saw themselves as sustainability ambassadors in these mixed groups. This was observed to lead to student frustration at the subject-specific focus of other students and instructors and increased expression of confidence in especially systems, futures, and values thinking as a result of these interactions. Students also indirectly listed the influence of courses from the first semester as foundational for these increases when asked where and how they learned to negotiate these differences in perspective. One student stated that the sustainability foundations and experience-based learning element should repeat in the third semester because by this stage students had acquired new perspectives and context. This statement was met with agreement when discussed during the focus group.

The Leuphana M.Sc. has one required course in the first semester and all other courses during the first and subsequent semesters are chosen from a predetermined list developed by the faculty of sustainability. One student described this experience embedded within a sustainability-oriented university as being in a “sustainability nest.” An exception to this characterization was *complementary studies* courses open to students specializing in other areas.

Table 4. Activity summary.

| Activity | Total number of reflective interviews in which the given activity is linked with competence development | | | | | |
|--|---|-----------|-----------|-----------|----------------|-----------|
| | Systems | Futures | Values | Strategic | Inter-personal | Total |
| Reflection | 1 | 7 | 5 | 1 | 5 | 19 |
| In-class task | 12 | 11 | 13 | 4 | 3 | 43 |
| Individual homework | 16 | 10 | 9 | 6 | 0 | 41 |
| Group work | 5 | 2 | 3 | 4 | 25 | 39 |
| Discussion with other students | 2 | 2 | 11 | 1 | 4 | 20 |
| Unsure | 4 | 16 | 16 | 20 | 8 | 64 |
| Previous experience more influential | 3 | 3 | 4 | 5 | 2 | 17 |
| Project work | 19 | 14 | 9 | 22 | 19 | 83 |
| Project-like work (e.g., case study, lab work, or other) | 4 | 6 | 6 | 5 | 3 | 24 |
| Thesis work | 6 | 5 | 2 | 6 | 2 | 21 |
| External work/experience | 7 | 6 | 5 | 1 | 10 | 29 |
| Instructor/advisor interaction | 1 | 4 | 1 | 0 | 2 | 8 |

Key

| Activity | Definition |
|--------------------------------|--|
| Project work | Activities that fulfill at least five of the six features defining project work for this study |
| Project-like work | Activities that fulfill 2–4 features defining project work, but do not meet the definition such as case studies and laboratory work |
| Thesis | Activities specifically described as related to the student's thesis |
| Group work | Instructor-specified activities performed with one or more other students which resulted in a deliverable such as a report, a presentation, a graphic, or similar |
| Individual homework | An instructor-specified task worked on alone outside of class such as course reading or a deliverable such as a report or presentation |
| Discussion with other students | A semi-structured or unstructured conversation in a class setting with other students about or related to course materials |
| In-class task | An instructor-specified task performed with the instructor present that does not fit other task definitions (i.e., completing a set of exercises, reading and responding to a paragraph, or similar) |
| Reflection | Mental activity in which the student thinks about their own progress, about studies, experiences, |
| Instructor/Advisor interaction | Discussion with a course instructor or the student's advisor |
| External experience | Activities not related to studies, but which occurred concurrently (e.g., personal political engagement, student job) |
| Previous Experience | Activities and experiences from prior to enrollment, such as work or previous studies |
| Unsure | Student does not think they have used or exhibited this competence |

The significance of bold value is to indicate the two most frequently occurring answers in each column.

Here students described a similar experience of being confronted with unexpected differences in knowledge and values and feeling responsible for representing sustainability-oriented perspectives during interactions with peers. The Leuphana program also requires students choose to take part in one of three available transdisciplinary research projects that span two semesters. This project became the primary competence driver from a student perspective due to the consistent praxis orientation and challenge of working with open-ended problems. Here, too, students listed the required sustainability course during the first semester as having a positive influence on their capacity in subsequent terms.

The GSS program is a combination of both curricula, dependent on the students' location in a given semester. In the first semester, the students in Germany take part in an experience-based learning unit based on Caniglia et al. (2016) which is intended to increase key competence development and capacity. ASU-based students engage in the experience-based learning activities based on Freire (2014) as part of the introduction to sustainability course shared with the ASU program. This is paired with a solution-oriented research-methods class

offered at both universities and built around the key competencies. Students must also select a multi-semester transdisciplinary research project to be carried out in groups of 3–4 students. This project changes location between Semesters 2 and 3, and the orientation and execution of the project must be adapted for this location change. Both the explicit competence-oriented instruction and the ongoing engagement in real-world embedded projects were listed as competence-building by students.

Non-course factors

Structural and bureaucratic factors

Each program presents students with challenges and opportunities based on the context and structure. The most apparent of these was the aforementioned international aspect of the GSS program. Students were required to plan and fund international flights and housing, to obtain visas, and to navigate the bureaucratic structures of two universities. These undertakings were not directly cited for competence, but students listed intercultural interactions and the difference in available opportunities and activities

both on and off campus as influential for their learning experience and personal development.

The ASU students described funding-driven activities such as working as teaching assistants, especially for undergraduate sustainability courses, as effective in aiding their positive competence development. One student was also severely affected by an unexpected loss of funding. This circumstance was first described as fostering all competencies as the student quickly devised and implemented plans to balance personal life with research while attempting to secure funding to finish their studies. However, this situation also had a negative impact, as the student was unable to take part in courses in the third semester. These courses were then taken concurrently with the student's thesis work in the fourth semester, which contributed to reported feelings of stress and burnout which negatively affected competence reporting.

Social and contextual factors

Not described explicitly by our respondents, but something that we observed was the graduate lounge which is a set of rooms at ASU only available to sustainability graduate students where they can work individually or together, store items, and prepare and eat meals. We observed ASU and GSS students both formally and informally meeting and exchanging in daily encounters. They often expressed positive opinions about the graduate lounge in conversation and these exchanges likely improved relationships which facilitated competence-driving activities such as collaboration, reflection, and discussion. The graduate advising office is integrated into the graduate lounge and we also saw students meeting formally and informally with staff for academic support and advice regularly. This feature was an intentional element of the graduate lounge and convenient access to support assisted students with stress and overcoming negative feelings which may also have had a positive influence on competence.

The Leuphana students, by contrast, did not describe specific features of the university or the surrounding community in detail. For them, the most prominent contextual factor was the absence of mention in student data. Their starting cohort of 38 students was four times larger than either of the other programs. In Fall 2018, 9,888 students were enrolled at Leuphana University compared with 111,249 students at ASU making the sustainability cohort a much larger proportion of the Leuphana student body. Students were expected to self-organize for group and project work and both Leuphana and GSS students found the coordination of schedules for multiple collaborative assignments

challenging. The smaller size of Leuphana University and the city of Lüneburg facilitated spontaneous meetings, but in ways not explicitly designed to do so and more difficult to observe, making the contextual relationship to competence-building interactions less transparent.

All students found socializing with their respective cohort to be a source of competence development and emotional support. All three programs included a first semester-bonding activity such as camping or hiking which all students found influential for forming social ties. While in Arizona, nine GSS students chose to rent a house together as a group. They all reported that this arrangement was a positive and supportive experience.

All students also described socializing outside of their program setting as influential. Most described explaining or defending sustainability concepts to family and friends as connected with values thinking and interpersonal competence. Attending conferences, workshops, and other external events also helped students recognize their own expertise.

Barriers to competence development

Competence barriers

Students were repeatedly unsure of whether they had developed or practiced a competence. This uncertainty was often paired with expressions of frustration. We reviewed all segments coded as "unsure/no competence development" and the core statement of each instance fell into one or more of the following categories:⁴

- *Lacked explicit instruction*: Student expressed this competence was not part of courses or activities taught.
- *Lacked opportunity to implement*: Student expressed familiarity with readings or concepts, but did not engage in activities using this competence.
- *Lacks knowledge*: Student expressed ignorance based on own background or (lack of) effort.
- *Unchallenged by curriculum*: Student felt their existing competence was adequate or higher than required for successful engagement in curricular activities.
- *Did not take time to implement*: This was specific to group and project work. The student expressed that the group members were aware of how to use a competence (e.g., making system diagrams, engaging in backcasting) but that the group did not take this step.
- *Lacked link between theory and praxis*: Student expressed awareness of theoretical information,

but was unable to imagine real-world examples of implementation.

- *Too stressed*: Student was unable to reflect on activities or perform at capacity due to curricular and non-curricular pressures.
- *Existential crisis*: Student found the scope and complexity of sustainability problems overwhelming and was unable to engage.
- *Personal failure*: Student attempted to put competence into praxis and had a negative result.

With the exception of *personal failure*, *existentially overwhelmed*, and *too stressed*, all categories occurred for all programs. *Lacked explicit instruction* was more common with the Leuphana and ASU students than the GSS students who had taken a first-semester course built around problem solving using the key competencies. *Personal failure* was cited by student GSS_2 for values thinking and interpersonal competence. Student ASU_3 listed *too stressed* for systems-thinking, futures thinking, and interpersonal competence. They described a stress-induced inability to fully engage, as shown by statements like, “I’m trying to be honest. I’m just burned out. I know this feeling is, it’s like, oh my God, I just need a break for a little bit.” ASU and GSS students cited *existentially overwhelmed* for futures-thinking competence and by ASU students for values-thinking competence. *Unchallenged by curriculum* was cited by students who found prior experiences such as a career, undergraduate studies, or other activities more influential. Individual students’ ability or inability to link activities with competence development had no observable effect on perception of overall competence development upon program completion.

Participants

As a result of thematic analysis of all initial interviews, four general learner types emerged based on a combination of student-personal background and student attitudes (see Table 5). We assigned the following descriptive levels to these categories: “the returning professional,” “the good student,” “the

activist/explorer,” and the “insider/strategist.” These labels broadly categorize student-personal profiles and how they interacted with the curriculum and their peers. This study recognizes that the relatively small number of participants makes broader generalization difficult, but here we use them as a conceptual shorthand that may prove useful for educators and researchers who observe similar patterns.

The returning professional

These students are typically either older than the rest of their cohort or are more socially mature due to long-standing relationships, career experience, and family planning. They feel they have already developed both competence and self-confidence through experience and career-relevant work, and can cite examples of where they have utilized key competencies prior to their graduate studies. They report improved career possibilities and/or self-fulfillment as study motivation and consider the time and resources for program participation a privilege and feel pressure to quickly return to work. This is especially true for students with partners and children. External activities include continuing with existing hobbies, family life, networking, and job interviews.

Returning professionals find challenging situations and self-driven exploration of topics beneficial. Lacking these opportunities, they cite past experiences and reflection as sources of competence development. These students tend to be more resilient to failure and frustration and they reflect on reasons for failure and discuss future strategies for improved results.

The good student

These students typically continue directly from their undergraduate studies. Their work experience is driven by subsistence or the desire to build a portfolio, rather than being career-driven. They see a graduate degree as an obvious next step and they focus their studies on getting good grades. They describe competence as coming directly from studies or ingrained personality traits, like being “good with people.” Their study relationship is a mixture of stress and concerns about self-worth linked to ability to fulfill instructor requirements. Main non-curricular activities are usually social and/or university related jobs and club activities.

These students typically source study-related activities such as in-class assignments, homework, reading or activities from previous studies as driving competence development. They generally demonstrate confidence in their own intelligence and abilities at the start but quickly change to expressing

Table 5. Learner type distribution by program.

| Program | Student | Background | Learner type |
|----------|---------|-----------------------------|------------------------|
| ASU | ASU_1 | Social sciences | Good student |
| ASU | ASU_2 | Business/finance | Returning professional |
| ASU | ASU_3 | Natural sciences | Returning professional |
| GSS | GSS_1 | Natural sciences | Good student |
| GSS | GSS_2 | Natural sciences | Explorer/activist |
| GSS | GSS_3 | Business/Finance | Returning professional |
| GSS | GSS_4 | Business/Finance | Insider/strategist |
| Leuphana | LUL_1 | Social sciences | Explorer/activist |
| Leuphana | LUL_2 | Social and natural sciences | Insider/strategist |
| Leuphana | LUL_3 | Natural sciences | Good student |

self-doubt when they face faced with challenges. These students have trouble coming up with competence examples when nothing from school work was explicitly related to competence.

The activist/explorer

These students typically took time between their undergraduate and graduate programs to travel and/or do volunteer work. They describe themselves as being on a personal journey of self-improvement which they link with a desire to solve world problems. This desire is also their reason for studying. These students describe themselves as curious, self-reflective, and enjoying learning about themselves and interaction with others. They take an explorative approach to studying where classes are jumping-off points for self-driven reading and reflection. They place high value on connections and activism and their main non-curricular activities are diverse and oriented around self-improvement through various therapeutic activities, martial arts, and involvement in cooperatives.

Activist/Explorers often cite a mixture of coursework, personal reflection, and interaction with others as driving competence. They tend to express a high sense of personal responsibility, and often harbor self-doubt. When faced with challenges, they usually regard difficulties as coming from personal failure or lack of competency.

The insider/strategist

These students are generally goal-oriented with a focus on career or personal development. They see the program requirements as suggestions and prefer to customize their schedule, perhaps requiring university permission. They are familiar with and network within the university system. Their previous activities are diverse and strategic, often with multiple degrees either completed or interrupted (depending on opinion of the degree's usefulness). They approach their academic pursuits as a challenge and desire to be pushed. They have a low tolerance for courses and activities that they do not feel are contributing to their goals and their choice of program is usually based on a career path, network, or other specific interest. Non-curricular activities typically include young professional circles, networking, activities related to university politics.

Insider/Strategists tend to cite undertakings in which they can take a personal and engaging role. They describe classes with real-world connection, outside activities, and past experiences as competence drivers and are quick to disengage when they find the activities less fruitful. These students generally cite confidence in their own abilities and they

approach challenges based on what they feel they can contribute or gain.

Intersection of profile and curriculum

Student responses to curricula, activities, and challenges aligned with these profiles. All participants expressed negative and positive emotions in connection with their study experiences and personal competence development. Returning *professionals* tended to seek open and complex assignments, though such work was also met with irritation when the underlying purpose was unclear. *Good students* were generally frustrated by open and complex assignments due to uncertainty about assessment, especially regarding how exactly to meet the requirements for their desired grade. *Activist/explorers* tended to internalize activities as a reflection of personal value, which also led to expressions of frustration and anxiety as their struggles were interpreted as evidence of their own (in)ability. *Insider/strategists* were least likely to associate competence with program-related activities, and were more likely to critique program elements and offer suggestions for how to improve student-competence development than reflect on their own growth.

Expressions of positive or negative emotions were the strongest predictors of student self-assessment of competence growth. Most students were, through reflection, able to describe how difficult situations that engendered conflict or stakeholder disengagement were still valuable. Returning professionals were especially likely to frame conflict or disappointment as an opportunity.

Decreases in achievement were always accompanied by a sense of helplessness and/or frustration. All students expressed frustration when working in applied projects. With good students, these emotions and the triggering situation were addressed through mediation either by an instructor or, in one instance, a fellow student who fit the returning professional category. All other categories of students attempted to mediate the difficulty themselves, with response to the outcome in line with the student's profile.

Discussion

Results confirm that participating in a graduate sustainability program which includes praxis-oriented elements and promotes student exchange both with stakeholders and people outside the sustainability community can increase students' self-perceived key competencies. This study examined competence development from a student-experience centered view and in the previous section we presented results based on several key variables (see Figure 3). In the following section, we examine the interplay of these factors to better understand and explain the

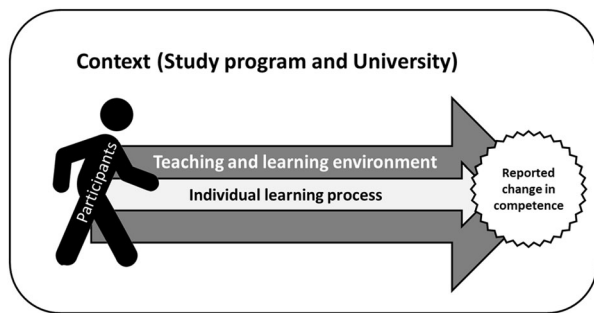


Figure 3. Key variables.

learning journey and what this means for curriculum design and instruction.

Learner self-perception and diversity

The competence self-assessment surveys is composed of snapshots of the students' mental and emotional states at a particular time. We cannot regard them as accurate and exactly predicting student potential. Self-assessment here is a metacognitive practice of evaluating what students believe they have done and could do in the future (Mok et al. 2006). Moreover, the ability to self-assess is a foundational component of competence because it requires the learner to understand what precisely competence comprises and what a successful result looks like (Boekaerts 1991; Brundiers et al. 2021). The self-assessment maps thus imply that the students mostly possess this foundational component (Schlösser et al. 2013) and confirm that the programs attract and admit students with the previous experiences and learning necessary for such.

Andrade (2019) expresses skepticism about the self-assessment of something as holistic as competence due to potential links to student self-concept and self-esteem. We observed this phenomenon especially in the *good student* and *explorer/activist* profiles. Yet, we argue that in the context of sustainability exactly these links become important. Being that *attitudes* are an essential component of competence, a student's self-concept and self-esteem are relevant in a practical sense (Boekaerts 1991; Brundiers et al. 2021; Wiek, Withycombe, and Redman 2011). Successful engagement with sustainability challenges requires student resilience through iterative processes which are often uncomfortable (Lake, Fernando, and Eardley 2016). Especially students with the *returning professional* and *insider/strategist* profiles bring past experiences of setbacks and failure and their learned coping mechanisms with them.

This may explain why *returning professionals* cited conflict as a source of competence development (though most students experienced some sort of conflict to some degree with one or more

instructors or influential faculty members), *insider/strategists* were dismissive and focused on other courses, and *activist/explorers* saw these interactions as personal failures and a source of shame. Shame stems from attributing setbacks to internal, unchangeable traits or how students *are*, whereas competence development comes from attributing setbacks to external, changeable circumstances or what students *do* (Förster, Zimmermann, and Mader 2019). Moving from shame to growth can be learned with the help of heterogeneous cohorts through positive examples and peer learning (Konrad, Wiek, and Barth 2021). For instance, one *good student* found themselves in a project group with negative interpersonal dynamics. Also present were *returning professionals* who took over mediation resulting in the former reporting feelings of pride and satisfaction. This participant then took leadership of similar activities in other courses.

Building competence

The results showed a complex relationship between experiences and competence. Underlying all the factors described by students were two common threads: (1) the balance of exchange and reflection and (2) the importance of challenges. The former assisted students in self-described personal growth. The latter was a source of described accomplishment and, sometimes, failure. Both are important features of competence-oriented curricula.

Reflection and exchange

Deep learning associated with integration of knowledge, skills, and attitudes necessary for competence development best occurs with certain underlying curricular features such as the opportunity to exchange with others and time and space to reflect (Kolb and Kolb 2017; Lave 2009; Wenger 2009). We found that exchange served two primary purposes: (1) as a reflective tool for working through and coping with experiences and (2) as a revelatory tool for exposing implicitly held knowledge and values. This process of engaging (and associated revelation), reflecting, and re-engaging are the basis for knowledge development according to transformational and experience-based learning theory (Andresen, Boud, and Cohen 2000; Caniglia et al. 2016; Kolb and Kolb 2012; Mezirow 1997). Reflection occurred mostly within cohorts or through self-dialogue. The deeper the existing relationship that students had with their dialogic partners, the more fundamental the moments of revelation proved to be. Revelation occurred in varying situations ranging from within cohorts to conferences and public engagements.

These external interactions exposed the students' knowledge and ability to themselves.

Challenge and setbacks

Complex challenges with real-world connections and consequences can be powerful competence drivers (Cörvers et al. 2016; Servant-Miklos, Holgaard, and Kolmos 2020). Positive practical experiences are expected to result in gains in student self-perceived competence, as seen in both the medical field (Smith, Grundmann, and Li 2018) and engineering (Kolmos, Holgaard, and Clausen 2021). In fact, most of our respondents did list praxis-oriented activities as affecting their competence development. Especially large increases in competence were associated with students engaging with tasks that at first appeared overwhelming but which ended successfully. The iterative process of anticipating and overcoming barriers, a key feature of project work (Thompson and Couto 2016), was the primary driver for strategic competence. For this reason, projects embedded in university programs are a valuable component to competence development as they offer students the rare chance to engage with complex problems and perceived high stakes within the safe environment of expert support should they need it before taking on similar tasks post-graduation (Lake, Fernando, and Eardley 2016).

Designing curricula for competence

Building exchange and reflection into a program can take multiple forms. This could be achieved by using course scheduling to ensure shared classes and breaks, which occurs during the first semester at ASU, or having required classes to create a shared knowledge foundation as seen in all three programs. This programmatic feature can also build a shared base for social comparison and group-identity construction (Wenger 2009). Providing spaces for collaboration in campus architecture can facilitate purposeful and spontaneous interaction.

Building contact with other specialized areas of study and external parties into curriculum creates context that is needed for the reflective exchange required for positive change toward sustainability (Matschoss et al. 2021). Ideally, universities should foster relationships with local residents and businesses to enable collaboration that can be embedded in the surrounding community (Vilsmaier and Lang 2015). Building and maintaining these networks takes time, effort, and competence from instructors and university staff, good will and interest from potential business and community partners, and

capacity from all involved (Leal Filho, Salvia, et al. 2021; Wiek et al. 2015).

Students also need to experience encounters with complex problems without becoming irreconcilably overwhelmed. This implies a heightened pressure on experiential learning environments and especially commitment by instructors to monitor, to scaffold, and to make appropriate interventions to ensure that students perceive the inevitable conflicts and setbacks as something to be overcome and not a source of personal failure (Förster, Zimmermann, and Mader 2019; Lake, Fernando, and Eardley 2016). This objective is best done through a combination of modeling expertise (Konrad, Wiek, and Barth 2021), which is especially important for complex problem solving, mediating the activities so that between independent work there are frequent check-ins to prevent students from shutting down or giving up (Förster, Zimmermann, and Mader 2019; Harmer and Stokes 2016; Lake, Fernando, and Eardley 2016).

Assisting with reflection through guidance and practice also helped students in the three programs that we investigated to work through frustration and to recognize growth. Regardless of personality profile, all students who engaged in experience-based learning featuring iterative and reflective cycles showed more resilience later in their studies. All students also positively experienced the reflective interviews. Repeatedly using the key competence framework to reflect certainly influenced student self-perception (Boekaerts 1991). The potential of competence self-assessment as praxis for sustainability education deserves further exploration.

Several researchers have demonstrated that a single course can positively influence competence, but incremental change can be difficult to measure (Caniglia et al. 2016; Remington-Doucette and Musgrove 2015; Remington-Doucette et al. 2013). We expected that student-centered praxis would positively contribute to competence development (Lozano et al. 2017) and indeed this was the case, but students found all activities useful. Assigned readings, lectures, and writing opportunities all contributed to student knowledge and sparked them to think and explore independently. This experience speaks to the importance of a coordinated curriculum, but it is simultaneously unrealistic to address all student needs with one class.

Most students had two fundamental prerequisites for reported competence development: an awareness of having used the competence and satisfaction with the result. All students were familiar with the article by Wiek, Withycombe, and Redman (2011). Both the ASU and GSS students also participated in courses where the key competence framework was

explicitly part of the course description and activities, but aside from the GSS research-methods course, student perception was less straightforward. For example, multiple students listed activities where we observed them applying learning from another class, and they neither cited nor were able to describe the link to the first class. While this may be frustrating for instructors, the finding also supports the concept of learning as a holistic process in which a student's entire embodied knowledge changes with experiences (Backman et al. 2019; Kolb and Kolb 2017; Mezirow 1997; Sipos, Battisti, and Grimm 2008). Most students focused on the activities currently relevant or recently completed. They also remarked on the difficulty of pinpointing competence development, as exemplified by one student who noted:

I feel like just getting trained in [interpersonal competence] ... [is constant] because I always have to discuss in groups in every course, and in my study program itself I meet people from every kind of discipline.

At the conclusion of our collaboration, each student received their past self-assessments, and most expressed surprise at what they wrote. The activities they listed had faded from memory and what remained was what we contend was a sense of holistic growth.

Conclusion

The journeys of the students in this tripartite study showed how the interaction of multiple factors of a graduate sustainability program are formative for key sustainability competence development. The individual activities, relationships, and interactions are mutually influential elements of that experience. Students learned as much from interacting with peers as from the formal instructional activities. These interactions were fluid and took place in class, while engaging in extracurricular activities, and during free time and they were further enriched through the reflection and exploration that was provoked. For this reason, we recommend taking into consideration how courses interact with each other and with students' other pursuits. Purposeful curriculum design to enable student exchange within a particular cohort and with external parties supports competence, and so does engagement with complex, real-world problems. Success in this area requires foundational knowledge and skills, and from instructor support to ensure that the balance between challenge and frustration remains positive. On the whole, program design is key so that no single class or instructor bears the burden of ensuring all important elements are present.

The two programs investigated for this study fit Sterling's (2001) model for fully integrated sustainability (Weiss, Barth, and von Wehrden 2021). Moving forward it would be worthwhile to explore academic initiatives that are emblematic of other models such as study programs that include sustainability classes or sustainability programs at institutions without a university-wide commitment to sustainability.

In the near-term future, students face multiple pressures. The real-world embedded projects, group collaboration, and spontaneous interactions have all been changed as a result of the COVID-19 crisis (Leal Filho, Price, et al. 2021). It was beyond the scope of this research to compare the competence development of the cohorts of these programs affected by the pandemic and the resulting curricular changes with those described here. Our focus has been on how to maintain the above-mentioned components in ways that are resilient to sudden, wide-sweeping emergencies. But what is a sustainability challenge if not something which is urgent, wide-reaching, and constantly changing?

Ethical approval

This research was reviewed and approved by the Arizona State University Institutional Review Board (Number HRP-503a). This study adheres to the ethical requirements for performing social research. All participants have signed forms indicating informed consent.

Notes

1. For this study, the components are the teaching and learning environment, teaching and learning process, the participants, and the context. We expand on this explanation in the methods section of the article.
2. For a more detailed overview, see Birdman, Barth, and Lang (2020).
3. This study relies on Birdman, Wiek, and Lang (2022) to define project work as: 1) Students work in self-regulating groups; 2) Students collaborate with experts and/or stakeholders in the project-relevant field; 3) Student-oriented learning practices encourage autonomous learning; 4) Work happens on site (i.e., where the relevant issue is situated); 5) The project targets a specific challenge with a defined goal including a timeline and benchmarks set with student input; 6) The objective is to increase student competence to identify and solve complex (sustainability) problems in real world settings (see Section 2 and Table 2).
4. It should be noted that all barriers were subjective and do not necessarily reflect the delivered curricular content.

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