A Matter of Connection

Competence Development in Teacher Education for Sustainable Development

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A Matter of Connection

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We cannot solve our problems with the same thinking we used when we created them.
(Albert Einstein)

"Educators remain key actors in facilitating learners' transition to sustainable ways of life, in an age where information is available everywhere and their role is undergoing great change. Educators in all educational settings can help learners understand the complex choices that sustainable development requires and motivate them to transform themselves and society. In order to guide and empower learners, educators themselves need to be empowered and equipped with the knowledge, skills, values and behaviours that are required for this transition." (UNESCO, 2020)

ABSTRACT

In response to the globally increasing environmental, social, and economic crises, we as humanity must leave the path of *business as usual* and learn new ways to know, think, and act which may enable us to build a more sustainable future for all. In their role as facilitators, teachers in general are considered one, if not the most important, factor for successful learning. The implementation of education for sustainable development (ESD) across all education systems and preparing students to act as future change agents and lead the societal transformation towards sustainability also largely depends on competent and committed teachers. Correspondingly, the focus of political agendas and scientific research increasingly shifts to the effective education of educators.

The different competence models that are currently being discussed in the international discourse around teacher education for sustainable development (TESD) suggest various sets of intended learning outcomes (ILOs). Yet, they usually share the assumption that teachers require ESD-related knowledge, pedagogical skills, and motivation to successfully implement ESD at the school level. In accordance with the concept of *ESD-specific professional action competence* (Bertschy et al., 2013), educational offers in ESD for pre-service teachers should also develop their content knowledge (CK), pedagogical content knowledge (PCK) as well as a positive attitude towards ESD. However, in the sense of a comprehensive construct, this concept has not yet been operationalized or measured. Furthermore, there is still a lack of deeper understanding as to how to best design individual courses as teaching and learning environments in TESD in order to support competence development in student teachers.

Based on a dual case study, this cumulative dissertation investigates how individual ESD courses, as part of the teacher education programs at Leuphana University in Lüneburg/ Germany and Arizona State University (ASU) in Tempe/USA, actually foster students' ESD-specific professional action competence. Furthermore, this work sheds light on the link between learning processes and outcomes, to reveal which factors actually affect the achievement of ILOs and competence development.

The findings of this study indicate that both courses under investigation eventually live up to their role and increased student teachers' competence and commitment to implement ESD in their future careers; yet, mainly due to their different thematic foci, to varying degrees. Additionally, the *four Cs* (personal, professional, social, and structural connections) were revealed as significant factors that support students' learning and should be considered when planning and designing course offerings in TESD, with the goal of developing students' knowledge, skills, and attitudes.

ZUSAMMENFASSUNG

In Anbetracht global anhaltender Umwelt-, Sozial- und Wirtschaftskrisen sind wir als Menschheit gefragt, den Weg des *business as usual* zu verlassen und neue Wissensformen sowie Denk- und Handlungweisen zu erlernen, die uns befähigen, eine nachhaltige Zukunft für alle zu gestalten. In ihrer Vermittlungsrolle werden Lehrer*innen allgemein als ein, wenn nicht gar der wichtigste Faktor für erfolgreiches Lernen betrachtet. Auch die Umsetzung von Bildung für eine nachhaltige Entwicklung (BNE) über alle Bildungssysteme hinweg sowie die Vorbereitung von Schüler*innen auf ihre Rolle als zukünftige Agenten des Wandels, die die gesellschaftliche Transformation in Richtung Nachhaltigkeit zu führen vermögen, hängt maßgeblich von kompetenten und motivierten Lehrer*innen ab. Entsprechend rückt die effektive Ausbildung von Lehrer*innen zunehmend in den Fokus politischer Agenden und wissenschaftlicher Forschung.

Die verschiedenen Kompetenzmodelle, die im wissenschaftlichen Diskurs rund um die Lehrer*innenbildung für eine nachhaltige Entwicklung (LBNE) diskutiert werden, legen jeweils eine Reihe verschiedener Lernziele fest. Dabei teilen sie jedoch die Annahme, dass Lehrer*innen sowohl BNE-bezogenes Fachwissen, pädagogische Fähigkeiten und Motivation benötigen, um BNE erfolgreich auf Schulebene umzusetzen. Auch dem Konzept einer BNE-spezifischen professionellen Handlungskompetenz (Bertschy et al., 2013) zufolge sollten die Bildungsangebote in BNE für Lehrer*innen in Ausbildung ihr Fach- und fachdidaktisches Wissen sowie eine positive Einstellung gegenüber BNE entwickeln.

Im Sinne eines umfassenden Konstruktes wurde dieses Kompetenzmodell allerdings noch nicht operationalisiert, geschweige denn gemessen. Darüber hinaus mangelt es nach wie vor an einem tieferen Verständnis darüber, wie einzelne Kurse als spezifische Lehr- und Lernumgebungen in der LBNE, strukturiert sein müssen, um die Kompetenzentwicklung auf Seiten der Lehramtstudierenden zu fördern.

Auf Grundlage einer dualen Fallstudie untersucht die vorliegende kumulative Dissertation, wie individuelle BNE-Kurse – als Teil der Lehramtstudiengänge an der Leuphana Universität in Lüneburg/Deutschland sowie der Arizona State University (ASU) in Tempe/USA – die Entwicklung BNE-spezifischer professioneller Handlungskompetenz tatsächlich unterstützen können. Außerdem wird die Verbindung zwischen Lernprozessen und Lernergebnissen explizit beleuchtet, um bedeutende Faktoren zu enthüllen, die das Erreichen der Lernziele beziehungsweise die Kompetenzentwicklung beeinflussen.

Die Ergebnisse der Studie zeigen, dass letztlich beide untersuchten Kurse ihrer Rolle gerecht werden und die Kompetenz und Bereitschaft der Studierenden erhöhen, BNE in ihrem zukünftigen Arbeitsumfeld umzusetzen – wenn auch zu unterschiedlichen Graden, was vor allem auf ihre inhaltlichen Schwerpunkte zurückzuführen ist. Zusätzlich wurden die vier Verbindungsformen (*the four Cs*), nämlich persönliche, professionelle, soziale und strukturelle Verbindungen als wichtige Faktoren ausgemacht. Die *four Cs* unterstützen die Lernprozesse der Studierenden und sollen bei der Planung und Gestaltung von Kursangeboten in LBNE berücksichtigt werden, welche zum Ziel haben, Wissen, Fähigkeiten und Einstellungen auf Seiten angehender Lehrkräfte zu fördern.

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LIST OF ABBREVIATIONS

ASU	Arizona State University
CAP	Competence Assessment Program
CBE	Competence-Based Education
CK	Content knowledge
CSCT	Curriculum, Sustainable development, Competences, Teacher training
DeSeCo	Definition and Selection of Competencies
EfS	Education for Sustainability
et al.	et alii (and others)
e.g.	exempli gratia (for example)
ESD	Education for Sustainable Development
HEI	Higher Education Institute
HESD	Higher Education for Sustainable Development
Ibid.	Ibidem (in the same source)
ICR	Inter-Coder Reliability
ILO	Intended Learning Outcome
K-8	Kindergarten through 8^{th} grade
NEP	New Ecological Paradigm
OECD	Organisation for Economic Co-operation and Development
PCK	Pedagogical content knowledge
Pts.	Points
RSP	Rounder Sense of Purpose
SE	Self-Efficacy
SD	Sustainable Development
SDG	Sustainable Development Goal
SSfT	Sustainability Science for Teachers
T&L	Teaching and Learning
TEfS	Teacher Education for Sustainability

TESD	Teacher Education for Sustainable Development
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNESCO	United Nations Educational, Scientific and Cultural Organization
USTESD	United States Teacher Education for Sustainable Development
USA	United States of America
WCED	World Commission on Environment and Development
WOT	Ways Of Thinking

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Jan-Ole Brandt

1 INTRODUCTION – PROBLEM STATEMENT

Facing global environmental, humanitarian and economic challenges, like climate change, the COVID 19-pandemic or social inequality and societal disruptions, the global community needs to be responsible in leading the world on a more sustainable path. This, however, requires profound changes in human lifestyles and behavior patterns. The Fridays for Future movement has currently shown that there are legions out there, asking for transformative rather than incremental change – holding particularly politicians accountable. Meanwhile it is undisputed that education in general and education for sustainable development (ESD) in particular can be described as main catalysts for building a better and more sustainable future for all (e.g., Cortese, 2003; UNESCO, 2014). As one of the most important leverages to sustainable development (Sachs et al., 2019), higher education for sustainable development (HESD) is expected to specifically educate so-called change agents (Rowe, 2007) equipping them with the required competences to act as the spearhead of the sustainability transformation process (Wiek et al., 2011). This is, for instance, reflected in prominent political agendas, such as the global Sustainable Development Goals (SDGs), which aim to stimulate action in areas of critical importance for humanity and the planet (UN, 2015). In accordance with the United Nations Educational, Scientific and Cultural Organization (UNESCO) and its new ESD roadmap for 2030, SDG 4.7 explicitly calls to *"ensure that all learners acquire the knowledge and skills needed to promote sustainable development"* (UNESCO, 2020).

Yet, consideration of ESD is not limited to the political arena; in academia, there are currently growing numbers of both publications addressing ESD and efforts to integrate sustainability in higher-education programs and curricula (Weiss & Barth, 2019). The successful implementation of ESD across all levels of education systems, however, depends on competent and committed multipliers (Timm & Barth, 2020). Hattie (2009), for instance, stresses the role of teachers for creating effective learning environments for ESD – also acknowledged by UNESCO, by dedicating one of five priority action areas on the ESD roadmap for 2030 to *"building capacities of educators"* (UNESCO, 2020). As facilitators of learning for sustainable development, teachers may be considered as crucial change agents, who hold the key to fostering more socially and environmentally sound behavior and making their students become responsible future citizens and competent problem solvers.

As such, teacher education for sustainable development (TESD) is on the rise in higher education institutions (HEIs) (Barth, 2015). Numerous universities in Australia, Germany, Spain, and Sweden have designed and implemented sustainability courses or modules in their teacher-education programs (Tomas et al., 2017; Bürgener & Barth, 2018; Jorge et al., 2015; Andersson, 2017). In other countries, however, such as the United States of America (USA), sustainability coursework in K-12 (pre-service) teacher education is much rarer (McKeown & USTESD Network, 2013). Furthermore, Evans et al. (2017) emphasized that ESD in initial teacher education *"is still an emerging area of curricular activity driven by individuals […, with] a very small research base"* (p. 413). Corresponding to the identified need for sustainability-literate teachers (Nolet, 2009), much of the existing research on TESD dealt with the actual achievement of intended learning outcomes (ILOs) and the development of specific competencies through individual interventions (Evans et al., 2017).

Eventually, the entitlement to implement ESD and apply innovative forms of teaching and learning places a high demand on educators and requires a toolbox of knowledge, skills and attitudes (Kang, 2019). In accordance with the concept of *ESD-specific professional action competence of teachers* (Bertschy et al., 2013), student teachers are expected to develop sustainability-related content knowledge (CK), pedagogical content knowledge (PCK) as well as the motivation to implement ESD at the school level (attitude). Yet, so far, this competence model has not been adequately operationalized for empirical investigation. Furthermore, whereas the increasing number of course offerings in TESD (Evans et al., 2017) elucidates the willingness of HEIs to take on the institutional responsibility and ensure effective teacher training, it largely remains equivocal how intended learning outcomes (ILOs) or ESD-specific competence development is to be achieved pedagogically. To understand what needs to be considered when designing and implementing TESD courses, with the aim to support competence development in pre-service teachers, the question of how students' learning actually takes place needs to be asked (Barth, 2015). According to Backman et al. (2019), this calls for impartial research where students' individual experiences are studied in depth to investigate the multitude of influences on their learning. In ESD research attempts have been made to link certain pedagogical approaches to the delivery of competencies (e.g., Dlouhá & Burandt, 2015; Lozano et al., 2017), while similar approaches in TESD are still missing.

Consequently, the aim of this thesis is to expand the existing research base in TESD, by operationalizing the concept of ESD-specific professional action competence for teachers (Bertschy et al., 2013) and purposefully link learning processes and outcomes at the micro-level of individual TESD courses. Based on a dual explanatory case study (Yin, 1984), it investigates in how far hybrid learning environments in TESD foster the development of ESD competencies and attempts to reveal concrete mechanisms that support or hinder student teachers' learning in conjunction with applied teaching and learning formats (pedagogical approaches).

With *Education for Sustainable Development* (*ESD*) at Leuphana University in Lüneburg/Germany and *Sustainability Science for Teachers* (*SSfT*) at the Arizona State University (ASU) in Tempe/Arizona, two courses were deliberately selected to compare and contrast prominent examples of how ESD can be implemented in teacher education. The two cases display a variance with respect to their institutional context, applied teaching and learning approaches, and intended learning outcomes. However, in order to gain knowledge on and depict both the learning processes in and outcomes of said courses, a variety of specific assessment tools needed to be adopted, further developed, tested and applied throughout the research. Finally, the empirical results reveal insights regarding the potential of prominent teaching and learning formats in TESD to ensure successful competence development as well as supporting and hindering factors that impact students' learning processes. Alongside the methodical contributions of this thesis, it further allows for a series of practical suggestions for other higher education institutes, teacher educators and educational planners with regards to designing their related study courses, programmes, curricula and syllabi in TESD.

2 STRUCTURE OF THESIS

In general, this dissertation is structured in an overarching framework paper (Chapter 1-6), published empirical contributions (Appendices 1-3) as well as thorough descriptions of the two specific investigated cases as well as the instruments applied (Appendices 4&5).

In the following Chapter 3, I provide the theoretical background of this thesis and describe the state of the art in terms of research and practice in teacher education for sustainable development (TESD). In order to demonstrate the relevance and positioning of this thesis, it will start with a brief introduction of relevant conceptions of higher education for sustainability (HESD) and TESD in particular. This will provide an overview of previous work and help to understand how this study is contextualized. Next, I describe my theoretical framework that clarifies how the key concepts of intended learning outcomes, learning processes as well as teaching and learning formats are understood and connected in this work. Finally, based on a specific literature review, I demonstrate the existing research gap. Chapter 4 presents the research design adopted to fill the identified research gap. Here, the concrete research questions and methodological considerations are formulated. Furthermore, brief case descriptions are provided and the variables to be covered (empirical design) as well as instruments and methods applied to collect and analyze the empirical data are introduced. This is to provide a comprehensive foundation and enable the reader to understand the reasoning behind the selection of cases as well as the applied approach to empirical research. Following, Chapter 5 synthesizes the results of the three published research articles – which form the heart of this dissertation – and illustrates the key findings of my empirical investigation. After presenting my approach to operationalize the concept of professional action competence for teachers I demonstrate how far the two courses under investigation actually fostered competence development in participating student teachers and reveal the factors impacting their learning during the interventions. Finally, Chapter 6 concludes with a brief summary considering quality criteria of mixed-method case study research as well as the limitations of this work. Finally, ideas for future research as well as the methodical and practical implications of the overall findings will be discussed.

3 THEORETICAL BACKGROUND

In this chapter I introduce the state of research and practice relevant for this thesis. First, I will briefly refer to the broader research landscape concerning education for sustainable development (ESD), as the interface of sustainability and educational science, in which this work is embedded. Then, it turns to the focus of this research work, which is in analyzing the contribution of hybrid course offerings in teacher education for sustainable development (TESD) to equip pre-service teachers with the required competencies to successfully implement ESD at the school level and act as multipliers and change agents in the interest of sustainable development (SD)[1].

3.1 Education for sustainable development

In the midst of the ongoing economic, social and environmental crises and the crossing of various planetary boundaries, such as climate change and biodiversity loss, which threaten the viability of the biosphere as well as human life on Earth (Rockström et al., 2009; Steffen et al., 2015), SD has become one of the hottest buzzwords in public, political and scientific discussions. According to Dobson (1996), already in the mid-1990s, more than 300 definitions were available for SD. However, despite the existence of not least culturally different approaches to SD, the most commonly used definition is that proposed by the so-called Brundtland Commission describing SD as a *"development that meets the needs of the present without compromising the ability of future generations to meet their own needs"* (WCED, 1987, p. 41). Even though, this definition has occasionally been subject of criticism, due to its vagueness in terms of operationalization and lack of provided implementation measures (Robinson, 2004). Another widely recognized approach explaining what lies at the heart of SD is the *triple bottom line* (Elkington, 1998), according to which governments, businesses and the civil society are asked to ensure *"a convergence between the three pillars of economic development, social equity, and environmental protection."* (Drexhage & Murphy, 2010, p. 2) More recently, in 2015, all United Nations Member States adopted the 2030 Agenda for SD with its 17 *Sustainable Development Goals* (SDGs) and 169 targets, aiming to provide a shared blueprint for peace and prosperity for people and the planet, both now and for the future (UN, 2015).

[1] The terms *sustainable development* and *sustainability* are used interchangeably in the context of this work.

Correspondingly, sustainability science aims to understand the complex and dynamic interactions between natural and human systems as well as contribute to finding solutions for multi-faceted problems in the context of SD (Mochizuki & Yarime, 2016). Furthermore, recognizing potential solutions and implementing the required strategies to achieve the SDGs and build a more sustainable future for all calls for fundamental changes in the ways we know, think and act (Wals & Corcoran, 2012). Considering SD as a learning process itself (Vare & Scott, 2007), education at large and education for sustainable development (ESD) in particular, can be described as main catalysts for SD to take effect (Cortese, 2003). Furthermore, UNESCO's new *ESD Roadmap 2030* explicitly emphasizes *"the role of education in the achievement of the inter-connected 17 SDGs."* (UNESCO, 2020, p. 16) Eventually, it builds on the vision of the United Nations Decade of ESD (2005-2014) and its successor, the Global Action Programme on ESD (2015-2019), to multiply and scale up ESD action.

The relationship between education and social change, however, is rather contested in the international discourse on ESD. Critics of the concept of ESD were already from the start concerned about the conceiving of it as a mechanical apparatus – implying that the objectives of SD have already been defined by others and education, in a sense, only leads to social reproduction (Jickling, 1992). Instead, Jickling and Wals (2008) emphasize the importance of creativity and undetermined dynamics for true change to occur. In response to this criticism and bridging the paradox aims of ESD – enabling change, while following the determined path towards SD – Vare and Scott (2007) propose the idea of two interrelated and complementary approaches to ESD (ESD 1 and ESD 2):

> *"[They] see ESD 1 as the promotion of informed, skilled behaviours and ways of thinking, useful in short-term where the need is clearly identified and agreed, and ESD 2 as building capacity to think critically about what experts say and to test ideas, exploring the dilemmas and contradictions inherent in sustainable living."* (Vare & Scott, 2007, p. 191)

Subsequently, different and strongly diverging perspectives were discernible regarding the idea of ESD and its conceptual implications. Partly resulting from the shortcomings of defining SD, also ESD has been subject to various interpretations and conceptualized differently in terms of its content, pedagogy as well as its intended learning outcomes (ILOs) (Tilbury & Mulà, 2009; Wals & Kieft, 2010).

3.2 Competent change agents and higher education for sustainable development

As universities are particularly expected to educate future change agents (Rowe, 2007) and prepare their graduates to act as the spearhead of the sustainability transformation (Heiskanen et al., 2016), higher education for sustainability (HESD) is perceived as one of the most important leverages for SD (Sachs et al., 2019). While general sustainability efforts and initiatives in higher education are rather diverse (Shephard, 2008), many share the notion that learners should develop certain competencies comprised of relevant knowledge, skills, and attitudes (e.g., Spady, 1994; Lambrechts et al., 2013; Pappas et al., 2015) – engaging head, hands and heart (Sipos et al., 2008). However, the educational literature on competencies in general, and competencies in sustainability in particular, entails a great deal of terminological ambiguity (Wiek et al., 2011), associating the term *competencies* with skills, abilities, capabilities, capacities, qualifications and other concepts (Baartman et al., 2007; Holdsworth & Thomas, 2020). In the context of this work, I follow the definition of Weinert (2001) to understand competencies as the interaction of knowledge, skills and attitude (or willingness) that are learnable and help the individual to cope successfully and responsibly with changing situations in a specific domain.

The general approach of competence-based education (CBE) and shifting from input to output orientation was already introduced with the reform of teacher education in the USA during late 1960s (Brown, 1994). Efforts like the OECD-led initiative on the *"Definition and Selection of Competencies (DeSeCo)"*, providing a conceptual framework for defining and evaluating competencies for what was then termed *"a successful life and a well-functioning society"* (Rychen & Salganik, 2003) broadly popularized this approach.

Also sustainability competencies, as intended learning objectives (ILOs) for sustainable development in higher education (Svanström et al., 2008) have been widely discussed in recent literature. Especially in the context of curriculum development (e.g. Sterling & Thomas, 2006) but also for course design, delivery, and assessment (Wiek et al., 2016), competencies serve as an important points of reference in backcasting approaches (Wiggins & McTighe, 2005) or constructive alignment (Biggs & Tang, 2011). To have a critical reference point for the knowledge and skill profile of students, Wiek et al. (2011) conducted a broad literature review and distilled from it a framework of key competencies in sustainability, which is currently considered one of the most influential contributions to the field (Grosseck et al., 2019).

Proposing the idea of an integrated *"research and problem-solving competence"*, Wiek et al. define (2011) and operationalize (2016) five interdependent key competences in sustainability: systems thinking competence, futures thinking or anticipatory competence, values thinking or normative competence, strategic thinking or action-oriented competence, and collaboration or interpersonal competence. Yet, underlining, among other things, the importance of values thinking and providing the normative orientation for all the other competencies, this seminal concept has recently been expanded:

> *"While there was general agreement on the framework and its main features, experts nuanced definitions, proposed a hierarchy (values-thinking competency as underpinning competency) and two additional key competencies (intrapersonal and implementation competencies), and specified learning objectives for aspiring sustainability professionals and for sustainability researchers in particular."* (Brundiers et al., 2020)

The relevance of an overarching competence as a central educational objective of ESD is also appealed to in Germany. Within the German discourse, it is often referred to the notion of *"Gestaltungskompetenz"* (shaping competence) (e.g., Haan, 2006; Barth, 2007). This shaping competence may be understood as *"having the skills, competencies and knowledge to enact changes in economic, ecological and social behavior without such changes always being merely a reaction to pre-existing problems."* (Haan, 2006, p. 22) As ESD is constantly dealing with highly complex problems – such as climate change or the survival of eco- and social systems – all of which *"have no one obvious optimal solution"* (Wiek et al., 2011, p. 203) – authors like Grunwald (2004) claim that related education is mainly problem-driven and solution-oriented. Since the 1990s, pedagogical approaches in general showed a considerable shift from rather transmissive, teacher-centered training and instruction to student-centered learning environments (Jonassen & Land, 2012). Furthermore, Barth and Michelsen (2013) found that current pedagogies for ESD in particular are *"based on social-constructivist learning theories and offer opportunities for dialogue, active and critical reflection."* (Ibid., p. 107).

3.3 Teacher education for sustainable development

The educational concept of *Bildung*, introduced by Wilhelm von Humboldt ([1792] 2015), may be understood as a student-centered approach, as it is based on the idea that students may contribute to societal change by developing their own individual self. Yet, according to Hopmann (2007), this can only be achieved by restrained teaching and *"opening up for the individual growth of the student."* (Ibid., p. 115).

When it comes to implementing ESD across education systems – at the school level in particular – and developing students' competencies in shaping a sustainable world, the role of educators is widely acknowledged. With regards to teaching in the classroom, as their professional core business (Tenorth, 2006), teachers are considered the decisive factor for successful learning in general (Biggs & Tang, 2011). Eventually, there is a strong correlation between a teacher's competence to create effective learning environments and students' actual achievement of ILOs (Darling-Hammond, 2000; Hattie, 2009). In the realm of teacher education for sustainability (TESD) with a focus on the facilitation of learning processes, this is mirrored in the common objective to develop pre-service teachers' *"capacity and (in some cases) commitment to embed SE [sustainability education] into their own teaching practices"* (Evans et al., 2017, p. 411). However, while teachers' competencies and commitment toward sustainability are considered essential success factors for the implementation of ESD in school practice (Barth, 2015), ESD is not yet well established in the teacher education in most countries (Evans et al., 2017). Thus, corresponding offers to educate the educators in ESD are urgently required (Andersson et al., 2013). This is also in accordance with UNESCO's program *ESD for 2030*:

> *"In priority action area 3 on building capacities of educators, the focus is on empowering educators with the knowledge, skills, values and attitudes needed for the transition to sustainability"* (UNESCO, 2020, p. 3)

Eventually, the professionalization of teachers is understood as a career-long process, ideally taking place across all phases of pre- and in-service teacher education (Döring-Seipel & Seip, 2019). However, this thesis merely revolves around the question of how individual sustainability courses in pre-service teacher education (within the university context) can foster students' competence to implement ESD at the school level in their role as intructors.

3.3.1 Competence models

Previously, various concepts of competencies have been discussed in TESD literature. Yet, in response to the call of the United Nations Economic Commission for Europe (UNECE) *"to offer curriculum models to teacher training institutes which are searching for attainable possibilities to integrate ESD in their curricula"* (Sleurs, 2008, p. 1), several of these concepts go beyond the idea of teachers as classroom instructors. Rather, they also consider the role of teachers in the institutional context – in connection with their colleagues – as well as the wider community (e.g., Sleurs, 2008; UNECE, 2013; Vare et al., 2019). Explicitly referring to the aforementioned *DeSeCo* initiative (Rychen & Salganik, 2003), the CSCT (Curriculum, Sustainable development, Competences, Teacher training) project defines teaching, reflecting/visioning, and networking, as overall competencies and perceives the teacher as an individual, a member of the educational institution and the society (Sleurs, 2008). UNECE (2013), on the other hand, defines 39 competencies that are based on UNESCO's four pillars of learning: learning to know; learning to do; learning to be; and learning to live together (UNESCO, 1996) – with the intention of providing a comprehensive framework for the professional development of educators in ESD. However, Vare et al. (2019) comment on this as follows:

> *"Despite these efforts, the UNECE ESD competence framework does not appear to have had the impact that was sought, largely because it remains a theoretical tool. The 39 competence statements are not expressed as assessable competences neither have they been tested against real educational contexts."* (Ibid., p. 6)

As the UNECE competencies appeared to be too complex, too repetitive and *"unmanageable"*, the Rounder Sense of Purpose (RSP) project proposed a new matrix of only 12 competencies, described as being of flexible nature and combinable as the context requires. Yet, according to the authors of the RSP, *"[f]urther work is required in testing and refining the RSP framework, particularly in the area of assessment."* (Ibid., p. 17) While the RSP competence framework represents a promising approach in terms of making competencies in TESD accessible in the future, it was developed during the same period as this dissertation and was simply not available at the start of my work.

Another suitable approach to competencies in TESD was put forward by Bertschy et al. (2013). Under the term of *ESD-specific professional action competence for teachers*, Bertschy and colleagues contextualized what Baumert and Kunter (2013) introduced in their COACTIVE model of professional action competence. Based on Shulman's (1987) considerations of what makes a competent teacher – originally proposing seven categories of knowledge that help teachers to promote comprehension among students – at least in the German discourse the differentiation of content knowledge, pedagogical knowledge, and pedagogical content knowledge prevailed (Bromme, 1997). Referring to the subject of math, the COACTIVE model of professional action competence for teachers builds on this concept and continues to distinguish between content knowledge, pedagogical knowledge, and pedagogical content knowledge. Yet, it further adds the domains of organizational and counseling knowledge (Baumert & Kunter, 2013). While this highlights aspects of (theoretical) professional knowledge, this model also considers elements of attitudes – namely beliefs, values, and goals; motivational orientations; and self-regulation (see Figure 1).

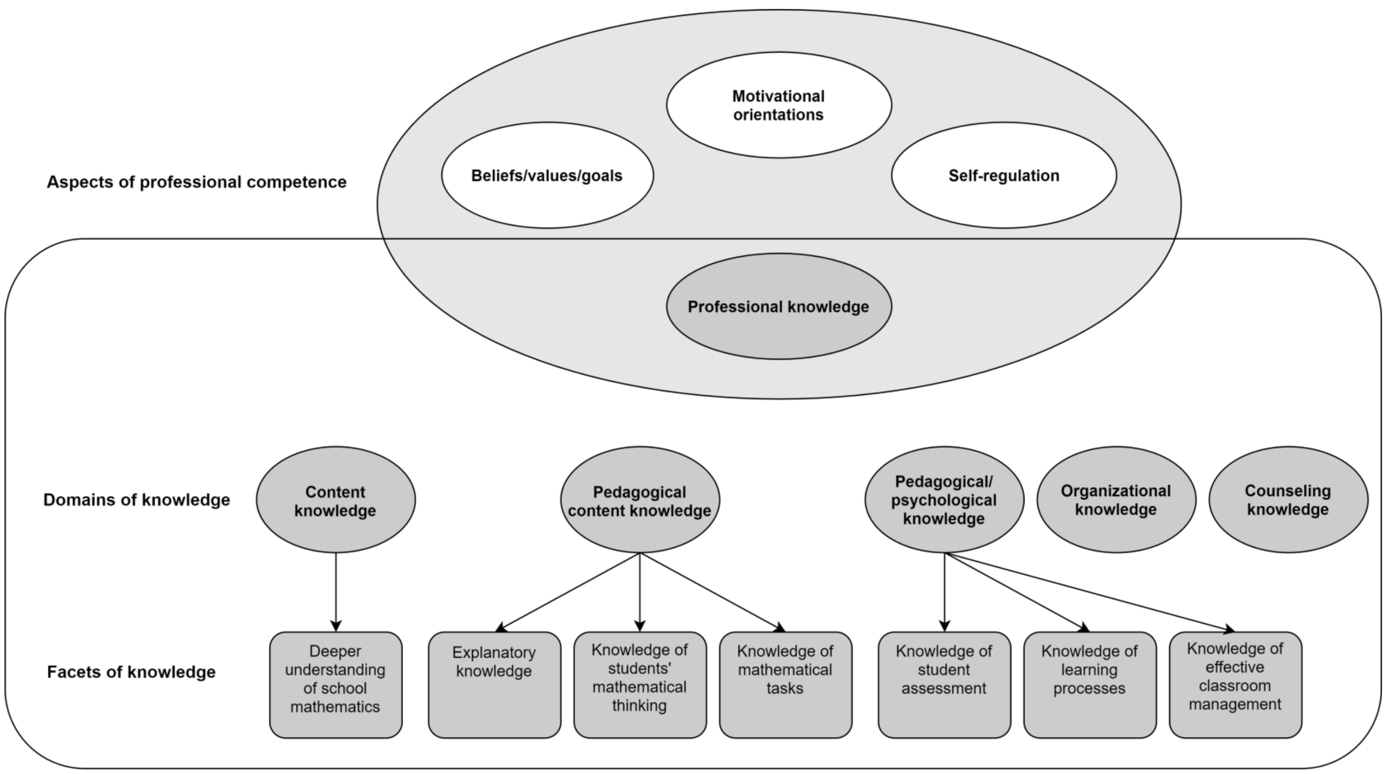

Figure 1: The COACTIV model of professional competence, with the aspect of professional knowledge specified for the context of teaching (adopted from Baumert & Kunter, 2013)

The concept of ESD-specific professional action competence for teachers, by Bertschy et al. (2013), followed the structural basis provided by COACTIVE model, distinguishing two key aspects particularly relevant for designing educational offers in TESD: *motivation and volition* (including beliefs/values/goals, motivation, and self-regulation) and *knowledge and ability* (representing the aspect of professional knowledge). In the context of ESD, *knowledge and ability* are understood as ESD-specific content knowledge (CK) as well as the corresponding pedagogical skill set (pedagogical content knowledge/PCK). This includes, for instance, an understanding of the concept of sustainability and the conflicts of goals and interests it entails (CK) as well as the ability to choose potential teaching topics and evaluate their suitability for ESD, make the pluralistic and complex nature of sustainability accessible for students, and design and implement effective learning environments (PCK). Motivation and volition, on the other hand, refers to competence components such as the perceived importance or relevance of SD as a challenge for society as a whole as well as *"the role of education as a resource for tackling of this societal task"* (Ibid., p. 5076). Accordingly, sustainability-related content knowledge (CK), pedagogical content knowledge (PCK), and the motivation and willingness (or positive attitudes) to implement ESD at the school level may be considered the three key domains of ESD-specific professional action competence for teachers as the overarching learning objective in TESD. Notably, the importance of PCK and CK for successfully enacting ESD at the school level is widely acknowledged in the literature (e.g., Scott, 1996; Summers et al., 2005; Symons, 2008). Furthermore, according to Tomas et al. (2017), positive attitudes are also likely to influence pre-service teachers' preparedness to engage in ESD as they commence their teaching careers.

3.3.2 Competence assessment

While the theoretical concept of ESD-specific professional action competence, introduced by Bertschy et al. (2013), is in line with the competence definition used in this thesis (Weinert, 2001), a practical operationalization of its individual competence components, in order to make it available for methods of assessment, is still missing. Recently, empirical research on TESD has often focused on assessing individual competence components of either CK (e.g., Esa, 2010; Redman & Redman, 2017), PCK (e.g., Rosenkränzer et al., 2017; Singer-Brodowski et al., 2019), or attitude (e.g., Tomas et al., 2017; Nousheen et al., 2020).

This thesis, however, goes one step further and provides a first attempt to operationalize and measure the entire construct of ESD-specific professional action competence for teachers. According to Baartman et al. (2007), a valid assessment of complex constructs like competencies and all its facets requires a combination of different methods or what they call a *"Competence Assessment Program"* (CAP). Figure 2 displays how the concept of ESD-specific professional action competence was operationalized in the context of this thesis.

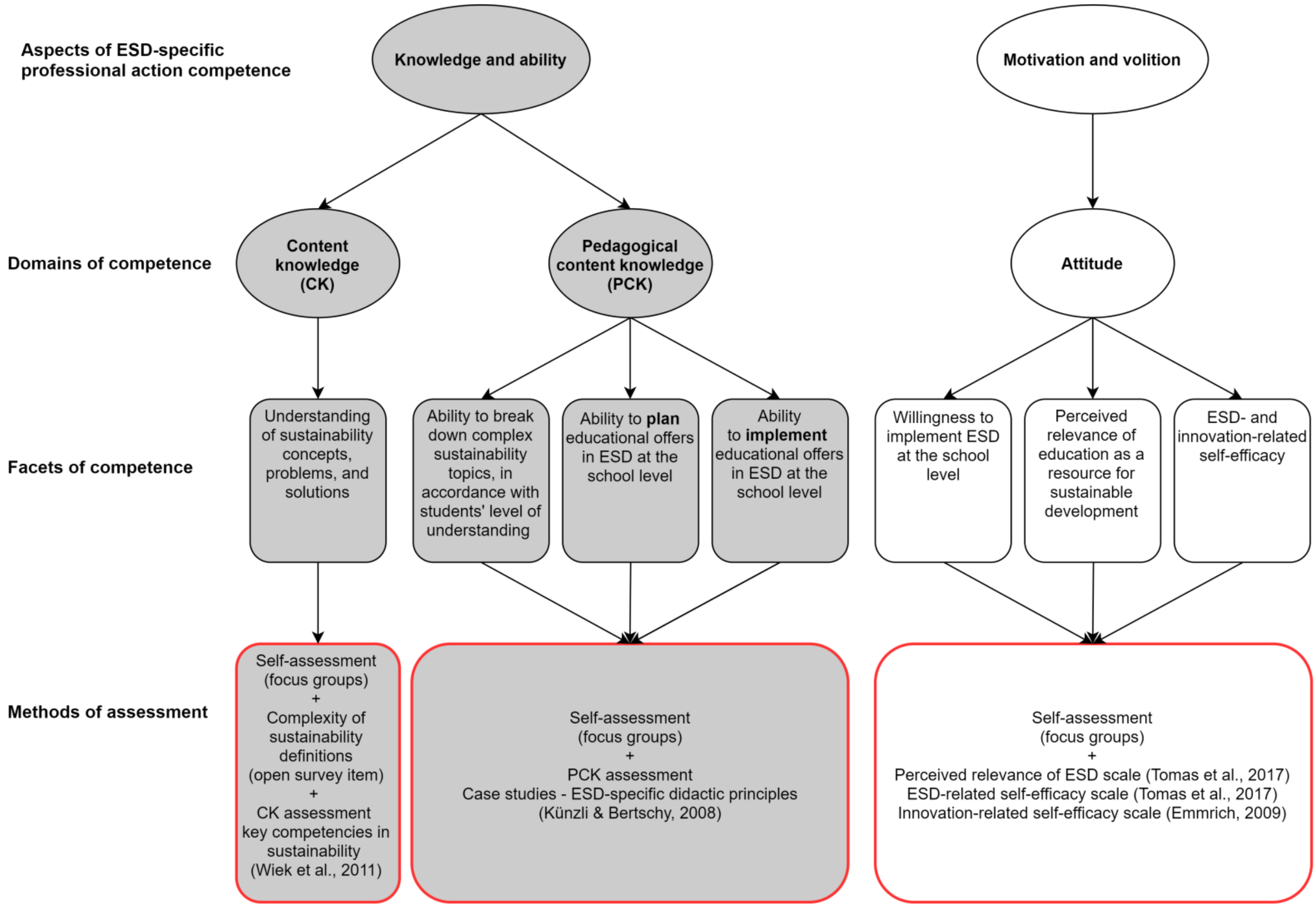

Figure 2: Operationalization of ESD-specific professional competence for teachers, in accordance with Bertschy et al. (2013)

As the interdisciplinary field of sustainability per se touches upon countless subjects and topics, it appears a hopeless endeavor to evaluate student teachers' factual knowledge about all existing sustainability issues. Still, CK is mostly measured by conventional tests (Redman et al., 2021). Here, pre-service teachers' CK was assessed based on the complexity of their sustainability definitions and ability to deal with the context-independent key competencies in sustainability, as introduced by Wiek et al. (2011).

Regarding ESD-related PCK, the current state of research lacks adequate assessment tools. In addition to contestable self-assessments (Cebrián et al., 2019) with respect to their ability to break down complex sustainability topics, as well as to plan and implement ESD units at the school level, case studies were used that tested students' capability to apply ESD-specific didactic principles, such as connected learning, participatory orientation and vision orientation (Künzli & Bertschy, 2008).

For the evaluation of students' attitudes toward ESD – indicating their motivation to teach related topics (Büssing et al., 2019) and described as a key factor for successful teaching (Lindemann-Matthies et al., 2009) – existing scales and constructs were applied in a survey format. While students' pro-ecological worldviews were measured by the revised NEP (new ecological paradigm) scale (Dunlap et al., 2000), also the perceived relevance of ESD-scale (Tomas et al., 2017) as well as ESD-related (Ibid.) and innovation-related (Emmrich, 2009) self-efficacy (SE) scales were implemented. Eventually, SE items cover students' trust in their own capabilities (Rieckmann, 2012) and positive attitudes toward ESD (see Chapter 4.4 and 4.5 for detailed descriptions of the analytical framework and applied instruments).

3.3.3 Pedagogies and competence development

Corresponding to the need for sustainability-literate teachers (Nolet, 2009), most recent research on competence development in TESD focused on the actual achievement of learning objectives (Evans et al., 2017). Eventually, it is important to assess whether existing teacher education programmes keep their promise and foster the development of relevant knowledge skills and attitudes that help student teachers to implement ESD at their future workplace (Cebrián et al., 2019). However, in order to reveal what factors affect them in achieving the ILOs, a focal shift is required from learning outcomes to learning processes and how students actually learn (Barth, 2015). Accordingly, as Backmann et al. (2019) suggested, this work aims to study students' learning experiences and investigate *"the multitude of influences on their learning"* (Backman et al., 2019, p. 149). Thereby, it will add to the limited body of literature on pedagogies for ESD (Summers et al., 2005).

As stated before, ESD in general has seen a significant shift from teacher to student-centered pedagogies as methods of instruction (Barth, 2015). For the context of higher education (HE), Biggs and Tang (2011) present a list of factors that may support students' learning processes. First, they highlight the importance of students' motivation and claim that learners in HE need to understand the value of engaging in the learning process.

In this regard, they emphasize the role that instructors and teaching staff play in increasing students' motivation, supporting learning activities that allow for deep learning, and providing valuable feedback. This followed by their approach to social learning and the idea that students learn both with and from one another, especially through pedagogical approaches like peer tutoring and group discussions. Building on existing knowledge and drawing structural interconnections between topics is also seen to improve learning (Biggs & Tang, 2011). More complex is the relation between emotion and cognition. While negative emotions, such as anxiety or fear of failure are considered barriers to learning (Ibid.), positive emotions may have a regulatory function and foster intrinsic motivation (Ryan & Deci, 2000).

Only few researchers attempted to explicitly link pedagogical approaches to the development of competencies (e.g., Dlouhá & Burandt, 2015; Lozano et al., 2017). Lozano et al. (2017), for instance, investigated the potential of different teaching and learning (T&L) formats and found that case study approaches, project- and problem-based learning, participatory action research, place-based environmental education, and lifecycle analyses are all generally promising approaches. They also note that covering all competencies that are relevant in the field of sustainability requires a diversity of methods (Ibid.).

In the field of TESD, research regarding the effectiveness of common pedagogies—such as lecture-style information delivery (e.g., Firth & Winter, 2007), discussion and reflection techniques (e.g., Corney & Reid, 2007), and future scenario exercises (e.g., Paige et al., 2008) – for competence development remain rather scarce (Evans et al., 2017). However, various approaches, such as problem-based-learning (PBL) have been found to foster pre-service teachers' CK and PCK (Peterson & Treagust, 1998) as well as their related self-efficacy (SE) (Haney et al., 2007). Inquiry-based learning may increase students' CK and positive attitudes toward sustainability (Kalsoom & Khanam, 2017). Furthermore, considering the much-cited theory-practice gap in general teacher education (Shulman, 1998), several authors have emphasized the importance of experience-based learning and creating real-life learning opportunities in TESD, in order to develop, test and reflect the relevant competencies (e.g., Frisk & Larson, 2011; Dicke et al., 2014; Kalsoom & Khanam, 2017). The notion of critical opportunities for *learning by doing* (Cebrián et al., 2019) is supported by the fact that experiential learning approaches and praxis-oriented pedagogies appear to foster ESD competencies in general (Jegstad et al., 2018) as well as ESD-related SE (Tomas et al., 2017) and CK and PCK (Nielsen et al., 2012) in particular.

Furthermore, Weiland and Morrison (2013), who found that courses focusing on either content or methods are equally effective in increasing student teachers' CK and PCK, recommend offering students the opportunity to plan and implement exemplary teaching and learning units: *"instructors should model for future teachers how to incorporate, integrate, connect, and combine content and practices to promote understandings of content and methods"* (Ibid., p. 1040). This makes sense as preservice teachers' understanding of how to teach ESD are expected to be consistent with how it was learnt (Abd-El-Khalick & Akerson, 2009), which further relates to the idea that engaging students in collaboration with professional stakeholders and forming links to educational practice enhance student teachers' learning (Tilbury, 2011; Zsóka et al., 2013). Explicitly referring to the development of ESD-specific professional action competence, Bürgener and Barth (2018) describe the promising approach of transdisciplinary living laboratories that incorporate the idea of scaffolding (Hannafin et al., 1999) and include project work with practice partners, which appear to enhance students' learning by allowing for insights into the professional field.

With regards to hybrid course offerings and the combination of face to face and online course delivery in TESD, Chin et al. (2019) emphasize the general potential of such blended learning approaches to be effective in preparing pre-service teachers to implement ESD in their future careers. On the one hand, (asynchronous) online learning may encourage students to confront issues more objectively and reflectively due to an improved focus on the content and less noise from face-to-face interactions (Ibid.). In the same context, Shelton et al. (2017) suggest that interactive digital storytelling videos are likely to outperform conventional online material, as they increase students' engagement and learning in the area of CK in particular. On the other hand, the lack of *"synchronous contact"* in online learning environments is by some considered a hindering factor (e.g., Whitehouse, 2008). Instead, others describe ESD as a process of social learning (Wals, 2007) and further underline the importance of social interactions and opportunities to cooperate and exchange ideas with others (e.g., Ojala, 2013; Dicke et al., 2014). Therefore, pedagogical approaches should encourage dialogue and the sharing of thoughts and ideas (Vare et al., 2019).

However, despite the different findings presented above, research on competence development in TESD is still scarce and scattered. As such, this thesis aims to make a comprehensive contribution to the field, by systematically operationalizing the concept of ESD-specific professional action competence for teachers (Bertschy et al., 2013) and purposefully linking learning processes in common T&L formats in TESD and learning outcomes at the micro-level of individual courses. Based on a dual explanatory case study (Yin, 1984), I specifically investigated how far hybrid learning environments in TESD foster the development of ESD-related CK, PCK, and attitudes and attempted to reveal concrete factors that affect student teachers' learning processes in conjunction with applied pedagogical approaches. As suggested by Backman et al. (2019), this work is based on the ontological and epistemological ideas of constructivism and focuses on the students themselves and their learning experiences, in the sense of multiple realities (Glasarsfeld, 1995; Guba & Lincoln, 1994).

4 RESEARCH DESIGN

As shown above, there is still a lack of (comparative) research on the link between common T&L formats in TESD, supporting or hindering factors impacting students' learning processes, and the actual achievement of ILOs in the sense of competence development. To address the identified research gap, this cumulative thesis project revolves around the following research inquiry and related sub-questions:

4.1 Research inquiry

How can the development of ESD-specific professional action competence be supported in single sustainability courses of teacher education programs that are not primarily devoted to ESD and in what way do individual teaching and learning environments differ in this regard?

- **Sub-question 1: Achievement of intended learning outcomes**
  To what extent is ESD-specific professional action competence for teachers actually developed through individual sustainability courses of teacher education programmes that are not primarily devoted to ESD?
- **Sub-question 2: Key factors impacting pre-service teachers' learning processes**
  What are the main factors that impact student teachers' learning processes in connection to different teaching and learning formats applied in individual sustainability courses of teacher education programmes that are not primarily devoted to ESD?
- **Sub-question 3: Comparison of different teaching learning environments**
  How do individual sustainability courses of teacher education programmes that are not primarily devoted to ESD – as specific teaching and learning environments – differ with respect to the development of ESD-specific professional action competence and related factors of support and/or hindrance?

To answer the individual sub-questions posed above, three research papers have been written based on empirical work and data, which are briefly described below. How these core contributions relate to my research inquiry is conceptualized in Figure 3.

<u>1st Article:</u> Brandt, J.-O., Bürgener, L., Barth, M. & Redman, A. (2019): "Becoming a competent teacher in education for sustainable development: Learning outcomes and processes in teacher education" In: *International Journal of Sustainability in Higher Education*, 20 (4), 630–653:

In the first article the construct of ESD-specific professional action competence, introduced by Bertschy et al. (2013), was first operationalized and competence development measured. Deploying a mixed-method approach, changes in students' understanding of the term *sustainability* (CK), their ability to apply ESD-specific didactic principles (Künzli & Bertschy, 2008) (PCK) as well as their ESD-related self-efficacy (Tomas et al., 2017), perceived relevance of ESD (Ibid.) and pro-ecological worldviews (Dunlap et al., 2000) (attitude) were considered as learning outcomes. This paper includes data collected from students enrolled in the course *Education for Sustainable Development* (*ESD*) at Leuphana University in Lüneburg/Germany in 2018 and primarily helps to answer sub-question 1.

<u>2nd article:</u> Brandt, J.-O., Barth, M., Merritt, E. & Hale, A. (2021): "A matter of connection: The 4 Cs of learning in pre-service teacher education for sustainability" In: *Journal of Cleaner Production*, 279, 123749:

The second empirical article was aimed at investigating students' learning processes in the course *Sustainability Science for Teachers* (*SSfT*) offered at Arizona State University (ASU) in Tempe/USA, which applies different teaching and learning formats. Here, a specific focus was on the supporting and hindering factors students perceived with regards to the individual formats as well as their impact on the development of ESD-specific professional action competence. Holding on the mixed-method approach, this paper explicitly draws a connection between specific teaching and learning formats, respective drivers and barriers to learning as well as the development of knowledge (CK), skills (PCK) and attitude. Based on data collected at ASU in 2017, this paper is bringing us closer to understanding the connection between learning processes and outcomes and provides valuable insights that mostly contribute to answering sub-question 2.

<u>3rd article:</u> Brandt, J.-O., Barth, M., Merritt, E. & Hale, A. (2021, under review): "Developing ESD-specific professional action competence for teachers: knowledge skills and attitudes to implementing ESD at the school level" In: *Environmental Education Research*:
The third and final core article of this thesis compares the two courses at Leuphana and ASU as individual teaching and learning environments – applying similar yet different pedagogical approaches and teaching and learning formats – with regards to both learning processes and outcomes. Based on Data from 2018, this paper investigates what the most important factors impacting students' learning processes are, in how far they differ between the two courses under investigation and how they influence the achievement of learning outcomes in the sense of developing ESD-related CK, PCK and attitude. The comparative nature of this final article helps me to answer sub-question 3.

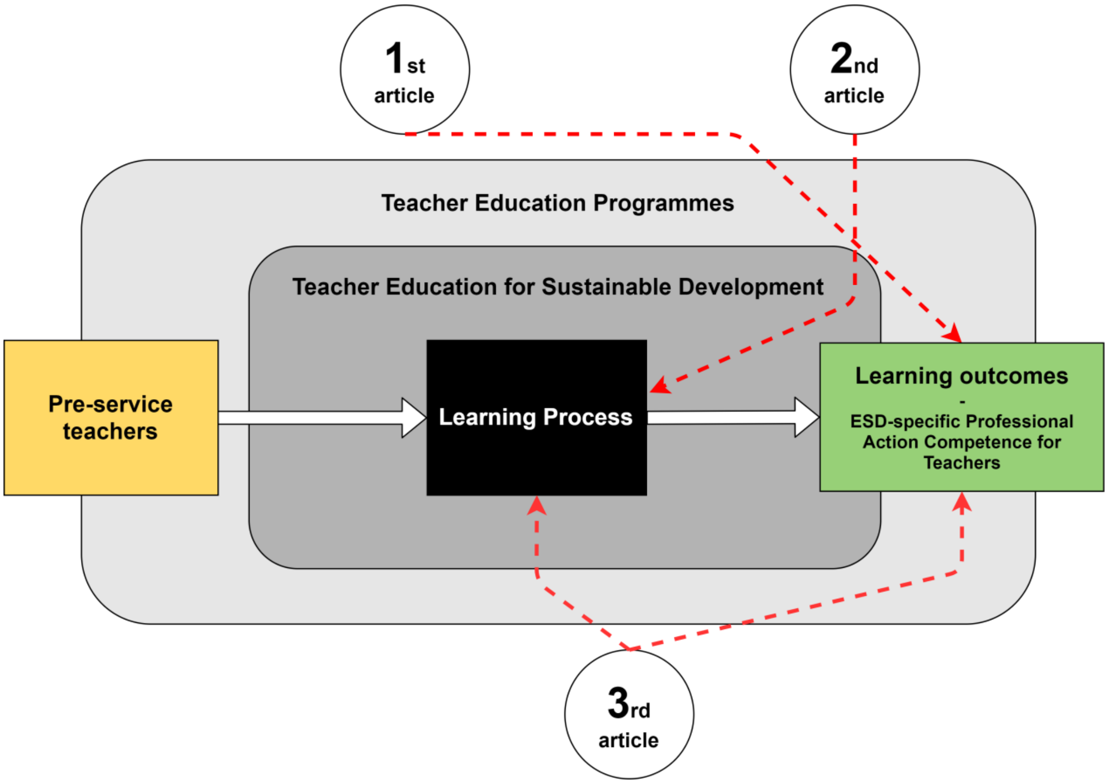

Figure 3: Contribution of empirical articles

4.2 Methodology – Case study approach

The research for this dissertation was conducted in the context of the Educating Future Change Agents project – an international cooperation between scholars and educational staff from Leuphana and ASU. The project framework ensured access to the field and largely determined what courses were available as units of analysis. In general, this thesis corresponds to the approach of a dual explanatory case study (Yin, 1984), which has a series of advantages and implications for methodological considerations, the empirical design as well as for the analytical process. The reasoning behind a case study approach was that it allows exploring individual TESD courses as bounded systems and offers the opportunity to study the various factors that make the unique character of a case (Creswell et al., 2007; Stake, 2005). As a preferable strategy to answer *how* and *why* questions, explanatory case studies investigate contemporary phenomena within their real-life contexts and allow contextual factors, and thus the singularity of a case, was taken into account (Yin, 1984). However, to overcome a plain descriptive and exploratory character, this research represents a dual explanatory case study – focusing on the phenomenon of learning and the development of ESD-specific professional action competence for teachers. While the usual business of single case studies is particularization and not generalization (Stake, 2005), multiple case studies and so-called cross-case comparisons are ultimately considered viable options to overcome the limitations of single case studies (West & Oldfather, 1995). Accordingly, I assume that *"a number of cases may be studied jointly in order to investigate a phenomenon, population, or general condition"* (Stake, 2005, p. 445). In accordance with Yin's (1984) five key components of case study, my research design includes (**i**) an overarching research question and related sub-questions, that are based on (**ii**) certain propositions, (**iii**) two selected cases as so-called units of analysis, (**iv**) a set of instruments (mixed method) for data collection and (**v**) a suitable approach to data analysis.

(i) The ***research question*** of "*How can the development of ESD-specific professional action competence be best supported in single sustainability courses of teacher education programmes and in what way do individual teaching and learning environments and pedagogical approaches differ in this regard?"* is based on the following propositions.

(ii) ***Propositions*****:** I assume that TESD courses have the common objective to develop ESD specific professional action competence for teachers, introduced by Bertschy et al. (2013), while individual teaching and learning environments and formats respectively have greater potential than others to foster the development of its three components –

CK, PCK and attitude. Additionally, it is assumed that learning is supported and/or hindered by certain factors. Based on the constructivist idea *"that people actively construct or make their own knowledge and that reality is determined by the experiences of the learner"* (Elliott, 2000, p. 256), I further propose that students have individual perceptions of their own learning and should be the preferred source of information about the phenomenon of learning.

(iii) As ***units of analysis*** two ESD courses were selected that form part of the teacher education programmes at Leuphana University (*Education for Sustainable Development*) and Arizona State University (*Sustainability Science for Teachers*), which, in turn, are not primarily devoted to sustainability. This enabled me to compare and contrast two prominent examples of how TESD is implemented at university course level. The two cases under investigation display a variance with regards to their institutional context, thematic foci and ILOs. Both modules employ novel T&L formats, namely hybrids of online and classroom activities, yet also apply conventional pedagogy of learning through the reception of course material as well as through reflections and discussions with the instructors and peers.

(iv) In order to ***link the data to the propositions*** – data collection was undertaken as a mixed-method approach with respect to an empirical design that considers five variables as key components of learning:

1. Institutional *context*
2. *Participants* and their pre-conditions
3. *Teaching and learning environment* of an individual course,
4. *Learning processes* of students, as well as
5. *Learning outcomes*

(v) The ***criteria for interpreting the data's findings*** are depending on the analytical framework (Chapter 4.4). For data analysis I had to distinguish between quantitative and qualitative data. On the one hand, the analysis of quantitative data, for instance, on students' demographics and competence development (achievement of learning objectives) was conducted using descriptive statistics and paired sample t-tests for pre-post comparison. The analysis of qualitative data from focus groups and interviews, on the other hand, was inspired by grounded theory – applying methods of open, axial, and selective coding as well as constant comparison (Corbin & Strauss, 2015) – and elements of qualitative content analysis (Mayring, 2000).

4.3 Case description

For a thorough understanding of the cases and increasing the reliability of the study, however, a detailed documentation is needed (Yin, 1984). Accordingly, a short description of both courses is provided, with regards to their curricular classification, key structure, primary teaching and learning formats and desired learning outcomes. For further information on the cases, an extended working paper called *"Case description: Competence development in teacher education for sustainable development at Leuphana University and Arizona State University"* (Brandt & Barth, 2020) was published, which is to serve as supplementary material to the three empirical articles mentioned above (see Appendix 4). It thoroughly describes teacher education for sustainable development (TESD) at Leuphana and ASU and provides additional information on the broader institutional context, detailed information about the actual sequence of learning activities and the different student cohorts under investigation. To fully understand the uniqueness of each case as well as the comparability between the two courses, the working paper also includes background information about the broader education systems in Germany and the US and the specific contexts of general teacher education.

4.3.1 Education for Sustainable Development (ESD) - Leuphana

The course *Education for Sustainable Development (ESD)* is the first of two sequential sustainability modules in the teacher-education program in *"Sachunterricht"* (basic social- and science studies) as one branch of the primary education at Leuphana University. The ESD module is a 150-hour unit that takes place every year during the summer term (2nd Semester). Over 14 weeks, approx. 80 students participate in a combination of (blended learning) lectures, tutorials, and seminar sessions. The design of the module follows a scaffold approach in four sequential steps: First, in a regular lecture format, students learn about the concept of ESD, its implementation, and how to design T&L environments in ESD. Beginning in Week 3, the lectures are recorded and offered in a flipped classroom setting to allow students to engage with the topic at their own pace as well as to enable them to ask questions and interact in face-to-face meetings. Second, the lecturer uses the model of cognitive apprenticeship (Collins et al., 1991) to demonstrate how to create a learning environment that supports the development of sustainability competence in school settings.

Third, students are divided into tutorials and work with the support of tutors on the outline of such a learning environment. This work also represents their first official assignment in the course. Fourth, students work on a case study in one out of three different seminars, in which they collaborate with a partnering school to implement an ESD lesson for a primary-education student's cohort. Table I outlines the specifics of the both courses in comparison.

4.3.2 Sustainability Science for Teachers (SSfT) - ASU

The *Sustainability Science for Teachers (SSfT)* course was launched in the fall of 2012. It is a three-credit, fifteen-week course that is mandatory in all elementary education programs (K-8) at ASU. The course aims to prepare pre-service teachers to implement ESD in their future career at school level. The intended learning objective is to develop student teachers' sustainability literacy a) by providing ESD-related content knowledge and fostering students' understanding of sustainability concepts and their application (CK) and b) by providing pedagogical content knowledge for ESD and developing students' ability to apply the ways of thinking (WOT) to explain sustainability concepts (PCK). The four ways of thinking (WOT) — strategic, futures, values, and systems thinking – relate back to the key competencies in sustainability (Wiek et al., 2011) and provide the overarching sustainability education framework for this course (Warren et al., 2014). *SSfT* follows a flipped learning approach, where content is provided in the online portion through *"digital storytelling"* (Robin, 2008). Students watch videos related to the weekly changing topics, take quizzes to check for their understanding of the content, and work on reflective assignments. As a second course component, students come to class for 75 minutes each week to discuss concepts and learn pedagogical strategies to integrate the content into their future teaching. While the class is usually divided into several sub-cohorts, all instructors use the same online content and are provided with the same weekly lesson plans. The in-class lessons vary each week, and include specific activities for each topic. The final project and overarching assignment for the course consists of a student-designed digital artifact that outlines a five-day learning unit on a sustainability topic of students' choice.

Table 1: Course attributes

COURSE NAME	**Education for Sustainable Development (ESD)** Leuphana	**Sustainability Science for Teachers (SSfT)** ASU
CURRICULUM	2nd semester - mandatory course of BA Teaching & Learning (Subject: Basic Social and Science Studies)	5th semester - mandatory course of BAE Elementary Education (K-8)
STRUCTURE	**13 x seminar session (weekly)** (incl. practical project implementation at a partner school) **7 x lecture (online + presence) + 7 x tutorial**	**15 x seminar session (weekly)** **15 x online session** (incl. videos, quizzes und assignments)
STUDENTS	**~ 80 students** (allocated to 3 seminars/ tutorials)	**~ 120 students** (allocated to 5 seminars)
FORM OF ASSESSMENT	**1. Individual written assignment:** Outlining a learning unit in ESD (30 out of 100 pts.) **2. Group presentation, incl. written report and individual reflection** Presenting an individual ESD lesson incl. rationale (70 out of 100 pts.)	**Participation** (150 pts.) **Quizzes** (130 pts.) **Reflections and contributions on the online platform ‚Blackboard'** (200 pts.) **Assignments** (150 pts.) **Group presentation** (50 pts.) **Final project outline** (60 pts.) **Final project peer-review** (60 pts.) **Final project – submission** (200 pts.) = 1000 pts.
KEY LEARNING OBJECTIVES	• Understanding of ESD as an educational perspective in primary education • Pedagogical content knowledge in ESD • Ability to plan and implement teaching and learning activities in a given class setting	• Ability to develop and communicate an understanding of sustainability concepts and their application • Ability to apply the WOT to explain sustainability concepts. • Identify, analyze and advocate for individual and collective actions that will contribute to a more sustainable world.

4.4 Analytical framework

As mentioned before, to ensure a holistic treatment of the phenomenon of competence development and capture a rich picture of students' learning processes, a variety of variables needed to be considered. Based on the idea that learning may be analyzed along five key elements, the Educating Future Change Agents research team jointly created an analytical framework including the following variables (Hannafin et al., 1999):

(1) The ***institutional context*** of a course implies the overall vision and mission of the university, the structure of its departments or faculty and the availability of resources. Further, the program's structure, conditions for student recruitment and overall learning objectives are to be covered.

(2) The ***teaching and learning environment*** of a course includes the course instructors, applied teaching and learning formats – meaning the physical and virtual setting, the sequence of different learning activities, material, and course-own learning objectives.

(3) The ***participants*** and what they bring to the course. This includes demographic information, previous work experiences, extra- and co-curricular activities, non-cognitive dispositions and their motivation to become a teacher.

(4) The ***learning processes***, occurring factors that support and/or hinder learning as well as pivotal moments of learning, and;

(5) The ***learning outcomes*** or the development of ESD-specific professional action competence (Bertschy et al., 2013) and its three main components of: sustainability-related content knowledge (CK), pedagogical content knowledge (PCK) and the motivation (attitude) to implement ESD at school level (see Figure 4).

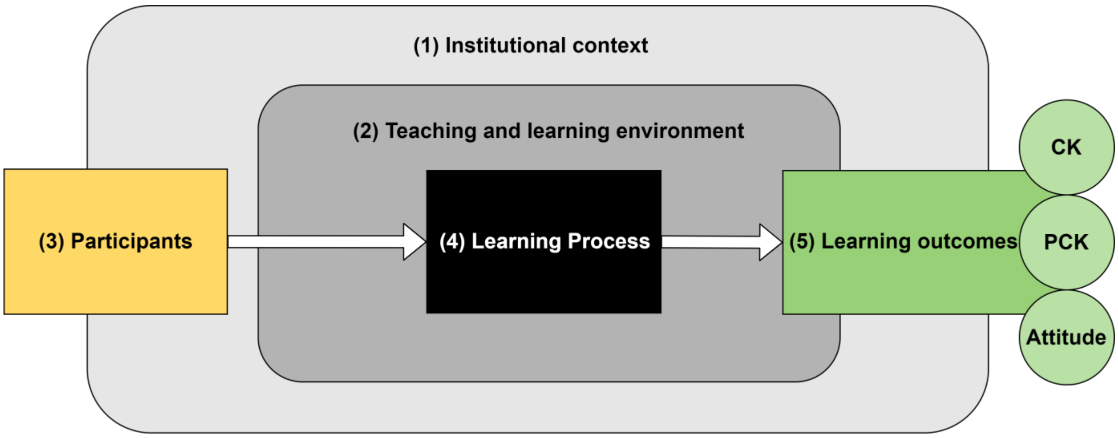

Figure 4: Empirical design

In the context of this study, I specifically investigated the phenomenon of learning processes (**4**) in different teaching and learning environments applying specific teaching and learning formats (**2**), reporting how supporting and/or hindering factors impact the achievement of intended learning outcomes and competence development in the students participating (**5**). To provide more contextual information also the individual backgrounds of students and what they brought to the course (demographic information, aspirations, previous work experiences, co- and extra-curricular activities and non-cognitive dispositions) (**3**) as well as the institutional context learning was situated in (**1**) was covered.

4.5 Instruments for data collection

In order to serve all these variables, multiple instruments and methods of data collection were applied, which allowed for triangulation, the combination of different methods in the study of the same phenomenon (Denzin, 1989). Furthermore, this ensures the overall construct validity (Creswell & Plano Clark, 2018). All instruments, including the detailed survey items, assessment tools, interview and focus group guides as well as the related code books, were published in form of a so-called instruments paper on ResearchGate (Brandt et al., 2020) and can be found in Appendix 5. The main objective of this instruments paper is to enhance transparency about how the research was conducted. Eventually, it is supposed to enable actual reproducibility of this research, which usually exceeds the scope of regular journal articles and cumulative dissertations. Fellow researchers, scholars, and practitioners are invited to comment, discuss, and contribute their thoughts and experiences. Despite the existence of an extended instruments description, as part of this dissertation's framework paper the data collection methods are briefly described below. How all the instruments contributed to covering the previously described variables is demonstrated in Figure 5.

4.5.1 Document analysis

To receive information about the institutional contexts (**1**) as well as the individual learning environments (**2**) I conducted an analysis of electronic institutional documents, such as the faculty websites, course syllabi, and manuals. According to Bowen (2009), document analysis is a systematic procedure for reviewing printed or electronic material, which rather requires data *selection* instead of data *collection*. This is often used in combination with other qualitative research methods as a means of triangulation. Like other analytical methods in qualitative research, document analysis requires the examination and interpretation of data in order to gain understanding and develop empirical knowledge (Corbin & Strauss, 2015). As institutional documents are usually not produced for research purposes, they often provide insufficient detail to answer a research question (Bowen, 2009). Therefore, document analysis was here triangulated with student surveys, focus groups, interviews and observations.

4.5.2 Observations

To gather additional data on variables **2** (teaching and learning environments) and **4** (learning process), non-participant observations of selected in-class sessions and outside activities were conducted. By applying a direct non-participating observation, I had the opportunity to get closer to the field of research while retaining the positions of an outsider or a guest (Kostera, 2007). After openly declaring my role, I observed and tried to understand the phenomenon of students' learning, without being actively involved with the human interaction in the field. Despite the vast amounts of information available, I was selective in my notes and what I perceived as relevant (Emerson et al., 2002). Being physically present during lectures, seminar sessions, and field trips allowed me to obtain information about the physical setting of students' learning and actual activities taking place during class time – including interactions between all protagonists involved and how the provided material was dealt with.

4.5.3 Student surveys

To collect information about the participants (**3**) and learning outcomes in terms of students' content knowledge (CK) and attitudes towards ESD (**5**) student surveys were conducted at the beginning and at the end of the semester (pre-post design). The first part was to provide demographics and background information about the students participating in the courses under investigation and asked them about their previous work experience, extra-curricular activities, and their motivation to become a teacher (open item). The second part included an open question asking for students' understanding of the term sustainability – here considered as sustainability-related CK – and used existing scales for pro-ecological world views (Dunlap et al., 2000), the perceived relevance of ESD (Tomas et al., 2017) as well as ESD-related (Ibid.) and innovation-related self-efficacy (Emmrich, 2009), measuring students' attitudes. In form of a pre-post comparison, based on paired sample t-tests, this second part of the survey actually aimed at measuring competence development in the students.

While surveys in general allow the compilation of sample characteristics for a large group in a short time (Esa, 2010), they only provide students' perceived level of sustainability competence, in the sense of subjective knowledge (Alkaher & Goldman, 2018), and not actual performance (Shephard et al., 2015).

4.5.4 Focus groups

To obtain detailed data on the learning process (**4**) as well as perceived learning outcomes (**5**), in terms of CK, PCK and attitudes, from the students' perspective, I conducted a series of focus groups (4–7 participants) at the end of the semester. The open-ended questions of the focus group guides (see Appendix 5) were to allow for organized reflective discussions (Kitzinger, 1994) on teaching and learning formats, processes, pivotal moments of learning and competence development, that could be analyzed with regards to a consensus on a given topic (Morgan & Krueger, 1993). In 2017, the focus group guide asked students for a general reflection on their learning process with regards to the different teaching and learning formats as well as the achievement of the intended learning outcomes of each course. The 2018 version, however, was enriched by a photovoice activity and remained more open in terms of students' learning outcomes. In the later version, the students were further asked to trace back their competence development (one competence each) and reflect upon drivers and barriers to their learning. The photovoice method, originally introduced by Wang and Burris (1994), was intended to support students' reflection processes. In using this method, the students took pictures of personal key learning moments over the semester, which then served as anchor points during the group reflections.

4.5.5 Instructor interviews

Semi-structured instructor interviews were conducted at the end of the semester to complement the focus groups with the perspective of course instructors on students' learning processes (**4**) and outcomes (**5**), and to gain a deeper understanding of pedagogical approaches shaping the teaching and learning environment (**2**). As one of today's key methods for gathering data in qualitative research (Yeo et al., 2014), semi-structured interviews *"consist of several key questions that help to define the areas to be explored, but also allows the interviewer or the interviewee to diverge in order to pursue an idea or response in more detail."* (Gill et al., 2008, p. 291)

In general, the guidelines for the conducted interviews consisted of pre-formulated, open questions that were held flexible in terms of chronological order and choice of wording. In accordance with Flick (2011), I aimed to cover certain core aspects (‘key themes’) of the research agenda, such as instructor profiles, as part of the teaching and learning environment, planned and actual activities (learning processes) and achieved competence development (learning outcomes).

4.5.6 CK-assessment

To further evaluate students’ sustainability-related CK, an assessment tool was developed and applied, including closed response questions which align with the key competencies in sustainability, as described by Wiek et al. (2011). In total, fourteen items were included and data was collected from the students before and after the semester. The final scores display the percentage of correct responses, which allowed for paired sample t-tests and pre-post comparison.

4.5.7 PCK-assessment

To assess students’ pedagogical content knowledge (PCK), I measured their capability to decide how well the ESD-specific learning principles of vision orientation, connected learning, and participatory orientation (Künzli & Bertschy, 2008) can be put into practice in selected case studies (Plesse, 2007). Ratings were based on two scores: First, it was determined how closely the students’ rating of whether the learning principles could be applied in each case study matched a rating by experts. This expert rating was determined by having every case study evaluated by four experts from the field of ESD in teacher education and averaging their scores. The difference between the experts’ rating and students’ scores were deducted from the potential maximum of four points, leading to a final score ranging from 0 to 4, which was again used for pre-post comparisons (paired sample t-tests). Second, students’ rationales for their ratings were assessed (codes ranging from 0 to 2). All coding was conducted by at least two researchers to achieve inter-coder reliability (ICR).

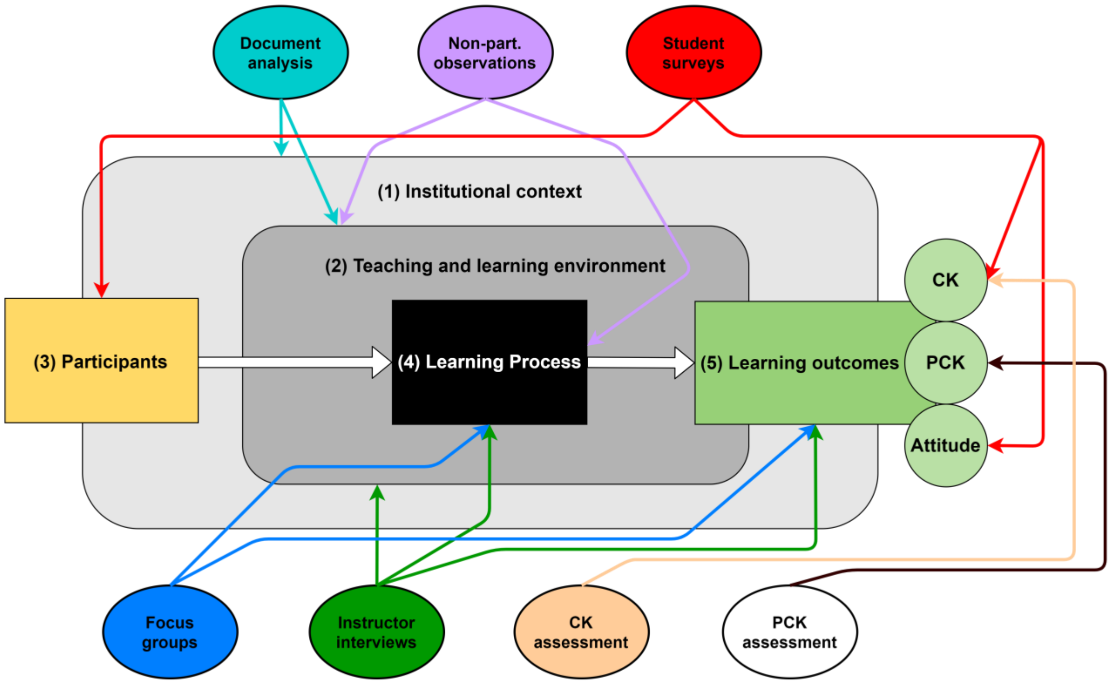

Figure 5: Contribution of individual instruments

4.6 Data analysis

Even though method triangulation was considered in all three empirical articles, their methodical foci differ significantly. While the first article primarily measured students' competence development in the Leuphana course and mostly dealt with quantitative data, the second article analyzed the learning processes for the ASU case, with respect to key factors impacting the development of students' competencies – mainly based on qualitative data from the focus groups. The third paper finally compared the two cases investigated with respect to both learning processes and outcomes, soundly combining quantitative and qualitative data.

The analysis of quantitative survey data was conducted using simple descriptive statistics (frequencies) for the demographics and paired-sample t-tests for a pre-post comparison of attitude scales and changes in students' understanding of the term sustainability over time (CK). To make quantitative analysis of sustainability definitions viable, they were coded by two independent researchers against a coding scheme considering both intergenerational and intragenerational perspectives as well as the multidimensional understanding of the concept, resulting in a score from 0 to 5 (see Appendix 5).

Inter-coder reliability (ICR) was tested, and differences were resolved communicatively on consensus. Also the pre- and post-course values from CK and PCK assessments were analyzed with paired sample t-tests, specifically checking for significant changes in students' ESD-related content knowledge and pedagogical skills and the impact of each intervention (Cohen's *d*-values).

The qualitative analysis of focus group and interview transcripts was oriented toward an understanding and reconstruction of the learning processes and outcomes, inspired by the coding paradigm of grounded theory, applying the methods of open, axial and selective coding as well as a constant comparison of statements (Corbin & Strauss, 2015). According to Bryant and Charmaz (2007), grounded theory is a structured, yet flexible methodology that is appropriate to use when little is known about a phenomenon, in particular if the aim is to construct an explanatory theory that uncovers a process inherent to the substantive area of research (Tie et al., 2019).

In general, I followed a two-step process of deductive and inductive coding. On the one hand, regarding the learning process, the *context* as well as the *teaching and learning environment* – including the *instructor*, applied *teaching and learning formats* as well as their *pro*s (advantages) and *con*s (disadvantages) were used as deductive codes. Further, the specific *role* a format played in the context of the overall learning process was considered deductively. Concerning the learning outcomes, the concept of ESD-specific professional action competence for teachers, introduced by Bertschy et al. (2013) provided *content knowledge* (CK), *pedagogical content knowledge* (PCK) and *attitude* as deductive codes. On the other hand, inductive codes were allowed to emerge within these deductive ones. For the learning outcome of PCK, for instance, the abilities to *plan* and *implement ESD units* as well as *breaking down complex sustainability topics* were added in the coding process. The final code book, where the teaching and learning formats of the *SSfT* course at ASU are presented, can be found in Appendix 5. The formats applied in the *ESD* course at Leuphana, such as lectures (flipped classroom), tutorials, seminar sessions, and the practical implementation of an ESD unit with a partner school, were coded following the same approach. Initially, three independent researchers applied open coding to four focus groups to ensure the ICR of the code book encompassing deductive and inductive in-vivo codes. In search of significant factors impacting students' learning, emerging categories, such as *"course structure"*, *"practical application"*, *"exchange with others"*, *"personal interest"*, and *"preconceptions about science and sustainability"*, were discussed with the broader research team to allow for different perspectives, increase plausibility, and ensure the reliability of this research.

Through several iterations of axial coding, *"connection"* was identified as a core category spanning across the other phenomena found in the data. While the concept of *relatedness* is mainly associated with a student's feeling that the teacher or instructor respects and values him or her, which is an important factor for students' motivation to engage (Niemiec and Ryan, 2009) and *connectedness* rather refers to students' connection to nature, a prominent topic in environmental education (Schultz, 2002), *connection* provides a more generic concept. Understood as *"the relationship of a person, thing, or behavior to someone or something else"* (Cambridge Dictionary), it has the potential to span across all aspects of the phenomenon of learning. Finally, personal, professional, social and structural connection, which emerged as inductive codes in paper two, were used in the third article as (deductive) selective concepts – still open for the inductive emergence of new facets. This, in turn, required procedures corresponding with qualitative content analysis (Mayring, 2000), such as the application of pre-defined categories (see Appendix 5) to the data of focus group and interview transcripts.

5 SYNTHESIS AND DISCUSSION OF RESULTS

This results section outlines how the insights gained from the three empirical articles help to answer the individual sub-questions of the overarching research inquiry. Summarizing and synthesizing the overall results is finally to provide the foundation for deriving scientific (methodical) and practical implications of this research endeavor and its findings.

5.1 Achievement of intended learning outcomes

- **Sub-question 1:**
  To what extent is ESD-specific professional action competence for teachers actually developed through individual sustainability courses of teacher education programmes that are not primarily devoted to ESD?

1st article:

Paper 1 operationalized the model of ESD-specific professional action competence for teachers (Bertschy et al., 2013) and measured competence development in the 2018 cohort enrolled in the TESD course *Education for Sustainable Development (ESD)* at Leuphana University in Lüneburg/Germany – considering the three components of knowledge (CK), skills (PCK) and attitude. While students' CK was assessed through their individual definition of the term sustainability (open question in the survey), a specific instrument to measure PCK was designed in cooperation with the co-authors of this article (see Chapter 4.5.7). Students' attitudes towards ESD were finally represented by their subject-related SE and the perceived relevance of ESD. Primarily based on a pre-post comparison of (semi-)quantitative data, the results of this first publication showed that the *ESD* course at Leuphana helped to significantly increase the overall complexity of students' sustainability understanding (CK). Even though this was not a specific focus or learning objective of the course. Also the ESD-related self-efficacy, as an important pre-requisite for effective teaching (Lindemann-Matthies et al., 2009) increased significantly, while the perceived relevance of ESD remained at a relatively high level. The insights with regards to students' PCK development were slightly more ambiguous. Eventually, the development of students' rating abilities with regards to ESD-specific didactic principles cannot simply be linked to their actual competence to implement ESD in the classroom. Nevertheless, at the end of the semester, an increased proficiency of students with regards to the learning principle of *participatory orientation* could be found, which played the most prominent role in the seminar project of the *ESD* module.

All in all, the findings of the first paper indicate that the *ESD* course at Leuphana fostered the development of ESD-specific professional action competence for teachers in students, by increasing their sustainability related content knowledge and motivation to implement ESD in their future careers. Additionally, the results from the PCK assessment indicate that the course helped developing pedagogical skills in accordance with its individual structure and thematic focus.

<u>2nd article:</u>

Alongside its focus on investigating students' learning processes in the *SSfT* course at Arizona State University (ASU) in Tempe/USA, the second paper also examined students' learning outcomes with respect to the development of ESD-specific professional action competence. Based on data collected in 2017, the results of this study indicate that also the *SSfT* course fostered students' positive attitudes towards ESD as well as an increased array of CK, in the sense of a better understanding of sustainability. Both students' ESD-related self-efficacy, perceived relevance of ESD, and pro-ecological worldviews – measured via the revised NEP scale (Dunlap et al., 2000) (attitude) – as well as the complexity of students' sustainability definition increased significantly over the course of the semester. While the perceived relevance of ESD was relatively high among the 2017 cohort of the *SSfT* course, their pro-environmental world views were similar to those of the German student teachers. However, as the *SSfT* course constituted, for the majority of the enrolled students, the first encounter with sustainability topics, their understanding of the term and related concepts was notably less complex (Brandt et al., 2019). Regarding the development of PCK, the insights were again rather ambiguous. According to students' self-assessment during the focus groups, they developed a certain theoretical understanding of how to implement ESD at the school level. Yet, they also complained about a lack of practical experience and reported uncertainty about how to break down complex sustainability topics for different age groups. Furthermore, students' self-reported learning outcomes related to PCK were sometimes difficult to distinguish from ESD self-efficacy, which rather represents students' trust in their own skills (Rieckmann, 2012). This underlined the importance of creating a PCK assessment tool that measures students' ESD-related pedagogical skills in a more objective and performance-oriented approach, as applied in the first article.

Overall, this study demonstrates that also the *SSfT* course at ASU supports the development of ESD-related professional action competence for teachers – in particular by fostering students' positive attitudes towards ESD and increasing their sustainability related CK. Especially the latter explicitly corresponds with the course-own learning objectives (see Chapter 4.3). During the focus groups, students also reported PCK-related learning outcomes. However, their statements predominantly referred only to a theoretical understanding of how to implement ESD in the classroom.

3rd article:

The third and final paper was to compare the two TESD courses at Leuphana and ASU with regards to both learning processes and outcomes. On the Leuphana side, this study was based on the same data as the first article. However, to reveal and compare students' self-reported learning outcomes the qualitative focus group data were again analyzed in more detail. For the ASU case, on the other hand, a fresh set of quantitative and qualitative data from 2018 was used to see if the findings concerning competence development in the 2017 cohort could be reproduced. Due to the culturally different approaches to PCK in Germany and the US, the previously developed PCK assessment tool could not be applied in this comparative study. Instead, PCK was measured based on the focus group data and self-reported learning outcomes referring to students' ability to plan and implement ESD units as well as to break down complex sustainability topics for children. The results of this article confirm that both courses under investigation supported the development of CK, PCK, and positive attitudes towards ESD, yet, to varying degrees. The numbers from the CK assessment as well as changes in the complexity of students' sustainability definitions indicate that the ASU course had a slightly bigger impact on students' CK development, while the Leuphana students started off with higher pre-course values in both measurements. This can be confirmed by more frequent statements made in the focus groups conducted at ASU that explicitly refer to CK-related learning outcomes. The Leuphana students, however, referred more often and more specifically to the development of PCK and their ability to plan and implement ESD units, whereas comparable statements made by ASU students were rare and remained rather general. Finally, a pre-post comparison of students' attitudes revealed that students' ESD-related self-efficacy (SE) increased significantly during both courses, whereas innovation-related SE only showed a significant increase on the ASU side. In both cases, the perceived relevance of ESD increased as well, yet only slightly and not significantly.

These survey results indicate an increase in positive attitudes towards ESD and are to some extent supported by the focus group data. Students from both courses confirmed that the perceived relevance of ESD as well as their motivation to implement ESD at the school level increased over the semester. Yet, more statements in relation to increased positive attitudes towards ESD as a learning outcome were made by ASU students.

5.2 Key factors impacting pre-service teachers' learning processes

- **Sub-question 2:**
  What are the main factors that impact student teachers' learning processes in connection to different teaching and learning formats applied in individual sustainability courses of teacher education programmes that are not primarily devoted to ESD?

1st article:

Despite its focus on competence development and learning outcomes, the first of the three empirical articles already provided initial indications as to what sort of learning processes actually contributed to achieving the different ILOs. Based on a first wide-meshed analysis of the focus group data gathered at Leuphana in 2018, three key themes emerged with regards to perceived drivers of students' learning. First, the interplay of lecture, tutorial, and seminar sessions (trinity of teaching and learning formats), which positively affected their competence to plan ESD units (PCK) and partly raised their awareness of the importance (attitude) and complexity (CK) of sustainability issues. Second, the value of practically implementing an exemplary ESD unit with a partnered school, which allowed for first insights into the teaching practice and fostered both their pedagogical skills (PCK), and their willingness and motivation to implement ESD in their future careers (attitude). Last but not least, the (discursive) exchange with fellow students and instructors, which confronted them with a plurality of perspectives, further strengthened their PCK, and occasionally helped to gain a deeper understanding of the complexity of sustainability issues (CK). These findings correspond with existing literature, suggesting that structural interconnections between topics (Biggs & Tang, 2011) and working with practice partners (Corney & Reid, 2007) facilitate effective learning and students can improve their knowledge through discussions and interactions (Vygotsy, 1978).

2nd article:

In the context of the second article, I specifically set out to investigate the phenomenon of learning processes and what factors affect students' achievement of ILOs in terms of the different teaching and learning formats applied in the *SSfT* course at ASU. Mainly based on the analysis of focus groups conducted in the fall of 2017, the key theme of *connection* emerged as the phenomenon that best describes students' learning processes. Overall, four forms of connection (*the four Cs*) became evident as most influential factors, each having its own characteristics and consequences associated with its presence or absence: social, structural, personal, and professional connection. The latter two manifestations – personal and professional connection – are both underlain by a fifth form, namely real-world connection (see Figure 6).

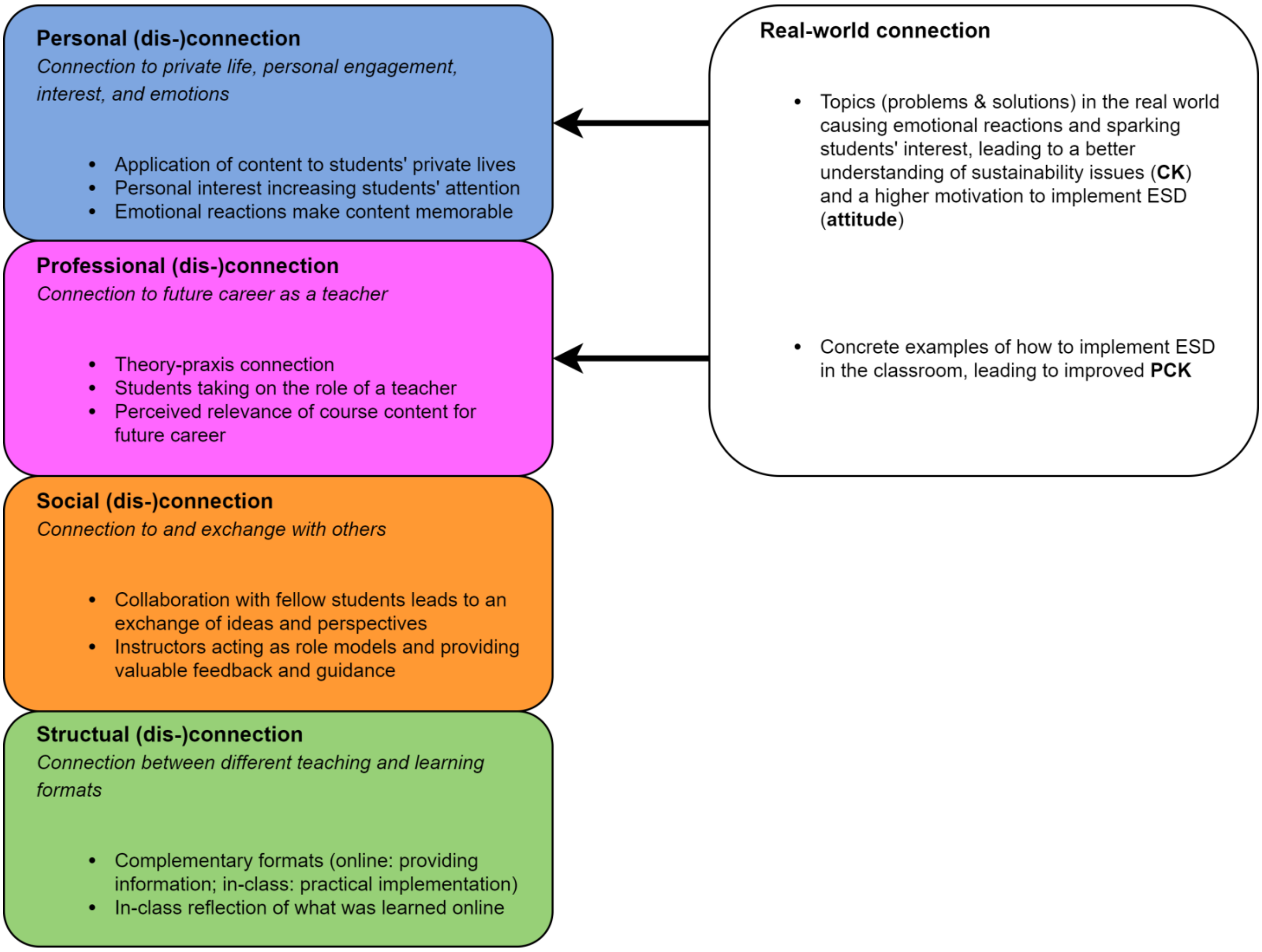

Figure 6: Forms of connection (adopted from Brandt et al., 2021)

The results indicate that a personal connection to the course content sparked students' interest, increased their attention, and improved their memory. Being engaged in hands-on activities or emotionally touched by videos with real-world connections increased students' motivation to engage with ESD (attitude) and helped them develop an understanding of the course content (CK) as well as how to apply it in their future classrooms (PCK). Personal disconnection, on the other hand, such as feelings of anxiety that result from the scope of the video material, sometimes prevented students from absorbing and retaining information (CK). This finding underlines the importance of emotions in affecting students' performance and learning (Immordino-Yang & Damasio, 2007). Second, professional connection and explicit links to the implementation of ESD at the school level fostered student competence development. Videos featuring examples of successful ESD implementation, working on the final project, or being engaged in activities equipped students with a portfolio of ESD lessons, strengthened their pedagogical skills (PCK), and increased their motivation to act as future change agents (attitude). Only a lack of practical experience and the missed opportunity to actually implement the final projects were seen as hindering factors. Again, this confirms previous findings, as Biggs and Tang (2011) already emphasized the role the perceived value and practical relevance of learning content in higher education at large, while Bürgener and Barth (2018) showed that the cooperation of TESD courses with partnered schools could enhance students' learning by incorporating a practical component and strengthening professional connections.

In the context of social connection, the role of the instructors was particularly highlighted. Their passion for sustainability was passed on to students and increased their motivation to engage with the related topics as well as the perceived relevance of ESD (attitude). Another key factor guiding students' learning processes was the feedback provided by the instructors. Furthermore, students' emphasized the value of exchanging ideas with their fellow students during group discussions and joint reflections in helping them to close knowledge gaps and develop their CK. This is in line with what was found to be true for the Leuphana case described in the first paper. Respectfully debating with the entire class as well as unbiased guidance by the instructor appeared to improve their pedagogical skillset (PCK). These results confirm the importance of social interactions and opportunities to exchange perspective in TESD (Whitehouse, 2008) and correspond with the idea that teachers are a decisive factor when it comes to the success in students' learning (Hattie, 2009)**.**

Finally, structural connection and deliberate links between different T&L formats played a role, particularly in affecting the development of CK. In this second study, structural connection was mentioned in cases of both supporting and hindering links (and disconnection). While the direct application of individual in-class activities to the final project and in-class reflections upon the online material were by some perceived as helpful to the overall learning process, others complained about dealing with two *disconnected* learning environments. With regards to the order of task in the online component of the course, some students appreciated that the quiz questions were already available prior to watching the videos, while others emphasized that this resulted in selectively processing information, which limited CK-related learning outcomes. Eventually, *the four Cs* should not be understood as separate entities but rather as interlinked elements that not only impact students' learning processes but also have the potential to foster, or hinder, one another. Figure 7 portrays the relevance of *the four Cs* to achieving the ILOs of CK, PCK and positive attitudes towards ESD through the different T&L formats applied in the *SSfT* course, highlighting the most dominant links with thicker arrows.

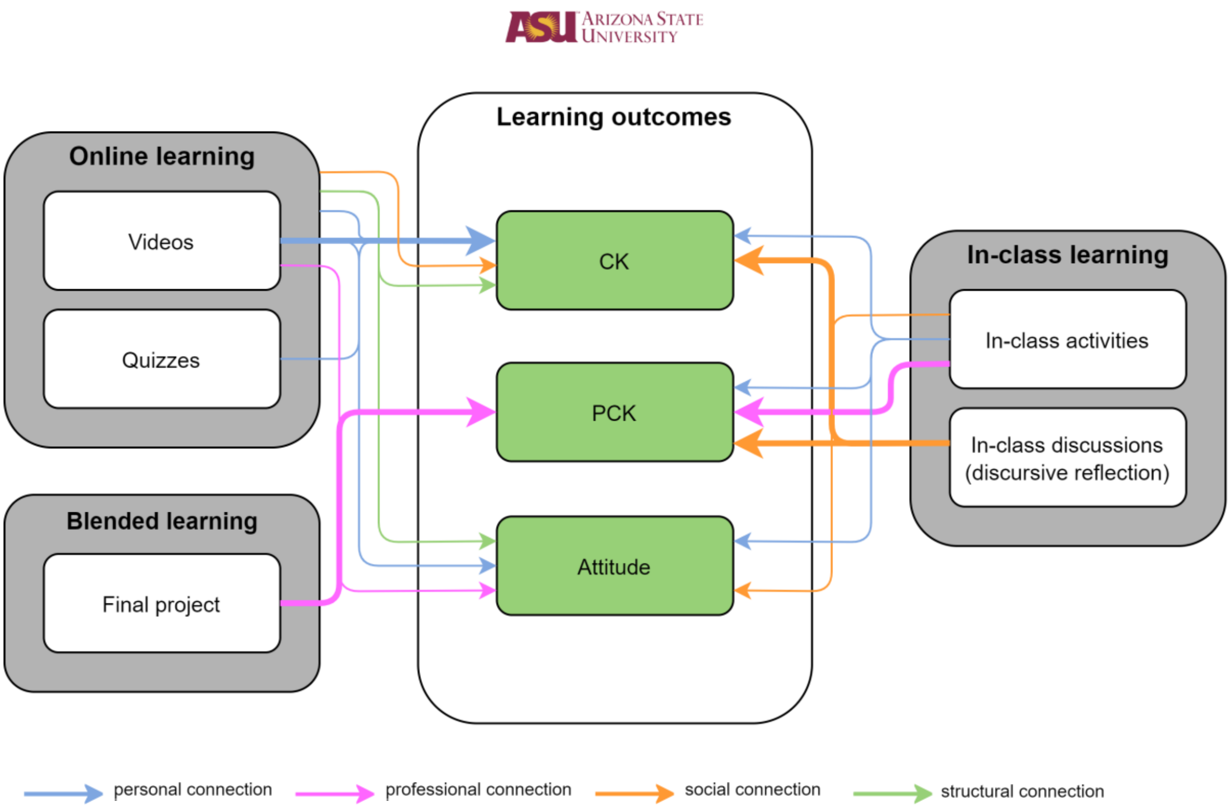

Figure 7: The impact of *the four Cs* on achieving ILOs in different T&L formats at ASU 2017 (adopted from Brandt et al., 2021)
Note: More dominant links are denoted by thicker arrows.

While most findings of this second paper appear generalizable to learning in higher education at large, rather than specific to the field of TESD, it makes sense that passionate, yet un-biased instructors and learning formats allowing for the discursive exchange of thoughts and ideas are crucial to support learning in relation to the complex, value-laden concepts of sustainability and ESD.

3rd article:

The final paper compared the two TESD courses at Leuphana and ASU with regards to both learning outcomes and processes. Based on focus group data from 2018, the third article eventually confirmed the four Cs as crucial factors affecting students' learning processes and their development of ESD-specific professional action competence for teachers. The results validate that structural connection (complementary T&L formats) and personal connection (the applicability of course content to students' private lives) supported the development of CK, while professional connection (the provision of practical examples and theory-praxis links) appeared as the key factor fostering students' PCK. Also, social connection (the discursive exchange with fellow students and feedback/guidance provided by the instructors) supported PCK development. With respect to developing positive attitudes towards ESD again professional and personal connection played a key role in both cases under investigation. However, increasing the level of detail, this article revealed certain differences between the two courses, not only regarding the achieved learning outcomes, but also concerning the effect of the four Cs in relation to applied T&L formats.

5.3 Comparison of different teaching learning environments

- **Sub-question 3:**

  How do individual sustainability courses of teacher education programmes that are not primarily devoted to ESD – as specific teaching and learning environments – differ with respect to the development of ESD-specific professional action competence and related factors of support and/or hindrance?

3rd article:

As shown in Chapter 5.1, the results of the third paper indicate that both courses under investigation supported the development of ESD-specific professional action competence for teachers – yet, to varying degrees. The overall findings reveal that the Leuphana course had a greater impact on PCK development, while the ASU course fostered students' CK and attitudes towards sustainability more strongly among students. In both cases, CK development was supported by structural connection and the fact that tutorial and seminar sessions built upon the knowledge provided in the lecture (Leuphana) or that video content laid the foundation for in-class discussions at ASU. After the 2017 cohort of the *SSfT* course at ASU had frequently mentioned hindering links or disconnections between individual T&L formats (1st article), the assigned course coordinator reconsidered these links and made valuable adjustments to the structure of the online portion, such as replacing some of the quizzes by reflective assignments. A second factor for successful CK development was personal connection. At Leuphana, the lecture content was particularly relatable and applicable to students' private lives, while at ASU, both the videos, quizzes, reflective assignments, and in-class activities concerned their personal actions and their implications. Furthermore, the online portion of the *SSfT* course allowed students to learn at their own pace (agency). This corresponds with the previous finding that asynchronous online learning facilitates students to confront issues more objectively and reflectively, due to better focus on the content and less noise from face-to-face interaction (Chin et al., 2019). Finally, professional connection and the practical implementation of an exemplary ESD unit at Leuphana (ensuring a valuable theory-praxis link) and social connection during in-class discussions at ASU further advanced students' CK.

Regarding PCK development, on the other hand, professional, structural, and social connection were the most important factors. The provision of exemplary lesson plans during the lecture and tutorial sessions (Leuphana) as well as the videos and in-class activities (ASU) particularly fostered students' ability to plan ESD units. At Leuphana, working on the assignment and practically implementing an exemplary ESD lesson at a partnered school ensured a valuable theory-praxis link and additionally helped to increased students' PCK (professional and structural connection). Also the ASU students gained additional PCK through structural connection as new knowledge from the videos was being practically applied during in-class activities. These findings support prior research, emphasizing the potential of experiential learning approaches for the development of ESD competencies in general (Jegstad et al., 2018) and CK and PCK in particular (Nielsen et al., 2012).

Moreover, the mutual exchange with fellow students about pedagogical methods during the seminar, as well as feedback and guidance provided by the teaching staff (social connection), were considered additional factors supporting PCK development in the Leuphana case. Also at ASU, students indicated that they felt encouraged by the instructor to implement ESD and reported that in-class discussions about how to do that were also helpful. This confirms the importance of social interaction and opportunities to exchange ideas (Ojala, 2013), and is in line with Biggs and Tang (2011), who claim that students learn with and from one another (social learning) and emphasize the role of instructors' feedback as a key factor guiding students' learning processes.

As for the development of CK and PCK, students' positive attitudes towards ESD were fostered by professional connection and the practical examples of how to implement ESD at the school level—provided by the practical implementation (Leuphana) as well as in-class activities and the final project (ASU). This corresponds to the previous finding that praxis-orientated pedagogies may enhance students' attitudes in the sense of ESD-related SE (Tomas et al., 2017). Finally, also personal connection and the applicability of the overall course content (Leuphana) and in-class activities (ASU) to students' private lives supported the development of positive attitudes. Students from both cases reported that they learned about the relevance of ESD when studying on their own—via the literature provided at Leuphana or during the online portion at ASU. While certain videos as well as the final project sparked the interest and excitement of ASU students, some felt particularly encouraged by the instructors (social connection). This might have improved their learning through an increased motivation to engage with the content. As positive emotions have a regulatory function for developing intrinsic motivation (Ryan & Deci, 2000), it can be assumed that teachers approaching ESD with positive emotions are also more likely to successfully implement ESD at the school level (Büssing et al., 2019).

Figure 8 and 9 display how *the four Cs* (personal, professional, social, and structural connection) have affected the achievement of ILOs in the context of the different T&L formats applied in the two courses under investigation. Thus, they deliver an answer to the question of how individual courses in TESD—as specific teaching and learning environments—differ with respect to the development of ESD-specific professional action competence and related factors of support and/or hindrance:

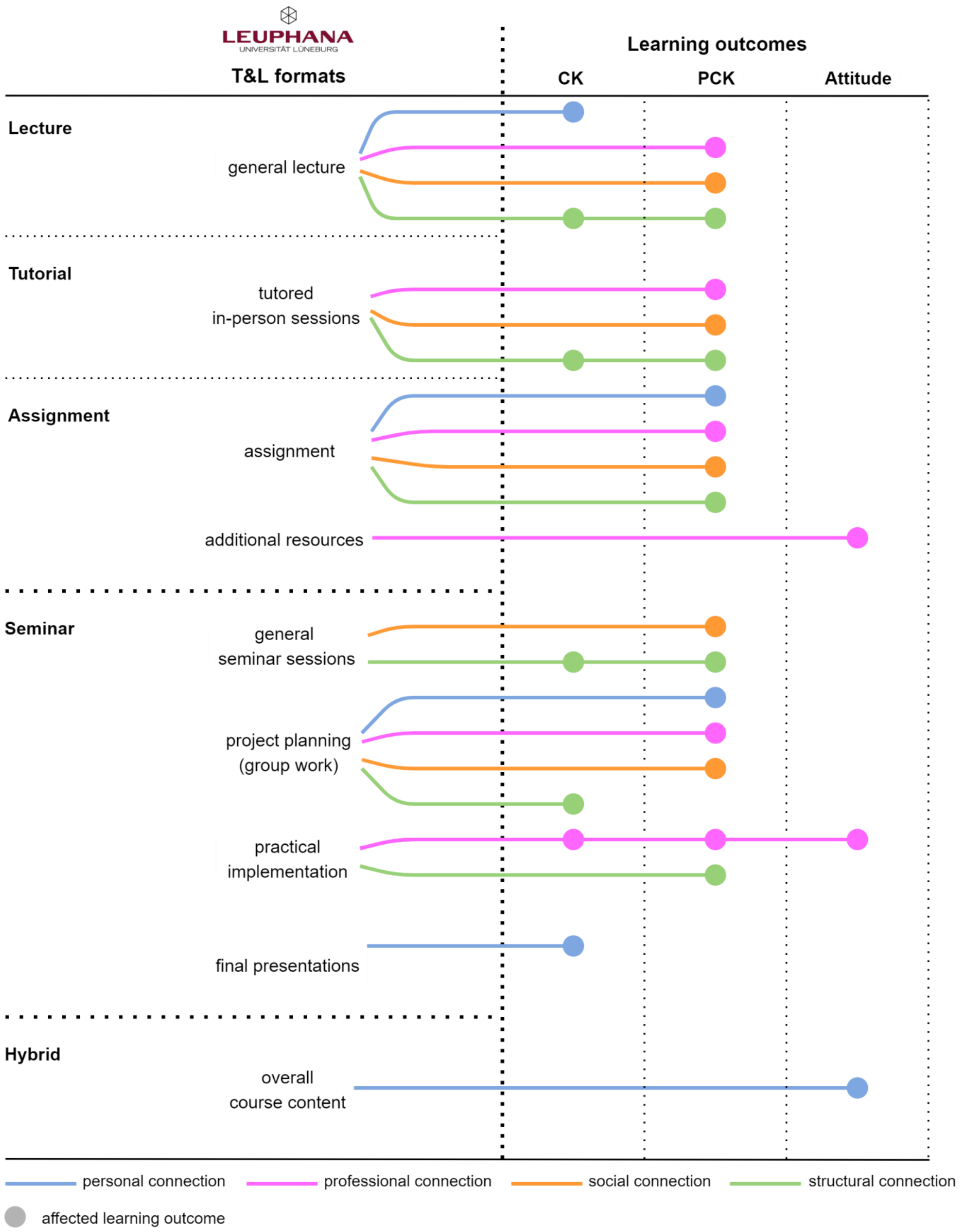

Figure 8: The impact of *the four Cs* on achieving ILOs in different T&L formats at Leuphana 2018

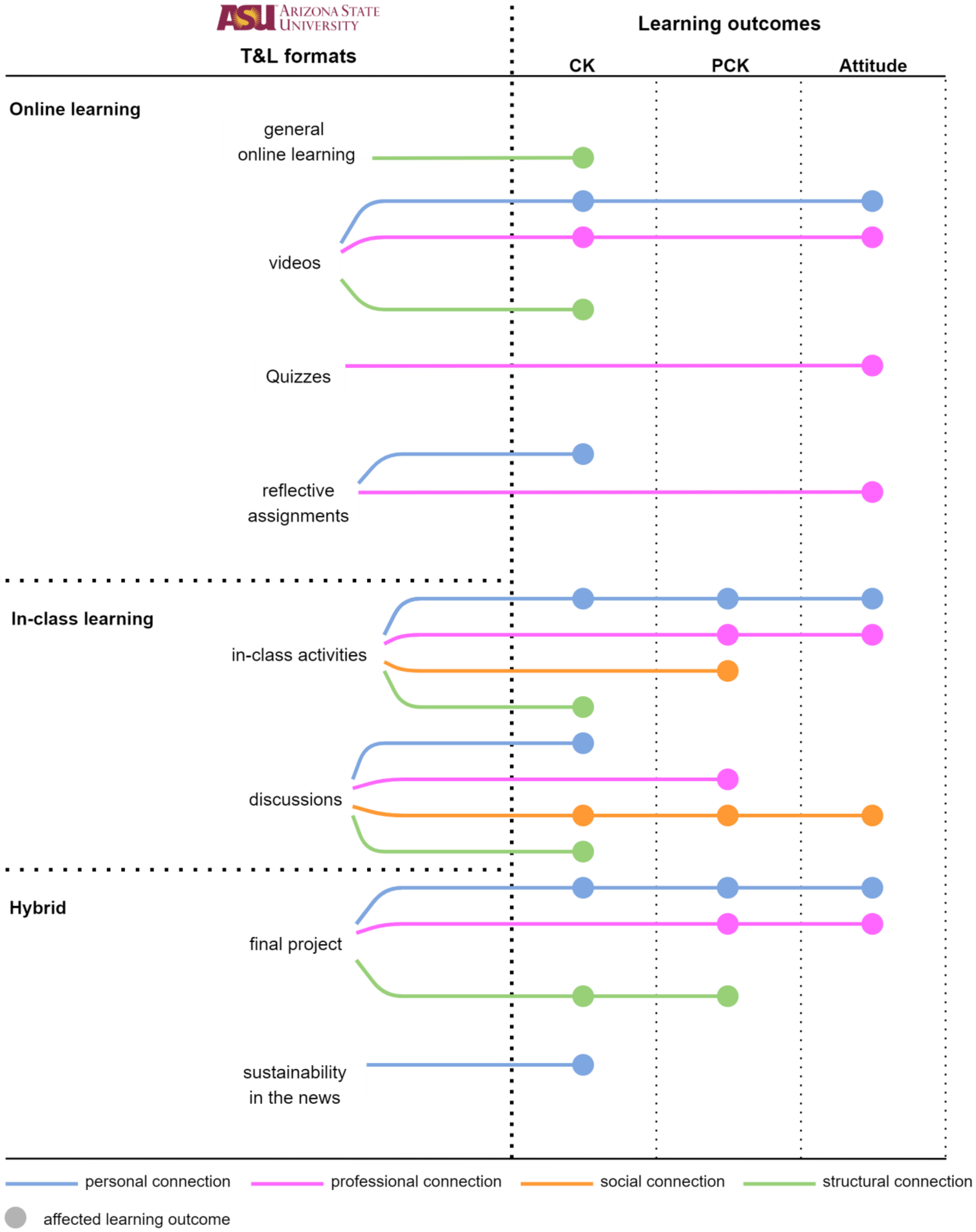

Figure 9: The impact of *the four Cs* on achieving ILOs in different T&L formats at ASU 2018

5.4 Summary

- **Overarching research inquiry:**
  How can the development of ESD-specific professional action competence be supported in single sustainability courses of teacher education programmes that are not primarily devoted to ESD and in what way do individual T&L environments differ in this regard?

In summary, the findings of this cumulative dissertation show that both cases under investigation (representing exemplary T&L environments) fostered ESD-specific professional action competence in participating pre-service teachers – yet, due to their thematic foci and with respect to each competence component, to a different extent. While the Leuphana course had a greater impact on students' PCK development and led to a more thorough understanding of ESD-related pedagogies, the ASU course appeared to support the development of students' content knowledge and positive attitudes towards ESD more. Due to the different course designs and foci in terms of content, this was partly expected. The *SSfT* course is explicitly set out to convey detailed factual knowledge about different sustainability topics, whereas the Leuphana course mainly revolves around the question of how to design teaching and learning units and settings in ESD. As stated before, it should be considered that for most ASU students the *SSfT* course constituted their first encounter with sustainability topics, whereas the Leuphana students had already completed a sustainability module in their first semester. However, the overall results concerning the achievement of ILOs confirm the general potential of single blended learning courses in TESD to be effective in preparing prospective teachers to implement ESD (Chin et al., 2019).

Regarding the question of what affects the development of ESD-specific professional action competence for teachers in individual (hybrid) course offerings in TESD, it was found that personal, professional, social, and structural connection (*the four Cs*) are to be considered as key factors affecting students' learning processes. The empirical data gathered at Leuphana and ASU further implicate that the development of students' CK was mainly supported by complementary T&L formats (structural connection) and the applicability of content to private life (personal connection). Positive attitudes towards ESD, on the other hand, were mostly fostered by the provision of practical examples and the perceived relevance of education at large (professional connection) as well as their interest in, emotional reactions to and the applicability of the course content (personal connection).

With respect to PCK development, however, professional, structural, and social connections were key factors, and significantly in the Leuphana case. The provision of exemplary lesson plans as well as the opportunity to run an exemplary ESD lesson in an actual school setting (linking theory and praxis) were perceived as particularly helpful (professional and structural connection). Furthermore, students from both cases emphasized the importance of mutual exchange and unbiased feedback/guidance from the teaching staff (social connection) as well as the personal interest in the topic of their assignment (Leuphana) and the final project (ASU), as the key formats, to enhance their pedagogical skills.
Based on these findings, I suggest to consider personal, professional, social, and structural connection (the four Cs) when planning TESD course offerings with the intention of fostering pre-service teachers' ESD-specific professional action competence or related ILOs. To enhance learning in relation to the complex and value-laden concepts of sustainability in teacher education, I propose the following actions:

- As students' personal connections to the course content enhance their understanding of the topics and motivation to actually engage, I advise to make course content relevant to students and recognize the relation between emotion and cognition.
- To ensure professional connection, I suggest that course offerings in TESD integrate tasks to design and implement or at least simulate exemplary ESD lessons and bridge the theory-praxis gap through real-world learning experiences, such as the cooperation with partnered schools.
- To account for the significance of social connection when dealing with sustainability topics and ESD, I recommend applying pedagogies that allow for open discussions and mutual exchange of thoughts and ideas as well as to provide profound feedback, in particular with regards to planning and implementing ESD units (PCK). As the *SSfT* cohort from 2017 repeatedly highlighted their appreciation for instructors that serve as role models, facilitating the learning process, I propose seeking out instructors who are passionate about sustainability and capable of presenting and discussing sustainability issues and solutions in an unbiased manner.
- Since structural connection facilitates students' engagement with and understanding of the course content, I recommend that those in the position to do so make considerate decisions about course structure and the order of tasks (particularly in online learning environments) and purposefully link different T&L formats.

Considering the essential need for CK in the development of pedagogical skills (PCK) (Kunter et al., 2013) and positive attitudes toward ESD (Lindemann-Matthies et al., 2011), it may be claimed that the *SSfT* course (ASU) and the *ESD* course (Leuphana) – with their different foci and ILOs – ideally complement one another and should be considered sequential elements of the same curriculum in TESD. Eventually, a balance is needed between the provision of CK and opportunities to obtain practical teaching experience.

6 CRITICAL REFLECTION AND OUTLOOK

In order to meet scientific requirements, research in general should undergo a critical reflection along a certain set of criteria. In this chapter, I therefore firstly describe in how far general quality criteria for mixed method case study research were met. In a second step, the limitations of this dissertation are critically reflected, before I finally reemphasize the practical and theoretical implications in the sense of societal and scientific contributions and close this work with a personal statement to classify my overall findings.

6.1 Quality criteria of research

According to (Yin, 1984), the overall research design of case studies as well as the processes of data collection and analysis should meet the quality criteria of transparency, validity and reliability. Considering the different requirements of quantitative and qualitative research in the field of medical education, Frambach et al. (2013) further propose a set of principles and techniques to enhance the quality of research, which I here use as a second point of reference.

In the previous chapters, I thoroughly demonstrated the development context of this dissertation. I presented the identified research gap, derived from existing literature, formulated corresponding research questions and explained how these were answered based on empirical data, collected by suitable methods. To complement the three empirical articles that form the very heart of this thesis, a detailed case description and an instruments paper have been published. These documents provide additional information about the two cases under investigation, their contextual conditions, T&L formats, and student cohorts as well as the overarching research design and applied methods for data collection and analysis. The level of detail available in these two supplementary publications exceeds the scope of usual journal articles and increases the *transparency* of my research and helps to better understand or classify related empirical results. Furthermore, I applied various strategies to increase the *validity*, *reliability* and *objectivity* of my research:

Investigating students' learning processes and the development of ESD-specific professional action competence in two different cases, I used a variety of data collection methods for methodical triangulation and repeatedly gathered information over the period of more than two years (two semesters per case). In order to minimize the effect of social desirability, data were treated anonymously. The students as participants have been assured in advance that their responses will not be individually revealed to the course instructors and have no impact on their grades. Furthermore, data collection and analysis were usually conducted in cooperation with other researchers, which should further increase the *credibility* of this study (Frambach et al., 2013).

To additionally ensure internal *validity*, I standardized the conditions for collecting data on the two cases, by applying the same observation protocol, focus group guide, and survey structure, partly including established constructs, such as the perceived relevance of ESD scale or the ESD-related self-efficacy scale (Tomas et al., 2017). Yet, other instruments, like the CK and PCK assessment, were newly developed in the context of this work and their results indicate that they require revision and additional testing. The sample sizes – representing more than eighty percent of the total population in both courses – allowed me to present the quantitative results of pre-post comparisons with regards to their statistical significance and considering effect sizes (Cohen's *d*). Nevertheless, it cannot be guaranteed that all effects observed can be attributed to students' participation in the two courses that represent the independent variables in my research (Frambach et al., 2013). After all, each module only represents one of many stimuli students were exposed to during the semester, while other curricular or extra-curricular activities, events and encounters may have affected students' CK, PCK and motivation to implement ESD in their future career as well. Correspondingly, the questions in the focus groups specifically asked the students to reflect upon learning in the particular courses. The fact that the structure and logic of my research design was replicated in the context of a dual explanatory case study (Yin, 1984) ensures an *external validity* of my research. The thick description of the phenomenon of learning and its contextual conditions as well as discussing *"the findings' resonance with existing literature from different settings"* enhances the *transferability* of my results (Frambach et al., 2013). Although, the findings may remain to a certain extent *'bound'* to this very dual case study and cannot simply be generalized, I want to kindly invite fellow researchers and practitioners to comment, discuss and contribute their thoughts and own experiences on that matter.

To meet the consistency criterion of *reliability*, I calculated Cronbach's alpha values for all scales applied in the survey, which indicated *construct reliability* across the board. Qualitative data from focus groups and interviews, on the other hand, were continuously and independently coded by at least two researchers (*inter-coder reliability*), following the coding paradigm of grounded theory and applying the methods of constant comparison (Strauss & Corbin, 1990). Through several iterations of open and axial coding, *"connection"* was identified as the core category spanning the other phenomena found in the data. Finally, the empirical results were frequently discussed with other researchers, was published in peer-reviewed journals and included verbatim quotes by the students – to let the data speak for themselves, which increases the *objectivity* and decreases personal biases (Frambach et al., 2013).

6.2 Limitations and future research

However, despite the specific consideration of quality criteria, this work also has certain limitations. One typical limitation of case studies, which also applies here, is that the overall results are in a way *'bound'* to the cases and cannot be generalized (Yin, 1984). On the one hand, both cases examined in this study are examples of common hybrid learning environments that revealed how competence development may be supported in individual TESD courses. On the other hand, they are characterized by special conditions that do not necessarily apply to other courses. While both Leuphana and ASU have a strong focus on sustainability in general, the so-called Leuphana Semester already introduces all students to concepts of sustainable development in the very beginning of their studies. Furthermore, the basic social and science branch of teacher education at Leuphana is comparably progressive and includes two mandatory ESD modules – one in the second and one in the fourth semester – of which only the first was in the very focus of this dissertation. Also the *SSfT* course at ASU is quite unique, not only as it is mandatory to all elementary education majors. With Nobel laureate Leland H. Hartwell and other stakeholders on board, funding was available to produce high quality digital storytelling videos and ensure consistent in-class activities. Yet, future research could adopt the proposed empirical design as well as the applied strategies to operationalize ESD-specific professional action competence for teachers for comparable studies on TESD courses at non-Western universities and teacher education institutions.

Initially, the goal of this work was to measure changes in students' ability and motivation to implement ESD at the school level. Yet, the actual assessment largely remained limited to instruments of self-assessment, surveys, and assessment tools that rather evaluated a combination of students' subjective and objective knowledge instead of conducting a performance-oriented skill evaluation. Despite significant resources and support from both institutions (Leuphana and ASU alike), this research was subject to certain time constraints. The time to develop, test, refine, and apply instruments that allow for comprehensive, performance-based competence assessment, while also conducting qualitative research on the learning processes, would have by far exceeded the scope of the four year EFCA project. Therefore, I invite future researchers to build upon my work in order to further develop and implement adequate instruments to measure student teachers performance, with regards to ESD-specific professional action competence in general and PCK in particular.

Eventually, the focus of this thesis was deliberately limited to investigating the development of student teachers' knowledge, skills, and attitudes that are required for successful in-class ESD teaching. It should be noted, however, that the professional role of teachers goes beyond that of mere classroom instructors and also concerns their actions within the institutional context as well as the wider community (e.g., Sleurs, 2008; UNECE, 2013; Vare et al., 2019). Referring to the concept of ESD-specific professional action competence for teachers (Bertschy et al., 2013), Timm and Barth (2020) recently proposed to add the domain of *"strategic and hierarchical knowledge"*, which may help teachers to expand their sphere of influence as change agents and *"implement ESD at the institutional level"* as well (Ibid.). To further understand the extent to which the student teachers actually apply what they have learned during TESD offerings in their professional career as teachers, future research could be designed as longitudinal panel studies, repeatedly gathering data on the same set of variables, even beyond their graduation.

All in all, I collected vast amounts of underused data, in particular, with respect to the pre-service teachers' motivations to become teachers, their previous work experience or extra-curricular activities. Based on these data, certain groups or clusters of students may show specific developments in terms of learning outcomes or perceive different factors that impacted their learning processes. Even though first attempts of cluster analyses remained without any significant results, the aspect of specific groups of learners appears worthwhile to take a closer look at. Finally, knowing how different students learn could inform course designers and educational planners in creating effective teaching and learning environments in TESD.

6.3 Theoretical and practical implications

Research and particularly sustainability research usually claims to make a valuable contribution, be it regarding the field of science and the development of novel scientific methods or with respect to society and its transformation towards sustainable development. Despite the limitations presented above, this dissertation has various theoretical and practical implications, making it a valuable contribution to the field of TESD.

In the scientific discourse revolving competence development in TESD, recent literature was mostly limited to measuring individual competence components of either CK (e.g., Esa, 2010; Redman & Redman, 2017), PCK (e.g., Rosenkränzer et al., 2017; Singer-Brodowski et al., 2019), or attitude (e.g., Tomas et al., 2017; Nousheen et al., 2020). Furthermore, research with regards to the link between learning outcomes and learning processes in connection with specific pedagogical approaches or different T&L formats was scattered and scarce. Hence, the comprehensive approach to measuring competence development, including all facets of ESD-specific professional action competence for teachers, according to Bertschy et al. (2013), reveals key factors that affected students' learning processes in individual TESD courses represent major scientific (theoretical) contributions of this work. In this context, the PCK assessment tool should be mentioned in particular. Although still requiring further testing and refinement, it allowed to capture quantitative results with regards to the competence component of ESD-specific PCK and, just like the overarching research design, provides a valuable foundation for future research.

The overall findings of this study have both theoretical and practical implications. Based on the theoretical assumption that the *four Cs* of personal, professional, social, and structural connection are to be considered as key factors affecting students' learning in TESD, I formulated a list of practical suggestions for the design of corresponding educational offers (see Chapter 5.4). Accordingly, following aspects are to be considered when aiming to enhance learning and foster the development of ESD-specific professional action competence in individual TESD courses: the course content should be relevant to the students; the relation between emotion and cognition should be recognized; opportunities for experiential learning and closing the theory-praxis gap should be given; pedagogies that allow for open discussions and mutual exchange of thoughts and ideas should be applied; unbiased feedback and guidance should be provided by (preferably passionate) instructors; different course elements and T&L formats should be purposefully linked.

This work also has certain societal implications, as the empirical results indicate that, by participating in the two courses under investigation, the students further developed their ESD-specific professional action competence and took the next step in their professionalization process. This implies that the socio-political mandate of integrating ESD across education systems and contributing to the education of future change agents (UNESCO, 2020) is promoted by the two TESD modules at Leuphana and ASU. Put differently, it could be shown that the two selected cases, in the sense of exemplary T&L environments, actually manage to increase students' capacity and motivation to implement ESD at the school level in their future careers as teachers. According to the empirical data, this largely relates back to the application of different T&L formats, ensuring personal, professional, social, and structural connection.

While one might claim that these findings regarding the importance of the overarching theme of *connection* and its different forms appear to be generalizable to learning in higher education per se, rather than specific to ESD or TESD, I would even go one step further. In a world that is characterized by increasing complexity, social acceleration and alienation (Rosa, 2019), it seems important to consider the connections within this all-encompassing system as valuable bridges and spheres of resonance. Especially in situations of diverging perspectives emerging conflicts, a conflict-embracing attitude is key (Konrad et al., 2020). After all, as one new way of knowing, thinking, and acting, we should be focusing on what connects us instead of what divides us – using our heads, hands, and hearts.

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APPENDIX 1 - Becoming a competent teacher in education for sustainable development: Learning outcomes and processes in teacher education

Citation

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Abstract

Purpose
This paper aims to provide a holistic approach to assessing student teachers’ competence development in education for sustainable development (ESD). This is to provide evidence on which teaching and learning formats help to foster which aspects of ESD-specific professional action competence in teachers. The studied competencies consist of content knowledge (CK), pedagogical content knowledge (PCK) and the willingness to actively support and implement ESD.

Design/methodology/approach
A multiple case study design was used on two sequential modules of a university’s teacher education program. A mixed-methods approach was applied that combined surveys, videotaped and PhotoVoice-supported focus groups, as well as pre- and post-assessment tools. Qualitative data analysis was based on the coding paradigm of the qualitative content analysis, whereas quantitative data were interpreted by means of descriptive statistics and paired sample t-tests.

Findings
The results from this study clearly indicate that the two courses contributed to a shift in students’ non-cognitive dispositions. The study also provides evidence on the students’ competence development and demonstrates how two different learning settings support different dimensions of teachers’ professional action competence in terms of ESD.

Originality/value
The triangulation of data enabled not only a mere competence assessment but also deeper insights into learning processes, as well as into the drivers of and barriers to competence development. Furthermore, the study introduces an innovative approach to assessing the development of PCK.

Keywords

case study; teacher education

1. INTRODUCTION

Education – and particularly education for sustainable development (ESD) – plays a central role in forming a society's capacity to address some of the most pressing challenges faced today (Barth et al., 2016). This trend is reflected in the international community's commitment to global Sustainable Development Goals (SDGs), one of which is to *"ensure inclusive and quality education for all […]"* (DESA, 2015). Accordingly, the Global Action Programme (GAP) aims to further develop and disseminate the findings of the UN Decade of "Education for Sustainable Development" (2005-2014) (UNESCO, 2014). More specifically, the GAP argues that everyone should have *"the opportunity to acquire the knowledge, skills, values and attitudes that empower them to contribute to sustainable development"* (UNESCO, 2014, p. 14).

Achieving this goal and ensuring adequate implementation of ESD at all levels will ultimately require a focus on teacher training both in a university setting and on the job in the form of continuous professional development (Redman et al., 2018). Consequently, the GAP includes a key action area with the explicit aim to *"strengthen the capacity of educators, trainers and other change agents to become learning facilitators for ESD"* (UNESCO, 2014, p. 35). In recent years, more and more countries have been including ESD as part of their priority areas of teacher education policies and practices (Ferreira et al., 2009; Higgins and Kirk, 2006; Standing Conference of the German Ministers of Education and Culture (KMK), 2016).

However, to prepare teachers for the challenge of implementing ESD at the school level, universities and teacher-education programs must embrace pedagogies that foster the competencies that enable teachers to serve as competent change agents (Bertschy et al., 2013; Howlett et al., 2016; Rieckmann, 2018; Qablan, 2018). The formulation and achievement of learning objectives in teacher education for sustainability nevertheless remains a complex task due to required knowledge of sustainability issues (content knowledge – CK), skills in designing effective teaching and learning formats (pedagogical content knowledge – PCK), and adequate willingness and motivation (attitude). While there is ongoing work concerning what competencies students need to become competent ESD teachers (Bürgener and Barth, 2018; Evans et al., 2017), the question remains as to the extent to which existing teaching- and learning formats actually support the development of these competences.

2. BACKGROUND

The broad and complex agenda of ESD (Stevenson, 2007) has tremendous potential to build agency as it offers manifold opportunities to empower people *"to contribute to a better future through mindset changes, critical reflection and building new skills"* (Reynolds, 2009, p. 109). Efforts to integrate ESD into education on a policy level (e.g. UN Decade, SDGs and GAP) explicitly highlight the role of educators (UNESCO, 2014). Nevertheless, ESD is not yet well established in most countries' teacher training or professional standards and is often disregarded (Evans et al., 2017). On the other hand, research results point out that teachers' competencies and commitment toward sustainability are essential factors in the successful implementation of ESD in school practice (Barth, 2015; Buchanan, 2012). Therefore, the provision of corresponding offers to educate the educators is urgently required, which underlines the importance of teacher-education programs, especially those that impact on the beliefs, values and attitudes of future teachers toward sustainable development (Andersson et al., 2013).

In order to ensure effective learning and produce the greatest potential learning outcomes from their students, teachers need corresponding competencies that enable them to create suitable learning opportunities (Guskey, 2010; Hattie, 2009). With the term competencies, we here refer to the combination of *"knowledge, ability and willingness in the availability of the individual to cope successfully and responsibly with changing situations"* (Weinert, 2001).

Building on Shulman's (1987) categories of what constitutes a competent teacher, Baumert and Kunter (2013) designed a model of teachers' professional competence that identifies professional knowledge, beliefs, motivation, and self-regulation as core aspects of teachers' competence (Baumert and Kunter, 2013). Concerning the competencies necessary for the successful integration of ESD into schools, several approaches exist that emphasize the role of educators and provide different competence models for ESD teachers (UNECE, 2013; Sleurs, 2008; Rauch and Steiner, 2013; Wiek et al., 2011). Warren et al. (2014) from Arizona State University (ASU), for instance, introduced a Sustainability Education Framework for Teachers (SEFT) that functions as *"a conceptual framework for analyzing and considering sustainability problems and solutions through a networked approach."*

However, Bertschy et al. (2013) were among the first to link the discussion on competencies in ESD with the broader discourse on teachers' professional competencies by adopting Baumert and Kunter's general model for the context of ESD. In further developing Baumert and Kunter's competence model, Bertschy et al. introduced an integrative model for *"ESD-specific professional action competency in Kindergarten and primary school [...], pivotal for the design of educational offers in teacher education institutions"* (Bertschy et al., 2013, p. 5075). In this context, the authors distinguish between two competence aspects: the aspect of motivation and volition (which combines Baumert and Kunter's competence aspects of beliefs, motivation, and self-regulation) and the aspect of knowledge and ability (which refers to Baumert and Kunter's professional knowledge), thereby merging the two fields of CK and PCK. While a knowledge and understanding of sustainability may not necessarily lead to the effective implementation of ESD (Cutter-Mackenzie and Smith, 2003; Cutter-Mackenzie and Tilbury, 2002; Kennelly et al., 2008; Stevenson, 2007), Symons (2008) suggested that knowledge – in addition to pedagogical skills and attitudes – supports the confidence and readiness of teachers to enact ESD at the school level. Another notable distinction comes from Timm and Barth (2018, under review), who have linked the competence profile of ESD teachers to a distinction of two action areas of change agents in schools that influence either the micro-level of their own teaching or the macro-level of school development.
Striving for the support of these competencies and orientations requires innovative and appropriate teaching and learning approaches. According to UNESCO's Roadmap for Implementing the GAP, new learning environments for students in teacher education must be designed in order to *"inspire learners to act for sustainability"* (UNESCO, 2014, p. 12) and to strengthen content and pedagogical knowledge with regard to sustainability and the motivation to bring about change (Vare, 2018). To provide such opportunities that enable pre-service teachers to develop, test and reflect upon these relevant competencies, specific real-life learning situations (Frisk and Larson, 2011) that focus on real-world problems (Brundiers et al., 2010) should be created. One promising approach to this goal is to offer space for collaboration with educational practitioners and close links to schools (Bürgener and Barth, 2018). However, in addition to the necessity of creating these kinds of learning opportunities in universities for future teachers, more thorough evaluations concerning their actual impact are needed (Evans et al., 2017), particularly with regard to how values, beliefs, and norms might be affected (Andersson et al., 2013).

Against this backdrop, our study aims to contribute to closing this research gap through the design and evaluation of suitable learning environments for the systematic competence development of student teachers and by uncovering the mechanisms that best foster this competence development.

3. RESEARCH DESIGN

To address the identified research gap, this study investigates the extent to which a specific learning setting in teacher education can contribute to student teachers' competence in ESD. Using Bertschy et al.'s model for *"ESD-specific professional action competency"* (2013) as a source of orientation, our focus lies on the development of motivational and volitional competence elements as well as on ESD-related knowledge and abilities. In order to be able to operationalize these aspects, learning outcomes and processes are investigated in a comparative case study (Stake, 2008) based on two sequential ESD modules of the teacher-education program *BA Lehren und Lernen* at Leuphana University in Lüneburg, Germany (see Section 4 for more details on the cases).

More specifically, this paper focuses on three closely interlinked elements:

RQ1:
- *What students bring to the two courses under investigation (i.e. relevant non-cognitive dispositions)*;

RQ2:
- *What students learn in the two courses under investigation (or more specifically, what impact the two modules have on students' abilities, knowledge and attitudes)*; and

RQ3:
- *How students perceive of their learning process in connection with their learning outcomes.*

Data were collected during the summer semester 2018 (April-July). Afterward, a mixed-method approach was implemented that covered a broad range of aspects of ESD competence for teachers, with a special focus on PCK and attitudes (motivation and non-cognitive dispositions). Figure 1 illustrates the instruments and timeline in which the instruments were used. Data collection was approved by the relevant ethical boards, which included written consent forms from all participating students.

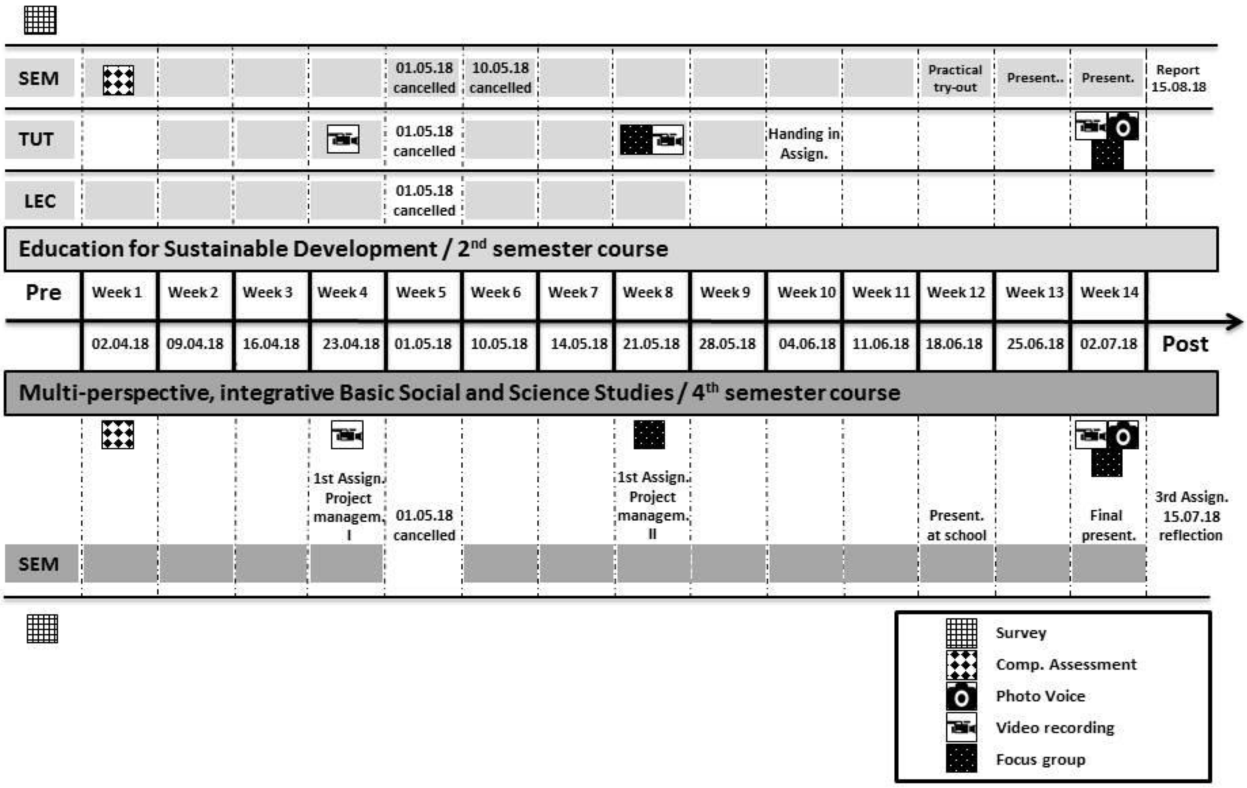

Figure 1. **Empirical design** – time plan of data collection in the summer semester 2018 at Leuphana University

3.1 Data collection

Multiple instruments were used to capture a rich image of the students' learning (see Table 1 for details): A pre- and post-course survey were conducted to capture students' individual backgrounds, their motivation to become a teacher, as well as their environmental attitude according to the revised NEP scale (Dunlap et al., 2000) (**RQ1**) and to identify changes in students' attitudes and understanding of sustainability (**RQ2**). In addition, an instrument for assessing the development of PCK was designed and applied. This instrument included four different case studies that described scenarios of ESD-related school projects (2 pre- and 2 post-), each of which was intended to enable the implementation of vision orientation, connected learning, and participatory orientation – as ESD-specific learning principles – to varying degrees. For these projects, students were asked a) to rate how well each principle could be implemented in the given case studies and b) to provide a rationale for their rating (see Appendix 1 for an exemplary case study).

Table 1: Instruments overview

SURVEY	**Pre-course survey (online/LimeSurvey) - *N* = 100 (2nd semester = 60/4th semester = 40)** • Previous work experiences (closed item with 8 checkboxes) • Extracurricular activities (closed item with 10 checkboxes) • Motivation to become a teacher (open item) • New-Ecological-Paradigm-(NEP-)Scale (15 five-point Likert items) (Dunlap *et al.*, 2000) **Post-course survey (paper-pencil) - *N* = 109 (56/53)** • Demographic information (items on age and gender) **Pre & Post** • Own definition of sustainability (open item) • Innovation-related self-efficacy scale (7 four-point Likert items) (Emmrich, 2009) • ESD-related self-efficacy scale (11 four-point Likert items) (Tomas *et al.*, 2015, supplemented by Bertschy *et al.*, 2013) • Perceived relevance of ESD scale (6 four-point Likert items) (Tomas *et al.*, 2015)
ASSESSMENT	**Pre- & Post-course competence assessment (paper-pencil) - Pre: *N* = 121 (65/56), Post: *N* = 109 (56/53)** **PCK -** ESD-related pedagogical content knowledge Evaluation of 2 different case studies of teaching and learning scenarios regarding ESD-specific learning principles according to Künzli and Bertschy (2008) (rating on 4 point Likert-Scale + open item for rationale) **CK -** ESD-related content knowledge 14 Multiple-Choice questions based on Wiek et al. (2011)
FOCUS GROUPS	**6 (4/2) Mid-term focus groups module (24-34 min.) - *N* = 28 (16/12)** encompassing open questions on how the students deal with the challenges of the seminars as well as drivers and barriers for the success of their projects **8 (6/2) End-of-semester focus groups, supported by PhotoVoice (52-71 min.) - *N* = 45 (31)/14)** encompassing open questions on WHAT and HOW the students have learned
INDIVIDUAL REFLECTIONS	**Written individual reflections (assignments) - *N* = 92** 2nd semester: reflection on one's personal role regarding the requirement of the group presentation as well as on the overall group processes during project work in the seminar 4th semester: individual - PhotoVoice supported - reflection on the seminar and individual learning processes regarding one's own professionalization

In conjunction with this instrument, a CK assessment was conducted that included 14 multiple-choice questions on various sustainability challenges covering key competencies in sustainability according to Wiek et al. (2011). However, these data were only collected for an additional study comparing sustainability courses in teacher education at Leuphana University and ASU and were not analyzed for this study. Furthermore, focus groups were conducted both mid-term and at the end of the semester in order to provide insights into learning processes and outcomes from the students' perspective (**RQ3**). To support their reflection, the PhotoVoice method – originally introduced by Wang and Burris (1994) – was implemented. In using this method, the students took pictures of personal key learning moments over the course of the semester, which then served as anchor points during the group reflections. Finally, written reflections as part of the students' assignments were analyzed.

3.2 Data analysis

An analysis of quantitative data from surveys and assessments was conducted with R and SPSS. In total, 72 students (39/33) took part in all the pre- and post-course surveys and assessment measures and could therefore be analyzed in all comparisons. While student backgrounds were characterized via basic descriptive statistics (frequencies), the pre-post comparison of CK, PCK, and attitude (self-efficacy and perceived relevance of ESD) were conducted using paired sample t-tests.

In order to determine *students' motivations to become a teacher*, the replies were coded based on the FIT choice scale (Watt et al., 2012), which distinguishes among *"task demand"* and *"task return"* (here combined into *"perception of the task"*), *"self-perception"*, *"prior teaching and learning experiences"*, *"social influences"*, and *"social dissuasion"* (here combined into *"socialization influence"*), *"intrinsic career value"*, *"personal utility value"*, and *"social utility value"* (here split into *"student-oriented utility value"* and *"society-oriented utility value"*). It is important to note that students may be motivated by various factors, and multiple codes could thus be applied per individual reply. Appendix 2 contains short rubrics and anchor examples of each motivation code. All coding was conducted by at least two researchers to ensure inter-coder reliability (ICR). In case of different scores, the researchers jointly reexamined the raw data to come to an agreement.

As an indicator of CK, changes in the *students' understanding of the term "sustainability"* over the course of the semester were measured. To do so, the students' open response definitions were assigned sub-scores for both the *"time perspective"* (0-3) and *"dimension orientation"* (0-2), resulting in overall scores of 0-5. Appendix 3 details the scoring with examples of each score. Again, all coding was conducted by at least two researchers who checked for ICR and resolved conflicts with communicative validation.

The *PCK assessment* sought to measure students' decisions of how well ESD-specific learning principles can be put into practice in each of the given case studies. Ratings were based on two scores: First, we determined how closely the students' rating of whether the learning principle could be applied in each case study matched a rating by experts. This expert rating was determined by having every case study evaluated by four experts from the field of ESD in teacher education and averaging their scores. The difference between the experts' rating and the students' scores (an absolute number) was deducted from the potential maximum of four points, leading to a score ranging from 0 to 4 (see Appendix 1 for an example of how calculations were performed). Second, the researchers rated the students' rationales for their ratings (codes ranged from 0 to 2). All coding was conducted by at least two researchers to achieve ICR. In case of different scores, the researchers jointly reexamined the raw data to come to agreement.

Qualitative data included the material from focus groups and written reflections. All data were transcribed and coded by at least two researchers for ICR. While only a random selection of 45 (31/14) students participated in the 2nd- and 4th-semester focus groups, all the written assignments of the 141 (76/65) students who consented to participate in this study were included. The qualitative analysis of the data – oriented toward the understanding and reconstruction of learning processes and outcomes – was carried out based on the coding paradigm of the qualitative content analysis developed by Mayring (2014). Following this familiarization with the material, the data were analyzed, and both in-vivo and theoretically derived categories were tentatively deduced using a shared codebook. Several feedback loops were incorporated to revise the categories, reduce the main categories and check their reliability (Mayring, 2014).

4 CASE DESCRIPTION

To address our research question, we deployed a comparative case study design. The cases we compared were two modules of the teacher-education program in *"Sachunterricht"* (basic social- and science studies) that form part of the primary education at Leuphana University. Both modules are oriented toward ESD and are mandatory, sequential modules for all teacher-education students.

4.1 Module "Education for Sustainable Development" (2nd Semester)

The module "Education for Sustainable Development" (taught in German) is a 150-h unit that is offered every year during the 2nd Semester (summer term, April to July). Over 14 weeks, approximately 80 students participate in a combination of (blended learning) lectures, tutorials and seminar sessions.

The design of the module follows a scaffold approach in four sequential steps: First, in a regular lecture format, students learn about the concept of ESD, its implementation, and how to design learning environments in ESD. Beginning in Week 3, the lectures are recorded and offered in a flipped classroom setting to allow students to engage with the topic in their own time and at their own pace as well as to enable them to ask questions and interact in face-to-face meetings. Second, the lecturer uses the model of cognitive apprenticeship (Collins et al., 1991) to demonstrate how to create a learning environment that supports sustainability competence development in school settings. Third, students are divided into tutorials and work by themselves and with the support of tutors on the outline of such a learning environment. This work also represents their first official assignment in the course. Fourth, students work on a case study in three different seminars, in which they collaborate with a school to implement an ESD lesson for a primary-education student's cohort. Table 2 outlines the specifics of the module in comparison with the second case.

The 2018 student cohort consisted of 81 students, predominantly female (85 per cent) and 21 years old on average. About half of these students had had previous professional experience, while 44 per cent had completed voluntary work in the social or ecological sector. Almost one-quarter of the students had engaged in additional educational activities, courses or certificates, and another 10 per cent had engaged in sustainability-related activities (data from pre-course survey).

4.2 Module “Multi-Perspective, Integrative Basic Social- and Science Studies” (4^{th} Semester)

The module “Multi-Perspective, Integrative Basic Social- and Science Studies” (taught in German) is oriented toward ESD and also offered on a yearly basis and takes place during the 4^{th} Semester (summer term) of the teacher-education program in *“Sachunterricht”* at Leuphana. The 150-h unit offers four project seminars on different topics with a maximum of 20 students in each seminar. Students can freely choose one of the seminars, which consist of weekly sessions over 14 weeks.

The 14 in-class seminar sessions are offered via team teaching by two lecturers, who facilitate the project work of student groups. Group work encompasses cooperation with practice partners from regional partner schools and local education centers (depending on the topic in each of the seminars). Over the course of the semester, the students work collaboratively on the development of coherent concepts for learning units to be implemented later into a concrete setting at the partner schools. To support this process, the structural design of the seminars follows the idea of an open learning environment (Glazer and Hannafin, 2006; Hannafin et al., 1999): By providing an enabling context (real-world challenges from the partner schools that are developed into manageable projects for the students), resources (e.g. written material, experts in field), tools (e.g. project-management tools, space for exchange between students as well as between students and practitioners), and scaffolds (close supervision at the beginning of the course, which is gradually phased out over the course of the semester), the students are able to analyze open-ended learning processes in ill-defined, ill-structured domains that are typical of sustainability-related problems (see Table 2 for the specifics of the module).

The 2018 cohort of this module comprised 63 students, 80 per cent of whom were female, with an average age of 22. More than one-third (35 per cent) of the students had already engaged in a professional activity, and 28 per cent had completed either a social or ecological year prior to their studies. One out of five students had engaged in additional educational activities or courses or had certificates, while 5 per cent claimed to have been active in sustainability projects (data from pre-course survey).

Table 2: Course attributes – both courses

CURRICULUM	2nd semester - Mandatory course of BA Teaching & Learning (Subject: Basic Social and Science Studies)	4th semester - Mandatory course of BA Teaching & Learning (Subject: Basic Social and Science Studies)
STRUCTURE	**13 x seminar session (weekly)** (incl. practical project implementation at a partner school) **7 x lecture (online + presence) + 7 x tutorial**	**13 x seminar session (weekly)** (incl. joint project work with practice partners from regional schools and other educational institutions)
STUDENTS	**81 students** (allocated to 3 seminars / 3 tutorials)	**63 students** (allocated to 4 seminars)
FORM OF ASSESSMENT	**1. Individual written assignment:** Outlining a learning unit in ESD (30 out of 100 pts.) **2. Group presentation, incl. written report and individual reflection** Presenting an individual ESD lesson incl. rationale (70 out of 100 pts.)	**1. Group assignment on project management (PM):** Written portfolio + presentation on PM controlling (30 out of 100 pts.) **2. Group presentation:** Presenting a coherent concept as final result of the project work (40 out of 100 pts.) **3. Individual written reflection** Individual reflections on the seminar and individual learning processes regarding one's own professionalization (30 out of 100 pts.)
KEY LEARNING OBJECTIVES	• Understanding of ESD as an educational perspective in primary education • Pedagogical content knowledge in ESD • Ability to plan and implement teaching and learning activities in a given class setting	• Translate theoretical considerations of ESD into practical teaching and learning settings • Ability to plan teaching and learning environments for ESD in school and out-of-school settings • Ability to collaborate and discuss with different stakeholders in formal education

4.3 Differences and similarities

Both sequential modules are mandatory and involve seminar sessions in addition to individual as well as group assignments as forms of examination. However, the specific learning objectives – and consequently, the thematic foci and overall course structures – differ significantly. The 2nd-semester module is designed to first introduce the concept of ESD as well as its implementation measures (lectures + tutorials) and second, to provide the opportunity for practical experience with a partner school at the end of the semester (seminar). The 4th-semester module, on the other hand, is focused on the project work of the students and their cooperation with practice partners to collaboratively create learning units that may later be implemented at the partnering schools. During this semester, the emphasis not only is on the teaching and learning setting in class but also includes learning about collaboration and what must happen when working with different stakeholders.

5. RESULTS

In the following section, we present the results of our analysis structured around the three parts of our research questions:

- **RQ1:**
  What students brought to the modules;
- **RQ2:**
  What students learned in the modules; and
- **RQ3:**
  How students perceived their own learning process and outcomes.

5.1 What students brought to the modules

In the pre-survey, we captured basic socio-demographic data and the experiences of students from both modules, some of which was used to describe the respective cohorts in the case study descriptions in Section 4. Additionally, we analyzed the students' motivation to become teachers using categories adapted from Watt and Richardson (2007) (see results in Table 3).

Table 3: Motivation to become a teacher – based on FIT-Choice Scale by Watt & Richardson (2012)

	2nd semester		4th semester	
	Percentage	*N*	Percentage	*N*
	100	**58**	**100**	**40**
Values	96.6	56	100	40
Intrinsic career values	43.1	25	55	22
Personal utility values	3.4	2	5	2
Social utility values (students)	81	47	80	32
Social utility values (society)	25.9	15	17.5	7
Socialization influence	20.7	12	7.5	3
Perception of the task	6.9	4	2.5	1
Perception of the self	8.6	5	5	2

These results show meaningful similarities between the two cohorts, with the vast majority of students being motivated by values. Motivational aspects that can be assigned to student-focused social utility values were most frequently mentioned. *"To support children while they grow up"* (S2_515) or *"to teach children and prepare them for their future life"* (S4_101) served as motivation for the career choice of four out of five students. Only 26 per cent (2nd semester) and 18 per cent (4th semester) of students referred to the societal level, such as *"making a contribution to the world and shaping the future"* (S2_550). The second major type of motivation was intrinsic career values, such as *"the imparting of knowledge"* (S2_546) and *"the joy of working with children"* (S2_531), which motivated 43 per cent of the 2nd semester students and more than half (55 per cent) of the 4th semester cohort. While the socialization influence (e.g. experiences from educational work or their own school days, including *"perceiving a former teacher as role model"* (S2_510)) impacted one in five students in the 2nd semester course, it played only a minor role for the 4th semester. Personal utility values (e.g. *"having a secure job"* (S2_563)), the perception of a task (e.g. *"gratitude of parents"* (S4_301)), and self-perception (e.g. the *"trust in my ability to become a good teacher"* (S2_506)) were rather uncommon motivational factors in both cohorts.

The students' scores on the revised NEP scale (displayed in Table 4) indicate that both cohorts began their semester with relatively strong pro-environmental worldviews, with slightly higher scores in the 2nd semester compared with the 4th. In the context of this study, the NEP scale displayed an acceptable construct validity and internal consistency for all 15 items (Cronbach's Alpha = 0.72).

Table 4: NEP - new ecological paradigm (1-5 Likert scale) – based on Dunlap et al. (2000)

	2nd semester			**4th semester**		
	N	*M*	*SD*	*N*	*M*	*SD*
Overall NEP scale	60	**3.98**	.38	40	**3.80**	.39
Sub-Dimensions						
Balance of nature [Items 3, 8(*R*) & 13]	60	**4.10**	.52	40	**3.98**	.51
Eco-crisis [Items 5,10(*R*) & 15]	60	**4.26**	.66	40	**4.08**	.57
Anti-Exemptionalism [Items 4(*R*), 9 & 14(*R*)]	60	**3.71**	.50	40	**3.61**	.50
Limits to growth [Items 1, 6(*R*) & 11]	60	**3.60**	.78	40	**3.32**	.67
Anti-Anthropocentrism [Items 2(*R*), 7 & 12(*R*)]	60	**4.21**	.46	40	**4.02**	.56

(*R*) = reverse-scored items from the scale

5.2 What students learned in the modules

In terms of learning outcomes, we report results on the three different aspects of CK, PCK, and attitudes and beliefs.

CK was not a focus of either course or of primary interest to this study and was measured only via the change in students' understanding and definition of the term sustainability. Table 5 depicts the respective results of the coded answers by semester. The sustainability definitions of both cohorts showed a significant increase in the overall complexity of students' understanding of the term. While students from the 2nd semester reached higher scores in both the pre- and post-test, it should be noted that the 4th semester students displayed the greater increase.

Table 5: Sustainability definitions – Paired t-tests (pre-post comparison):

	Pre-test			**Post-test**					
	N	*M*	*SD*	*N*	*M*	*SD*	*df*	Cohen's *d*	Sig.
(overall) Sustainability definitions (0-5) time perspective + dimension orientation									
2nd Semester	45	**2.80**	1.31	45	**3.33**	1.15	44	**.36**	*
4th Semester	30	**2.13**	1.38	30	**3.00**	1.11	29	**.49**	**
Time perspective (0-3) 0=no time perspective, 1=future perspective, 2=intergenerational perspective, 3=inter-and intra-generational perspective									
2nd Semester	45	**1.73**	.94	45	**2.02**	.84	44	**.30**	*
4th Semester	30	**1.27**	1.14	30	**1.67**	.92	29	**.28**	
Dimension orientation (0-2) 0=no dimensions mentioned, 1=one-dimensional perspective, 2=multi-dimensional perspective									
2nd Semester	45	**1.07**	.86	45	**1.31**	.87	44	**.20**	
4th Semester	30	**.87**	.82	30	**1.33**	.84	29	**.48**	**

** Significant at the .01 level (2-tailed)
* Significant at the .05 level (2-tailed)

PCK is reported as two scores:

(1) closeness to the rating of experts in two case studies for opportunities to apply ESD-related learning principles; and
(2) the rating of their respective rationales (Tables 6 and 7).

The rating of the rationale in the 2nd semester displayed a slight increase in two out of three of the learning principles, albeit without statistical significance. The rating of the opportunities showed no change in two of the learning principles yet revealed a significant increase in participation orientation. A similar picture was painted for the 4th semester. While the rating of the rationale remained largely on the same level, a highly significant increase could be seen in the rating of one learning principle (connected learning), with no significant change in the other two principles.

Table 6: PCK assessment Rating – Paired t-tests (pre-post comparison)

	Pre-test			Post-test					
	N	*M*	*SD*	*N*	*M*	*SD*	*df*	Cohen's *d*	Sig.
Vision orientation									
2nd Semester	65	2.45	.42	56	2.42	.40	52	-.05	
4th Semester	56	2.43	.46	51	2.62	.54	45	.24	
Connected learning									
2nd Semester	65	2.17	.55	56	2.13	.48	45	-.04	
4th Semester	56	**2.04**	.62	51	**2.50**	.57	45	.50	**
Participation orientation									
2nd Semester	65	**2.52**	.48	56	**2.74**	.48	52	.25	*
4th Semester	56	2.59	.60	50	2.71	.60	45	.15	

** Significant at the .01 level (2-tailed)

* Significant at the .05 level (2-tailed)

Table 7: PCK assessment Rationale – Paired t-tests (pre-post comparison)

	Pre-test			Post-test					
	N	*M*	*SD*	*N*	*M*	*SD*	*df*	Cohen's *d*	Sig.
Vision orientation									
2nd Semester	44	.72	.58	48	.82	.51	41	.14	
4th Semester	43	.88	.52	34	.86	.60	33	.07	
Connected learning									
2nd Semester	49	1.36	.63	49	1.41	.55	47	.06	
4th Semester	44	1.35	.57	36	1.21	.59	34	-.23	
Participation orientation									
2nd Semester	45	1.13	.73	49	1.11	.75	42	-.02	
4th Semester	45	1.08	.67	35	1.05	.67	34	-.16	

Students' attitudes and beliefs were measured against the scales of ESD-related self-efficacy (SE), innovation-related SE, and perceived relevance of ESD (Cronbach's alpha = 0.72-0.79). Paired t-tests were run of a pre-post comparison of students' attitudes and beliefs and revealed that innovation- and ESD-related SE increased significantly in both modules, whereas the perceived relevance of ESD remained at a high level (Table 8). The only statistical differences between the two cohorts were the different pre-values for ESD-related SE.

Table 8: Attitude scales – Paired t-tests (pre-post comparison)

	Pre-test			**Post-test**					
	N	*M*	*SD*	*N*	*M*	*SD*	*df*	Cohen's *d*	Sig.
Innovation-related self-efficacy (1-4 Likert scale)									
2nd Semester	48	**3.13**	.40	47	**3.17**	.34	45	**0.15**	
4th Semester	34	**3.02**	.31	33	**3.17**	.37	32	**0.36**	*
ESD-related self-efficacy (1-4 Likert scale)									
2nd Semester	49	**2.98**	.37	45	**3.28**	.28	44	**0.80**	**
4th Semester	34	**3.12**	.35	33	**3.25**	.33	32	**0.39**	*
Perceived relevance of ESD (1-4 Likert scale)									
2nd Semester	49	**3.55**	.34	47	**3.60**	.40	46	**0.12**	
4th Semester	34	**3.44**	.40	34	**3.46**	.39	32	**0.06**	

** Significant at the .01 level (2-tailed)
* Significant at the .05 level (2-tailed)

5.3 How students perceived their learning process in connection with their learning outcomes

Concerning the students' perceived learning processes and outcomes, we identified emerging themes for each semester that detail specific key moments and how these moments contributed to different learning outcomes (for an overview, see Figure 2 for the 2nd semester and Figure 3 for the 4th semester).

Based on the 2nd semester focus groups and reflections, three key themes emerged regarding the students' learning processes and perceived key moments or drivers of learning:

(1) the trinity of learning formats (lecture, tutorial and seminar);
(2) the practical implementation; and
(3) the exchange with others.

Each theme appears to have contributed to several learning outcomes. While most learning outcomes mentioned by the students can be assigned to teaching skills (PCK), raised awareness, behavior change, or the willingness to implement ESD in their future careers as teachers (attitude), content-related knowledge gains (CK) occurred only sporadically.

Overall, the students appreciated the different learning formats of the course and recognized their different purposes. Lectures were perceived of as a format for learning more about the theory of ESD and as generally being a place of knowledge transfer. Conversely, the seminars offered the opportunity for students to apply knowledge and to practice practical implementation:

> Both formats were appreciated as *"the link between the different learning formats of lectures and seminar sessions allowed for connected learning"* (S2_567). While the practical implementation, in particular, taught students *"how to break down complex topics for children"* (S2_537), the interplay of *"content from the lecture [...], examples from the tutorial, and the practical implementation"* (S2_530) fostered students' general competence in planning ESD teaching- and learning units: *"What we learned is to plan a teaching and learning unit. I do not think that we could do it now, off the cut, but we gained an understanding of what is relevant and could probably deal more flexibly with a similar assignment. And I think that is a central – if not the most central – skill you need if you want to teach"* (S2_506).

With respect to changes in attitudes, students reported an increased awareness of environmental issues:

> In detail, *"the complexity of sustainability"* was – at least according to S2_577 – triggered by talking about mobility and accessible resources in the seminar.

Furthermore, students mentioned actual behavioral changes:

> Motivated by finalizing the first assignment – in which *"everything came together and suddenly made sense"* – S2_550, for example, *"started to rethink and integrate sustainability more into [his/her] life, like reducing waste production."* While learning moments that led to behavioral change ranged from different learning formats to personal shopping experiences, S2_506 also claimed that *"even privately, sustainability has become an important topic that influences [his/her] perspectives and [he/she] think[s] that is also a consequence of the seminar"*.

Another aspect driving students' learning processes was the exchange with others, particularly with fellow students:

> This helped them to understand and implement theoretical foundations, such as the *"interconnection between the different ways of thinking"* (S2_550).

In addition to the first two outcomes of the course, many students formulated their willingness to implement ESD in their future career at the end of the course:

> However, whereas some stated that *"there is no doubt that [they] will implement ESD in [their] future career as a teacher"* (S2_506), others were more hesitant, saying that this implementation may not occur *"as detailed as it was taught in this course"* (S2_513).

In addition to these learning outcomes, students mentioned limiting factors that might have a negative impact on the outcomes:

> One such limiting factor was a lack of practical experience at this point in the educational program, which allowed students to realize that *"more knowledge about learning principles and practical experience is required to get a feeling of how to design teaching and learning units."* Consequently, students emphasized the need for continuation and repetition, as ESD *"might get lost over time if not continuously repeated"* (S2_503).

Students also critically reflected on the feasibility of ESD in practice:

> They were not sure *"if [they] would have the opportunity to actually implement it later at school"* (S2_531) or if they were already at a point of being able to design and implement entire learning units. As one student stated, *"The theoretical foundation of implementing ESD should now be laid out. We only have to become confident in applying it"* (S2_503).

Data from the 4th semester cohort revealed two key aspects relating to the learning process:

(1) self-directed group work; and
(2) collaboration with practitioners,

both of which led to different learning outcomes. Similar to the 2nd semester, these outcomes mainly related to pedagogical- or project-management skills, such as collaborating and communicating (PCK) and students' motivation to implement ESD in their future careers as teachers (attitude).
Above all, students appreciated the self-directed group work:

> *"Although we split up in groups, we didn't lose track of the overall objective"* (S4_103).

Exchange and cooperation with others in different group constellations helped students to develop shared objectives and work out jointly consistent products corresponding to the task:

> *"Over and over again, we somehow had to manage to discuss […] and bring everything together"* (S4_104). This group work also led to strong willingness to assume responsibility and ownership of work packages *"because everybody somehow did everything punctually […] and everyone really stuck to deadlines"* (S4_114). Moreover, *"what is recurring in this cooperation […] is to take responsibility"* (S4_103).

Students also valued the close collaboration with practitioners:

> An important support mechanism was the direct feedback during the work process, such as *"the discussion and presentation with practice partners when [they] 'received feedback and could clarify queries'"* (S4_101). Authentic challenges also *"created practical relevance […] that led to real-world learning experiences"* (S4_114).

Generally, students perceived and appreciated ESD as an iterative process. As One student stated:

> *"You can re-develop and re-design everything over and over again. There are so many possibilities for action"* (S4_107).

These key learning moments were identified by the students as having had an impact on specific learning outcomes. By participating in the seminar, they first and foremost felt more capable of communicating and collaborating:

> *"When you had a great idea in mind but it wasn't supported by the others at first, […], you had to learn how to deal with many different interests"* (S4_103).

Furthermore, most of the students noticed that they were able to plan activities and to act strategically after the seminar since they had learned how to apply project-management tools:

> *"The first thing is project management. […] Generally, [you learn] how it works and everything you should consider in this context"* (S4_114). Moreover, the students had to learn how to deal with uncertainties *"because [they] first had two sessions in which [they] drafted random ideas. And then, for the first time, [they] realized what might actually be viable"* (S4_102).

Ultimately, the majority of the students verbalized having the motivation and volition to actively create and implement ESD learning opportunities in their future careers. As one student stated:

> *"This will definitely be a major component for me in basic social- and science studies"* (S4_107), which underlines the perceived relevance of ESD.

For the students, ESD also provided a high degree of freedom to pursue their own ideas:

> *"You can do so much with ESD. It's not only about discussing how to deal with climate change. There is so much more"* (S4_106).

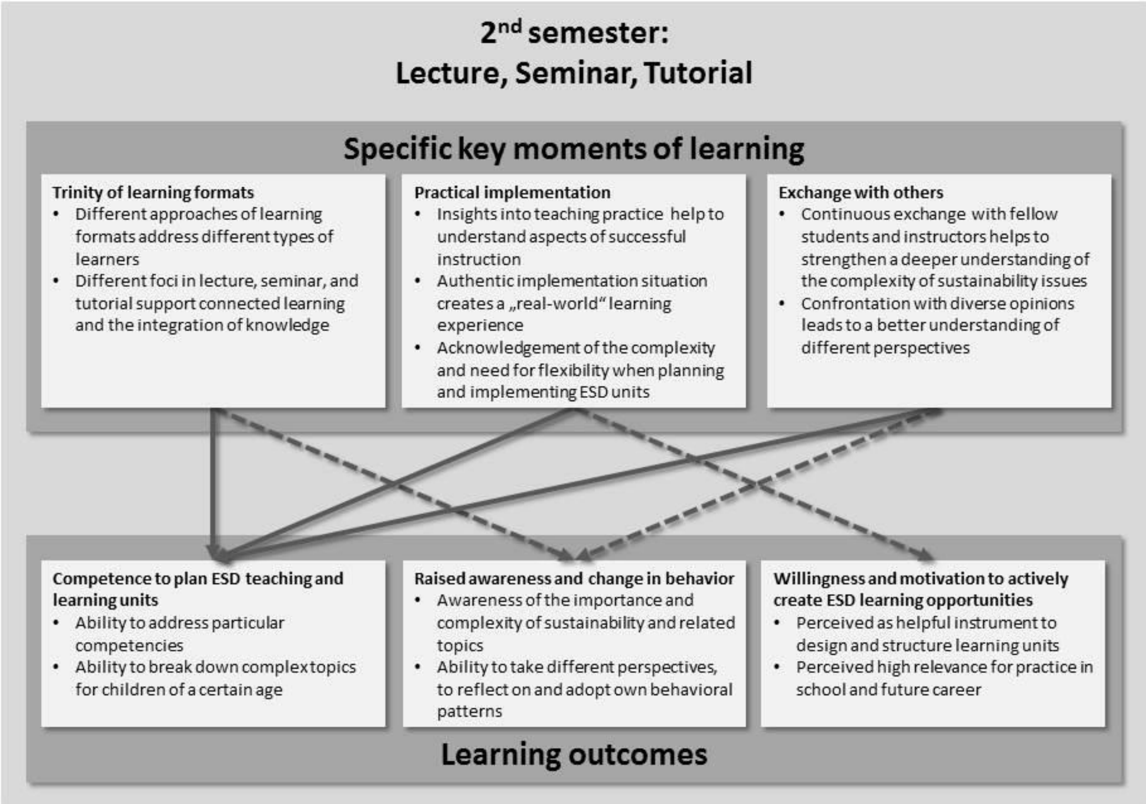

Figure 2. **Key moments and learning outcomes 2nd semester**

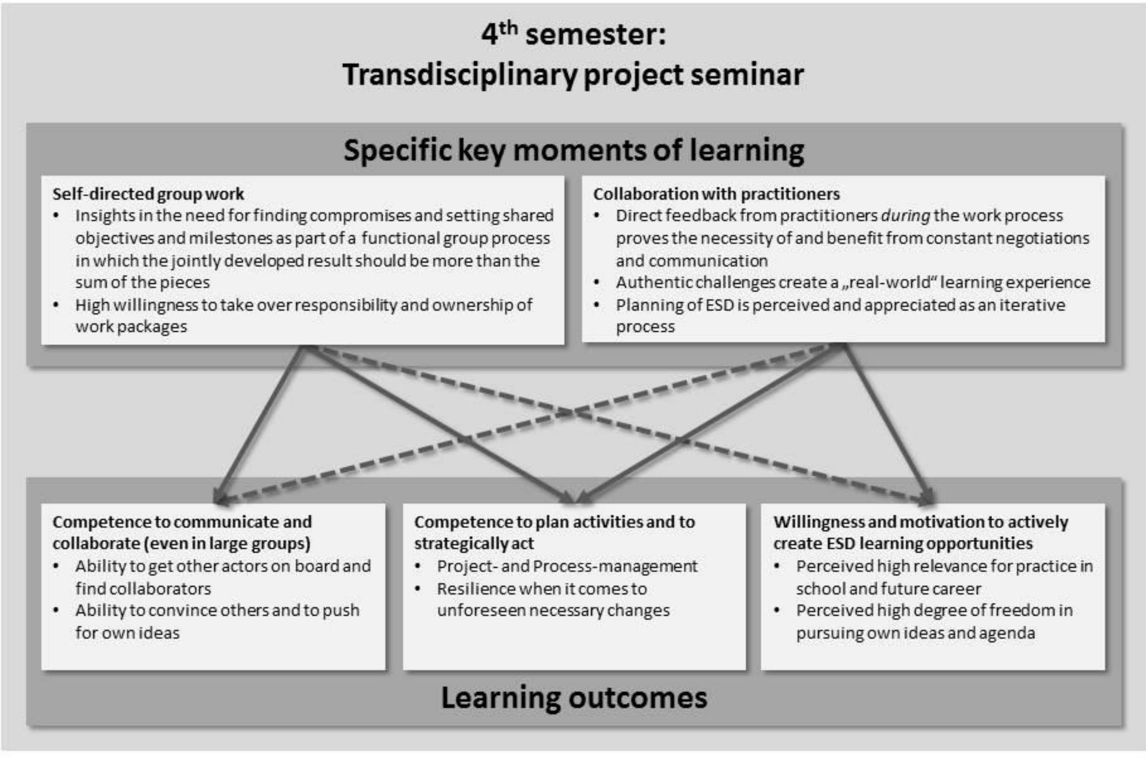

Figure 3. **Key moments and learning outcomes 4th semester**

6 DISCUSSION

The literature on teacher ESD lacks a consensus regarding what the most relevant elements of ESD-specific (professional-action) competences are and how they should be addressed. While Redman and Redman (2017) point out the importance of strengthening subjective knowledge to achieve behavioral changes, Singer-Brodowski (2017) highlights the development of PCK as an essential aspect of the professional development of educators. Kieu et al. (2016), on the other hand, emphasize that the evaluation of ESD courses should focus more on attitude change and motivation. The present study provides a holistic approach to assessing students' competence development in terms of ESD. By using Bertschy et al.'s (2013) competence model as a theoretical basis, it facilitates the detailed analysis of the development of CK and PCK and of changes in motivational aspects and beliefs (attitudes). To capture a rich picture of students' learning, a mixed-methods research approach was used that enabled not only a competence assessment but also deeper insights into learning processes and into the drivers of and barriers to competence development.

While relying on existing instruments to capture ESD-related attitudes, no instrument to assess PCK could be found in the literature. The instrument we developed used case studies and rated the performance of students' responses, which offered rich insights despite coming with certain limitations. For example, the rating scheme did not measure the extent to which the students elaborated on their answers. Moreover, the open-response format left room for different degrees of students' willingness to invest time and effort in answering and interpretation on the part of the researchers. Finally, the given examples of the learning principles differed in terms of their levels of detail, and the data suggest that they also differed in terms of how easy they were to answer. These concerns will need to be taken into greater account in the further development of the instrument.

A number of interesting results emerged regarding our three primary research interests of what students bring to the modules, what they learn in the modules, and how they learn. Data indicate that the younger, 2nd semester cohort had more experience in professional environments. Furthermore, they were motivated to a greater extent by social utility values that go beyond their future students and focus more on making a difference at an institutional or societal level.

This finding is in line with the slightly stronger pro-environmental attitudes of the 2nd semester cohort. Both cohorts came into their respective courses with strong pro-environmental attitudes, which were notably higher compared with other student cohorts, such as undergraduate psychology students at the University of Utah (Amburgey and Thoman, 2012), Turkish pre-service German teachers (Alyaz et al., 2016), and 1st year students from five different programs at Otago University in New Zealand (Harraway et al., 2012). However, this finding may not indicate a more pro-environmental student population *per se* as our sample consisted predominately of female students, who have been repeatedly shown to have more pro-environmental worldviews (Zelezny et al., 2000; Shephard et al., 2009). Moreover, these results might also be linked to the fact that all students at Leuphana University complete a module on sustainability in their first semester (Michelsen, 2013), which may be more actively present in minds of the 2nd semester cohort.

When it comes to meeting learning outcomes, the results are ambiguous. While we saw significant increases in both modules with regards to ESD-related SE, innovation-related SE increased significantly only in the 4th semester course. This corresponds to the fact that this module focuses on implementing innovation within the scope of a whole school approach. The 2nd semester cohort, on the other hand, focuses on the implementation of ESD-related teaching and learning units. Little change occurred in perceived ESD relevance which might be at least partly explained by relatively high pre-course values – a phenomenon that corresponds with earlier findings by Tomas et al. (2015). The higher pre-course values of 4th semester students regarding ESD-related SE met the expectations as the concept of ESD had already been introduced to these students the year before. The increase in students' self-efficacy – together with what we found in the focus groups and from other qualitative data – demonstrate an increased awareness of the importance of ESD as well as students' willingness to implement it in their future careers. This finding underlines the potential of the specific design of both modules to have an impact on attitudes and the motivation to actively create ESD learning opportunities.

Although not a specific focus or learning objective of the two modules, a significant increase in the complexity of students' understanding of the term *"sustainability"* was found. In accordance with Symons (2008), this might be an additional factor promoting ESD-related SE in students. Their successful improvement in PCK is more unclear. The development of students' rating abilities cannot simply be linked to their educational level even though more expertise was expected the further along students were in their study program.

We can, however, find increased proficiency with regard to some ESD learning principles. Interestingly, these principles played the most prominent role in the seminar projects of the two modules – namely participatory orientation and the participatory approaches in the 2nd semester and connected learning and projects dealing more with complexity and interconnectedness in the 4th semester. Nevertheless, further elaboration of the assessment tool and re-testing the same 2nd semester students during their 4th semester may lead to more detailed and robust insights.
In the end, both cohorts displayed a significant increase in the complexity of their sustainability understanding (CK) as well as in their self-efficacy; moreover, their motivation to implement ESD in their future careers increased (attitude). Additionally, the results related to PCK provide first indications that both course formats and their pedagogical approaches help in developing various pedagogical skills in accordance with the individual structure and thematic focus of each module. This finding is supported by qualitative data and statements by students in the focus groups. Regarding ESD-specific professional action competence for teachers, according to Bertschy et al. (2013), the students' *knowledge* and *ability* as well as their *motivation* and *volition* were improved by the two courses under investigation. However, skills in project-management and the ability to communicate and collaborate with different stakeholders – as seen in the 4th semester cohort – cannot be directly correlated with Bertschy et al.'s model. Nevertheless, in context of ESD, these skills and abilities can be transferred, for example, to Vare's (2018) competence framework, particularly to its learning outcomes of *practice* and *reflection*.

7 CONCLUSION

When we compare what has been learned in the two modules, it is necessary to take the different intended learning outcomes into account at the outset. Due to the thematic foci and formulated learning objectives, learning progress in the 2nd semester was primarily expected to occur in connection with PCK. Thus, whereas students became more familiar with the concept of sustainability and felt more capable of dealing with the complexity of sustainability-related issues, the main focus of the course was on creating teaching- and learning units for ESD by addressing certain competencies. In the 4th-semester course, however, the main emphasis lay on the development of competencies beyond CK and PCK.

This emphasis occurred in the focus groups, where students themselves highlighted the further development of their ability to plan activities for ESD and to collaborate with different stakeholders. However, while qualitative data suggest that students were aware of and appreciated the different foci in the modules as they represented important yet distinct aspects of becoming teachers for ESD, quantitative data do not provide as clear a distinction of what aspects of ESD-specific (professional action) competence were developed. Competence development appears to be more of a continuous learning process over the course of this specific bachelor program. Hence, the chance for systematic and holistic competence development needs to be provided not only once but also in recurring courses during the entire process of educating future teachers at universities and beyond.

Nevertheless, qualitative data revealed that the practical implementation in the 2nd semester and the collaboration with practice partners in the 4th semester strongly affected learning outcomes, such as the development of the competence to plan ESD learning units. These elements can also lead to increased motivation to implement ESD, which corresponds with others' findings (Corney and Reid, 2007; Redman, 2013; Singer-Brodowski, 2017) and confirms the need for learning formats that facilitate authentic, real-world encounters and problem-oriented tasks in combination with the challenge of collaborating with partners in practice to support the development of ESD-specific competencies in teacher education.

Note:

The abbreviations in the results section refer to anonymized ID numbers of the participants (IDs beginning with "S2_" represent students in the 2nd semester and IDs beginning with "S4_" relate to students in the 4th semester).

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APPENDIX A – *Instrument to assess the development of PCK* - Exemplary Case Study

Who does chocolate make (un)happy – Teaching unit on the topic of chocolate
12-week-long teaching unit for all class levels of elementary schools (as well as across levels) on the topic of chocolate.

Learning objectives:
The children know the different stakeholders along the production process of chocolate as well as their individual interests and can identify interactions between them. They can critically reflect on their own role regarding the consumption of chocolate and differentiate and justify criteria for consumer decisions. They recognize possible effects of their own actions on the stakeholders and understand that there are various alternative options for action, each of which leads to different outcomes. They can take a variety of the stakeholders' viewpoints and seek solutions according to their respective demands.

Process:
To start off the unit, the children think about what it would be like if chocolate didn't cost anything. Afterwards, they learn about some of the stakeholders within the field of chocolate and discuss what impact free chocolate could have. During an excursion to the supermarket and subsequent taste testing they learn about various products, prices, labels, and the interests of the consumers. Over the course of the class, the children learn about the production process of chocolate: From the cocoa bean on the plantation to the chocolate in the supermarket. In addition, they talk about the countries growing the beans, the conditions under which they are cultivated and the trade in cocoa. Through role playing games the children reflect on the demands of the different stakeholders as well as the impact of changing conditions. The class closes with a renewed debate on the initial question.

Task: How well can the following learning principles be put into practice in the given example? Please tick one box each and give a brief explanation for your choice.

Vision orientation
The lesson is aimed at a desired plan for the development of society and not a disaster scenario.

- ◯ Can be put into practice to a large extent
- ◯ Can partly be put into practice
- ◯ Can hardly be put into practice
- ◯ Cannot be put into practice at all
- ◯ Not clear from the information available

Please give a brief explanation of your evaluation
(where appropriate based on a concrete example)

Connected learning

Interconnectedness in the fields "local – global", "environment – economy – socio-culture" and "present-day – future" is implemented in class in a clear and instructive way.

- ◯ Can be put into practice to a large extent
- ◯ Can partly be put into practice
- ◯ Can hardly be put into practice
- ◯ Cannot be put into practice at all
- ◯ Not clear from the information available

Please give a brief explanation of your evaluation
(where appropriate based on a concrete example)

Participatory orientation

Pupils take part in selected decisions which concern the child alone or the class as a whole, and they share the consequence of these decisions.

- ◯ Can be put into practice to a large extent
- ◯ Can partly be put into practice
- ◯ Can hardly be put into practice
- ◯ Cannot be put into practice at all
- ◯ Not clear from the information available

Please give a brief explanation of your evaluation
(where appropriate based on a concrete example)

Calculating the rating score:

Student rates "can hardly be put into practice": **2**
Expert rates "can be put into practice to a large extent": **4**

Difference between student and expert: **4-2 = 2**

Rating Score = Max Score – |Difference (Student vs. Expert)| = 4 – 2 = 2

APPENDIX B – *Students' motivation to become a teacher* – coding details

Code	*Meaning*	*Exemplary answers*
Socialization influence	Social dissuasion & persuasion	*"My family and friends said I would make a good teacher."*
Prior teaching and learning experience	Experiences made in previous teaching and learning scenarios	*"I already did an internship at an elementary school. That experience had an impact on my career aspiration to become a teacher."*
Perception of the task	High demand, social status, salary	*"It is a great challenge that I am ready to take up."* *"Positive feedback through success as well as the gratitude on the part of children and their parents."*
Self-perception	Perceived teaching abilities	*"I like helping others and I am good at conveying things. Since my work at the Clara-Grunwald School, I trust in my ability to be a good teacher."*
Intrinsic career value	Interest in and enjoyment of the career as a teacher	*"To have a versatile job that I enjoy and where I can work with children."*
Personal utility values	Job security, time for family, job transferability	*"I want a (financially) secure job (...)."* *"(...) personal reasons are paramount, such as good conditions to start a family."*
Social utility values – focus on children	Shape the future of children	*"I want to challenge and support kids and help them on their journey through life."*
Social utility values – focus on society	Make a social contribution on an institutional and/or societal level	*„My motivation is to make a contribution to the world and shape the future by teaching kids."*

APPENDIX C – *Students' understanding of the term 'sustainability'* – scoring details

Time perspective		
Score	***Meaning***	***Exemplary answer***
0	no time perspective mentioned	-
1	future perspective	*"To act environmentally conscious and future oriented […]."*
2	intergenerational perspective	*"To me, sustainability means to reduce my own ecological footprint so far as future generations can live as carefree as I do."*
3	inter- and intragenerational perspective	*"Sustainable development means that we should treat our resources carefully and distribute them fairly so that both generations of today and the future can fulfill their basic needs."*
Dimension orientation		
Score	***Meaning***	***Exemplary answer***
0	no dimensions mentioned	-
1	one dimensional perspective	*"In my opinion, sustainability implies that we should live in harmony with nature."*
2	multi-dimensional perspective	*"Sustainability means the interplay of ecological, economic, social, and cultural perspectives."*

APPENDIX 2 – A matter of connection: The 4 Cs of learning in pre-service teacher education for sustainability

Citation

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Abstract

Teacher education for sustainability (TEfS) aims to prepare future educators for their role as societal change agents by developing in them specific sustainability competencies. Whereas previous literature has dealt extensively with concepts and empirical work connected to learning objectives in TEfS, this paper links these learning outcomes, or what student teachers learn in individual course offerings, to the learning process—how they learn. In this way, we reveal factors of common teaching and learning formats in TEfS that may either foster learning or hinder it. At Arizona State University (ASU), the TEfS course *Sustainability Science for Teachers* (*SSfT*) is a mandatory component of all elementary-education (K–8) programs. As similar requirements appear in more and more teacher-education programs, it is important to understand how learning in course offerings like *SSfT* should be designed in order to best support student achievement of intended learning outcomes.

More than 100 pre-service teachers and four instructors, all taking or teaching the SSfT course at ASU, participated in this single explanatory case study, which adopted a mixed-methods approach. To richly portray students' learning processes, as well as the outcomes of their learning in the course, this study involved non-participatory observations, a pre/post-course survey, end-of-semester focus groups, and semi-structured interviews. Its findings suggest that four forms of connection (*the 4 Cs*) namely personal, professional, social, and structural, are particularly impactful on students' learning in the SSfT course. Finally, these insights are accompanied by a set of recommendations as to what to consider when planning and designing similar TEfS course offerings. Future research should focus on the K–12 students of educators trained in education for sustainability (EfS) to understand the extent to which educators can use their new skills and knowledge to empower and motivate K–12 students to persistently engage in real-world projects that contribute to systemic change.

Keywords

teacher education; education for sustainability; education for sustainable development; learning process; drivers & barriers; competence development; connection

1 INTRODUCTION

The potential of education for sustainable development (ESD) to contribute to the much-needed global sustainability transformation is widely recognized in the literature (Lotz-Sisitka et al., 2015; Barth and Michelsen, 2013). Higher education institutions serve a critical role in educating future change agents and equipping them with the competencies required to engage in leading society on a more sustainable path (Cortese, 2003). The essential role of teachers in creating effective learning environments and success in students' learning (Hattie, 2009) has also been acknowledged by the United Nations Educational, Scientific and Cultural Organization (UNESCO). In fact, UNESCO dedicated one of five priority action areas on the ESD roadmap for 2030 to *"building the capacities of educators to more effectively deliver ESD"* (UNESCO, 2020).

Competent and committed teachers are required to advance sustainability and ESD (Timm and Barth, 2020). Notably, this focus on teacher education for sustainable development (TESD) is not limited to political agendas. In academia, a growing body of research has addressed TESD (Evans et al., 2017) and the integration of sustainability in higher education programs (Barth, 2015). Furthermore, universities worldwide have designed and implemented sustainability offerings in their teacher education programs (Andersson, 2017; Brandt et al., 2019; Jorge et al., 2015; Tomas et al., 2017). Corresponding to the identified need for sustainability-literate teachers (Nolet, 2009), much of the recent research has dealt with the actual achievement of intended learning outcomes (ILOs) and the development of specific competencies (Evans et al., 2017). However, understanding what must be considered when designing TESD courses to support competence development in pre-service teachers requires a shift to considering how students learn (Barth, 2015). According to Backman et al. (2019), this calls for *"impartial research where students' individual experiences are studied in depth [to investigate] the multitude of influences on their learning"* (Backman et al., 2019, p. 149).

Previous attempts have been made to link specific pedagogical approaches to the development of competencies (e.g., Dlouhá and Burandt, 2015; Lozano et al., 2017). However, Brandt et al. (2019) first operationalized the model of ESD-specific professional action competence for teachers (Bertschy et al., 2013), purposefully linked learning processes and outcomes, and revealed concrete mechanisms that fostered competence development in the hybrid course environment of a TESD course at Arizona State University (ASU) in the United States of America (USA) (Brandt et al., 2021).

This empirical work highlighted that personal, professional, social, and structural connections (i.e., *the four Cs*) are significant factors that impact learning in TESD. Based on a dual explanatory case study (Yin, 1984), this paper investigates how far these findings can be confirmed for the subsequent cohort enrolled in the *Sustainability Science for Teachers* (*SSfT*) course at ASU and a hybrid TESD course at Leuphana University in Germany, called *Education for Sustainable Development* (*ESD*).

2 THEORY

While much research elaborates competencies for sustainable development and discusses various pedagogical approaches, too little has thus far investigated the links between common teaching and learning formats in TEfS, factors of student learning processes that hinder or support learning, and the real achievement of intended learning outcomes (Svanström et al., 2008).

According to Shephard (2008), sustainability initiatives in higher education are extremely diverse. Still, many refer to the idea that learners should develop a certain set of competencies, along with the related knowledge, skills, and attitudes (e.g., Azeiteiro et al., 2015; Lambrechts et al., 2013; Pappas et al., 2015). In teacher education, this is reflected in the overall aim of developing student teachers' *"capacity and (in some cases) commitment to embed SE [sustainability education] into their own teaching practices"* (Evans et al., 2017, p. 411). A decade ago, Nolet (2009) coined the term of *"sustainability-literacy"* in the teaching context, emphasizing the *"ability and disposition to engage in thinking, problem solving, decision making, and actions associated with achieving sustainability"* (p. 421). Since then, several approaches to teachers' EfS competencies have been introduced and discussed (e.g., UNECE, 2013; Sleurs, 2008; Timm and Barth, in press; Vare, 2018). Translating the general key sustainability competencies laid out by Wiek et al. (2011) into specific ways of thinking (WOT), Warren et al. (2014), for instance, introduced a Sustainability Education Framework for Teachers (SEFT) that functions as *"a conceptual framework for analyzing and considering sustainability problems and solutions through a networked approach"* (p. 5). Building on Shulman's (1987) categories of what constitutes a competent teacher, Baumert and Kunter (2013) designed a model of teachers' professional action competence; that model was contextualized for EfS by Bertschy et al. (2013).

Their concept of an *"ESD-specific professional action competency for teachers"* considers sustainability-related content knowledge (CK), pedagogical content knowledge (PCK) and the drive to implement EfS at the school level (attitude) to be key learning objectives. Accordingly, Brandt et al. (2019) operationalized this construct by measuring changes in students' understanding of the term sustainability (CK) and their ability to apply EfS-specific didactic principles (PCK) (Künzli and Bertschy, 2008), as well as their EfS-related self-efficacy (Tomas et al., 2015), perceived relevance of ESD (Ibid.) and pro-ecological worldviews (Dunlap et al., 2000) (attitude).

Among the most common pedagogical approaches in TEfS are place-based experiential methods and inquiry methods, as well as modeling strategies for EfS that student teachers can apply in the future (Evans et al., 2017). Further prominent teaching and learning formats, as modes of instruction, include discussion and reflection techniques (e.g., Corney and Reid, 2007), concept mapping (e.g., Åhlberg et al., 2005), role-plays (e.g., Aleixandre and Gayoso, 1996), problem-based inquiries (e.g., Bore, 2006), problem-solving activities (e.g., Jenkins, 1999), future-scenarios exercises (e.g., Paige et al., 2008), and lecture-style delivery of information (e.g., Firth and Winter, 2007). Acknowledging the lack of research on the link between competence development and individual teaching and learning formats, Lozano et al. (2017) undertook an attempt to close this gap. While the researchers do show that case studies, project- and problem-based learning, community-service learning, jigsaw teamwork, participatory action research, place-based environmental education, and lifecycle analyses are all generally promising approaches, they note that covering all competencies requires, in fact, a diversity of methods (Lozano et al., 2017). In the field of teacher education, research regarding the effectiveness of pedagogical strategies is rather scarce (Evans et al., 2017). Kalsoom and Khanam (2017) showed that inquiry-based learning may yield positive changes in student teachers' knowledge and attitudes regarding sustainability issues. In the context of a hybrid sustainability course, Shelton et al. (2017) suggest that interactive digital storytelling videos may outperform conventional videos insofar as their potential to increase students' engagement and learning in the area of content knowledge (CK). Referring to the development of ESD-specific professional action competence, Bürgener and Barth (2018) describe the promising approach of transdisciplinary living laboratories that incorporate the idea of scaffolding (Hannafin et al., 1999) and include project work with practice partners. Brandt et al. (2019) elaborate on the additional potential of a blended learning course with lectures (flipped classroom), tutorials, and project-based seminar sessions in which students cooperate with partnered schools.

Considering the link between learning processes and related outcomes, this paper seeks to open the much-cited 'black box' of learning in an attempt to reveal what actually supports or hinders students' learning on their paths to become change agents equipped with the knowledge (CK), skills (PCK) and motivation (attitude) required to implement EfS in K–8 schools.

Focusing on learning in higher education at large, Biggs and Tang (2011) present a list of factors supportive of students' learning. Among other items, they highlight the importance of motivation, claiming that learners must understand the value of engaging in the learning process. Indeed, they emphasize the role that instructors and teaching staff play in increasing students' motivation, supporting learning activities that allow for deep learning, and providing powerful feedback during the learning process. This is in line with Biggs and Tang's (2011) idea of social learning, in which students learn both with and from one another through pedagogical approaches like peer tutoring and discussion groups. Also seen to improve learning are building on existing knowledge and drawing structural interconnections between topics. Anxiety, on the other hand, which may be caused by the perceived threat of failure, is identified as a major barrier to learning.

In EfS, we have seen long-lasting paradigms shift from teacher-centered pedagogies to learner-centered ones, from input-to output-orientation, and from content-to problem-and-solution-orientation (Barth, 2015). Considering the oft-cited theory–practice gap in general teacher education (Shulman, 1998), Frisk and Larson (2011) emphasize the importance of creating real-life learning opportunities in TEfS, through which the relevant competencies can be developed, tested, and reflected. The value of such opportunities is supported by the idea that engaging in early collaboration with schools and forming links to educational practice enhance student teachers' learning (Bürgener and Barth, 2018). In connection with the online delivery of sustainability courses in teacher education, Whitehouse (2008) describes the lack of *"synchronous contact"* and of the clarifying exchange of ideas as a hindering factor. Varga et al. (2007) and Bore (2006) further report that not all pre-service teachers are accustomed to student-centered and constructivist approaches to learning and may therefore experience difficulties with such approaches, perhaps even manifesting a tendency to resist them. Yet Littledyke and Manolas (2011), who introduced ideological and epistemological drivers and barriers for EfS, argue that constructivist pedagogy *"is particularly relevant"* (p. 93). Epistemologically, we here refer to ideas of constructivism, conceiving of teaching and learning not as matters of transmitting information but rather of engaging students and centering them—and their learning processes—as the focus (Glasarsfeld, 1995).

3 METHODOLOGY

To address the research gap identified and shed light on the link between individual teaching and learning formats (or instructional strategies) in TEfS, related factors that support or hinder students' learning processes, and the achievement of specific learning objectives, this paper seeks to answer the following research question:

What supporting and hindering factors impact pre-service teachers' learning processes in teacher education for sustainability (TEfS), and how do their effects on the achievement of intended learning outcomes at the course level vary according to the applied teaching and learning formats?

This research is a single explanatory in-depth case study (Yin, 1984) focusing on the course *Sustainability Science for Teachers* (*SSfT*) taught at Arizona State University (ASU). In this context, we focus on three closely interrelated sub-questions:

(i) *To what extent are the intended learning outcomes of the course actually achieved?*

(ii) *What are the primary supporting and hindering factors impacting the learning processes of pre-service teachers in connection with different teaching and learning formats?*

(iii) *What individual key moments of learning provide concrete insights into learning processes that impact students' achievement of curricular learning objectives?*

3.1 The case

The *SSfT* course—designed by an interdisciplinary team of scientists, educators, and design experts—launched at ASU in the fall of 2012. It is a three-credit, fifteen-week course, and it is mandatory across all elementary-education (K–8) programs at ASU. The course has been further refined and developed into various iterations since its inception in 2012. It is geared towards preparing pre-service teachers to be sustainable citizens and educators who implement EfS with their future students (Merritt et al., 2019).

Its primary objective is to develop sustainability literacy among pre-service teachers by (a) providing EfS-related content knowledge and fostering students' understanding of sustainability concepts and their applications (CK); and (b) providing pedagogical content knowledge for EfS and developing students' ability to apply ways of thinking (WOT) to explain sustainability concepts (PCK).

The four WOT—strategic, futures, values, and systems thinking—are connected to the key competencies in sustainability (Wiek et al., 2011) and provide an overarching *"sustainability education framework"* (Warren et al., 2014), engaging students with the course content. These WOT help the students to think deeply about the content from different perspectives, imagine various scenarios for the future, and analyze systems in order to strategize how best to initiate change in society (Merritt et al., 2018). The course uses a flipped-learning approach in which content is shared in the course's online component through "digital storytelling" (Robin, 2008). Students watch videos related to the weekly topics, take quizzes to assess their understanding of content, and work on reflective assignments. As a second component of the course, students come to class for 75 min each week to discuss concepts and learn pedagogical strategies to integrate course content into their future teaching practices (see Fig. 1). While the class is divided into several cohorts, all instructors teach the same online content, are provided with weekly lesson plans, and meet monthly to discuss pedagogical strategies. By exploring sustainability-related topics (see Figure A), pre-service teachers learn about sustainability concepts, develop EfS competencies, and engage with various pedagogical approaches with the goal of fostering their ability to effectively teach EfS in K–8 settings. The in-class lessons, which vary each week, include specific activities such as the 'Hot Dog' activity—a systems-thinking endeavor in which students map all of the inputs, outputs, and components of the food system needed to produce a hot dog (see Appendix A). The final project and overarching assignment of the course consists of a student-designed digital artifact that outlines a five-day learning unit on a sustainability topic of the student's choice. A broader case description provides greater detail about the contextual conditions, as well as individual learning activities, of the *SSfT* course (Brandt and Barth, 2020).

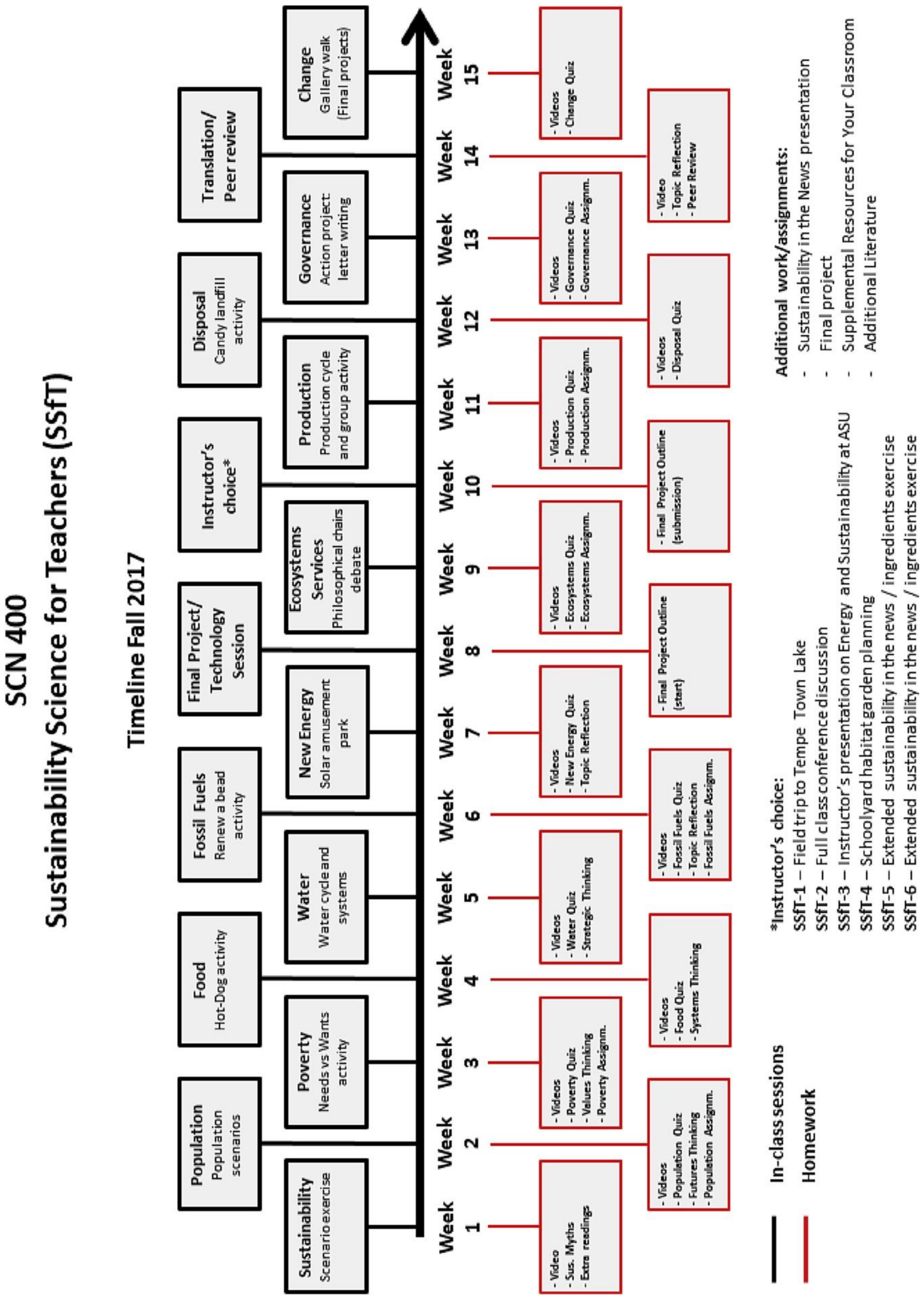

Fig. 1: *SSfT* course outline (fall 2017)

3.2 Data collection

Data was collected during the fall semester (August–November) of 2017, adopting a mixed-methods approach in order to capture a rich image of the students' learning processes and outcomes (see Table 2). Data collection was approved by the Institutional Review Board. The 2017 fall cohort 2017 consisted of 122 students—grouped into 6 sub-cohorts (SSfT-1–6)—of which 104 consented to participate in the research (see Table 1).

Table 1: *SSfT* cohort (fall 2017)

NUMBER OF STUDENTS (CONSENTED) Student IDs: S1_300–S1_421	122 (104)		
GENDER	Female:	91.9 % (72)	
	Male:	8.9 % (7)	(No reply: 25)
AGE	20 years or younger:	27.6 % (21)	
	21-25 years:	59.2 % (45)	
	26 years or older:	13.2 % (10)	(No reply: 31)
NUMBER OF INSTRUCTORS (CONSENTED) Instructor IDs: T_008–T_011	4 (4)		

A survey was administered both before and after the course to identify the learning outcomes associated with students' sustainability-related content knowledge (CK) and their motivation to implement EfS (attitude). Non-participatory classroom observations helped to better understand the course context and to account for differences between sub-cohorts. Data on learning processes, as well as on perceived learning outcomes with regard to pedagogical skills in EfS (PCK), were collected through student focus groups of 4–7 participants each and semi-structured interviews with instructors. All instruments, including the detailed survey items, interview and focus-group guides, and all related code books, are available on ResearchGate (Brandt et al., 2020).

Table 2: Overview of instruments

SURVEY To identify students' perceptions of their learning outcomes (CK & attitudes)	**Pre- & Post-course survey (online/LimeSurvey) (n_{pre}=90, n_{post}=79, $n_{pre\&post}$=66)** • New Ecological Paradigm Scale (15 five-level Likert items) (Dunlap et al., 2000) • EfS-related self-efficacy scale (7 four-level Likert items) (Tomas et al., 2015) • Perceived-relevance-of-EfS scale (6 four-level Likert items) (Tomas et al., 2015) • Self-reported definition of sustainability (open item) **Pre-course survey** • Previous work experience (closed item with 8 checkboxes) • Extracurricular activities (closed item with 10 checkboxes) • Motivation to become a teacher (open item) **Post-course survey** • Demographic information (items on age and gender)
FOCUS GROUPS To identify students' perceptions of their learning outcomes (PCK)	**18 end-of-semester focus groups (approx. 35 min.) (n = 95)** encompassing open questions about: (1) How students would describe their learning process, particularly concerning perceived drivers of and barriers to their learning (2) The extent to which they felt they achieved the explicit learning objectives of the course and what the key moments of learning were in this regard (3) What was particularly helpful to their personal learning process and what they would change about the course if they could
INSTRUCTOR INTERVIEWS To identify instructors' perceptions of students' learning processes and outcomes, as well as the specifics of the teaching and learning environment	**4 end-of-semester interviews (approx. 35 min.)** encompassing open questions about: • The instructors' career paths • Their individual approaches to teaching and learning both in general and in this particular course • Their perception of learning processes and achievement of the course-specific learning objectives among their cohort of the fall 2017 semester
NON-PARTICIPATORY OBSERVATIONS To identify the specifics of the teaching and learning environment	**Observation notes (52 sessions)** encompassing notes about: • The teaching and learning environment • The materials and teaching approaches used • In-class activities and learning processes

3.3 Data analysis

The analysis of quantitative survey data was conducted using simple descriptive statistics (frequencies) for the demographics and paired-sample t-tests for a pre/post comparison of attitude scales and changes in students' understanding of the term sustainability over time. To make quantitative analysis of the latter phenomenon viable, students' definitions were coded by two independent researchers against a coding scheme considering both intergenerational and intragenerational perspectives as well as the multidimensional understanding of the concept, resulting in a score from 0 to 5 (see Appendix B). Inter-coder reliability (ICR) was tested, and differences were resolved communicatively.

The qualitative analysis of focus-group and interview transcripts was oriented towards understanding and reconstructing the learning processes and outcomes, following the coding paradigm of grounded theory and applying the method of constant comparison (Strauss and Corbin, 1990). To create a robust coding scheme and ensure ICR, three researchers applied open coding to four of the eighteen focus-group transcripts (>20%), resulting in a code book encompassing both deductive and inductive (in vivo) codes. In search of significant factors impacting students' learning, initially emerging categories such as "course structure," "practical application," "exchange with others," "personal interest," and "preconceptions about science and sustainability" were discussed with the broader research team to allow for different perspectives and interpretations. Through several iterations of axial coding, "connection" was identified as a core category spanning the other phenomena found in the data.

4 RESULTS

4.1 Learning outcomes

We examined the extent to which the intended learning outcomes—increased motivation to implement EfS (attitude and beliefs), sustainability-related content knowledge (CK), and pedagogical content knowledge (PCK)—were actually achieved. Students' attitudes and beliefs were measured against the revised NEP scale developed by Dunlap et al. (2000) to trace ecological worldviews, the perceived relevance of EfS, and EfS-related self-efficacy (SE) (Tomas et al., 2015), with acceptable-to-good Cronbach's Alpha (α) values falling between 0.61 and 0.74.

A pre/post comparison using paired t-tests revealed that students' ecological worldviews, the perceived relevance of EfS, and EfS-related SE increased significantly during the course (see Table 3). Content knowledge (CK) was measured by the changes in students' definitions and understanding of the term *sustainability*. Table 4 depicts the results of the coded answers given before and after the course, showing a significant increase in the complexity of students' understanding of the concept of sustainability.

Table 3: Attitude scales

	Pre-test			**Post-test**					
	N	*M*	*SD*	*N*	*M*	*SD*	*df*	Cohen's *d*	Sig.
Revised NEP scale (15 items; 1–5 Likert scale)									
SSfT fall 2017	62	**3.71**	.42	62	**3.92**	.39	61	**.60**	**
Perceived relevance of EfS (6 items; 1–4 Likert scale)									
SSfT fall 2017	63	**3.54**	.43	63	**3.77**	.31	62	**.59**	**
EfS-related self-efficacy (7 items; 1–4 Likert scale)									
SSfT fall 2017	64	**2.61**	.50	64	**3.26**	.31	63	**1.34**	**

Table 4: Understanding of Sustainability (CK)

	Pre-test			**Post-test**					
	N	*M*	*SD*	*N*	*M*	*SD*	*df*	Cohen's *d*	Sig.
(overall) Sustainability definitions (0-5) time perspective + dimension orientation									
SSfT fall 2017	64	**1.38**	1.03	64	**2.20**	1.15	63	**.62**	**
Time perspective (0–3) 0 = no time perspective, 1 = future perspective, 2 = intergenerational perspective, 3 = intergenerational and intragenerational perspective									
SSfT fall 2017	64	**.78**	.63	64	**1.11**	.86	63	**.38**	**
Dimension orientation (0–2) 0 = no dimensions mentioned, 1 = one-dimensional perspective, 2 = multidimensional perspective									
SSfT fall 2017	64	**0.59**	.66	64	**1.09**	.79	63	**.55**	**

** Significant at the .01 level (2-tailed)

Students' self-reported change in their pedagogical content knowledge (PCK) is assessed through a variety of statements about developing the ability to later implement EfS at the school level. *"Teaching sustainability and combining it with other curricula"* (S1_325), for instance, was explicitly facilitated by this course. However, while some students highlighted that the course prepared them to implement EfS at various grade levels, others reported difficulties in breaking down the complexity of sustainability topics in fashions appropriate to different age groups:

> *"If I wanted to do sixth grade, I feel like even breaking it down to that, without completely like breaking them down, would be difficult."* (S1_341)

Students generally seemed to have gained a certain theoretical understanding of how to implement EfS at the school level, yet they pointed to a lack of practical experience:

> *"I got at least an idea of the topics, to be like, okay, well, I can create a lesson plan …, but it is more just like a basis thing, like it wasn't anything like that I'm able to like go out and teach it right away."* (S1_336)

Referring to the lesson plans from the final project, another student added:

> *"It's preparing me for how I'm going to create my lessons in the future and kind of giving me ideas on what that's like in a real classroom, and of course like maybe now it's not going to work, and I can adjust later on when I gain more experience as a teacher."* (S1_333)

A similar picture emerged with regard to students' ability to apply the four ways of thinking (WOT) to explain sustainability concepts. While some students reported that they *"found it really easy to implement [the WOT] in [their] final project [s]"* (S1_337), others continued to encounter difficulties distinguishing between the WOT: "*they kind of blend together in my mind"* (S1_354). The majority of students, however, seemed to have had an approximate understanding of the WOT. This appearance is confirmed by the assessment made by the course instructors, who reported that students *"seem to grasp that idea"* of the WOT and sustainability issues per se, whereas it remained unclear whether students had become capable of implementing them in their future teaching careers.

> *"We don't perform as well on the learning objectives related to the ways of thinking than we would do on ones related to understanding, you know, sustainability problems across the variety of domains."* (T_008)

4.2 Learning process

Utilizing the analytical paradigm of grounded theory (Strauss and Corbin, 1990), we analyzed learning according to six key elements: (1) the teaching and learning environment (context), (2) the participants and their backgrounds (causal conditions), (3) the learning process (phenomenon), (4) factors supporting or hindering the learning process (intervening conditions), (5) ways of dealing with those intervening factors (strategies), and (6) the different learning outcomes (consequences). In the context of this study, we specifically set out to investigate the phenomenon of learning processes (element 3) and how the pedagogical approaches (element 1), reported supporting or hindering factors (element 4), and related strategies (element 5) impacted the learning outcomes (element 6). Students' individual backgrounds as causal conditions (element 2) were not part of this study's focus.

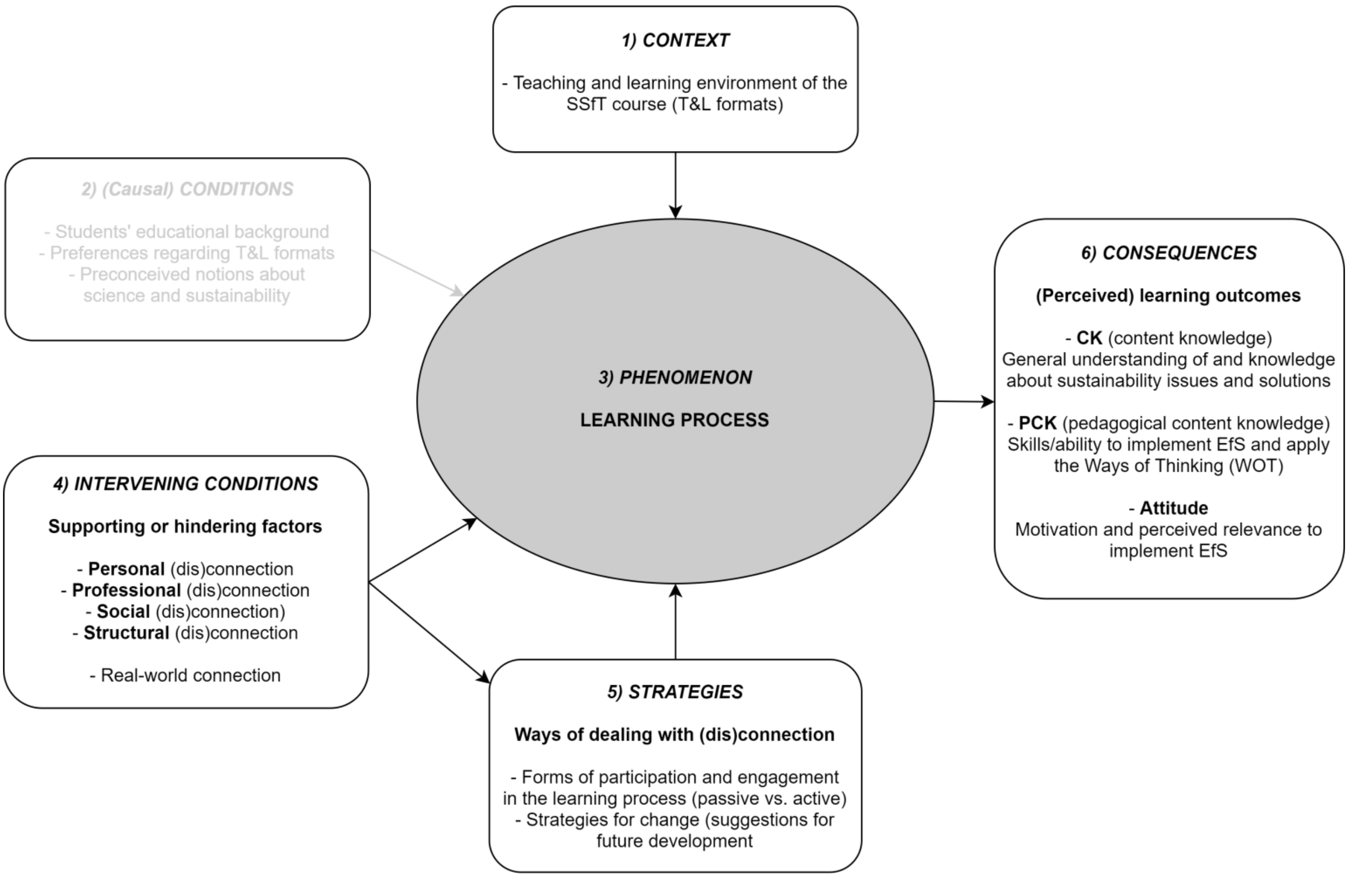

Fig. 2: Axial coding scheme of learning in the *SSfT* course

Fig. 2 shows the axial coding scheme that emerged from the overall analysis. While non-participatory observations informed us about the teaching and learning formats used in the course (context), the survey provided information about students' CK and attitudes as learning outcomes (consequences). Last, but not least, the focus groups shed light on the supporting and hindering factors (intervening conditions) that impacted students' learning processes, the related strategies, and the extent to which students believed that they developed PCK as a result of taking the course (consequences).

The key theme of *"connection"* emerged from the analysis of the focus group data as the phenomenon that best describes the learning process. Connection generally refers to *"the relationship of a person, thing, or behavior to someone or something else"* (Cambridge Dictionary). In the context of learning in the *SSfT* course, four forms of connection became evident as influencing factors, each having its own characteristics as well as unique consequences associated with its presence or absence: social connection, structural connection, personal connection, and professional connection. The latter two manifestations, personal and professional connection, are both underlain by a fifth form: real-world connection (see Fig. 3).

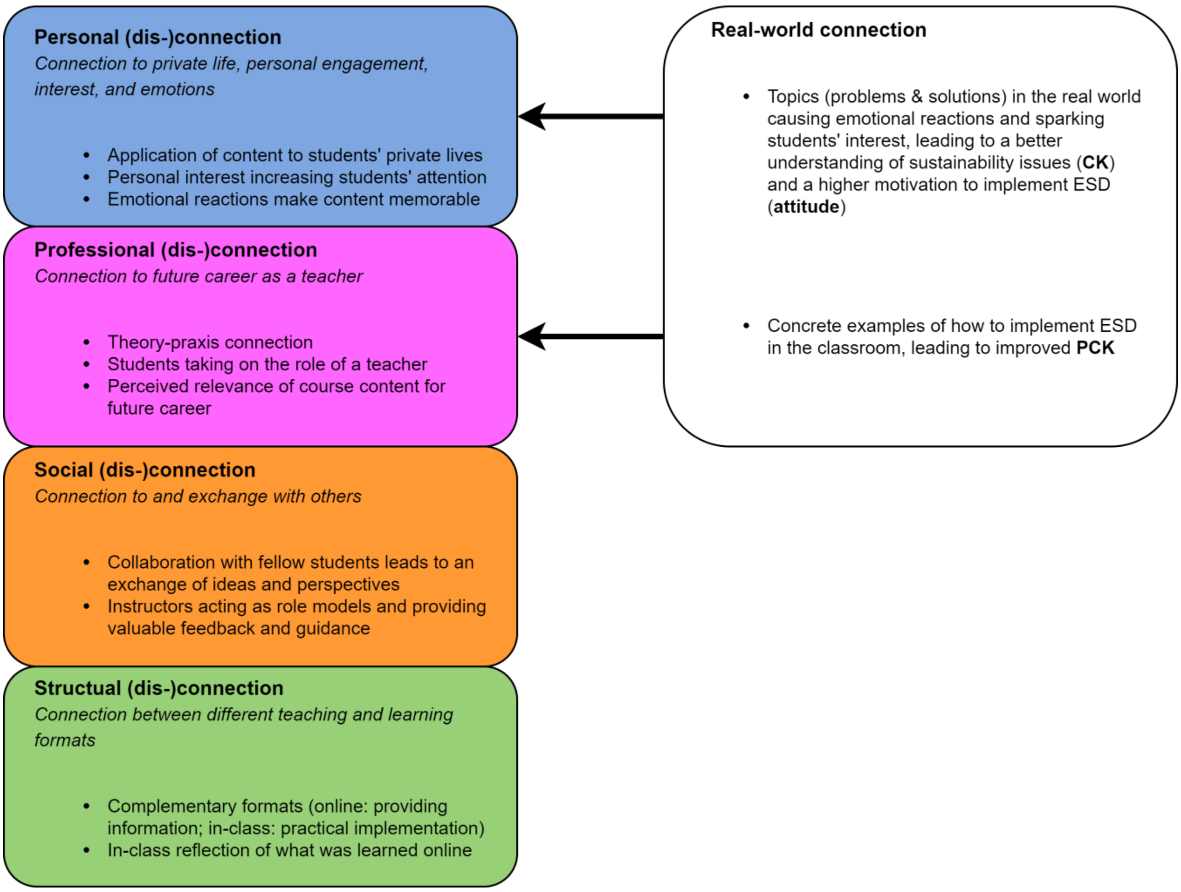

Fig. 3: Forms of connection

Below, we elaborate on these forms of connection, which we term the 4 Cs, by revealing their impacts on intended learning outcomes in the context of relevant teaching and learning formats. Fig. 4 portrays the relevance of *the 4 Cs* to achieving the stated learning objectives through the different teaching and learning formats of the *SSfT* course, highlighting the most dominant links with thicker arrows. We also introduce strategies applied in cases of disconnection, and finally, we present individual key moments of learning that best represent the each form of connection.

4.2.1 Personal connection

The phenomenon of personal connection involves the individual engagement, interest, and emotions sparked in students by the learning process. Further, it implies their agency in the learning process and the applicability of course content to their private lives (personal relationship). Eventually, students' hands-on engagement and emotional reactions to the content, activities, and structure of the course appear to both increase their interest in the course topics and improve their memory of what has been learned (see Appendix C1).

4.2.1.1 Teaching and learning formats, intervening conditions, and outcomes

Several students appreciated opportunities to learn at their own pace (online learning) and emphasized the importance of relevant and relatable videos, which appeared particularly helpful in closing knowledge gaps (CK). The real-world connection elucidated by videos sparked students' emotions, increased their interest, and caused the information to be more deeply absorbed. Additionally, some videos were perceived as particularly engaging and had positive impacts on students' motivation (attitude):

> *"There were some [videos] where I was like, okay, I'm ready, let's go change the world"* (S1_365).

Explicitly linking personal engagement to an improved understanding of content (CK), students emphasized the importance of hands-on activities. Demonstrating a connection between hands-on activities and students' motivation (attitude), some students traced their excitement about the course back to feeling engaged within the classroom. In-class activities, having established a personal relationship to the course content, they were also linked to students' PCK:

> *"The activities we did in-class made it more, I don't know, relatable, even further than the videos, because you could see, like, how we could use it in future classrooms."* (S1_319).

The quizzes, on the other hand, were partly perceived as *“lower-level-thinking assignments … [that] didn’t resonate as deeply”* (S1_305). The impact of quizzes on overall course grades put pressure on some students, and consequently, they suggested replacing the quizzes with reflective tasks.

Even though several students enjoyed watching the videos, many struggled with the quantity of material. Some even indicated that dealing with too much information caused them to feel anxious. One strategy that students applied in such cases was to stop watching the videos and start *“guessing the answers to the quiz”* (S1_369), which led to information being lost (CK). Occasionally, students went so far as to state that some of the videos were boring. Some of these students also tended to decrease engagement and cease watching the videos, while others forced themselves to complete their work. Hence, while personal interest seems improve the learning process by enhancing the degree of attention paid, personal disconnection leads to just the opposite:

> *“You know we’re learning about something, but when you’re just sitting there like ‘when is this going to be over,’ like that’s all you’re thinking about, you’re not even paying attention to the video at that point.”* (S1_378)

4.2.1.2 Exemplary key moments

Some videos seem to have resonated especially strongly with students and stuck with them after watching. A video dealing with the production of attire, for instance, was particularly relatable: *“we all want the jeans to look a certain way”* (S1_345). Students reported enjoying a variety of in-class sessions, but hands-on activities like the solar-amusement-park exercise, for which students were asked to build their own miniature park rides, induced unique levels of excitement. Discussing personal engagement, students indicated that this activity helped them to dig deeper into the topic of renewable energy:

> *“I really liked that one, kind of like, because some content, I covered the understanding through the video, and like in class, through the activity, I kind of [really] get into it.”* (S1_327)

Even though the homework assignments were rarely mentioned in conjunction with personal connection, the fossil-fuels assignment, in which students calculated their own carbon footprint, was perceived as a key moment:

> *“That’s when we thought about things that we could, like, implement into our lives, like in a year, in a month … I thought that was really impactful.”* (S1_305)

The governance assignment, in contrast, elicited different feelings in students. That assignment, in which students wrote letters making political demands to policymakers and politicians, created feelings of agency in students as they were put in a position to express their opinions. It also ensured a personal connection, as students were able to select an issue of personal interest.

4.2.2 Professional connection

The phenomenon of professional connection corresponds to the link between theory and practice. Here, the key aspects are students' role in the learning process, opportunities to practically implement EfS, and expected learning outcomes with respect to applicability in future classrooms (see Appendix C2).

> *"One of the biggest parts of this class is like, how can we do this in the future?"* (S1_385)

4.2.2.1 Teaching and learning formats, intervening conditions, and outcomes.

Students described it as helpful to take the perspective of—and be treated as—an actual teacher during the course, and they appreciated the applicability of course content to their future classrooms. Concerning in-class activities, students indicated that by the end of the semester, they appreciated having a portfolio of activities they would be able use:

> *"I think the greatest learning came from the in-class activities that we did, that were interactive and hands-on and also gave us an example, a strong example, of what we can do in our future classrooms to integrate sustainability."* (S1_358)

Continuing to link these activities to a broadened pedagogical repertoire, students reported an improved ability to apply the different WOT (PCK):

> *"Because [of] the activities that were aligned with [them] … we know how to actually use those ways of thinking."* (S1_375)

The videos, which introduced each topic, were generally considered to help develop an understanding of sustainability concepts (CK). Yet in terms of professional connection, some of the videos not only enhanced students' factual knowledge but also provided examples of how to implement EfS (PCK). In the same context, the videos' real-world relevance, and *"visually seeing it"* (S1_353), made the information more memorable. Some, however, raised the critique that there could have been greater emphasis on implementation strategies, especially for different age groups:

> *"Alternative activities for different grade levels, I think, would be helpful. So, more of, like, the teaching in class."* (S1_335)

Accordingly, some students proposed spending a second day in class each week to focus on implementation. And while many students claimed that the final project did entail professional connection—as the project was *"all about how we would teach it"* (S1_315)—others emphasized the lack of opportunities for practical implementation. Students suggested that future renditions of the course would be improved by engaging in practice simulations of the final projects with the seminar group.

4.2.2.2 Exemplary key moments

The *SSfT* alumni video, in which former students of the course reported on their current EfS practices, represents an exemplary key moment of learning in the area of professional connection. Students appreciated seeing *"teachers who have taken this course and how they've applied it to [the] classroom now"* (S1_333), and they asked for additional practical examples of EfS implementation:

> *"I want to see more teachers being like, 'okay,' like, 'hi, I'm a third-grade teacher, I incorporate sustainability through this [method]'."* (S1_343)

Watching this particular video led to a genuine increase in students' self-efficacy, as well as an attitude best expressed by *"we can do that"* (S1_367). Furthermore, students perceived several in-class activities as applicable in their future classroom. An activity on the water cycle and human water systems, for instance, was seen as helpful in comprehending the different WOT and recognizing *"diverse preferences of students regarding learning formats"* (S1_353). The hot-dog activity and its systems-thinking approach towards food production also seemed applicable to students' future careers:

> *"Even younger students ... can make those connections ... [and] really understand the systems thinking."* (S1_330)

4.2.3 Social connection

Social connection refers to the feedback and guidance conveyed by the instructor by modeling sustainable behavior and engaging approaches towards teaching and learning, as well to as the exchange of thoughts and perspectives (sharing knowledge) with fellow students—through interactive activities and in-class discussions, for instance (see Appendix C3).

4.2.3.1 Instructor

Many students highlighted the motivational influence of a passionate instructor who modeled sustainable behavior. The outcomes associated with such admirable instructors are a keener interest in the topics discussed and an increase in those topics' perceived relevance:

> *"She [the instructor] was so passionate that you're like, 'okay, this is important,' like 'I really need to focus.'"* (S1_318)

Another supporting factor was the course's unbiased approach to teaching, which considered both the benefits and drawbacks of sustainability. Students also appreciated guidance and feedback, particularly during in-class reflections on online material, and claimed that the instructor explicitly helped them to close their knowledge gaps (CK):

> *"The driving factor for learning was just that our teacher was so knowledgeable in sustainability … he was like our sustainability Google that we could just ask any question."* (S1_354)

4.2.3.2 Teaching and learning formats, intervening conditions, and outcomes

A learning format frequently mentioned as allowing for social connection to play out was in-class discussions and discursively reflections upon the online material. These exchanges with others supported students' learning. Underscoring the benefits of in-class discussions, students highlighted the value of *"connecting together how [sustainability] really influences our day-to-day life"* (S1_371). In other words, in-class discussions created a personal connection. The prevalence of discursive exchanges of thoughts and reflections on the online material appeared to lead to a better understanding of the topics (CK):

> *"When we sat in our groups, talking about it, it helped me understand better, like, what we're doing, and like, why we all feel that way [that] we do about the topic."* (S1_300)

Moreover, respectful debates and hearing out the opinions of all students in class were explicitly linked to practicing values thinking and improving students' PCK. With respect to the online class component, on the other hand, several students stated that they missed receiving immediate feedback from the instructor and interacting with fellow students. Students reported that these losses negatively impacted their understanding of the material (CK):

> *"I feel like when it's just online, I don't really get that interaction with people, and … I don't [understand] the content as much as I should."* (S1_306)

4.2.3.3 Exemplary key moments

Students appreciated the opportunity to give one another peer feedback as part of the final project, exchanging ideas about their individual teaching and learning units, which added to their PCK:

> *"… to be able to see other people's topics as well, and I feel like, 'hey, that is something else we can talk about in our classroom.'"* (S1_308)

The in-class debate (known in class as philosophical chairs) over the social, ecological, and economic implications of building the Dakota Access Pipeline helped students practice their values thinking (CK):

> *"I thought that was a really good activity to kind of get us to, like, use the different thinking, and values thinking particularly; I feel like we were able to argue, like see a lot of people's opinions come out and, like, what values they had."* (S1_375)

In the comparable 'needs vs. wants' activity (a component of the poverty unit), students jointly decided what is wanted, as opposed to needed, in life:

> *"It was like different values, you know, it's 'you prefer this over this.' … So, that was kind of like, your own values thinking, and it was really cool to see like, you know, you resonate with someone else."* (S1_344)

4.2.4 Structural connection

The structural dimension of connection entails a consistent course structure and the explicit link between individual teaching and learning formats. The key focus here is on the relationship between individual components of online learning—such as videos, quizzes, and assignments—and in-class activities, as well as discursive learning scenarios in face-to-face sessions (see Appendix C4).

4.2.4.1 Teaching and learning formats, intervening conditions, and outcomes

Within the focus groups, the different teaching and learning formats were mainly discussed against the backdrop of their perceived roles and respective (dis)advantages. Broadly, students reported that the online portion had provided relevant information, while the in-class sessions had been useful in clarifying and implementing the material that had been learned online. While a few students claimed to dislike dealing with two different learning environments that *"need to be conjoined"* (S1_326), the majority appreciated that the two components of the hybrid course format complemented each other. Several students highlighted that the online portion laid a foundation by introducing the different topics, thereby preparing the students for in-class sessions, which expanded upon the videos in turn:

> *"It was impactful, watching the videos about the different types of thinking, that's like when I originally learned from the video. And so then, in the class, I like, actually implemented it, but I learned from the videos what the difference is between each."* (S1_376)

As mentioned above (section 4.2.3), reflecting (discursively) in class upon the online material was perceived a major driver of learning. However, hindering elements were also present with respect to structural connection. Students repeatedly referred to the link between videos and quizzes and the actual order of online tasks. Grade-oriented students appreciated that quiz questions could be used to contextualize the videos because the questions were already available prior to watching; others, however, emphasized that this resulted in limited learning outcomes and a loss of relevant information (CK):

> *"I felt like I was watching the videos more to answer the quiz than for my own understanding."* (S1_314)

Discussing the strategies they applied when encountering this sort of structural disconnection, which caused partial decreases in personal engagement with the learning process (attitude), some students reported that they had found ways to score highly on the quizzes without even watching the videos—although doing so (e.g., by Googling the answers to the quiz) meant renouncing true learning:

"As soon as I found out you can get a good score without watching the video, it kind of took away from learning, because it just made it easier to get around actually learning." (S1_354)

4.2.4.2 Key moments of learning

Individual in-class activities such as the hot-dog activity (from the food unit) and the renew-a-bead activity (fossil-fuels unit) were directly incorporated into the final project. Consequently, students understood the final project as drawing a structural connection and linking the different teaching and learning formats:

"Our signature assignment in this class is like, we're taking what we learn from one of the lessons and building off of that." (S1_336)

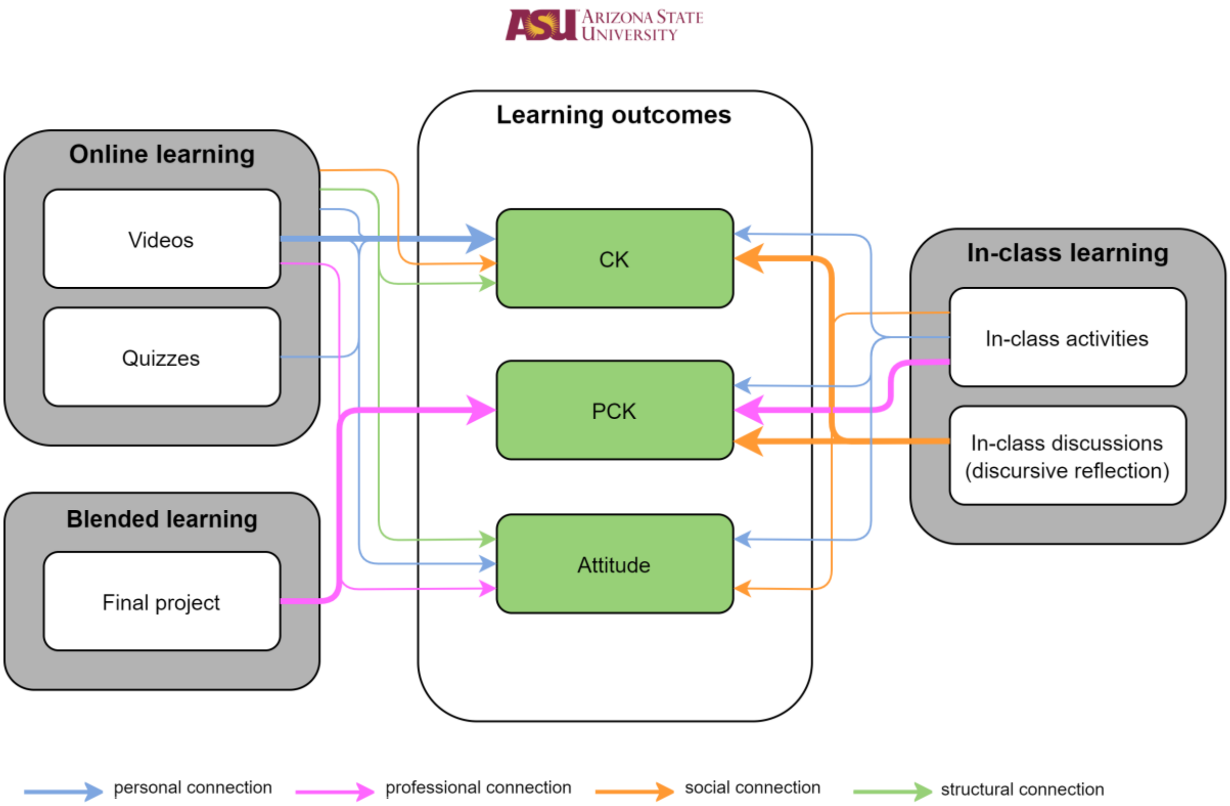

Fig. 4: The impact of the four Cs on achieving ILOs in different T&L formats at ASU 2017
Note: More dominant links are denoted by thicker arrows.

5 DISCUSSION AND OUTLOOK

The academic discussion surrounding teacher education for sustainability (TEfS) has yet to come to a consensus as to the most relevant elements of EfS-specific competences and how they should be addressed in pre-service teacher education. According to the competence model developed by Bertschy et al. (2013), TEfS is expected to develop student teachers' sustainability-related content knowledge (CK), their skillset (PCK), and their willingness and motivation (attitude) to implement EfS at the school level.

Examining students' learning outcomes from the *SSfT* course (see RQ sub-question i), the results of this study indicate that the participating students have developed both a more positive attitude towards EfS and an improved array of CK, in the sense of a better understanding of sustainability. While the perceived relevance of EfS was relatively high among the *SSfT* students, their pro-environmental worldviews (measured via the NEP scale) were quite similar to those of German pre-service teachers. However, as the *SSfT* course constituted, for the majority of ASU students, a first encounter with sustainability, their understanding of the term and concept was notably less complex (Brandt et al., 2019).

Insights regarding PCK development, on the other hand, remain rather ambiguous. Although the students developed a certain theoretical understanding of how to implement EfS at the school level, they still lacked practical experience, and they reported uncertainty about how to apply the WOT and break down sustainability concepts for different grade levels. Furthermore, students' self-reported learning outcomes, with respect to PCK and their ability to implement EfS, are sometimes difficult to distinguish from EfS-related self-efficacy items that cover students' trust in their own capabilities. What is missing is an adequate instrument for measuring PCK development in a performance-oriented approach, which would allow researchers to move away from contestable self-assessments. It is further important to consider that teachers generally play two roles, each related to a specific set of intended learning outcomes: the role of the professional (instilling CK, PCK, and attitude) and that of the global citizen (raising awareness and inducing behavior change). This latter role, however, was not the focus of this study.

With respect to learning from the different teaching and learning formats of the *SSfT* course (see sub-questions ii and iii), four forms of connection (*the 4 Cs*) manifested as key factors impacting students' learning processes. As described above, a personal connection to the course content sparked students' interest, increased their attention, and improved their memory.

Being engaged by hands-on activities or emotionally touched by documentary videos with real-world relevance increased students' motivation to engage with EfS (attitude) and helped them develop an understanding of the course content (CK) and how to use it in their future teaching careers (PCK). Personal disconnection, on the other hand—such as feelings of anxiety that result from the scope of the video material—sometimes prevented students from absorbing and retaining information. This finding accords with recent insights from a study by Ojala (2013), and it substantiates findings in the interdisciplinary field of neuroscience and education that pointing to a role of emotions in affecting students' performance and learning (Immordino-Yang and Damasio, 2007). However, while negative emotions can be difficult to handle and may cause students to stop what they are doing, they also have the potential—when treated with constructive regulation strategies—to incite critical thinking and reflection (Ojala, 2013).
Second, professional connection—referring to explicit links to (future) implementation of EfS at the school level—supported students' learning processes. Whether it was through a video featuring successful *SSfT* alumni, working on the final project, or being engaged in activities that equipped students with a portfolio of EfS lessons, professional connection—supported by a layer of real-world connection—strengthened students' pedagogical skills (PCK), as well as their motivation to act as future change agents (attitude). Only the lack of practical experience and the missed opportunity to implement the teaching and learning units used in students' final projects were seen as hindering factors. The importance of the perceived value and practical relevance of learned material has already been emphasized in previous work concerning higher education at large (Biggs and Tang, 2011). With particular regard to TEfS, Bürgener and Barth (2018) showed how open learning environments and cooperation with partnered schools could enhance students' learning by incorporating a practical component and strengthening the professional connection. Future research should focus on K–12 students in the classrooms of EfS-trained educators. It is crucial to understand the extent to which educators can use the ways of thinking and knowledge they have learned to empower and motivate K–12 students to persistently engage in real-world projects that contribute to systemic change.

In the context of social connection, the role of instructors was particularly highlighted. Instructors' passion for the course content was passed on to students and increased their motivation to engage with sustainability topics, their perception of the relevance of EfS, and the attention they paid to the course content. As also described by Biggs and Tang (2011), instructors' feedback was another key factor guiding students' learning processes in this study. Furthermore, students' ability to exchange thoughts and ideas with their classmates in group discussions and discursive reflections helped them to close knowledge gaps and develop their CK. Respectfully debating the social, ecological, and economic implications of major projects like the Dakota Access Pipeline with the entire class, as guided by an unbiased instructor, gave students further practice in values thinking and improved their pedagogical skillset (PCK). These results confirm the importance of social interaction and opportunities to exchange ideas, not only in TEfS (Whitehouse, 2008) but also in pluralistic approaches and deliberative communication in EfS at large (Ojala, 2013). While So and Brush (2008) have already showed that collaborative learning in health education is more satisfying to students, the *SSfT* cohort indicated that face-to-face interaction is not merely satisfying but fundamental when learning about sustainability. Students identified the need to understand one another's values and perspectives through respectful discussion.

Finally, a structural connection and deliberate links between different learning formats have proven to be important, particularly in affecting the development of students' content knowledge (CK). In the context of this study, structural connection was only mentioned in cases of hindering links, or disconnection. While the order of tasks associated with the online course component had a limited impact on students' motivation to engage with the material, the direct application of individual in-class activities to the final project and the in-class reflections upon the online material was perceived as helpful to the overall learning process. This too corresponds to the findings of Biggs and Tang (2011), who claim that building on existing knowledge and establishing structural interconnections between topics directly improve learning.

Above all, *the 4 Cs* are not separate entities—rather, they are interlinked elements that not only impact students' learning processes but also have the potential to foster, or hinder, one another. While most findings presented here appear generalizable to learning in higher education at large, rather than specific to the field of TEfS, it is clear that passionate yet un-biased instructors and learning formats that allow for the discursive exchange of thoughts and ideas are crucial to supporting learning in connection with the complex, value-laden concepts of sustainability and EfS.

It is worth mentioning that the course we investigated was characterized by special conditions that do not necessarily apply to other courses around the globe. Not only is the course mandatory for all elementary-education majors, but the financial resources it has amassed since its launch in 2012 make this case particularly unique. With Nobel laureate Leland H. Hartwell and other external stakeholders on board, funding was available to produce high-quality digital storytelling videos and ensure consistent in-class activities. On the other hand, the *SSfT* course serves as an exemplar of hybrid TEfS courses as it includes a variety of teaching and learning formats applied worldwide.

Although our results are to a certain extent *'bounded'* to this case study and cannot be simply generalized, we take the final step of providing a list of recommendations based on student feedback about their learning processes.

- As the *SSfT* students have repeatedly highlighted appreciation for instructors that serve as role models, thereby facilitating the learning process, we recommend seeking out instructors who are passionate about sustainability and capable of presenting and discussing sustainability issues and solutions in an unbiased manner.
- Since structural connection facilitates engagement with and understanding of the course content, we highly recommend that those in the position to do so make considerate decisions about course structure and the order of tasks, particularly in online learning environments.
- Students' personal connections to the course content enhance their motivation and understanding. We advise that content is made relevant to students and that the relationship between emotion and cognition is recognized.
- To account for the significance of social connection and face-to-face interaction, which was particularly emphasized when dealing with sustainability topics, we advise that opportunities be guaranteed for discursive reflected and group discussions of sustainability issues and sustainability solutions.
- To finally do justice to the professional connection and improve students' pedagogical repertoire as well as their willingness to actually implement EfS at the school level, we recommend that tasks be integrated to design and implement—or at least simulate—exemplary EfS lesson plans, e.g., through cooperation with partnered schools.

Many of these elements were present in the observed course, and they may be useful design elements to consider for other EfS courses.

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APPENDIX A – *The hot dog activity*

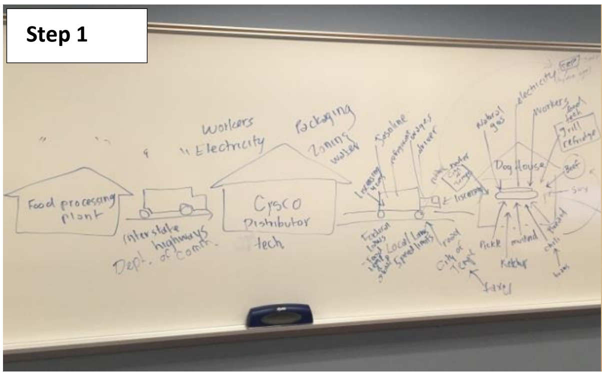
Hot dog activity (food week) - https://www.youtube.com/watch?v=FW6MXqzeg7M

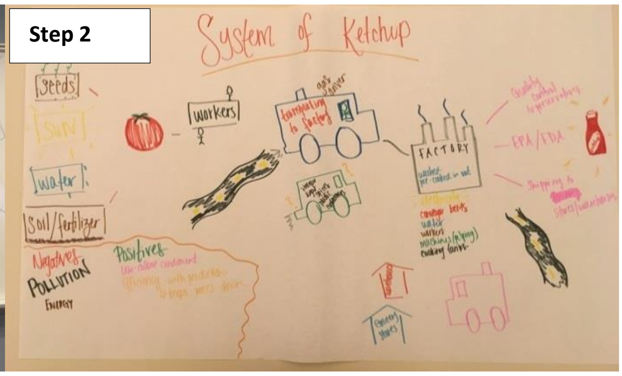
Procedure:

- In a first step, the instructor co-constructs the diagram of a hot dog's production cycle with the students, allowing for discursive interaction between all protagonists.
- In a second step, the class breaks up into sub- groups of 4 to 5 students who repeat that exercise for one of the hot dog's condiments (bread, sausage, ketchup, mustard etc.).
- In a third and final step, the results are being presented to and discussed with the whole class.

Rationale:

When examining the content for the food week the idea is to uncover the problems and solutions associated with food supply through the lens of systems thinking. The students should learn to consider how one component of a system can influence and change the system as a whole. The activity is explicitly linked to SDG No. 2: *"End hunger, achieve food security and improved nutrition and promote sustainable agriculture"* (UN, 2015) and ties back to the idea of *"crosscutting themes"* within the K-12 Next Generation Science Standards (NGSS).





APPENDIX B – *Students' understanding of the term 'sustainability'* – scoring details

Time perspective		
Score	***Meaning***	***Exemplary answer***
0	no time perspective mentioned	-
1	future perspective	*"To act environmentally conscious and future oriented […]."*
2	intergenerational perspective	*"To me, sustainability means to reduce my own ecological footprint so far as future generations can live as carefree as I do."*
3	inter- and intragenerational perspective	*"Sustainable development means that we should treat our resources carefully and distribute them fairly so that both generations of today and the future can fulfill their basic needs."*
Dimension orientation		
Score	***Meaning***	***Exemplary answer***
0	no dimensions mentioned	-
1	one dimensional perspective	*"In my opinion, sustainability implies that we should live in harmony with nature."*
2	multi-dimensional perspective	*"Sustainability means the interplay of ecological, economic, social, and cultural perspectives."*

APPENDIX C1 – *Personal connection*

Personal (dis)connection

Support

Allowing for individual pace/agency (**online learning**)

Real-world connection sparking emotions (**videos**)

Personal engagement & Personal relation/ interest in the content (**videos & in-class activities**)

Hindrance

Grades putting pressure (**quizzes**)

Amount of information causing anxiety (**videos**)

Boring content (**videos**)

Learning process

Online learning:
"You got to do it yourself and you could go at whatever pace you needed to understand it" (S1_377)

Videos:
"There are some videos that we really want to watch and you know, we actually get knowledge from […] they're really super interesting and you're like wow, like that's amazing" (S1_378)

"You would watch like a documentary […] it would draw you into it and like keep you interested and entertained a little bit. […] the reality of it would sink in." (S1_353)

"It was just too much information which is part of my anxieties, it is like when too much information is being thrown at me, I don't really know how to sort through it" (S1_346)

"There were some where […] I was like, okay, I'm ready, let's go change the world" (S1_365)

Quizzes:
"It's huge pressure. Because for a while I wasn't like getting that good of grades on them and I was like, crap, like what am I going to do now?" (S1_367)

In-class activities:
"I think the group activities and the actual projects that we did, that's where a lot of my learning and understanding came from, because those were just hands-on, really fun activities" (S1_353)

"This is the only class that I looked forward to, like, oh, yay, it's Thursday, like I don't even care that I have to wake up earlier […]. I know we're going to actually be doing something and then I look at the clock and then it's like, oh, class is over." (S1_365)

"The activities we did in-class made it more, I don't know, relatable even further than the videos, because you could see like how we could use it in future classrooms […]" (S1_319)

Strategies

suggestion: replace the quizzes with reflective tasks

Stop watching videos/start guessing answers to the quiz
vs.
Forcing themselves to keep watching the videos

Outcomes

Achieved objectives

Increased understanding/ knowledge/**CK** (**online learning & in-class activities**)

Increased motivation/**attitude** (**videos & in-class activities**)

classroom implementation/**PCK** **(in-class activities)**

Missed objectives

Losing information/**CK** (**online learning**)

APPENDIX C2 – *Professional connection*

Professional (dis)connection

Support

Taking teachers perspective (**Hybrid course format**)

Explicitly thinking about how to implement EfS (**in-class activities & final project**)

Creating a portfolio of activities for future career (**in-class activities**)

Providing examples of (successful) EfS implementation (**videos**)

Hindrance

Too little connection to future classroom (**Hybrid course format**)

Lack of opportunities for practical implementation (**Hybrid course format**)

Learning process

Hybrid course format:
"I feel like this is just more like a professional development, meaning where I'm like, I already feel like a teacher and oh, I'm going to go implement this in my classroom." (S1_308)

In-class activities:
"[…] having this class be like 'but how are you going to teach it?' or 'how are you going to this with your students?' that was really helpful. […] Not just what are you going to provide your students with, but how are you actually going to help them learning it, achieve this subject area." (S1_301)

"it was kind of like our own portfolio, because in each assignment we had to do an activity that we could use in our future classroom, that related to the content of the week" (S1_344)

Videos:
"the videos […] gave us plenty of information, examples and so, when we do put it in our curriculum, we are not totally lost about it, they tell us like different grade levels we could use, like start sustainability in, it was really, it made it easier." (S1_307)

"I feel like I wanted more of like how I can teach this or incorporate this into my content when teach it myself. […] last week included a video where three teachers talked about how they incorporate sustainability in their curriculum and I'm just like, okay, I want more of that." (S1_337)

Final Project:
"with the final projects that we're doing […] being able to incorporate sustainability concepts in the standards that are in place with the common core is totally capable" (S1_368)

"[…] it's preparing me for how I'm going to create my lessons in the future and kind of giving me ideas on what that's like in a real classroom." (S1_333)

"We're doing the final [project], we're not actually going to be like teaching it really. It is kind of like just important for you, so it would be cool to have one […] that we could actually do with the class." (S1_400)

Strategies

suggestion: have a second day in class per week

suggestion: simulating the final project with the seminar cohort

Outcomes

Achieved objectives

Ability to incorporate EfS in the classroom/apply the WOT & Portfolio of activities/**PCK** (**final project & in-class activities**)

Increased motivation/**attitude** (**Hybrid course format & videos**)

Missed objectives

Lacking the practical experience to implement EfS/**PCK** (**Hybrid course format**)

APPENDIX C3 – *Social connection*

Social (dis)connection

Support

Passionate instructor modeling sustainable behavior (**in-class activities**)

Instructor being unbiased about sustainability topics (**in-class discussions**)

Instructor's guidance/ feedback on the learning process (**In-class discussions/ reflecting online material**)

Exchange with others/ sharing perspectives and opinions (**In-class discussions/ reflection upon online material**)

Hindrance

Lack of guidance/ feedback by the instructor (**assignments & in-class activities**)

Lack of interaction (**online learning**)

Learning process

Instructor:

"I also learned from her like to be super organized and like passionate about what you do. […] she made this class worth it […] this is the only science class that I've ever paid attention to and ever liked […and] the first science class that I actually participated in and like actually care about" (S1_367)

"having a helpful teacher who's passionate the whole time helped, at least it helped most of those I've talked to in class. […] her passion would make me interested in learning about the topic." (S1_300)

"[The instructor is] looks at both sides of it, of how being sustainable can actually hurt us and how it can benefit us, she talks about both sides of it and I think that helps a lot" (S1_377)

"when we did the reflections on the videos, that would help me, because the I could go back and look at everything and then she would also give us comments of like if we were on the right track of what we learned from the video" (S1_328)

"the driving factor for learning was just that our teacher was so knowledgeable in sustainability […] he was like our sustainability Google that we could just ask any question" (S1_354)

In-class activities/discussions:

"I would come into class and if I had questions, like could figure out where I went wrong, what I didn't understand, it was an easier way and it made it more interesting for me." (S1_302)

"what I loved about the course was in-class discussion, I really loved being able to hear the people's opinions respectfully and to have a respectful debating and I feel like that helps with our learning because we're able to see, use values thinking to see different point of views. [...] discussion is huge" (S1_368)

"when we sat in our groups, talking about it, it helped me understand better like what we're doing and like why we all feel that way we do about the topic" (S1_300)

Online learning:

"I kind of liked how this one was set up, that it was more of a hybrid, because I feel like when it's just online, I don't really get that interaction with people and I don't get the content as much." (S1_306)

"I guess another barrier would be the online thing. I'm not more of an online learner, I'm more of an in-person, I would rather be there and know of the due dates and have a syllabus and have a teacher to ask questions. And for me that was a big limiter on that." (S1_314)

Strategies

suggestion: replace quizzes with in-class discussions about the videos

Outcomes

Achieved objectives

Increased motivation, interest and perceived relevance/**attitude** (**in-class activities**)

WOT, Values thinking in particular/**PCK** (**in-class discussions**)

Closing knowledge gaps & Increased understanding/**CK** (**in-class discussions**)

Missed objectives

Lack of understanding the content/**CK** (**online learning**)

APPENDIX C4 – *Structural connection*

Structural (dis)connection

Support

Complementary T&L formats (**Hybrid course format**)

(In-class) reflection upon online material (**Hybrid course format**)

Quizzes setting focus for the videos (**online learning**)

Hindrance

Lack of in-class reflection upon videos (**in-class activities**)

Hindering connection between videos and quizzes/order of tasks (**online learning**)

Disconnection between assignments, videos and quizzes (**online learning**)

Learning process

Hybrid course format:

"The fact that I got to watch the videos and then go to class and apply it myself was really helpful" (S1_318)

"If you didn't do the online work, you wouldn't have been successful in the actual classroom or been able to discuss it." (S1_340)

Online learning:

"Sometimes the secondary activities in the lessons, kind of felt disconnected sometimes. Like, there would be the video and it would be all cool and sometimes we would have […] to like write, you know, some short answers on stuff and sometimes those felt like they didn't connect to it." (S1_300)

"I would watch most of the videos, too, but then like, on some of the questions, I would be like, what the heck is that? Like, and I'd feel so dumb because I'm like, wait, I just saw the videos, like why didn't I get it?" (S1_365)

"I felt like I was watching the videos more to answer the quiz than for my own understanding." (S1_314)

"Make the quiz more relevant to the video or the video more relevant to the quiz […] just so that the students stay more engaged throughout the videos, not just like looking for your answers." (S1_357)

In-class activities:

"[…] having like a quick five minute debrief of like […] these are the videos, the questions for it, let's talk about it now, you know, not just, oh yeah, like here's a quick quiz." (S1_314)

Strategies

Googling the answers to the quizzes

suggestion: reconsider the connection between online learning formats

suggestion: replace quizzes with an in-class debrief or writing a summary

Outcomes

Achieved objectives

-

Missed objectives

Decrease in understanding of the content/**CK** (**online learning**)

Decrease in engagement and self-efficacy/**attitude** (**online learning**)

APPENDIX 3 - Developing ESD-specific professional action competence for teachers: Knowledge, skills, and attitudes in implementing ESD at the school level

Citation

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Abstract

Equipping future change agents with the competencies to lead the societal transformation towards sustainability requires competent and committed teachers that effectively implement Education for Sustainable Development (ESD) across the education system. Based on a dual case study, this paper investigates how individual ESD courses in teacher education programs at Leuphana University (Germany) and Arizona State University (USA) support the development of ESD-specific professional action competence for teachers (Bertschy et al., 2013). Applying a mixed-method approach, the specific focus is on the links between supporting or hindering factors that affect pre-service teachers’ actual achievement of intended learning outcomes (ILOs). The findings indicate that both courses increased students’ competence – yet, to varying degrees. The 4Cs (personal, professional, social, and structural connections) were revealed as the most significant factors affecting students’ learning and should be considered when designing course offerings in Teacher Education for Sustainable Development (TESD) with the goal to develop students’ knowledge, skills and attitudes.

Keywords

teacher education; education for sustainability; education for sustainable development; learning process; learning outcomes; drivers & barriers; competence development; connection

1 INTRODUCTION

The potential of education for sustainable development (ESD) to contribute to the much-needed global sustainability transformation is widely recognized in the literature (Lotz-Sisitka et al., 2015; Barth and Michelsen, 2013). Higher education institutions serve a critical role in educating future change agents and equipping them with the competencies required to engage in leading society on a more sustainable path (Cortese, 2003). The essential role of teachers in creating effective learning environments and success in students' learning (Hattie, 2009) has also been acknowledged by the United Nations Educational, Scientific and Cultural Organization (UNESCO). In fact, UNESCO dedicated one of five priority action areas on the ESD roadmap for 2030 to *"building the capacities of educators to more effectively deliver ESD"* (UNESCO, 2020).

Competent and committed teachers are required to advance sustainability and ESD (Timm and Barth, 2020). Notably, this focus on teacher education for sustainable development (TESD) is not limited to political agendas. In academia, a growing body of research has addressed TESD (Evans et al., 2017) and the integration of sustainability in higher education programs (Barth, 2015). Furthermore, universities worldwide have designed and implemented sustainability offerings in their teacher education programs (Andersson, 2017; Brandt et al., 2019; Jorge et al., 2015; Tomas et al., 2017). Corresponding to the identified need for sustainability-literate teachers (Nolet, 2009), much of the recent research has dealt with the actual achievement of intended learning outcomes (ILOs) and the development of specific competencies (Evans et al., 2017). However, understanding what must be considered when designing TESD courses to support competence development in pre-service teachers requires a shift to considering how students learn (Barth, 2015). According to Backman et al. (2019), this calls for *"impartial research where students' individual experiences ... are studied in depth ... [to investigate] the multitude of influences on their learning"* (Backman et al., 2019, p. 149).

Previous attempts have been made to link specific pedagogical approaches to the development of competencies (e.g., Dlouhá and Burandt, 2015; Lozano et al., 2017). However, Brandt et al. (2019) first operationalized the model of ESD-specific professional action competence for teachers (Bertschy et al., 2013), purposefully linked learning processes and outcomes, and revealed concrete mechanisms that fostered competence development in the hybrid course environment of a TESD course at Arizona State University (ASU) in the United States of America (USA) (Brandt et al., 2021).

This empirical work highlighted that personal, professional, social, and structural connections (i.e., *the four Cs*) are significant factors that impact learning in TESD. Based on a dual explanatory case study (Yin, 1984), this paper investigates how far these findings can be confirmed for the subsequent cohort enrolled in the *Sustainability Science for Teachers* (*SSfT*) course at ASU and a hybrid TESD course at Leuphana University in Germany, called *Education for Sustainable Development* (*ESD*).

2 THEORETICAL BACKGROUND

Universities play a crucial role in re-orienting society toward sustainability and educating change agents by equipping students with the competencies required to engage with and find solutions for the significant sustainability challenges of the modern world (Wiek et al., 2011). While sustainability efforts and initiatives in higher education are rather diverse (Shephard, 2008), many share the notion that learners should develop certain competencies comprised of relevant knowledge, skills, and attitudes (e.g., Azeiteiro et al., 2015; Lambrechts et al., 2013; Pappas et al., 2015). In the realm of teacher education, this is mirrored in the overall objective to develop pre-service teachers' *"capacity and (in some cases) commitment to embed [sustainability education] into their own teaching practices"* (Evans et al., 2017, p. 411). Thus, various approaches to developing teachers' ESD competencies have been discussed in the literature (e.g., UNECE, 2013; Sleurs, 2008; Timm and Barth, 2020; Vare, 2018). Based on Shulman's (1987) considerations of what makes a competent teacher, Baumert and Kunter (2013) put forward the idea of a professional action competence for teachers, which was contextualized for ESD by Bertschy et al. (2013). According to their concept of an *"ESD-specific professional action competency for teachers"*, the key learning outcomes in TESD include sustainability-related content knowledge (CK), pedagogical content knowledge (PCK), and the motivation to implement ESD at the school level (attitude). Notably, the role of PCK in ESD is widely acknowledged, whereas the role of CK is rather contested. Some have argued that factual knowledge and the understanding of sustainability issues and solutions do not necessarily lead to the effective implementation of ESD (e.g., Kennelly et al., 2008; Stevenson, 2007). However, Symons (2008) claimed that CK—in addition to PCK and positive attitudes—indeed supports teachers' confidence in and readiness to enact ESD at the school level. Also, according to Tomas et al. (2017), positive attitudes are likely to influence pre-service teachers' willingness to engage in ESD as they commence their teaching careers.

Focusing on competence development at the micro-level of courses—with individual topics, learning objectives, and pedagogies (Weiss and Barth, 2019)—the construct was first operationalized by Brandt et al. (2019). In a single case study on a TESD course at Leuphana University in Lüneburg, Germany, CK was measured by changes in students' sustainability definitions, PCK by their ability to apply ESD-specific didactic principles according to Künzli and Bertschy (2008), and attitude by their ESD-related self-efficacy (SE) (Tomas et al., 2017), perceived relevance of ESD (ibid.), and pro-ecological worldviews (Dunlap et al., 2000).

In response to the lack of research on links between teaching and learning (T&L) formats and the achievement of ILOs in higher education for sustainable development (HESD) (Svanström et al., 2008), Lozano et al. (2017) investigated the potential of different formats and found that the general development of sustainability competencies requires a diversity of teaching methods. Furthermore, Biggs and Tang (2011) presented a list of factors that support student learning in higher education, such as intrinsic motivation, constant feedback and building on existing knowledge. In the field of TESD, research regarding the effectiveness of common T&L formats—such as lecture-style information delivery (e.g., Firth and Winter, 2007), discussion and reflection techniques (e.g., Corney and Reid, 2007), and future scenario exercises (e.g., Paige et al., 2008)—for competence development remain rather scarce (Evans et al., 2017). However, praxis-oriented tutorials have been proven to enhance students' ESD-related SE (Tomas et al., 2017). Examples of such tutorials include interactive digital storytelling videos that increase students' engagement and learning in the area of CK (Shelton et al., 2017) as well as inquiry-based learning that fosters students' knowledge and positive attitudes toward sustainability (Kalsoom and Khanam, 2017).

Explicitly referring to the development of ESD-specific professional action competence, Bürgener and Barth (2018) elaborated on the approach of transdisciplinary living laboratories that incorporate the idea of scaffolding (Hannafin et al., 1999) and include project work with practice partners. In the same context, Brandt et al. (2019) described the potential for a blended learning TESD course at Leuphana University that applies lectures (flipped classroom), tutorials, and project-based seminar sessions where students cooperate with partner schools. Thereafter, Brandt et al. (2021) went one step further by adding key factors that support or hinder students' learning processes. By investigating a hybrid TESD course at ASU, they found that four forms of connection (i.e., *the four Cs*) – namely personal, professional, social, and structural connections – may be significant factors that affect students' learning processes and the development of ESD-specific professional action competence among teachers (see Figure 1).

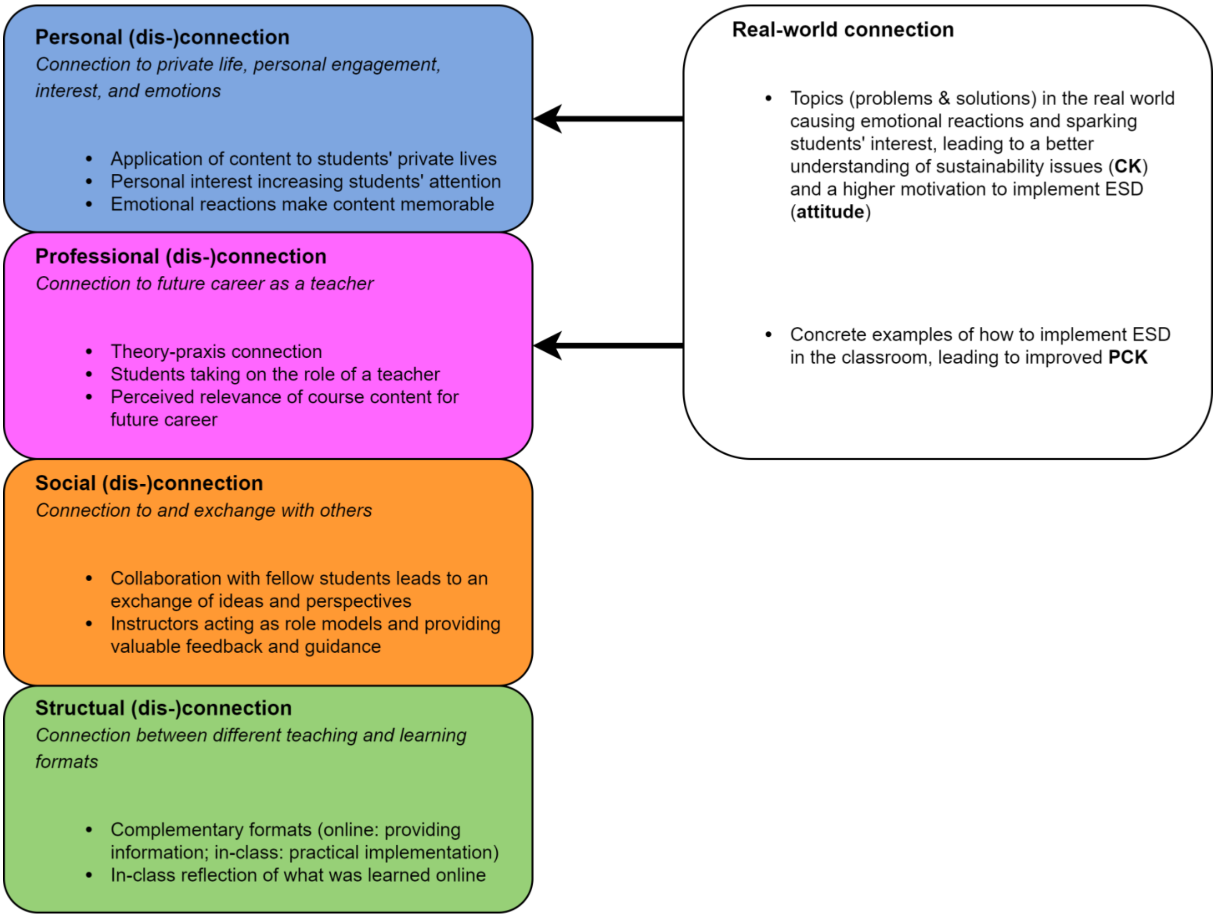

Figure 1: Forms of connection (Brandt et al., 2021)

While personal connection and students' interest in course content generally increased their attention, being actively engaged during in-class activities or emotionally touched by video material particularly increased students' motivation to engage in ESD (attitude) and helped them develop an understanding of sustainability issues (CK) and how to implement ESD in classrooms (PCK).

Also, the professional connection and explicit links to the future implementation of ESD units at the school level appeared to support students' learning since certain videos provided practical examples of in-service teachers and course alumni teaching ESD. Furthermore, the in-class activities and final project (key assignment) equipped students with a portfolio of ESD lessons (PCK) and increased their motivation to put that into action (attitude). In the context of social connection, the role of teaching staff in providing unbiased guidance and valuable feedback was highlighted in the previous study. Additionally, the discursive exchange of ideas during in-class discussions helped students develop their CK and improved their pedagogical skillset (PCK). Ultimately, a structural connection and deliberate links between the different formats applied in the course supported students in understanding the content provided (CK).

Notably, *the four Cs* are not separate entities that affect students' learning processes. Instead, they are interlinked elements with the potential to foster or hinder one another in the sense of an overarching learning environment (Brandt et al., 2021). As a follow-up contribution, this paper seeks to reveal how far these findings can be confirmed for the subsequent cohort enrolled in the course at ASU and transferred to the aforementioned TESD course at Leuphana University. By deliberately considering the link between learning processes and outcomes from different T&L formats, the present study aimed to shed light on how best to design TESD course offerings that foster student teachers' ESD-specific professional action competence (Bertschy et al., 2013). Ultimately, we considered students' sustainability-related knowledge (CK), pedagogical skills (PCK), and motivation to implement ESD in their teaching careers as key learning objectives in TESD. As suggested by Backman et al. (2019), we based our work on the epistemological ideas of constructivism by focusing on students and their learning experiences (Glasarsfeld, 1995).

3 MATERIALS AND METHODS

The present study was designed as a dual explanatory case study (Yin, 1984) of two TESD courses: one at Leuphana University of Lüneburg in Germany called *Education for Sustainable Development* and one at ASU in the USA called *Sustainability Science for Teachers*. We focus on two interrelated questions:

(i) *What learning outcomes did students achieve through these two courses and how do these outcomes differ from one another?*

(ii) *What were the main supporting or hindering factors that affected students' achievement of ILOs in terms of the different T&L formats applied?*

3.1 The cases

To achieve a thorough understanding of cases and increase the reliability of studies, detailed documentation is required (Yin, 1984). Here, we provide a short description of both courses in terms of their key structure, primary T&L formats, and desired learning outcomes. For further information on the cases, we published an extended working paper (Brandt and Barth, 2020) that serves as supplementary material for this empirical article.

3.1.1 Education for Sustainable Development

Education for Sustainable Development is the first of two sequential sustainability modules in the teacher education program in Basic Social and Science Studies (German: Sachunterricht), which is one branch of the primary education program at Leuphana University. The *ESD* module is a 150-hour unit that runs every year during the summer term (second semester) and builds upon the first-semester module called Science Bears Responsibility (Responsibility and Sustainability), which introduces students to key sustainability concepts (Michelsen, 2013). Over 14 weeks, approx. 80 students participate in a combination of (blended learning) lectures, tutorials, and seminar sessions. The design of the module follows a scaffold approach in four sequential steps. First, in a regular lecture format, students learn about the concept of ESD, its implementation, and how to design learning environments in ESD. Beginning in Week 3, the lectures are recorded and offered in a flipped classroom setting that allows students to engage with the topic at their own pace and enables them to ask questions and interact in face-to-face meetings. Second, the lecturer uses the model of cognitive apprenticeship (Collins et al., 1991) to demonstrate how to create a learning environment that supports the development of sustainability competence in school settings. Third, students are divided into tutorials and work with the support of tutors to outline such a learning environment (this work also represents their first official assignment in the course). Fourth, students work on a case study in one out of three seminars, in which they collaborate with a partnering school to implement an ESD lesson for a cohort of primary education students. Table 1 outlines the specifics of both courses to provide a comparison between them.

3.1.2 Sustainability Science for Teachers

The course *Sustainability Science for Teachers* (*SSfT*) was launched in the fall of 2012. It is a three-credit, 15-week course that is mandatory for all elementary education programs (K-8) at ASU. The course aims to prepare pre-service teachers to implement ESD at the school level. The intended learning objective is to develop student teachers' *"sustainability literacy"* via the following means: a) by providing ESD-related CK and fostering students' understanding of sustainability concepts and their application (CK); b) by providing PCK for ESD and developing students' ability to apply the ways of thinking (WOT) to explain sustainability concepts (PCK) (Merritt et al., 2019). The WOT (i.e., strategic, futures, values, and systems thinking) relate to the key competencies in sustainability (Wiek et al., 2011) and provide the overarching sustainability education framework for this course (Warren et al., 2014).

SSfT follows a flipped learning approach, where content is provided in the online portion through *“digital storytelling”* (Robin, 2008). Students watch videos related to weekly topics, complete quizzes to assess their understanding of the content and work on reflective assignments. As a second course component, students attend class for 75 minutes per week to discuss concepts and learn pedagogical strategies to integrate the content into their future teaching. While the class is usually divided into several sub-cohorts, all instructors use the same online content and are provided with the same weekly lesson plans. The in-class lessons change each week and include specific activities for each topic. The final project and overarching assignment for the course consists of a student-designed digital artifact that outlines a five-day learning unit on a sustainability topic chosen by the students individually.

Table 1: Course attributes

COURSE NAME	**Education for Sustainable Development (ESD)** Leuphana	**Sustainability Science for Teachers (SSfT)** ASU
CURRICULUM	Second semester Mandatory course for BA (Bachelor of Arts) Teaching and Learning (Subject: Basic Social and Science Studies)	Fifth semester Mandatory course for BAE (Bachelor of Arts in Education) Elementary Education (K–8)
STRUCTURE	**13 x seminar sessions (weekly)** (incl. practical project implementation at a partner school) **7 x lectures (online + in person) + 7 x tutorials**	**15 x seminar sessions (weekly)** **15 x online sessions** (incl. videos, quizzes, and assignments)
STUDENTS	**81 students** (allocated to three seminars + three tutorials)	**130 students** (allocated to five seminars)
FORMS OF ASSESSMENT	**Individual written assignment:** **Creating an ESD learning** unit (30 pts.) **Group presentation** (incl. a written report and individual reflection) **Presenting an individual ESD lesson** (incl. rationale) (70 pts.) = 100 pts.	**Participation** (150 pts.) **Quizzes** (130 pts.) **Contributions on Blackboard** (200 pts.) **Assignments** (150 pts.) **Group presentation** (50 pts.) **Final project: outline** (60 pts.) **Final project: peer-review** (60 pts.) **Final project: submission** (200 pts.) = 1000 pts.
KEY LEARNING OBJECTIVES	• Understanding ESD from an educational perspective in primary education • Gaining ESD-related pedagogical content knowledge • Ability to plan and implement teaching and learning activities in a given class setting	• Ability to develop and communicate an understanding of sustainability concepts and their application • Ability to apply the WOT to explain sustainability concepts • Ability to identify, analyze, and advocate for individual and collective actions that will contribute to a more sustainable world

The two cases show several differences and similarities regarding their key design elements, which makes a comparative case study particularly interesting. While both courses generally follow the overall concept of blended learning in a hybrid course structure, they include different T&L formats. The *ESD* course at Leuphana complements a flipped classroom lecture style with student-led tutorials and project-oriented seminar sessions, where students gain their first practical experience in a professional environment (project work with a partner school). The *SSfT* course at ASU combines elaborate video content, quizzes, and online assignments with in-class activities to provide practical examples of how to implement ESD at the school level. While the Leuphana course revolves around the question of how to design T&L units and environments in ESD (PCK), the course at ASU introduces different sustainability topics every week and is focused on conveying CK, which leads to a different set of ILOs. Despite the different foci of both modules, students create their own ESD-related T&L unit as their key assignment. Due to the different time slots/schedules of the respective programs at Leuphana (2nd semester) and ASU (5th semester), the participants differ in terms of their age and previous experience with sustainability and ESD. At Leuphana, students complete a module focused on sustainability in their first semester, whereas the SSfT course is most ASU students' first encounter with sustainability and related topics as well as ESD as an educational concept.

3.2 Data collection

Data were collected during the spring semester of 2018 (April–July) at Leuphana and during the fall term (August–November) at ASU. Data collection followed a mixed-method approach, which was used to capture a rich picture of students' learning processes and outcomes. Data collection was approved by the Institutional Review Boards of both institutions.

The Leuphana cohort was divided into three seminar groups and consisted of 81 students, of which 77 gave their consent to participate in this research. These students were predominantly female and 21 years old on average. The ASU cohort consisted of 130 students that were grouped into five sub-cohorts (SSfT-1–5), of which 105 consented to participate in the research. While these students were predominantly female, they were an average of one year older than those of the German cohort (22 years old) (Table 2).

Table 2: Cohorts

	Education for Sustainable Development (ESD) – Leuphana	**Sustainability Science for Teachers (SSfT)** – ASU
NUMBER OF STUDENTS (CONSENTED) Student-IDs:	81 (77) S2_502 to 582	130 (105) S2_300 to 407
GENDER	Female: 88.5% (46) Male: 11.5% (6) (No reply: 21)	Female: 95.3% (61) Male: 4.7% (3) (No reply: 41)
AGE	*M* 20,78	*M* 21,69

3.3 Instruments:

A pre- and post-course survey was conducted to identify learning outcomes regarding students' motivation to implement ESD in their future careers as teachers (attitude). In addition to an open-ended question asking for students' sustainability definitions in a pre-post comparison, a CK assessment was conducted that included 14 multiple-choice questions on various sustainability challenges that align with the key competencies in sustainability, as described by Wiek et al. (2011). The students were scored based on the percentage of correct responses, which allowed for paired sample t-tests and a pre-post comparison. Data on the learning process and perceived learning outcomes regarding pedagogical skills in ESD (PCK) were collected through student focus groups (4–7 participants per group). To support students' reflection process, the focus groups were enriched by a photovoice activity—a method originally introduced by Wang and Burris (1994). In using this method, the students took pictures of personal key learning moments throughout the semester, which then served as anchor points during the group reflections.

Table 3 summarizes the instruments used in the present study. For more detailed information, we published an extended instruments paper (Brandt et al., 2020), which serves as supplementary material for this article.

Table 3: Instrument overview

SURVEY	**Pre- and post-course survey** **(n_{pre} = 124 – 60 (Leuphana)/64 (ASU), n_{post} = 129 – 56/73, $n_{pre\&post}$ = 96 – 49/47)** • Perceived relevance of the ESD scale (six four-level Likert items) (Tomas et al., 2017) • ESD-related self-efficacy scale (11 four-level Likert items) (Tomas et al., 2017), supplemented by Bertschy et al. (2013) • Innovation-related self-efficacy scale (seven four-level Likert items) (Emmrich, 2009) • Definition of sustainability (open item) **Pre-course survey** • New ecological paradigm (NEP) scale (15 five-level Likert items) (Dunlap et al., 2000) • Previous work experience (closed item with eight checkboxes) • Extracurricular activities (closed item with 10 checkboxes) • Motivation to become a teacher (open item) **Post-course survey** • Demographic information (items on age and gender)
CK ASSESSMENT	**Pre- and post-course assessment** **(n_{pre} = 124 – 68 (Leuphana)/56 (ASU), n_{post} = 126 – 56/70, $n_{pre\&post}$ = 94 – 49/45)** • ESD-related content knowledge (14 multiple-choice questions, based on Wiek et al. (2011)
FOCUS GROUPS	**11 (6/5) end-of-semester focus groups (PhotoVoice) (approx. 45 min.)** **(n = 31/29)** Open questions: (4) What skills/competencies did the students develop during the semester? (learning outcomes) (5) How did the students learn and what affected students' learning processes in the course(s) under investigation? (learning process) (6) What are the causal links between the learning processes and learning outcomes? (process tracing)

3.4 Data analysis

The analysis of quantitative survey data was conducted using simple descriptive statistics (frequencies) for the demographics and paired sample t-tests to obtain a pre-post comparison of attitude scales and changes in students' CK scores as well as their understanding of the term *'sustainability'*. To make the latter available for quantitative analysis, students' definitions were coded by two independent researchers against a coding scheme considering inter- and intragenerational perspectives as well as the multi-dimensional understanding of the concept, resulting in a score from 0 to 5 (see Appendix 1).

Inter-coder reliability (ICR) was considered and differences were resolved communicatively. The qualitative analysis of focus group transcripts was oriented toward an understanding and reconstruction of the learning processes and outcomes by following a deductive-inductive coding paradigm and applying the method of constant comparison as an element of grounded theory (Strauss and Corbin, 1990). We used the different learning formats applied in the two courses, the ILOs (namely CK, PCK, and attitude) as well as the four forms of connection (i.e. *the four Cs*) as deductive codes. Additionally, we allowed new codes to emerge inductively with the hope that they would provide information regarding the quality of links between the three sets of deductive codes. Coding was performed by two researchers to ensure ICR. The coded segments were then exported from MaxQDA to an EXCEL file, where duplicates were deleted, sub-categories were built, and connections between learning formats, processes, and outcomes were highlighted. This resulted in six tables (one for each case and learning outcome) that include where (T&L formats) and how (forms of connection) competence development occurred. These tables are complemented by selected quotes from the students (see Appendix 2-7). Additionally, German quotes were translated into English by the first author.

4 RESULTS

First, we examined the extent to which the ILOs – i.e., increased sustainability-related CK, PCK, and motivation to implement ESD (attitude) – were achieved. In a second step, we searched for indications of where (T&L formats) and how (impact factors) learning occurred. Table 4 summarizes the different learning outcomes, applied T&L formats, and main impact factors on students' learning processes.

Table 4: Overview of learning outcomes, T&L formats, and learning processes

LEARNING OUTCOMES	T&L FORMATS (LEUPHANA)	T&L FORMATS (ASU)	IMPACT FACTORS (LEARNING PROCESSES)
CONTENT KNOWLEDGE (CK) - General knowledge of sustainability concepts, issues, and/or solutions - Understanding the complexity of sustainability	**LECTURE** - Regular lectures (weeks 1–2) - Flipped classroom + in-person Q&A sessions (weeks 3–7)	**ONLINE LEARNING** - Videos (digital storytelling) - Quizzes - Reflective assignments	**PERSONAL CONNECTION** - Personal interest - Emotional reactions - Agency - Applicability of content to private life
PEDAGOGICAL CONTENT KNOWLEDGE (PCK) - Ability to plan ESD units - Ability to implement ESD units - Ability to break down complex sustainability topics for children	**TUTORIAL** - In-person tutored sessions (support for the assignment)	**IN-CLASS LEARNING** - In-class discussions - In-class activities (hands-on and reflective)	**PROFESSIONAL CONNECTION** - Theory-praxis connection - Applicability of content to a future teaching career
ATTITUDE - Perceived relevance of ESD - Willingness to implement ESD at the school level	**ASSIGNMENT** - Assignment (designing an exemplary lesson plan for an ESD unit)	**HYBRID** - Final project (creating a digital artifact outlining an ESD unit)	**SOCIAL CONNECTION** - Exchange of ideas and perspectives - Provision of feedback, support, and guidance
	SEMINAR - General seminar sessions - Project planning (group work) - Practical implementation (cooperation with school) - Final presentations		**STRUCTURAL CONNECTION** - Deliberate links between different T&L formats - Complementary T&L formats

Upon investigating students' learning outcomes from the *ESD* course at Leuphana and the *SSfT* course at ASU, the results indicated that both modules supported the development of ESD-specific professional action competence for teachers to varying degrees. The overall results reveal that the Leuphana course had a greater impact on PCK development, while the ASU course appeared to foster CK and positive attitudes toward sustainability more strongly among students. In both cases, CK development was mainly supported by structural connection (complementary T&L formats) and personal connection (applicability of content to students' private lives and agency). While Leuphana students further highlighted the importance of theory-praxis transfer through practical implementation (professional connection), ASU students emphasized the crucial discursive exchange during in-class discussions (social connection). Regarding PCK development, the professional connection was the key factor. The provision of exemplary lesson plans in lectures (Leuphana), videos, and in-class activities (ASU) – as well as opportunities to gain practical experience during the assignment, run an exemplary ESD lesson (Leuphana), and work on the final project (ASU) – were perceived as particularly helpful. Moreover, social connection and mutual exchange among fellow students regarding the planning and implementation of ESD units, as well as feedback and support from the teaching staff and practice partners (Leuphana), were considered important. At Leuphana, even the structural connection between the assignment and practical implementation (linking theory and praxis) – as well as the fact that the assignment (Leuphana) and final project (ASU) allowed students to work on a topic of individual interest (personal connection) – seemed to support PCK development. Regarding increasing students' positive attitudes toward ESD, students from both cases reported that they learned about the importance of ESD when studying on their own – during the online portion (videos, quizzes, and assignments) at ASU and via the literature provided at Leuphana. Furthermore, practical examples of how to implement ESD (professional connection) that were provided by the in-class activities and final project at ASU, as well as the practical implementation at Leuphana, appeared to serve as crucial support factors. The personal connection and applicability of the overall course content (Leuphana) and in-class activities (ASU) to students' private lives supported the development of positive attitudes, while the videos and final project sparked interest and excitement among ASU students, some of which felt strongly encouraged by their instructors (social connection).

4.1 Content knowledge

CK was first measured by changes in students' definitions of the term *'sustainability'*. Table 5 presents the results of coded answers provided before and after the course, which show a significant increase in the complexity of students' understanding of sustainability through both courses. While the Leuphana students started with higher pre-course values, the effect sizes (Cohen's *d*) indicate that the ASU course had a slightly stronger impact on students' understanding of sustainability. The results of the CK assessment show a slight increase in students' sustainability-related CK, with Leuphana students showing higher starting values (Table 6).

Table 5: Sustainability definitions: Paired t-tests (pre-post comparison)

	Pre-test			**Post-test**					
	N	*M*	*SD*	*N*	*M*	*SD*	*df*	Cohen's *d*	Sig.
(overall) Sustainability definitions (0–5) Time perspective + dimension orientation									
ESD	45	**2.80**	1.31	45	**3.33**	1.15	44	**.36**	*
SSfT	46	**1.98**	1.00	46	**2.57**	1.07	45	**.51**	**
Time perspective (0–3) 0 = no time perspective, 1 = future perspective, 2 = intergenerational perspective, 3 = intergenerational and intragenerational perspective									
ESD	45	**1.73**	.94	45	**2.02**	.84	44	**.30**	*
SSfT	46	**0.96**	.84	46	**1.33**	.79	45	**.39**	*
Dimension orientation (0–2) 0 = no dimensions mentioned, 1 = one-dimensional perspective, 2 = multi-dimensional perspective									
ESD	45	**1.07**	.86	45	**1.31**	.87	44	**.20**	
SSfT	46	**1.02**	.61	46	**1.24**	.77	45	**.48**	

** Significant at the .01 level (2-tailed)
* Significant at the .05 level (2-tailed)

Table 6: Content knowledge assessment: Paired t-tests (pre-post comparison)

	Pre-test			**Post-test**					
	N	*M*	*SD*	*N*	*M*	*SD*	*df*	Cohen's *d*	Sig.
ESD	49	**.70**	.20	49	**.73**	.21	48	**.15**	
SSfT	45	**.44**	.17	45	**.47**	.18	44	**.21**	

** Significant at the .01 level (2-tailed)
* Significant at the .05 level (2-tailed)

In the analysis of focus group data, CK was understood as the general knowledge and understanding of sustainability issues, solutions, and concepts. In terms of CK development, Leuphana students reported that they gained only *"little new knowledge"* (S2_528). However, a few statements explicitly referred to a better understanding of sustainability concepts such as the quadruple bottom line[2] (S2_550) and specific seminar topics on mobility (e.g., S2_514) and sustainable breakfast (e.g., S2_519). However, some emphasized a lack of deeper CK due to the focus on methods:

> *"Much more has to be done on the topic, really focusing on the content. We are doing a lot about methods [...]. You can't learn everything there is in the world, but, I don't know, somehow deepening the specific content knowledge wouldn't be so bad either."* (S2_541)

Also, ASU students reported an increased understanding of the complexity of conflicting values in sustainability (S2_304) and concepts such as the triple bottom line (S2_301). However, they most frequently mentioned topics such as different energy sources and their benefits and drawbacks (e.g., S2_312) or modes of production, consumption, and disposal (S2_324, S2_369, and S2_405), which were often explicitly linked to their personal connection to the content:

> *"I think just throughout the course, I went to be more aware of how my actions can affect the future of our environment because I just buy things at the store and don't really think about the impact it has on the world. But I also learned how to see things more through a lens of sustainability than I had in the past. And I learned kind of like how everything goes through a process and there are like different parts of the process that do different things to our environment, some good and some bad."* (S2_312)

Leuphana students noted that they primarily gained their CK via the interplay of the various formats of the course (i.e., lecture, tutorial, and seminar) and through a sense of structural connection. Lectures were generally considered to have laid the foundation for CK by providing content that was subsequently dealt with and deepened in the tutorial and seminar sessions:

> *"I think by doing our own projects in the seminars, and in parallel to the lectures, we could specialize in concrete topics that deepened our knowledge and helped us realize how to implement it."* (S2_526)

[2] At Leuphana, sustainability is considered as the interplay of economic, environmental, social, and cultural aspects. At ASU, instructors focus on the triple bottom line and do not address cultural aspects as explicitly.

The second factor in CK development was personal connection, which was represented by the lecture content being applicable to students' private lives (e.g., S2_531). Moreover, the surprising relevance of seminar topics became clear during the final seminar presentations:

> *"I learned a lot about mobility and how it is connected to sustainability. Because we have now seen four presentations or four projects, and I would not have associated them with [sustainability] at first."* (S2_519)

Finally, the practical implementation, which provided a glimpse into practice (professional connection) and complemented the other formats (structural connection), helped students to understand the complexity of sustainability topics:

> *"I was stunned by how complex a topic can be and from how many different perspectives you can look at it. It started in the lecture, which was more the theoretical part and where he [the lecturer] introduced and presented it once. Then, the group meetings were actually the next relevant point. Simply because we dealt with it in depth and were able to understand it better. And then, at the elementary school, we saw what it actually looks like and what knowledge networking and transfer look like for the children—and not only for ourselves."* (S2_577)

Similar to the Leuphana cohort, the ASU students mainly referred to elements of structural and personal connection as factors supporting CK development. According to their statements, the in-class activities built upon what was learned online (e.g., S2_355). More specifically, the videos were perceived to provide relevant information and lay the foundation for in-class discussions (S2_351), which allowed for valuable discursive exchange (social connection):

> *"For me, if I had never done the activities hands-on, I would've never really understood the concepts. And being able to make my own connections to my previous learning and this new information given to me was crucial to my learning."* (S2_355)

> *"The videos were like enough information, but then I felt like I made more connections when we like actually talked in the class."* (S2_351)

Furthermore, working on the final project appeared to support students' understanding of selected sustainability topics by connecting everything that was learned from the SSfT course (structural connection):

> *"I'm like really working hard on this website right now and it takes like a lot of time. And I really like connecting what we kind of learned in this class [...] it's helping me for my lesson planning, but also helping me just kind of like get a deeper understanding of what the water cycle is, how we impact it, how animals use it—like the sea life and all that—and that's something really important to me."* (S2_353)

Even more frequently, the students referred to the importance of personal connection for CK development. For instance, learning at home with the videos (personal time management/S2_397) or working on the final project (topic of personal choice/S2_353), facilitated students' agency and supported their learning. Also, the fact that online (videos, additional resources, and assignments) and in-class learning (hands-on activities and discussions), as well as the final project, were applicable to students' private lives, personal actions, and their implications facilitated CK development:

> *"This was the assignment we did look at, like, our carbon footprint and how much our actions affected the globe. And I do not know, I just, I thought this helped my learning a lot because I learned a lot about myself and like how my actions are affecting the planet [...] and I learned a lot about how much food Americans eat and throw away too. So, it kind of also related to my final project. [...] And then I also wrote about the videos that we watched on like the different energy sources. I thought like those had a lot of like good information in them that I did not know about, on how they could like benefit us, like economically, socially, and environmentally."* (S2_301)

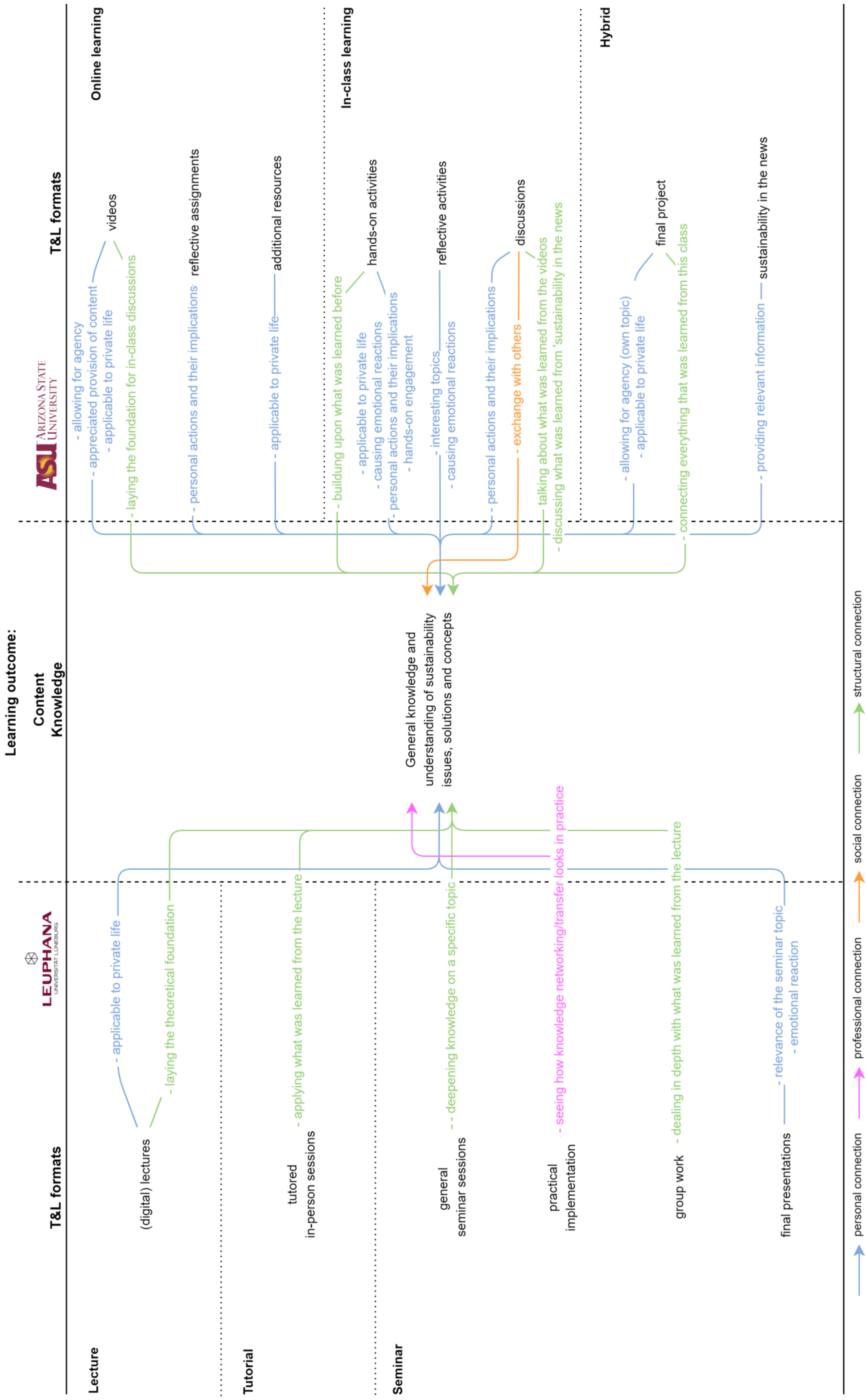

Figure 2: Developing ESD-related content knowledge

4.3 Pedagogical content knowledge

Changes in students' PCK were assessed via self-assessment based on statements from the focus groups. We focused on the abilities to plan and implement ESD at the school level and break down complex sustainability topics for children as PCK-related learning outcomes.

The focus group data revealed that, when compared to the students from ASU, the Leuphana students referred more frequently and specifically to developing PCK. Their statements regarding the ability to plan ESD units, for instance, were versatile and range from general ones (e.g., when referring to lesson planning (e.g., S2_503)) to specific structural elements of T&L units. While some students mentioned selecting methods for the actual implementation of ESD at the school level (e.g., S2_518), others referred to planning around certain learning objectives, the formulation of specific tasks and guiding questions as well as the application of ESD-specific learning principles (e.g., S2_550):

> *"I would say that from the lecture, I mainly learned that it is about objective-oriented teaching. So, I mean I already knew that before, but now it is even more in focus when you consider certain didactic principles and orient toward the ways of thinking and first looking at 'OK, what do you want to achieve and what do I connect that to in the end?'"* (S2_550)

However, according to S2_518, planning ESD units based on ILOs instead of topics initially felt counter-intuitive. Others claimed that even though they learned how to "develop lesson plans" and *"formulate complex topics in a way that children can also memorize and learn from them"*, they lack practical experience (e.g., S2_554) and require repetition (e.g., S2_541) to successfully plan ESD units. However, the data generally showed that the practical examples of how to design lesson plans provided in lectures (e.g., S2_540, S2_558), as well as those gained from practical experience during assignments (S2_526) and project implementation as part of the seminar (e.g., S2_514, S2_554) (professional connection), supported the development of PCK and helped students in the Leuphana course learn how to break down complex ESD topics for children:

> *"Yes, I have making complex topics suitable for children. And that actually started with the lecture, where we broke down an overarching topic into a child-friendly topic, which could also be dealt with in class. […] And during the implementation of the seminar this week, it was just noticeable that, above all, we cannot use complicated technical terms that they don't know yet because then they switch off or don't understand us at all."* (S2_554)

Regarding planning competence, Leuphana students also more frequently referred to their ability to implement ESD units in their future classrooms (e.g., S2_526, S2_519), often linking this ability to cooperation with their partner school (seminar). This allowed for a *"first glimpse into everyday teaching life"* (S2_514), which showed *"how things work in reality"* (S2_576). Furthermore, discursive exchange with fellow students about assignments (e.g., S2_576), feedback from seminar instructors during the planning phase of their projects (e.g., S2_554), and the guidance, support, and individual feedback provided by tutors (tutorial) (e.g., S2_503) (social connection) played crucial roles in this regard:

> *"Alongside the lecture, the tutorial was really quite relevant and deepened the knowledge, especially since there was always individual help and the clarification of unclear terms, and we were always treated individually. Then, the assignment where everything T_205 said could be applied and individually examined. And since then, I have the feeling that I know what I am talking about. Before, it was all a bit vague and now it is concrete lesson planning and I know what to do."* (S2_503)

When referring to the assignment (S2_537) and cooperation with their partner school (S2_512), some students complained about the lack of feedback (social connection) in other learning formats. Additionally, the links between different course elements were emphasized (structural connection). The assignment facilitated students' agency (personal connection), built on what was learned from the lecture and tutorial sessions (e.g., S2_506, S2_548), and laid the theoretical foundation for the seminar and practical implementation (S2_540, S2_541). Nevertheless, some students claimed that they still experienced difficulty connecting ESD to certain topics (e.g., S2_518), which once again highlights the lack of practical experience and the need for individual repetition:

> *"I don't have the feeling that I am leaving this class with a handbook on how to implement ESD. […] Actually, I should watch a video or an exemplary lesson, a super positive example. Like, how would it have to look like to say, 'This is a successful ESD unit'?" […] I understood the concept of ESD, but I will really have to practice it and hope we will be given the opportunity to do that too. Otherwise, it would be like getting a piece of cake and having it taken away again after one bite."* (S2_541)

As previously stated, fewer statements from ASU students explicitly referred to PCK development. Furthermore, their statements on PCK-related learning outcomes largely remained rather general (e.g., S2_351):

> *"I feel like after this class, I feel like I know how to better like incorporate this [sustainability] into other subjects and things and how to get them like caring about it, something like that."* (S2_351)

Regarding the ability to plan and implement ESD units, the ASU students mainly highlighted the importance of professional connection and practical examples provided by the videos (e.g., S2_378) and in-class activities (e.g., S2_397). Some students stated that they felt encouraged by the instructor to engage in the activities and view the material from the perspective of their future students (e.g., S2_369). Additionally, S2_397 emphasized the positive impact of in-class discussions and the mutual exchange of ideas regarding how to implement ESD at school (social and professional connection). Also, it was evident that the final project provided students with a chance to gain valuable practical experience, particularly regarding the planning of ESD units (e.g., S2_379) and breaking down complex sustainability topics (e.g., S2_369). Similar to the key assignment at Leuphana, it also provided the opportunity to work on a topic of personal interest (personal connection):

> *"The skill that I focused on was how to write a lesson plan. First, we learned the importance of it, we discussed the value of it, [...] and then we were assigned to create a website or some sort of digital artifact on a sustainability topic of our choice. Then I did a lot of research. I saw what other teachers were doing and that's really the main way I learned"* (S2_383).

While the final project was eventually perceived as helping to "connect everything" that was learned in this course (S2_353), the importance of a structural connection – also for PCK development – was further supported by the link between online and in-class learning. For example, according to S2_397, the videos laid the foundation for the in-person activities:

> *"Obviously it's a hybrid course, so a lot of our information gathering was done through the videos, online, and on our own time. But then when we came to the class, T_010, our instructor, did a great job of showing how we can implement it in a classroom."* (S2_397)

However, while several students claimed they learned how to create grade-appropriate ESD units (e.g., S2_369), others were limited to topics they related to (S2_302) or dealt with during the final project (e.g., S2_310). For example, S2_301 emphasized persistent difficulties in breaking down complex topics for younger students.

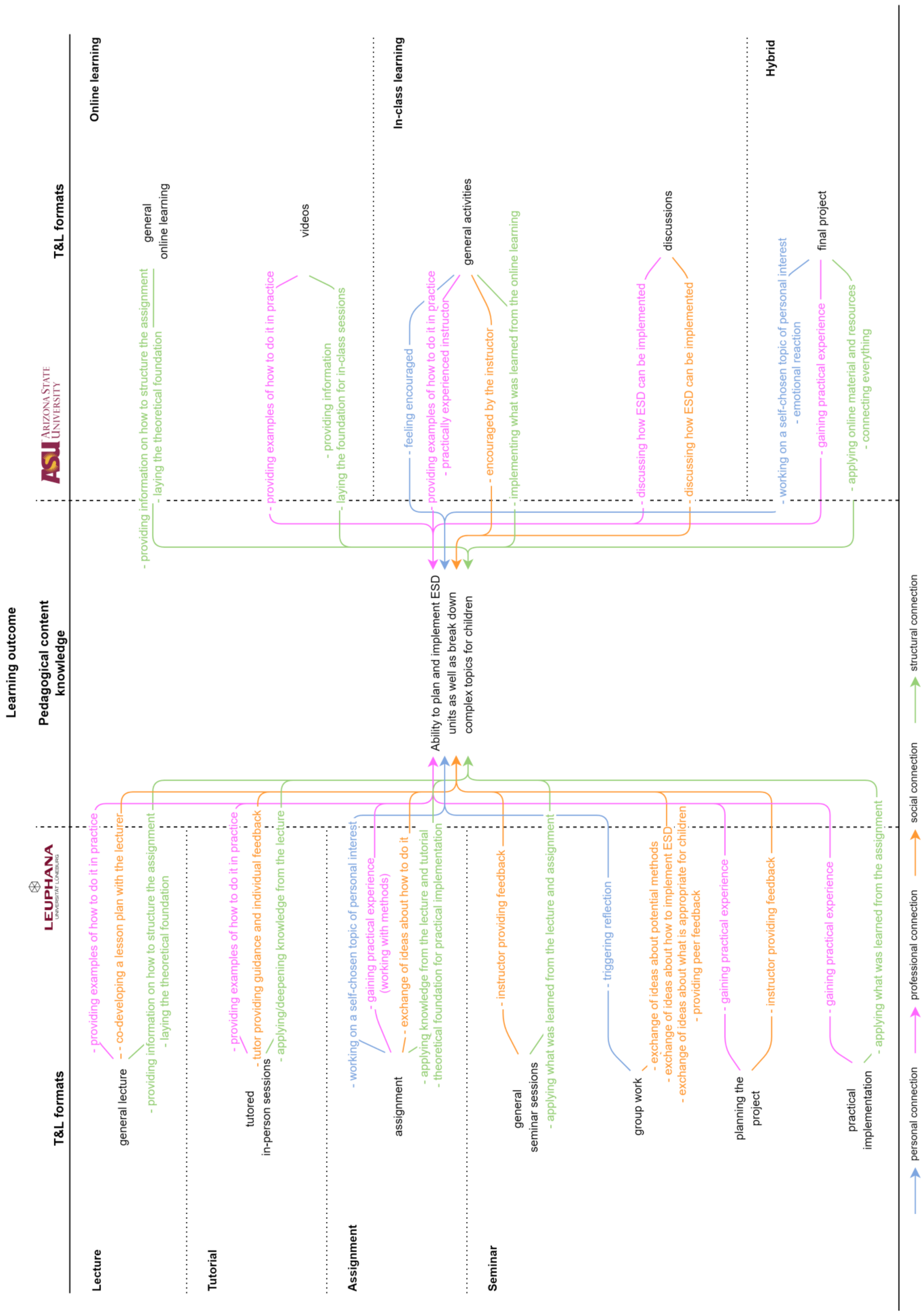

Figure 3: Developing ESD-related pedagogical content knowledge

4.3 Attitude

Students' attitudes were measured against the innovation-related SE (Emmrich, 2009), ESD-related SE, and perceived relevance of the ESD scale (Tomas et al., 2015), which showed acceptable-to-very good Cronbach's alpha (α) values (0.68–0.90).

A pre-post comparison using paired t-tests revealed that students' ESD-related SE increased significantly during both courses, whereas innovation-related SE only showed a significant increase on the ASU side. In both cases, the perceived relevance of ESD also increased, but only slightly and not significantly (see Table 7).

Table 7: Attitude scales

	Pre-test			**Post-test**					
	N	*M*	*SD*	*N*	*M*	*SD*	*df*	Cohen's *d*	Sig.
Innovation-related self-efficacy (seven items; 1–4 Likert scale)									
ESD	46	**3.13**	.39	46	**3.18**	.33	45	**0.17**	
SSfT	46	**3.01**	.41	46	**3.30**	.40	45	**0.65**	**
ESD-related self-efficacy (11 items; 1–4 Likert scale)									
ESD	46	**2.98**	.36	46	**3.27**	.28	45	**0.81**	**
SSfT	42	**2.79**	.42	42	**3.39**	.39	41	**1.21**	**
Perceived relevance of ESD (six items; 1–4 Likert scale)									
ESD	46	**3.55**	.34	46	**3.59**	.40	45	**0.11**	
SSfT	45	**3.48**	.39	45	**3.53**	.47	44	**0.11**	

** Significant at the .01 level (2-tailed)
* Significant at the .05 level (2-tailed)

The survey results – which indicated an increase in positive attitudes toward ESD – are supported by the focus group data to some extent. Students from both courses confirmed that the perceived relevance of ESD and their motivation to implement ESD at the school level have increased over the semester. However, more statements concerning attitude as a learning outcome were made by ASU students.

Leuphana students that noted an increase in perceived ESD relevance highlighted the importance of different learning formats, discussion, and reflection time in informal learning scenarios. They also noted that the course content was applicable to their private lives (e.g., S2_519) (personal connection):

> *"Right, I chose the relevance of education for sustainable development […]. Like S2_526, I learned that, for example, through going for walks and conversations. […] Going for a walk simply helps me to reflect on things. And then in the tutorial, the practical application of what was learned from the lecture was that there were so many connections to my everyday life. […] And then again, very specifically when working on our project."* (S2_519)

According to S2_559, the ESD literature – initially provided as an additional resource to support students in their work on the assignment – increased the perceived importance of ESD despite an *"overload"* of the topic being perceived in the overall program:

> *"Because before this semester, I was like, 'Oh, ESD! I cannot hear it anymore. It gets a bit on my nerves.' But yeah, it is true that this text showed me that 'Yes, it is important. And where should the children learn about it if not at school?"* (S2_559)

The opportunity to run an exemplary ESD unit as part of the seminar (e.g., S2_518, S2_559) and the fact that ESD is required by school curriculums (professional connection) increased students' willingness to implement it in the future. Interestingly, some of the Leuphana students not only referred to attitude as a course outcome but also indicated that the perceived relevance of ESD and the motivation to implement ESD are directly linked since the former influences the latter:

> *"I realized why what is being done is so important, like bringing the children closer to nature and going out and appreciating nature and sustainability aspects. […] And with this realization that it is important, there was also the motivation to do it."* (S2_541)

However, some students doubted that ESD will be consistently implemented in the way it was conceived of in the ESD module – even though they scored above average on the two scales of ESD SE and the perceived relevance of ESD in the post-course survey (S2_513) or already perceived ESD as relevant before the course (S2_503).

Also, the ASU students indicated that the SSfT course increased their perceived relevance of ESD (e.g., S2_304) and their motivation to implement it in their future classrooms (e.g., S2_329, S2_333). Again, certain statements show that both aspects tend to be correlated:

> *"I think for me, it [the course] showed me that it is important to start teaching sustainability at a young age. […] So, yeah, I can definitely see myself trying to always implement those things for kids."* (S2_339)

According to the focus group data from ASU, the observed increase in students' positive attitudes toward ESD was mostly promoted by professional connection and opportunities to gain practical experience through in-class activities (e.g., S2_304) or the final project (e.g., S2_329). Furthermore, the course highlighted the potential impact of educating others about sustainability, which was only assigned to content provided by the online formats (i.e., videos, quizzes, and assignments) (e.g., S2_369):

> *"There is this one unit where we learned about different teachers and how they've kind of made a change in their communities and kind of brought more awareness to their communities about different sustainability issues. And there is one interesting video about a little fourth-grade girl who made this huge difference after the BP oil spill and drawing sea animals. […] Kids are some of the most powerful change-makers in the world and teachers can kind of help develop that."* (S2_369)

Additionally, students' personal interest in the content (provided by the videos (S2_369), the applicability of certain in-class activities to students' private lives (e.g., future scenarios (S2_302) and agency (S2_383)), and the excitement felt when working on the final project (S2_379) (personal connection) supported the development of positive attitudes toward ESD:

> *"The final project was really good because we got to actually make a unit plan […] looking at the standards and seeing how you can actually incorporate them in your classroom. So, it kind of got me excited, like 'Oh, I kind of want to teach this lesson and put things in there and actually go through the whole day'."* (S2_379)

Finally, data from the ASU students showed that social connections and students feeling particularly encouraged by discussions with their instructors played important roles in fostering their motivation:

> *"T_010 told us one teacher will encounter like 10.000 students in their teaching career, so even if you just mention it once that's going to be in their minds for probably forever, so, I feel very confident about this topic."* (S2_400)

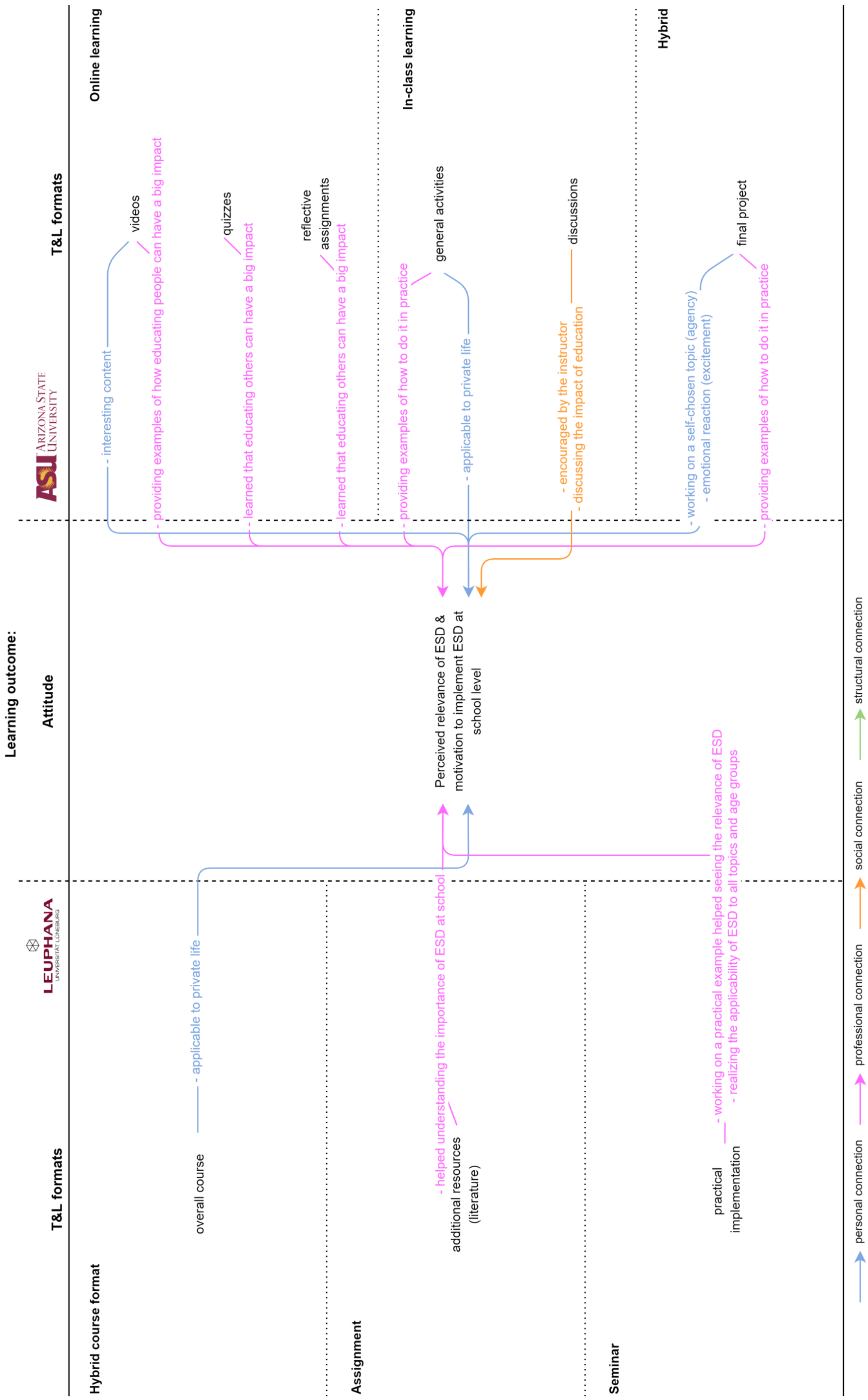

Figure 4: Developing positive attitudes towards ESD

5 DISCUSSION

When applying the concept of ESD-specific professional action competence for teachers (Bertschy et al., 2013), TESD is expected to develop student teachers' sustainability-related CK, their ability (PCK), and motivation (attitude) to implement ESD at the school level. This is in line with the broad agreement that sustainability knowledge, skills, and commitment are crucial pre-requisites for effective teaching in TESD (Evans et al., 2017). Although Timm and Barth (2020) added the perspective of teachers as change agents at the institutional level – as well as constructs such as sustainability or environmental literacy referring to the responsible behavior and desirable citizenship action of teachers as role models (Roth, 1992; Nolet, 2009; Hollweg et al., 2011) – we focused on their competence in implementing ESD in the classroom.

5.1 Learning outcomes

Empirical research has often focused on assessing the individual competence components of CK (e.g., Esa, 2010), PCK (e.g., Rosenkränzer et al., 2017), or attitude (e.g., Tomas et al., 2017). In the present study, we went beyond that by operationalizing and measuring the entire construct of ESD-specific professional action competence for teachers while shedding light on the learning processes and revealing key factors affecting students' learning in blended learning TESD courses. By confirming that blended learning courses in TESD effectively prepare prospective teachers to implement ESD (Chin et al., 2019), the results of this study indicate that both modules under investigation supported the development of CK, PCK, and positive attitudes toward ESD to varying degrees. The overall findings reveal that the Leuphana course had a greater impact on PCK development and led to a more thorough understanding of pedagogies such as ESD-specific didactic principles and competence orientation, while the ASU course appeared to more strongly foster students' CK and positive attitudes toward sustainability. Due to the different course designs and foci in terms of content, this was partly expected. The *SSfT* course aims to convey more detailed factual knowledge regarding sustainability topics (CK), whereas the Leuphana course revolves around the question of how to design T&L units and environments in ESD (PCK). Furthermore, it should be considered that, for most ASU students, the *SSfT* course constituted their first encounter with the topic.

On the contrary, the Leuphana students already completed a module focused on sustainability in their first semester and thus began the intervention with more complex sustainability knowledge. These general results regarding students' learning outcomes slightly contradict those observed by Weiland and Morrison (2013), who found that courses focusing on either content or methods are equally effective in increasing student teachers' CK and PCK. Therefore, we agree with Lindemann-Matthies et al. (2011), who advocated a balance between the provision of CK and opportunities to obtain practical teaching experience. However, during the analysis of focus group data, students' self-reported learning outcomes regarding PCK were sometimes difficult to distinguish from ESD-related SE items that covered students' trust in their own capabilities (Rieckmann, 2012) and positive attitudes toward ESD. To overcome the limitations of self-assessments (Cebrián et al., 2019) and previous attempts to measure students' PCK in a performance-oriented approach (e.g., Rosenkränzer et al., 2017; Brandt et al., 2019), future research should focus on the development and implementation of adequate instruments to assess ESD-specific PCK in this context.

Regarding students' attitudes toward ESD – which indicate their motivation to teach related topics (Büssing et al., 2019) – the results of this study demonstrate an increased willingness of students from both cases to implement ESD in their future classrooms. This confirms the previous finding that participating in a TESD course may generate pro-sustainability beliefs and norms among future teachers (Andersson, 2017). Regarding ESD-related SE, which has been described as a key factor for successful teaching (Lindemann-Matthies et al., 2009), the results showed a significant increase. However, only a minor change was observed in the perceived relevance of ESD, which could be partly explained by relatively high pre-course values – a phenomenon that corresponds with earlier findings by Tomas et al. (2017). While these results confirm the results of a previous study on the ESD course at Leuphana (Brandt et al., 2019), students reported significant increases in the perceived relevance of ESD in previous cohorts of the *SSfT* course (Brandt et al., 2021; Merritt et al., 2019).

5.2 Learning processes

Regarding the question of what influences the development of ESD-specific professional action competence for teachers, especially concerning applied T&L formats, we found that *the four Cs* (i.e., personal, professional, social, and structural connections) described by Brandt et al. (2021) were confirmed as key factors impacting students' learning processes in both courses. For instance, CK development was mainly fostered by deliberately linked T&L formats and the fact that tutorial and seminar sessions at Leuphana built upon the knowledge provided in lectures or that video content laid the foundation for in-class discussions at ASU (structural connection). This corresponds to the findings of Biggs and Tang (2011), who claimed that building upon existing knowledge and establishing structural interconnections between topics directly improves learning. Since most of the 2017 *SSfT* cohort mentioned structural connection in the context of hindering links or creating a disconnection between formats (Brandt et al., 2021), the course coordinator appears to have read the signs correctly and made valuable adjustments to the course's structure.

The second factor affecting successful CK development was personal connection, which is in line with Beane (1995), who claimed that *"sources of curriculum ought to be problems, issues, and concerns posed by life itself"* (p. 616). According to the Leuphana students, the lecture content was particularly relatable and applicable to their private lives. At ASU, the online portion of the course allowed students to learn at their own pace (agency), while the videos, quizzes, reflective assignments, and in-class activities related to students' personal actions and their implications. This might have increased the perceived value of engagement in the course, which Biggs and Tang (2011) considered another general driver for successful learning. Furthermore, asynchronous online learning might encourage students to confront issues more objectively and reflectively due to an improved focus on the content and less noise from face-to-face interactions (Chin et al., 2019).

The most important factors supporting the development of PCK were professional, structural, and social connections. Dealing with exemplary lesson plans during the lecture and tutorial sessions (Leuphana) as well as the videos and in-class activities (ASU), respectively, fostered students' ability to plan ESD units. At Leuphana, the opportunity to gain practical experience while working on the assignment and running an exemplary ESD lesson (i.e., practical implementation) ensured a valuable theory-praxis link and helped to further increase students' PCK (professional and structural connection).

Also, at ASU, the link between videos and in-class activities was perceived to help to improve PCK since new knowledge was being practically applied. These findings support prior research pointing to the importance of experiential learning approaches for developing ESD competencies in general (Jegstad et al., 2018) and CK and PCK in particular (Nielsen et al., 2012). Considering the highly cited theory-praxis gap in teacher education (Shulman, 1998), Frisk and Larson (2011) emphasized the importance of real-life learning opportunities for competence development in TESD. Additionally, Bürgener and Barth (2018) highlighted that cooperating with partner schools enhances students' learning by allowing for insights into the professional field. Finally, discursive exchanges with fellow students about pedagogical methods during seminars and valuable feedback and guidance provided by teaching staff were considered additional factors supporting PCK development in the Leuphana course. Also, at ASU, students indicated that they felt encouraged by their instructors to implement ESD and reported that in-class discussions about how to do that were also helpful (social connection). This confirms the importance of social interaction and opportunities to exchange ideas (Ojala, 2013), is in line with the work of Biggs and Tang (2011) – who claimed that students learn with and from one another (social learning) – and emphasizes the role of instructors' feedback as a key factor guiding students' learning processes.

As with CK and PCK development, students' positive attitudes toward ESD were fostered by the fact that the practical implementation (Leuphana), in-class activities, and final project (ASU) provided practical examples of how to implement ESD in practice (professional connection). This corresponds to the previous finding that praxis-oriented pedagogies are the most relevant aspect to enhancing students' ESD-related SE (Tomas et al., 2017). Furthermore, personal connections fostered students' positive attitudes. The overall course content (Leuphana) and the in-class activities (ASU) were perceived as applicable to their private lives, while the videos and final project sparked the interest and excitement of ASU students, which might have improved their learning through an increased motivation to engage in the content. Since positive emotions have a regulatory function by developing intrinsic motivation (Ryan and Deci, 2000), it can be assumed that teachers approaching ESD with positive emotions are also more successful (Büssing et al., 2019).

5.3 Limitations and conclusions

Numerous students, especially from ASU, explicitly claimed that the *SSfT* course motivated them to engage with sustainability issues. However, although this might be a desirable outcome, according to Bertschy et al. (2013), it relates to the civic responsibilities of all individuals and does not pertain to the specific professionalization process of teachers. Furthermore, students frequently referred to the value of reflection time in informal learning situations, such as during sports or being outside in nature. However, despite the importance of reflection to adapting educational practices in ESD being stressed by authors such as Varga et al. (2007), it was not intentionally planned for in our cases and thus not considered in this paper. While the results remain *'bounded'* to the two cases investigated in this study to a certain extent, both modules are representative examples of hybrid course offerings in TESD applying rather common T&L formats. Furthermore, most results appear to be generalizable to learning in higher education rather than being specific to ESD or TESD. Nevertheless, the results confirm that personal, professional, social, and structural connections (i.e., *the four Cs*) should be considered key factors when planning TESD course offerings that aim to foster pre-service teachers' ESD-specific professional action competence. To enhance learning with the complex and value-laden concepts of sustainability in teacher education, we propose the following actions:

- Purposefully link different course elements or T&L formats
- Make course content relevant to students and recognize the relationship between emotion and cognition
- Bridge the theory-praxis gap through real-world learning experiences
- Apply pedagogies that allow for open discussions and mutual exchange of thoughts and ideas

Considering the essential need for CK in the development of pedagogical skills (PCK) (Kunter et al., 2013) and positive attitudes toward ESD (Lindemann-Matthies et al., 2011), we claim that the SSfT course (ASU) and the ESD course (Leuphana) – with their different foci and learning outcomes – ideally complement one another and could be considered sequential elements of the same curriculum in TESD.

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APPENDIX 1 – *Students' understanding of the term 'sustainability'* – scoring details

Time perspective		
Score	***Meaning***	***Exemplary answer***
0	No time perspective mentioned	-
1	Future perspective	*"To be environmentally conscious and future-*oriented *[...]."*
2	Intergenerational perspective	*"To me, sustainability means reducing my own ecological footprint so that future generations can live as carefree as I do."*
3	Inter- and intragenerational perspective	*"Sustainable development means that we should treat our resources carefully and distribute them fairly so that both generations of today and the future can fulfill their basic needs."*
Dimension orientation		
Score	***Meaning***	***Exemplary answer***
0	No dimensions mentioned	-
1	One-dimensional perspective	*"In my opinion, sustainability implies that we should live in harmony with nature."*
2	Multi-dimensional perspective	*"Sustainability means the interplay of ecological, economic, social, and cultural perspectives."*

APPENDIX 2 – *Content knowledge - Leuphana*

Where (learning formats)	How (forms of connection)	Example quotes
	General knowledge of sustainability issues and/or solutions	
Overall course	Deepening what was learned from the Leuphana semester (**structural connection**)	S2_526
Lecture	Introducing the concept of ESD – laying the foundation (**structural connection**)	S2_526
	Knowledge from the lecture is applicable to private life (**personal connection**)	S2_531
Tutorial	Applying what was learned from the lecture (**structural connection**)	S2_526
Seminar	Deepened our knowledge of a specific topic	S2_526
- Final presentations	Surprised about the relevance of mobility for sustainability (**personal connection**)	S2_519
Informal learning **- Going for a walk**	Reflecting upon what was learned from the **lecture** (**structural connection**)	S2_526
	Reflection through visualization (**personal connection**)	S2_526
	Complexity of sustainability	
Lecture	Providing the theory (**structural connection**)	S2_577
Seminar **- Group work**	Dealing with what was learned from the **lecture** in depth (**structural connection**)	S2_577
-Practical implementation	Observing how knowledge networking and transfer appear in practice (**professional connection**)	S2_577
Undefined	Through working with the WOT – applicable to many topics	S2_518
	Sustainable lifestyle alternatives	
Undefined	Important to consider using sustainable instead of harmful products (**personal connection**)	S2_506
Lack of sustainability-related content knowledge		
Misunderstanding sustainability		S2_528
Have not learned a lot of new things in the course		S2_513, S2_528
Lacking deeper content knowledge		S2_541

Example quotes (CK/Leuphana):
"I understood that there are sustainable alternatives to certain products, where you think they are totally unsustainable. And that is an important process to consider using sustainable instead of harmful products." (S2_506)

"I also wrote down mobility. I don't know in how far, but it was the topic of our seminar so to speak. And in the beginning I couldn't imagine what it was going to be like. […] And it showed me that even a topic that I thought, and that might sound wrong, was not that relevant. How should I say that? I learned a lot about mobility and how it is connected to sustainability. Because we have now seen four presentations or four projects and I would have not associated them with it at first." (S2_519)

"That was relatively early in the semester, even the first week. And I went for a walk with my dog, and I always go in the suburbs of Lüneburg across the fields and so on. And there we still had the lecture with T_205, where ESD was introduced to us. What it is and how we should implement it, et cetera. And, when you go for a walk, you actually reflect automatically. And that is actually how I perceived it. Because you get the visualization of how it is in the countryside. How the mobility is in the countryside. And there you have it right in front of your eyes. And then a lot of the terms like mobility and sustainability totally played a role. And then the first bees came and it became a chain reaction of knowledge." (S2_526)

"Not necessarily something new, as we all had the Leuphana semester and we are all confronted with sustainability at the Leuphana and in Lüneburg. But especially because this module is meant to be on ESD only and because we are all teachers for Basic Social and Science Studies and that needs to be conveyed. And, therefore, I would say that it went deeper. But everybody knew what it is and what sustainability is. But how deep can we go? And I think he tried to convey that in the first on to three lectures. And then the tutorial started and we could apply it more." (S2_526)

"I think by doing our own projects in the seminar, and parallel to lecture, we could specialize on on concrete topic, deepened our knowledge and realized how to implement it." (S2_526)

"I have picture number 41, where you can see a bamboo toothbrush and that picture is from one of our group members and she wrote that she integrates all the knowledge about sustainability and what she learned more and more into her everyday life and that this toothbrush fits really well. And that is similar to me, too, that I pay attention to living sustainability, living sustainably. So yeah, I thought that fits quite nicely." (S2_531)

"I was stunned by how complex a topic can be and from how many different perspectives you can look at it. It started in the lecture, which was more the theoretical part and where he [the lecturer] introduced and presented it once. Then the group meetings were actually the next relevant point. Simply because we dealt with it in depth and were able to understand it better. And then at the elementary school, how it actually looks like and how the knowledge networking and transfer looks like for the children, and not only for yourself." (S2_577)

Little new knowledge:
"I think in the course we actually, yeah, we planned the lesson, but if I think back, in terms of content, there wasn't really something new." (S2_513)

"Regarding ESD in theory, I have to say that now, after the semester, I actually haven't learned so much new, because I already dealt with ESD in the last semester. […] The four ways of thinking were new to me and also very interesting. But, other than that, I don't have the feeling that I have learned a lot of new things." (S2_528)

"Much more has to be done on the topic, really focusing on the content. We are doing a lot about methods […]. You can't learn everything there is in the world, but, I don't know, somehow deepening the specific content knowledge wouldn't be so bad either." (S2_541)

Misunderstanding sustainability:
"Still, I was totally disappointed, because we did something on health education. Why are we doing health education? That has nothing to do with sustainability." (S2_528)

APPENDIX 3 – *Pedagogical content knowledge – Leuphana*

Where (learning formats)	**How** (forms of connection)	**Example quotes**
	Planning ESD units	
	General (theoretical) understanding of how to plan ESD units	
Lecture	Providing theory and practical examples (professional connection)	S2_558, S2_540
Tutorial	Tutor providing examples as well as guidance, support, and individual feedback (social connection)	S2_503, S2_536, S2_540, S2_548
	Applying and deepening knowledge from the lecture (structural connection)	S2_503
Assignment	Transferring theoretical knowledge from lecture and tutorial (structural connection)	S2_506, S2_548
	Practical experience/first glimpse into everyday teaching life (professional connection)	S2_514, S2_554
	Talking about how to do it (social connection)	S2_576
Seminar	Direct application of what was learned in the lecture and assignment (structural connection)	S2_503, S2_548
- Project planning	Instructor feedback (social connection) triggering reflection (personal connection)	S2_548
- Practical implementation	Practical experience/first glimpse into everyday teaching life, seeing what is feasible (professional connection)	S2_514, S2_548, S2_554
	Overall structure of ESD units	
Lecture	Providing information about how to structure the assignment (structural connection)	S2_513, S2_540, S2_541
Assignment	Applying what was learned from the lecture and laying the foundation for the practical implementation (structural connection)	S2_540, S2_541
Practical implementation	Implementing what was learned from the assignment (structural connection)	S2_540, S2_541
	Starting with intended learning outcomes	
Tutorial	Tutor providing feedback and clarification (social connection)	S2_575
Assignment	Working on a topic of personal interest (personal connection)	S2_518, S2_526
	Taking the perspective of a teacher (professional connection)	S2_526
	Realizing that it is a smart thing to start with ILO	S2_575
Seminar - Project planning	Thinking about what to convey and how to convey it	S2_528
Informal learning	Talking to friends about it (social connection)	S2_575
Additional resources	Read about it	S2_575
	(Adequate) selection of methods	
Seminar (group work)	Exchange with others about potential methods to implement ESD units (social connection)	S2_531
Assignment	Learned about different methods and how to apply them in practice (professional connection)	S2_518

Difficulties with planning ESD units		
Lacking experience		S2_506
Repetition required		S2_540, S2_541
Little methodical knowledge		S2_513
Lacking the competence to formulate tasks in a pedagogically valuable manner		S2_577
	Implementing ESD units	
Lecture	Providing knowledge and laying the foundation for the **tutorial** (**structural connection**) Instructor providing practical examples of how to implement ESD units (**professional connection**)	S2_551 S2_518
Tutorial	Working with the knowledge from the **lecture** (**structural connection**) Tutor providing feedback and guidance (**social connection**) Providing an overview of how to implement ESD in class, including ILOs, etc.(**professional connection**)	S2_551 S2_518, S2_568 S2_518
Assignment	Providing the theoretical foundation for the **practical implementation** (**structural connection**) Going through the process and getting ideas Unrealistic scenario (**lack of professional connection**) Lack of immediate feedback from the instructor (**lack of social connection**)	S2_576 S2_518 S2_575 S2_537
Seminar **- Practical implementation**	Observing how ESD could be implemented with children/what works in practice (**professional real-world connection**) Practically applying what was learned from the **assignment** (**structural connection**) Lack of feedback from the teachers/practice partners (**lack of social connection**)	S2_514, S2_537, S2_551, S2_568, S2_576 S2_551 S2_512
- Group work	Discussing different opinions on how to implement ESD units (**social connection**) Providing each other with (peer) feedback (**social connection**), triggering reflection (**personal connection**)	S2_547, S2_568 S2_518
Informal learning	Discussions with others (exchange of thoughts and ideas), especially about the **assignment** (**social connection**) Reflecting upon the **assignment** while going for a walk or doing cardio training (**personal connection**)	S2_540, S2_547, S2_551 S2_551
Difficulties with implementing ESD units		
Remaining theoretical - lacking practical experience		S2_575
Still difficult to connect ESD to some topics		S2_518
Difficult to choose what topics to focus on		S2_526, S2_531
Not knowing when and how to implement ESD (lack of practical examples)		S2_541

Breaking down complex topics		
Lecture	Learning about the methods and laying the foundation (structural connection)	S2_530
	Helpful in connection with the tutorial (structural connection)	S2_502
	Lecturer providing practical examples (professional connection)	S2_554
	Co-developing a lesson plan with the lecturer (social connection)	S2_554
Tutorial	Providing examples of lesson plans (professional connection)	S2_530
	The lecture was helpful in connection with the tutorial (structural connection)	S2_502
Assignment	Application – seeing if I understood it correctly (structural connection)	S2_530
	Laying the theoretical foundation for the practical implementation (structural connection)	S2_575
	Applying the assignment to a self-chosen topic (personal connection)	S2_502
Seminar	Instructor providing feedback (social connection)	S2_554
- Group work	Exchange of ideas about what is appropriate for children (social connection)	S2_554
- Project planning	Practice (professional connection)	S2_503
- Practical implementation	Observing what works in practice (professional connection)	S2_514, S2_530, S2_554
	Applying what was learned from the assignment (structural connection)	S2_575
Difficulties with breaking down complex topics for children		
Still difficult to break down complex topics for children		S2_541, S2_547, S2_577
Risk of moralizing instead of communicating all facts and different perspectives		S2_541, S2_547
Lack of (practical) experience		S2_513, S2_550

Example quotes (PCK/Leuphana):

Planning ESD units:

"Alongside the lecture, the tutorial was really quite relevant and deepened the knowledge, especially as there was always individual help and clarification of unclear terms and we were always treated individually. Then the assignment where everything T_205 said could be applied and individually examined. And since then I have the feeling that I know what I am talking about. Before, it was all a bit vague and now it is concrete lesson planning and I know what to do." (S2_503)

"I also have the adequate application of methods or that we have learned about different methods. Especially during the assignment I realized ‚Yes, these methods would be good for that because then I can connect this and that. Plus, I got to know new ones as well." (S2_518)

"We had to write an assignment, which really was a preliminary step to a lesson plan. Thus, we go in the direction designing lessons plans, but there we had to think specifically about how I would proceed as a teacher." (S2_526)

"I would say that from the lecture I mainly learned that it is about objective-oriented teaching. So, I mean I already knew that before but now it is even more in the focus that you consider certain didactic principles and orient toward the ways of thinking and first looking at 'OK, what do you want to achieve and what do I connect that to in the end'." (S2_550)

Implementing ESD units:

"Basically, the lecture and the tutorial helped me a lot, because you got the knowledge and then revised it again. And, yes, also conversations helped me, when I talked to my parents about it or so. Especially when it came to the assignment that you might have spoken to your mother or so: "Mom, do you have another idea for XYZ?" That helped me a lot. And then you have, like what you do with going for a walk, for example, I do it with sports. If you do cardio or something, then you might also think about your assignment again, how can I implement that or how can I do that? Right, and in the end, the project that we set up as a group, made it clear: 'Okay, that's exactly how you could somehow possibly implement it with the children." (S2_551)

"I [now] have the competence to address ESD in class, independent from the topic really. In the beginning, through the lecture contents, it became clear what kind of topic it is, what it is about, how important it is and how to integrate it, also through the examples of T_205. Then through the tutorial, while working on your own lesson plans, seeing whether what you have considered is actually coherent and fits with the concept of ESD. […] Then, through the group work in the seminar, where we frequently discussed how to implement that later in the classroom […]. And in the end, the implementation, where we really tried it out with the school children and realized what is possible, what works and what doesn't." (S2_568)

Breaking down complex topics:

"Yes, for me it was first about breaking down the sustainability dimensions for children, in other words, breaking down the great complexity that is involved in the concept of sustainability and not only pushing through what is given to us, but also to consider the knowledge of the children and classify it in the context of their age. Especially for that the lecture in cooperation with the tutorial was very good and also the assignment, where one had to implement that with a self-chosen topic and age group." (S2_502)

"For my competence I wrote down 'how to bring together scientific and child-friendly aspects'. In this regard, we had to learn the topics and methods from the lecture in the beginning of the semester, but then also the examples from the tutorial of how teaching and learning units actually look like. That helped me a lot. And then, of course, the elaboration of the assignment on the end, (showing) whether I understood it correctly, whether I approached it correctly. […] what was also quite interesting was the confrontation with the children during the station work [practical implementation]. There, I felt, we were lacking a bit of a real-world connection and that was quite interesting." (S2_530)

"Yes, I have ‚making complex topics suitable for children'. And that actually started with the lecture, where we broke down an overarching topic to a child-friendly topic, which could also be dealt with in class. And there T_205 presented us his lesson plan, which he also developed together with us. And in the seminar it went on to us getting our main topic and then we should each think about potential sub-topics […] like what belongs to this topic and what is understandable for children. And, yes, then it started with group work. And then the exchange in the seminar started and everyone had different ideas about what is actually suitable for children. And as a result, our topics kept on changing, because we always wanted to make it more child-friendly. In the beginning everyone had a different idea and then T_216 said a little something about it and it did - then the idea also changed a bit. And during the implementation of the seminar this week, it was just noticeable that, above all, we cannot use complicated technical terms that they don't know yet, because then they switch off or don't understand us at all. And our example made it clear that we have to formulate questions precisely if we want to know something from children." (S2_554)

Lack of capability to implement ESD units:

"I don't have the feeling that I am leaving this class with a handbook on how to implement ESD. […] Actually, I should watch a video or an exemplary lesson, a super positive example. Like, how would it have to look like to say 'This is a successful ESD unit'?" […] But I mean we are only in the second semester. We haven't learned much yet. So, yeah, I think it is a process and it was a good start. […] I understood the concept of ESD, but I will really have to practice it and I hope we will be given the opportunity to do that too. Otherwise, it would be like getting a piece of cake and having it taken away again after one bite." (S2_541)

Difficulties with breaking down complex sustainability topics for children:

"I find it really totally difficult, because you have to be incredibly competent in the topic, in order to know what is actually healthy and to give the right answers. Is it healthy in moderation or may be not healthy? The question is healthy for whom, healthy for you, for the animal, for the environment? These are question where you at some point think 'what am I telling the children?'" (S2_541)

APPENDIX 4 – *Attitude – Leuphana*

Where (learning formats)	**How** (forms of connection)	**Example quotes**
	Perceived relevance of ESD	
Overall course	There were so many connections to my everyday life (**personal connection**)	S2_519, S2_576
Informal learning **- Going for walks** **- Conversations**	I learned that, for example, through going for walks and conversations. […] Going for a walk simply helps me to reflect on things (**personal connection** **+** **social connection**)	S2_519
- Day in the park	Making connections to private life (**personal connection**) and talking about sustainability (**social connection**)	S2_541
Additional resources **- Literature on ESD**	The literature by Haan (2006), which was read for the **assignment**, affected the **seminar** (**structural connection**) and helped me understand the importance of ESD at school (**professional connection**)	S2_559
Undefined	Required in the core curriculum (**professional connection**)	S2_559
	Willing to implement ESD units	
Seminar **- Practical implementation**	Could imagine implementing something similar to the practical implementation (**professional connection**) **– see perceived relevance of ESD**	S2_559
	Realizing the applicability of ESD across all ages and topics (**professional connection**)	S2_518, S2_568
Informal learning **- Walk in the forest**	Realized how much I am looking forward to it (**personal connection**)	S2_502
- Day in the park	With the realization that ESD is important, there was also the motivation to implement it (**professional connection**) **– see the perceived relevance of ESD**	S2_541
Undefined	It's going to be difficult not to implement ESD/obvious to do it (**professional connection**)	S2_502, S2_550
	…especially considering how it can be connected to everyday life (**personal connection**)	S2_550
	Would be willing to implement it (**professional connection**), yet still wondering how far it can be implemented	S2_526
Difficulties with motivation to implement ESD at the school level		
Doubting that every step will be consciously planned according to what was learned from the course		S2_513
Could do it, but it is exhausting to implement ESD		S2_503

Example quotes (Attitude/Leuphana):

Perceived relevance of ESD:

"Yes, at the beginning of the semester, after the first semsester, I just knew 'Okay, ESD is somehow important for the subject of Basic Social and Science Studies, because we always addressed this over the last semester." (S2_503)

"Right, I chose the relevance of education for sustainable development, because that is very broad and it was difficult to focus on one thing only. Like S2_526, I learned that, for example, through going for walks and conversations. […] Going for a walk simply helps me to reflect things. And then in the tutorial the practical application of what was learned from the lecture and that there were so many connections to my everyday life. […] And then again very specifically when working on our project." (S2_519)

"And I have to say that learning for me takes place outside of the university as well. Somehow, I always take it with me and try to process it in my everyday life. And that is why. It was just a day where I didn't do anything for the uni and I was lying in the park with my roommate. We played around the entire day and felt like we were six again. The first moments where I realized why it is so important what is being done, like bringing the children closer to nature and go out and the appreciation of nature and sustainability aspects. And on that day we also talked a lot about it, not in the context of school, but sustainability in general. And so, yeah, a day where I thought that it is an important task and it is good that we deal with this at the uni. And with this realization, that it is important, there was also the motivation to do it." (S2_541)

"There is the text by Gerhard de Haan shown and, looking back, I would say that the text, also through the intense assignment, impacted the seminar for me […] and you also understood what it means and why it is important that we as teachers convey that to the children. Because before this semester, I was like: 'Oh, ESD! I can not hear it anymore. It gets a bit on my nerves.' But yeah, it is true that this text showed me 'Yes, it is important. And where should the children learn about it if not at school?" (S2_559)

"And on the back it says that you became aware how much waste we actually produce and how important the sustainability topic actually is. And I totally see what you mean, because because I also noticed that through this seminar and the lecture and the tutorial you simply pay more attention to what you perceive in your surroundings. […] My previous awareness of that was completely different. I drove past it and thought: "Oh well, such a scrap dump" and drove on. And now one would already be thinking about it, like why is that so and what kind of consequences does it actually have and so on. That has just changed." (S2_576)

Willing to implement ESD:

"Yeah, I can identify well with this picture, as I am frequently walking my dog in the forest and as a forest or village child and nature-loving person in these moments I clearly realize how much I am looking forward to bring children closer to the importance of species conservation, whether in the animal or plant world. […] To me it is actually self-explanatory to relate it to any topic at some point." (S2_502)

"I would also say that it was helpful that we could practically try it out and see how it works, what opportunities you have and when we were visiting that second grade class we could really see that ESD is not only a topic for the higher grades but it can also be implemented with lower grades." (S2_518)

"But about the approach, I could imagine to implement it, but I always wonder in how far it can be implemented." (S2_526)

"I believe that it is difficult not to implement ESD when you have seen that ESD can be connected to every part of life in whatever way." (S2_550)

"I would also say, for one thing, it is required in the core curriculum that you do it. But I can now also better imagine myself doing that. […] Definitely! Also I think especially something like we did on Tuesday. That was really nice. And I think the children would be interested in that too." (S2_559)

Doubts about the feasibility to implement ESD/despite perceived relevance:

"But I really believe that, I mean we are still only in the second semester, but if it continues like that, I have to say, if I would go to school now I could take care of it, but I think I might let it slide, just because it is exhausting." (S2_503)

"I don't believe that I will plan ahead like 'this is going to support connected learning' or 'that will foster participatory orientation' and so on. I do think that I will do it, but not every single step like we legitimized it here, going through it in your head to see if everything is considered." (S2_513)

APPENDIX 5 – *Content knowledge – ASU*

Where (learning formats)	How (forms of connection)	Example quotes
	General knowledge of sustainability issues and/or solutions	
Overall course	Awareness of the environmental impact of certain products I buy/greenwashing vs. true sustainability efforts (**personal connection**)	S2_333
	Increased awareness about the impact of personal actions (**personal connection**)	S2_312
Production unit	How the way certain things are being produced affect us and the environment (**personal connection**)	S2_324
	Learned how everyday items are made (**personal connection**)	S2_353
Disposal unit	Really concerned me (**personal connection**)	S2_324
Online learning **- Videos**	Gathering general information online and in our own time/ appreciated retaining new information through the videos (**personal connection**) Missing subtitles – hard to retain all the information	S2_397 S2_310, S2_302 S2_310
	Learning about sustainability issues around the world, which was appreciated and helped me to see the bigger picture (**personal connection**)	S2_302, S2_310, S2_357
- Disposal videos	Learning about how the things I use are disposed of (**personal connection**)	S2_353
- Disposal and production videos	Learned about the impact of everyday things and their production cycles, laying the foundation for **in-class discussions** (**structural connection** + **personal connection**)	S2_351
- Energy videos	Learned about different energy sources and their implications/how they can benefit us (**personal connection**)	S2_387, S2_301
In-class activities **- Hot dog activity**	Learned about the production of the food we eat and how that impacts our environment (**personal connection**)	S2_339
- Researching companies' sustainability efforts	Interesting that some companies are trying to make a difference (**personal connection**)	S2_310
- Researching production cycles	Getting mad about the production cycle of straws (**personal connection**)	S2_353
- Future scenarios	Learning about the future disappearance of certain products, which made me care about this course (**personal connection**)	S2_302
- Renew a bead activity (energy unit)	Building upon facts about energy sources learned before (**structural connection**), eye-opening to visually see it/applicable to private life (**personal connection**)	S2_400
- Nature walk	Learned how the garden maximizes space, which was appreciated (**personal connection**)	S2_387

- In-class discussions:	Reviewing and discussing the impact of an energy bill on our community (**personal connection** + **social connection**)	S2_333
on disposal	Learning about how the things I use are disposed of (**personal connection** + **social connection**)	S2_353
on production and disposal	Learned about the impact of everyday things and their production cycles/making the connections by discussing what was learned from the videos (**structural connection** + **personal connection** + **social connection**)	S2_351
Assignments - Carbon footprint	Learned about the environmental, social, and economic effects of my actions (**personal connection**)	S2_301
Final project	Learned how much food Americans throw away (**personal connection**)	S2_301
	Learned about food waste and pollinators	S2_310
	Gaining a deeper understanding of the water cycle and how we impact it through connecting it to what we learned in this class (**structural connection**), a topic that is important to me (**personal connection**)	S2_353
Sustainability in the news	Learned about renewable energy through the presentations	S2_387
Undefined	The three Rs (reduce, reuse, recycle) as one way we can work to create a better future (**personal connection**)	S2_357
	Learned about the child labor conditions in other countries, which is sad (**personal connection**)	S2_373
	Learned that water is an important resource, which resonates with me since I am from California (**personal connection**)	S2_405
Sustainability concepts		
Videos	Learned about the triple bottom line through personal stories from people (**personal connection**)	S2_379
Sustainability in the news	Presentations by fellow students provided information related to the triple bottom line (**personal connection**)	S2_379
In-class activities - Hands-on activities	Being engaged in hands-on activities helped create connections to what was previously learned in theory (**structural connection** + **personal connection**)	S2_355
- In-class discussions	Discussions on **sustainability in the news presentations** (**structural connection** + **social connection**)	S2_379
Sustainable lifestyle alternatives		
Videos	Learned how to be more sustainable through the videos (**personal connection**)	S2_302, S2_371
Additional resources - Reading literature and doing research	Learned how to be more sustainable (**personal connection**)	S2_302
Lack of sustainability-related content knowledge		
Misunderstanding sustainability		S2_303

Example quotes (CK/ASU):

"This was the assignment we did look at like our carbon footprint and how much our actions affected the globe. And I do not know, I just, I thought this helped my learning a lot, because I learned a lot about myself and like how my actions are affecting the planet and yeah, I do not know. I learned a lot about the impacts it has, like the environmental, economic and social effects, that it can have and I learned a lot about how much food Americans eat and throw away too. So, it kind of also related to my final project." (S2_301)

"And then I also wrote about the videos that we watched on like the different energy sources. I thought like those had a lot of like good information in them that I did not know about, on how they could like benefit us, like economically, socially and environmentally." (S2_301)

"I never really knew what sustainable really was until like this class. It is just terrible to say, but I never really knew what it meant. And now I do. […] I am starting to think about the future and how to come up with right plan for my life, where I could be more sustainable, which leads into how to be sustainable. And I learned how to be, through a lot of ways, with many articles and research and just our videos […] like a video about fracking, because I never really had heard of it. But, like these videos really opened up my eyes, because I got to read it and stuff too, just how to be sustainable. And I am excited to try it, like to try new ways every other week and stuff." (S2_302)

"And then the slides that showed what drinks and food will be gone by 2050, which I have already talked about. But I, those really just made me want to care about this class." (S2_302)

"I definitely think like food waste or the pollinators, like I did on my final project, like I could definitely talk about that and give like facts on that one." (S2_310)

"And then, one of my other one's was investigating company's sustainability practices. […] I found out so much and that was really interesting to me, like to know that other companies are really trying to make a difference." (S2_310)

"Not all of the videos had transcriptions underneath them, so it was kind of hard to catch some of the information that we were being quizzed on. […] There was lots of pausing going on. […] I liked watching the videos, because I did feel that I retained a lot of the information, but if we had the transcription, so I could like go through and take notes on it, would have been nice, too." (S2_310)

"I think just throughout the course I went to be like more aware of how my actions can affect future of our environment because I just buy things at the store and don't really think about the impact it has on the world. But I also learned how to see things more through a lens of sustainability than I had in the past. And I learned kind of like how everything goes through a process and there is like different parts of the process that do different things to our environment, some good some bad." (S2_312)

"How much stuff goes into a landfill and other facts like our water table eventually really concerned me […] So, I said I learned about waste management, how things are like thrown away in the processes they go through, the four ways of thinking, the water cleaning process, the best ways of recycling. […] And then how the way products are made affects us and the environment." (S2_324)

"Over the course of the semester I learned how be more aware about the products that I buy and how their impact might be more harmful to the environment than they actually say. Because you have some of those products, they say that they are green or they are natural, but they are just saying that to try to get people to buy them when they are actually not truly helpful or beneficial for the environment. One thing we also learned or covered was that there is an energy bill up to vote on in state of Arizona and we kind of reviewed that to discuss how it would impact our community if it was passed or if it was not passed. I was just being more aware about the products and everything that has an impact on the environment in everyday use." (S2_333)

"I also learned about how we get the products that we eat. So, like for example like mustard, where every ingredient comes from and how all comes together, like the process that goes through from packaging, to making to delivery, everything like that and how some of those things affect our environment." (S2_339)

"So the biggest thing for that was the videos and discussions that we did about production and waste, Just because like I never really thought about things like what goes into making a pair of jeans, or where they go when we're done with them. So those are the biggest things for me. […] the videos were like enough information, but then I felt like I made more connections when we like actually talked in the class." (S2_351)

"I'm like really working hard on this website right now and take like a lot of time. And I really like connecting what we kind of learned in this class […] to make a lesson plan, come up with the activities, and then like kind of tie it all together […] it's helping me for my lesson planning, but also helping me just kind of like get a deeper understanding of what the water cycle is, how we impact it, how animals use it like the sea life and all that and that's something really important to me." (S2_353)

"We did ours on straws and I looked into the process of making straws and it's absolutely ridiculous. You are going to throw it away. You're going to use it once, toss it. I was so mad. […] From our videos, and like, just kind of our discussions as well, just seeing how everyday things that I use get disposed of, and then like how that affects the environment. […] And then the next one I have is learning the process of how everyday items are made." (S2_353)

"For me, if I had never done the activities hands-on, I would've never really understood the concepts, and being able to make my own connections to my previous learnings and this new information given to me, was crucial to my learning." (S2_355)

"So like, obviously like we learned a lot about like the 3 Rs and recycling, like reuse and like all that, and I thought that was like really important because that's one way that we can get started into like a better future." (S2_357)

"The videos that we saw each week they were not just based on only one region of the world. And it was nice to see that […] those videos showed me what the truth is like in other parts of the world. […] And, yeah, that helped me like see like the big picture, not just in my area but like in the world." (S2_357)

"Watching the videos online, I learned various things people are doing around the world to be more sustainable. The videos also gave us ways that we could be more sustainable." (S2_371)

"I did the sustainability concepts. […] I feel, the social, economic and environmental, I feel like I got that a lot from the weekly videos because they would have personal stories from people […] and then I also think the weekly presentations helped a lot because there would be a group each week that would talk about something that was relevant […] and related to that we would have like a class discussion based off of that, so I feel like that really drilled in my head that social, economic, environmental and how they tie together to sustainability." (S2_379)

"This is a picture of the little herb garden and it's like right out there and I think that T_010 showed us that on our, like the little nature walk that we did. And this person talked about how like it maximizes space. That's why I thought that was cool and it just gives us more resources." (S2_387)

"I also learned more about the renewable energy sources because […] a lot of people did presentations on them and so I understood which ones were better, which ones were worse and the implications of all of them. […] so each week T_010 had us watch, like, two videos about, like, two different sources and then we had to fill out a graphic organizer and […] then at the bottom we picked the one we thought was best for the environment and then which one we thought was the worst for the environment." (S2_387)

"So, one of the big focuses in class was the different types of energy. First we learned the difference between non-renewable and renewable energy, and then we looked into the implications of each. […] And then we used projects that would literally show the sources being used up […]. That was more eye opening to visually see it, and then, just connecting it to life, like, seeing, like, how ASU practices those energy, like there are solar panels around campus and stuff like that." (S2_400)

Misunderstanding sustainability:

"Being sustainable is easier than I thought, because what I always thought was like you have to be completely vegan, you have to do all this stuff. But really it is cut out meat once a week and it will help it. Like carpooling, it is a lot of small things that you could easily do that make the difference and it is not like you have to, you have to go all out immediately." (S2_303)

APPENDIX 6 – *Pedagogical content knowledge – ASU*

Where (learning formats)	How (forms of connection)	Example quotes
	Planning ESD units	
	General (theoretical) understanding of how to plan ESD units	
Overall course	Instructor providing resources that could be used in the classroom (**professional connection**)	S2_301, S2_369
Videos	Seeing how teachers plan ESD units in practice (**professional connection**)	S2_383
In-class activities	Dealing with examples of how to teach science around official learning standards (**professional connection**)	S2_397
In-class discussions	Discussing the relevance of ESD (**social connection**)	S2_383
Final project	Making a lesson plan, looking at the standards, and seeing how you can incorporate them in your classroom (**professional connection**)	S2_379
	Got me excited (**personal connection**)	S2_379
	Practice lesson planning with a topic of personal interest (**personal connection**)	S2_383
	Learned how to use **online material and resources** to create a lesson plan (**structural connection**)	S2_397
	Helped me with how to make lesson plans and connect everything (**structural connection** + **professional connection**)	S2_353
	(Adequate) selection of methods	
In-class activities	Instructor providing practical examples and activities that could be used (**professional connection**), which was encouraging (**personal connection**)	S2_369
Difficulties with planning ESD units		
Lack of resources to implement ESD units for different grade levels		S2_351
	Implementing ESD units	
Online learning - Videos	Providing the information, laying the foundation for the **in-class activities** (**structural connection**)	S2_397, S2_375, S2_397
Videos	Showing practical examples of how to implement ESD units (**professional connection**)	S2_378, S2_405
In-class activities	Instructor providing examples of how to implement what was learned from the **online learning** in the classroom (**structural connection** + **professional connection**)	S2_375, S2_378, S2_397
	Practical experience of the instructor (**professional connection**)	S2_375
	Encouraged by the instructor (**social connection**) to… …take a student's perspective on the material (**professional connection**)	S2_369 S2_369, S2_397
- Solar amusement park	Helped me to see how to integrate sustainability into the classroom (**professional connection**)	S2_375, S2_373
In-class discussions	Talking about how to implement ESD in the classroom (**social connection** + **professional connection**)	S2_397
Final project	Creating a lesson plan connected to a self-chosen topic (**personal connection**)	S2_378

Undefined	We can implement ESD (**professional connection**)	S2_405
	Only connected to certain topics	
Poverty video	Emotional reaction to the video (**personal connection**)	S2_310
Final project	On topics I chose myself (**personal connection**)	S2_310, S2_383, S2_353
Undefined	On topics I can relate to (**personal connection**)	S2_302
Difficulties with implementing ESD units		
Some topics require more research		S2_349
ESD is not yet part of the official learning standards		S2_351
	Breaking down complex topics	
In-class activities	Instructor engaging students in activities (**social connection** + **personal connection**)	S2_369
- Water cycle activity	Learning about different learning styles (**professional connection**) was fun (**personal connection**)	S2_369
Final project	The whole concept of our final project is how to make it understandable to students (**professional connection**)	S2_369
Difficulties with breaking down complex topics for children		
Still difficult to break down complex topics for children		S2_301, S2_303

Example quotes (PCK/ASU):

Planning ESD units:

"And then lastly, I chose our final assignment because, like I said, I really like, I don't know, like we haven't had a class yet on how to make lesson plans but I feel like this is really helping me like with how to make lesson plans. And it also helps me like connect everything." (S2_353)

"The skill that I focused on was how to write a lesson plan. First, we learned the importance of it, we discussed the value of it, […] and then we were assigned to create a website or some sort of digital artifact on a sustainability topic of our choice. Then I did a lot of research. I saw what other teachers were doing and that's really the main way I learned" (S2_383)

Lack of methods/resources:

"I do kind of wish like, not necessarily from the course, but just in general, that there was like more resources of how to teach it to the kids, like based on grade levels and stuff […] So I feel like if there was more resources about like how to implement it, even into other subjects or just into science and things like that, or like videos you could show them, or, like she did show us a couple of books but if there was like a library of books that we could show them and choose from, I feel like that would be more helpful." (S2_351)

Implementing ESD units:

"So, mine is how to incorporate sustainability in the classroom, um, mostly the same as what they said, the online videos gave us the content so that we could experience examples of the implications in the classroom, um, also I think a big part of it was T_009 experience in the elementary classroom, because I think if we had a professor who just researched how to implicate it." (S2_375)

"I picked how to incorporate sustainability into kind of content, because by doing the class activities because she gave us real life examples on how we could do this in our future classrooms and what we did could be used across multiple grade levels, so it's nice to see. And then the unit plan that we're designing kind of, because we had to pick something and then make it, so how sustainability goes in it and then T_009 did some read alouds which gave us good books to use on like how we can use literature in sustainability. Um, and then the, our videos every week there was often teach it ones, where it was, like, real life teachers and how they were doing sustainability things in their classroom, and it was just nice to see how people are doing it." (S2_378)

"Obviously it's a hybrid course, so a lot of our information gathering was done through the videos and online and on our own time, but then when we came to the class, T_010, our instructor, did a great job of showing how we can implement it in a classroom. So, we were kind of like given general information online and then in the classroom environment with T_010, we were kind of taught how to implement it in the classroom and we practiced ways in which that could be done, […] like thinking from our students' perspectives, like how they would interact with this material." (S2_397)

Indicating an increased self-efficacy:

"I think that T_009 herself did a really good job […] making us take it to the next level (everyone affirms) and kind of encouraging us to think about it in terms of students, because she herself brought in a lot of resources, she was like "Oh, I did this with my fourth graders" or this is just what you could do with first graders (everyone affirms). So then it's making us think "Oh, wow, like, I could do that too," and, like, we've done things in class where she shows really cool resources, like we know that we can use those as a teacher and I think that it's important to know." (S2_369)

*"I think this [*Solar amusement park activity] *helped me see, like how we can incorporate sustainability into the classroom without making it, like, a whole sustainability lesson."* (S2_375)

Only on certain topics:

"I feel like it was easy for us to connect to everything and relate to it. So, everything that I relate to, I could probably be able to teach, just because I live that." (S2_302)

Learned how to do it, but it is not in the standards yet:

"So my first one is 'how to engage students in carrying out sustainability', because coming into this class I was kind of like thinking "Yeah, this is super important but like can't touch so much else, like so many other things going on while we care about this". Because like it's not on tests or anything, you worry about math and reading and that's basically all we need, but I feel like after this class I feel like I know how to better like incorporate this into other subjects and things and how to get them like caring about it, something like that." (S2_351)

Breaking down complex topics for children:

"I talked about how we can develop lesson plans and appropriately introduce sustainability to students, like that's the whole concept of our final project is like how can we take this what we've learned at a college level and make it understandable to students […] And then T_009 obviously engaging us in different activities, like, we did this whole thing where we got to study the water cycle or water systems and then explain to the class in a way that worked for us. So people did like drawings and some people went for a more kinesthetic track […] and then one group made like a water conservation song, so that was really funny." (S2_369)

Difficulties with breaking down complex topics for children:

"I think just like the specific content within all these subjects could be a little bit difficult for kids, like depending on the age. Like, if you did this with like seventh or eighth graders I feel like you can definitely go into more detail, because they would be able to like understand it, but for lower grades, I think just like the general information about like the main topics. You know, like food and water and like recycling and all that could be useful, but as far as like diving deep into the content, I feel like it could be a little bit difficult." (S2_301)

APPENDIX 7 – *Attitude – ASU*

Where (learning formats)	**How** (forms of connection)	**Example quotes**
	Perceived relevance of ESD	
Overall course	It is important to start teaching sustainability at a young age. If I had known those things when I was little, maybe I could have started making a difference (**personal connection** + **professional connection**)	S2_339
Videos	Through the videos, I learned that educating people on how to help the environment can have a big impact	S2_373
- Change videos	Interesting videos made me realize the importance of helping children become change-makers (**personal connection** + **professional connection**)	S2_369
Quizzes	Learned through the quizzes that educating people on how to help the environment can have a big impact (**professional connection**)	S2_373
Assignments - On solar cooking	Educating people can have a large impact (**professional connection**)	S2_379
In-class activities	Meaningful activities that could be implemented at school (**professional connection**)	S2_304
- Future scenarios	Informing others about sustainability and its impact on personal lifestyles (**personal connection**)	S2_302
- In-class discussions	Encouraging talks with the instructor about the potential impact of educating people on how to help the environment (**social connection**)	S2_373, S2_400
- Group projects	Learned through the group projects that educating people on how to help the environment can have a big impact (**professional connection**)	S2_373
Final project	Implementing ESD through field trips (ensuring real-world connection) can empower children to make a difference (**professional connection**)	S2_329
Undefined	Important to start at an early age to develop sustainable habits, only learned about recycling in elementary school (**personal connection**)	S2_304
	Important to make children more science-focused (**professional connection**)	S2_405
	Willing to implement ESD units	
Overall course	Made me think about how to implement ESD because I am a future teacher (**professional connection**)	S2_387
In-class activities - Solar amusement park	In particular, hands-on activities can be implemented with any grade level (**professional connection**)	S2_379
Final project	Showing how ESD can be implemented in the classroom (**professional connection**) got me excited to implement it (**personal connection**)	S2_379
	Working on a self-chosen topic made me realize that it is possible, so I hope that I will implement it in the future (**personal connection** + **professional connection**)	S2_383
Undefined	I think there is always a way you can incorporate it into a classroom. We need to consider the future of our world and preach that to the students (**professional connection**)	S2_339

Undefined	Classroom management and field trips to integrate sustainability into the everyday lives of the children (**professional connection**)	S2_324
Difficulties with motivation to implement ESD at the school level		
Systemic barriers and required approval from the school		S2_333
Motivated to implement ESD, but lacking the resources to do it for different grade levels		S2_351

Example quotes (Attitude/ASU):

Perceived relevance of ESD:

"Ever since she [the instructor] put up these statistics at like 2050 Wine, Coffee, like all seafood, all these foods are going to be gone by 2050, really just like opened up my eyes like that this is real, and I do not know I thought it was crazy. Just cause these things, and Chocolate too, these things we use every day and you can never picture it without it. […] honestly, that day texted all my friends, I even posted the PowerPoint, because I was like this is nuts. […] And everyone was like texting me back and saying like "What is this? Why?" Like no one knows this stuff, we would never have learned it if we were not in this class. So, it is important." (S2_302)

"I am not saying the course was easy, I am just saying, if you separate individual activities, I think, they were doable, but impactful and meaningful, so I think that you could add it in once a week or something like that. Anything like what we have done. […] And then I said start teaching a subject of sustainability at early age, meaning everything I ever heard growing up or being in elementary school was recycle, recycle, recycle. And it was just paper, just paper. So, you don't think recycling means anything. And then the subject disappears until you are forced to take it in a college course and then it comes to light. So, I think it should be more important in our schools, because if you grow up with this idea, then it is there, it is not like trying to be forced into someone who already has its bad habits." (S2_304)

"I like the idea of implementing it into the classroom, outside of like lessons. Because then the kids do not feel like they are sitting there and just having to hear one more thing that they don't care about. I also think that, and I did it in my final project, too, was having a field trip. So mine was like to a charity called "Feed my starving children". So, having kids just be a part of something kind of helps them realize more what they can do for sustainability, that they may not realize they are capable of. Just because kids are like 'Well I am a kid, what am I going to do?' But if we are able to implement it in their classrooms, then they are able to see that they can make a difference." (S2_329)

"I think for me, it showed me that it is important to start teaching sustainability at a young age, because I was learning things, I am twenty years old and I have never really like thought about or heard about. And so if I had known those things maybe when I was little maybe I could have started making the difference." […] So, it is almost like we need to like take into consideration the world's future and also as teachers like be preaching that to students and showing them ways that they could still make the world a place to live." (S2_339)

"The last thing I put was watching videos about how educators and students have changed the face of sustainability, so there is this one unit where we learned about different teachers and how they've kind of made a change in their communities and kind of brought more awareness to their communities about different sustainability issues. And there is one interesting video about a little fourth grade girl who made this huge difference after the BP oil spill and the drawings of sea animals, so I was like I think that's actually cool because you can't underestimate kids. Kids are some of the most powerful change makers in the world and teachers can kind of help develop that." (S2_369)

"The one that I chose was that educating people can have a big impact. (...) so I just put watching the videos and then just talking, doing like our big talks with T_009 and then group projects, and then just doing the quizzes. […] Just, like, educating people on how to help with the environment and everything and you just tell one person and they'll tell the next person and so on and so forth and that'll just have a big impact for the environment." (S2_373)

"And then another one was how educating people can have a large impact and change minds because I know for one assignment in the class there was something about solar cooking and how when they gave them to certain people who would look for food and spend hours cooking. And when they educated them on using solar panels and solar cooking, it saved so much time, they were able to make more money and so I just think, doing things like that, educating them on how to certain things like that can have a large impact." (S2_379)

"I feel like science does need to come into every other content area, which it could, so just learning how we were able to incorporate it helped a lot by, like, making our kids more science focused." (S2_405)

Willing to implement ESD units:

"I think maybe I am looking more for a classroom management almost and like set-up about doing maybe supplements and stuff that would be like 'Oh, this one is just for paper, this one is just for plastic water bottles, this one is just for cans' and like telling kids like where like all your trash goes and then […] go on a field trip or something. Like taking that part and having the kids realize like 'Oh, like you are getting money from recycling or this is how much you are going to save like the ocean and maybe ocean pollution type of things and stuff like that. So, it is not necessarily lesson plans but like implementing it in their daily life." (S2_324)

"Yeah, just it is going to be hard to a little bit because we have to follow state rules or like district rules for what the school wants us to teach the kids. So, it is we are only going to be able to do so much in classroom unless the school approves it completely. So, we can do little what we can, but we can start make some progress." (S2_333)

"I think there is always a way you can incorporate it into a lesson that you have to teach. So, you can do sustainability as well maybe like a math lesson. Like, there is always a way to like incorporate it some type of way, I think. So, yeah, I can definitely see myself trying to always implement those things for kids." (S2_339)

"Like we are always taking in consideration of like our own future. But we are never really thinking about like if the world is still going to be there for us to get to that future. So it is almost like we need to like take into consideration the world's future and also as teachers like be preaching that to students and showing them ways that they could still make the world a place to live." (S2_339)

"I think the final project was really good because we got to actually make a unit plan, so it's actually putting together, looking at the standards and seeing how you can actually incorporate them in your classroom. So, it kind of got me excited, like 'Oh, I kind of want to teach this lesson and put things in there and actually go through the whole day', so I think that part was really helpful." (S2_379)

"Especially doing the hands on, like, solar panel thing, like, she said we can do that with any age level, grade level" (S2_379)

"I think I could, especially with this unit, where we are free to choose our topic, I feel, like, I did a lot more research and now, through taking this class, I see that sustainability is not just turning off the lights when you're not using it. It is like more than that, so, I feel like there are a wide variety of topics that I could implement and it's not difficult to do. Like through this unit, like mine was water conservation, I didn't think I could teach that to kindergartners, but I'm realizing that it is possible, so, I think that I can and I hope that I will in the future." (S2_383)

"It [the course] made me start to think more about science and how I can implement it more, because I am a future teacher." (S2_387)

"Going off of that, like, just adding that meaning to the curriculum will leave a mark in the child's mind. Like, T_010 told us one teacher will encounter like 10.000 students in their teaching career, so even if you just mention it once that's going to be in their minds for probably forever, so, I feel very confident with this topic. […] I would say I would implement it into the reading and then bring in an outside source. So, in my old job there was this guy, but he would dress up as a dinosaur and he was called Recyclosaurus, and he would come in and he would teach them and the kids love it, they all love it, so I would do something like that." (S2_400)

Motivated to implement ESD but lacking the resources to do it for different grades:

"I do kind of wish, not necessarily from the course, but just in general, that there was like more resources of how to teach it to the kids, like based on grade levels and stuff, just because like teaching is important but if you're teaching like in kindergarten, they don't learn science. […] So I feel like if there was more resources about like how to implement it, even into other subjects or just into science and things like that […] I feel like that would be more helpful." (S2_351)

APPENDIX 4 – Case description: Competence development in teacher education for sustainable development at Leuphana University and Arizona State University

Educating Future Change Agents
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 delivering 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 which usually exceeds the scope of journal articles. Fellow researchers, scholars and practitioners are invited to comment, discuss and contribute their thoughts and own 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

Meeting the global ambition to implement education for sustainability at levels largely depends on competent and motivated teachers. Accordingly, teacher education for sustainable development (TESD) aims to equip future educators with specific content knowledge, the ability to implement adequate teaching and learning scenarios and increase their motivation to do so. Whereas previous literature has dealt extensively with concepts and empirical work around learning objectives, the TESD case study of the Educating Future Change Agents (EFCA) project links learning outcomes or WHAT student teachers learn to the learning processes or HOW they learn. To inform the empirical research of the case study, this working paper provides a detailed case description of individual TESD courses at Leuphana University of Lüneburg (Germany) and Arizona State University (USA). By describing contextual conditions, the teaching and learning environment as well as applied teaching formats and student cohorts we aim to increase the transparence of our research and help to better understand related empirical results.

Keywords:
education for sustainable development; teacher education; sustainability; higher education; competence development; teaching and learning; drivers and barriers; case study

Zusammenfassung

Um das globale Ziel einer Umsetzung von Bildung für nachhaltige Entwicklung auf allen Ebenen zu erreichen bedarf es insbesondere kompetenter und motivierter Lehrkräfte. Entsprechend ist LehrerInnenbildung für nachhaltige Entwicklung (LBNE) bemüht, zukünftige Lehrerinnen und Lehrer mit spezifischem Fachwissen und Fertigkeiten auszustatten, angemessene Lehr- und Lernszenarien umzusetzen, sowie sie sie motivieren, dies auch in die Tat umzusetzen. Während vorangegangene Literatur sich ausgiebig mit Konzepten und empirischer Arbeit rund um die Lernziele einer LBNE beschäftig hat, verbindet die LBNE Fallstudie des Educating Future Change Agents (EFCA) Projektes Lernergebnisse oder WAS Lehramtsstudierende lernen mit den dazugehörigen Lernprozessen beziehungsweise WIE sie lernen. Um die empirische Forschung der Fallstudie zu informieren, liefert das vorliegende Working Paper eine detaillierte Fallbeschreibung einzelner LBNE Kurse and der Leuphana Universität in Lüneburg (Deutschland) und der Arizona State University (USA). Durch die Beschreibung der jeweiligen Kontextbedingungen des Lehr- und Lernumfeldes, angewendeter Lehrformate sowie der Studierenden-Kohorten soll die Transparenz unserer Forschung erhöht und die Einordnung empirischer Ergebnisse erleichtert werden.

Keywords:
Bildung für nachhaltige Entwicklung; LehrerInnenbildung; Nachhaltigkeit; Hochschulbildung; Kompetenzentwicklung; Lehren und Lernen; Treiber und Barrieren; Falstudie

1 THE EDUCATING FUTURE CHANGE AGENTS PROJECT

The Educating Future Change Agents (EFCA) project produced empirical insights on how higher education can support student development of key competencies in sustainability. The research was conducted jointly by Leuphana University of Lüneburg, Germany and Arizona State University, Tempe, Arizona, USA from 2016 to 2020. The project comprised five studies, each of which included in-depth case studies and comparative studies at the course, curriculum, and institutional level. Cases were selected to ensure a high degree of both similarity and variance within and across cases and to represent the widely recognized fields of sustainability education, namely, education of sustainability professionals, teachers, and entrepreneurs.

All studies were grounded in a single analytical framework that informed both data collection and analysis. Based on this framework, each study adopted its own suite of research methods (methods appropriate to the relevant research questions) while still coordinating and sharing insights on methods among the studies. Each study produced a set of results specific to the case(s) and contexts studied. In the final phase of the project, results from the individual studies were synthesized into general insights useful for researchers, educators, and administrators in the field of sustainability education.

Results of the EFCA project have been widely published and can be found on ResearchGate: https://www.researchgate.net/project/Educating-Future-Change-Agents. This working paper series provides previously unpublished background material and additional information with the aim of facilitating greater understanding of the research that was carried out. It is our ambition to be as transparent as possible, offering thorough case documentation and in-depth information on the instruments and analytical steps we undertook.

1.1 Case Research Project

Focusing on the micro-level of the EFCA project, this working paper complements the case study research on the cases of teacher education for sustainable development (TESD) at Leuphana and ASU, by describing the related course offerings in detail. Research on the course level (micro) is being conducted through multiple case studies, exploring *"bounded systems"* and offer opportunities to study the manifold factors that produced the unique character of each case (Creswell, 2007; Stake, 2005).

As a preferable strategy to answer ‘how’ and ‘why’ questions these studies allow contextual factors, and thus the singularity of a case, to be taken into account (Yin, 1984). Multiple case studies and so-called cross-case comparisons (West & Oldfather, 1995) are considered viable options to overcome limitations of single case studies: *“A number of cases may be studied jointly in order to investigate a phenomenon, population, or general condition”* (Stake, 2005, p.445).

For a thorough understanding of the cases and increasing the reliability of the study, a detailed documentation is needed to provide insights into the case specifics (Yin, 1984). Hence, this working paper describes the cases of TESD at Leuphana and ASU and their related course offerings along the individual ‘course environment’ (including institutional support, structure of study programs, access to resources etc.), the ‘course structure’ (including applied teaching and learning formats/ pedagogies), ‘desired learning outcomes’, and the different ‘cohorts’ under investigation (including descriptive information about the participants). To fully understand the uniqueness of each case but also the comparability between TESD at both institutions, some background information on the specific context of teacher education and the school system in Germany and the US is provided as well. The actual results of the case study research, mainly focusing on the learning processes and outcomes – in terms of competence development through the investigated interventions (courses) –, on the other hand, are covered in separate scientific articles (Brandt, Barth, Merritt, & Hale, under review; Brandt, Bürgener, Barth, & Redman, 2019).

1.2 The multiple Case Study – Teacher education for sustainable development

The EFCA-TESD comparative case study addresses the overarching research question of how the development of sustainability competencies for teachers can be best supported in single courses as part of teacher education programs at Leuphana and Arizona State University, which are not primarily devoted to sustainability.

We purposefully selected the two cases to be able to compare and contrast two prominent examples of how ESD can be implemented in teacher education on a course level. The two cases display a variance with regards to the teaching and learning context, teaching and learning approaches (settings and formats), and desired learning objectives (variations of competencies composition), which will be illustrated at the end of the two case descriptions.

Both courses investigated in this case study employ novel teaching and learning formats, namely hybrids of online and classroom activities. Furthermore, this multiple case study on TESD is focused on discursive learning, which implies that the focus here is on the more conventional pedagogy of learning through the reception of course material (online) as well as through reflections and discussions with the instructor(s) and peers (in the classroom).

2 TEACHER EDUCATION FOR SUSTAINABLE DEVELOPMENT AT LEUPHANA UNIVERSITY (CASE 1)

The first case in this working paper is TESD at Leuphana University in Lüneburg, which is delivered as a mandatory module in the second semester for students of Basic Social and Science Studies (BSSS) (Sachunterricht) within the BA (Bachelor of Arts) teacher education program of Teaching and Learning (Lehren & Lernen), preparing students to become teachers of BSSS in primary schools.

Context of the case study

2.1 Teacher education in Germany and Lower Saxony

Teacher education in Germany is organized in consecutive Bachelor (six semesters) and Master (four semesters) programs. Teacher education reflects the staged German school system (Cortina & Thames, 2013) where children after primary education (4–6 years, depending on the state) can choose between three different secondary school forms: Hauptschule, with a final examination after grade 9 (Hauptschulabschluss) or grade 10 (Realschulabschluss), Realschule, with a final examination after grade 10 (Realschulabschluss), and Gymnasium, with a final examination after grade 12 or 13, depending on the state (Abitur), qualifying students for higher education. The fourth type of secondary school is the Gesamtschule, a combination of the Hauptschule, Realschule, and Gymnasium. This case study focuses on teacher education for primary education at Leuphana University in Lower Saxony, where the academic phase of three plus two years is followed by an in-service training phase (18 months) organized by the respective state authority (Cortina & Thames, 2013). As in all other universities in the federal state, student teachers at Leuphana are required to choose two instructional subjects for their BA studies while taking additional courses to develop their professional knowledge in general educational sciences.

2.2 The Leuphana model of teacher education

Leuphana University is one of eight universities in Lower Saxony in which teacher education is offered as a university degree. Originally founded as a teacher-training college in 1946, the University of Lüneburg was granted university status in 1989, making it a relatively young university in Germany. Since 2006, the university has been registered as Leuphana University of Lüneburg, with an academic mission that is primarily guided by the ideas of humanism, sustainability, and application-orientation. It is known for its strong sustainability focus, visible, for example, in the establishment of Europe's first Faculty of Sustainability[3]. Since the mid-2000s, education in the four faculties at Leuphana (Education, Humanities and Social Sciences, Sustainability, and Business and Economics) is structured in three schools—College (Bachelor's studies), Graduate School (Master's and doctoral studies) and Professional School (continuing education for professionals).

Leuphana College offers students a unique introduction to their studies: the so-called Leuphana Semester. During the Leuphana Semester, students are engaged in interdisciplinary modules where they acquire the fundamental methods for a scientific course of study and learn how to write scientific papers and present results in an academic environment. One of those interdisciplinary modules is called Science Bears Responsibility (Responsibility and Sustainability). It introduces the students to key concepts of sustainability, such as the Sustainable Development Goals (Barth & Timm, 2011; Michelsen, 2013). At the same time, in subject-specific modules, the students receive an introduction to the content and methods of their main subject[4].

As one of the three Bachelor programs in teacher education, Teaching and Learning (Lehren und Lernen) combines the study of two school subjects with educational science as well as psychological and socio-cultural topics. Integrated into the schedule of the overall 180 ECTS program are supervised internships in a school that allows students to analyze and reflect on the requirements of the teaching profession. Also, there are opportunities to complete a semester abroad. Figure 1 shows the structure of the entire program and how many ECTS[5] points are assigned to the different study modules.

As a BA program, Teaching and Learning has a standard study period of six semesters. However, students can also apply for part-time study. The program is only offered in German and is thus directed at prospective students with a good command of the German language. The

[3] https://www.leuphana.de/en/university.html
[4] https://www.leuphana.de/en/college/study-program/leuphana-semester.html
[5] European Credit Transfer and Accumulation System

program starts every year in October (Winter Semester) with an overall intake of 265 students. All applicants are recommended to take part in a self-assessment with a Career Counseling for Teachers (CCT), to get a realistic impression of the content, working procedures, and specific requirements of the teaching profession and to explore and reflect on their suitability for the job as a teacher. The results of the CCT are discussed in the subsequent interview, which is why this self-assessment is a key component of the application process at the College. The CCT results, however, have no direct impact on the final selection decision. Students can choose from 11 different school subjects: German, English, Mathematics, Biology, Chemistry, Religion, Art, Music, Politics, Sports, together with BSSS (Sachunterricht), with an emphasis on the following specific subject areas: Natural Science, Geography, History, or Politics[6].

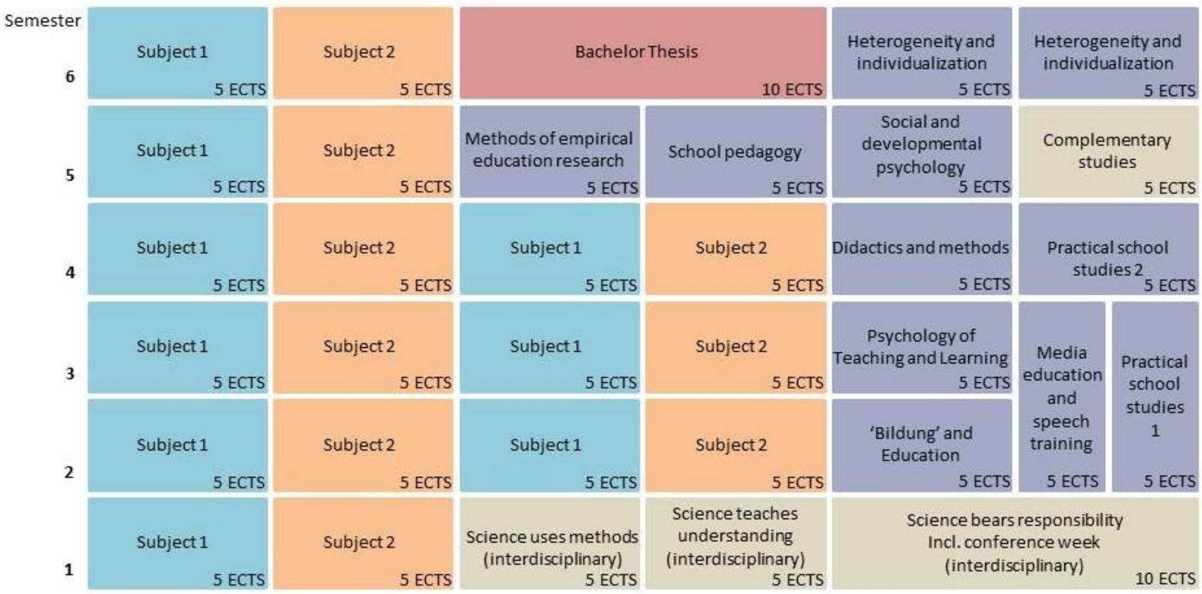

Figure 1: Structure of the teacher education study program Teaching and Learning[7]

2.3 Subject – Basic Social and Science Studies

BSSS, as a subject, is taught in primary education at German elementary schools. It deals with socially relevant issues in particular and is oriented toward ESD. The idea is to enable students to participate in societal processes and explore the world through social, cultural, natural, technical, historical, and spatial perspectives[8].

[6] https://www.leuphana.de/college/bachelor/lehramt/lehren-und-lernen.html
[7] https://www.leuphana.de/fileadmin/user_upload/college/Bachelor/2_Major_Flyer/Lehren_und_Lernen.pdf
[8] https://www.leuphana.de/college/bachelor/lehramt/lehren-und-lernen/sachunterricht.html

At Leuphana, the BSSS branch of the Teaching and Learning program offers places to 46 students each year. It introduces them to content knowledge and pedagogical content knowledge of the subject. It also covers a subject-related understanding of the term education (Bildung), including the elements of multi-perspectivity, problem-orientation, and the scientific approach. Furthermore, Leuphana's student teachers reflect on the role of schools in the (German) educational landscape as well as their duties as future teachers. The 662 applications for 46 spots (Winter Semester 2019/20) show the high level of interest of students in the program and lead to a selection of students with above-average final school exam grades.
In the context of project work and seminars, students get the chance to practice being a teacher in a research-oriented manner. As an interdisciplinary subject, BSSS offers students the opportunity to experience and discuss the interconnection of discipline-related approaches, which are deepened in the study of the reference subjects (Geography, History, Natural Sciences, and Politics), in all teaching formats of the subject (Ibid., see also Figure 2).

Figure 2: Overview of modules in Basic Social and Science Studies[9]

As part of the BSSS subject, students have to complete two sequential study modules explicitly dealing with sustainability and ESD: Education for Sustainable Development (2nd semester) and Multi-Perspective, Integrative Basic Social- and Science Studies (4th semester). This case study focuses on the first module.

[9] https://www.leuphana.de/fileadmin/user_upload/Aktuell/files/Gazetten/Gazette_15_15_Sachunterricht.pdf

2.4 Module: Education for Sustainable Development

The first module is called *Education for Sustainable Development* (Bildung für eine nachhaltige Entwicklung), and it takes place in the second semester of the BSSS branch in Teaching and Learning. It is a mandatory, 150-hour unit that is offered every year during the summer term (April to July). Table 1 summarizes some of the key characteristics of this course:

Table 1: Attributes of the Education for Sustainable Development module (Leuphana)

Course Title	***Education for Sustainable Development***
Curriculum	**Second semester –** Mandatory course in BA Teaching & Learning
Structure	**13 x seminar session (weekly)** (incl. practical project implementation at a partner school) **7 x lecture (online + live) + 7 x tutorial**
Students	**~80 students** (allocated to three seminars)
Form of Assessment	**1. Individual written assignment:** Outlining a learning unit in ESD (30/100 pts.) **2. Group presentation, incl. written report and individual reflection** Presenting an individual ESD lesson incl. rationale (70/100 pts.)
Key Learning Objectives	• Understanding of ESD as an educational perspective in primary education • Pedagogical content knowledge in ESD • Ability to plan and implement teaching and learning activities in a given class setting

2.4.1 Learning objectives

This module builds upon students´ learning in the first semester, where they are introduced to BSSS and related educational theory. It introduces them to Education for Sustainable Development as a framework for the BSSS. It familiarizes them with the basic steps of the design of learning environments. Accordingly, at the end of this module, students are expected to have a basic understanding of how to select learning objectives, content, and methods against the background of the guiding principles of ESD and how to apply them in the design process of learning environments for primary education students.

2.4.2 Pedagogical approach (teaching and learning formats)

Over the 14 weeks of the semester, students participate in a combination of (blended learning) lectures, tutorials, and seminar sessions. The design of the module follows a scaffold approach in four sequential steps:

(1) First, in a regular lecture format, students learn about the concept of ESD in general, its implementation, and how to design teaching and learning units in ESD. From week 3 to week 7, the lectures are recorded and offered in a flipped classroom setting to allow students to engage with the topic in their own time and at their own pace and to enable them to ask questions and interact in the additional face-to-face meetings each week.

(2) The lecturer uses the model of cognitive apprenticeship (Collins et al., 1991) to demonstrate how to create a learning environment that supports sustainability competence development in school settings.

(3) From week 3 to week 7, students are divided into tutorials and work individually, with the support of tutors, on the outline of such a learning environment. This work also represents their first official assignment in the course (seminar room).

(4) In three different seminars, student groups work on a case study, in which they collaborate with a school to implement an ESD lesson for primary-education students.

2.4.3 Lectures and tutorials

The lectures introduce ESD, not as an additional topic or subject, but as an innovative concept with a new perspective on educational processes, having various consequences regarding desired learning outcomes, content, and methods for teaching and learning. Overall, the lectures focus on the question of what the concept of ESD implies with regards to school and teaching. The specific focus is on the potential of ESD for students and teachers to be highly motivated and qualified for the practical implementation of EDS. Furthermore, the lectures consider the foundations of educational policy, the international discourse on ESD, and forms of implementing ESD across educational areas that have an impact on schools and teaching. As mentioned above, the lectures teach students about the concept of ESD. They provide practical knowledge on the implementation of ESD and on related didactic principles, such as vision-orientation, participation-orientation, and connected learning (Künzli & Bertschy, 2008).

The lectures are followed by tutorials led by senior students. In the tutorials, the theoretical knowledge from the lectures is deepened, and students can implement what they learned in the lectures to develop a BSSS teaching and learning unit. Through the online platform Moodle, the students have access to the material (lecture slides) and additional literature. Table 2 shows the sequence of activities in the lectures and tutorials.

2.4.4 Seminar

In the ESD seminar, students deal with the concept of ESD and try out a first practical implementation. In groups of 3–5 students, they design teaching and learning units around topics like mobility (e.g., car sharing), nutrition (e.g., package free breakfast) or the use of space (e.g., redesigning the schoolyard) to be implemented with children in a partner elementary school at the end of the semester. Students begin to look at these topics through the lens of ESD and learn how to design suitable teaching and learning settings that support children in developing their shaping competence (Gestaltungskompetenz) (Haan, 2006). Table 3 exemplifies the sequence of activities in such a seminar.

Table 2: Sequence of activities – Lectures + tutorial 2018

Session	Topic
01	***Regular lecture:*** **ESD as an educational concept for Basic Social and Science Studies** Content: After clarifying questions about the formalities of the overall module, the first lecture introduces ESD as an educational concept and provides an overview of the historical development of ESD.
02	***Regular lecture:*** **Education for or as Sustainable Development?** Content: The second lecture deals with the objectives of ESD, the contradiction between instrumental and emancipatory approaches, competence orientation as a possible solution as well as the development of a competence concept in ESD.
03	***Flipped classroom:*** **Sustainability key competencies (KCS)** Content: The third lecture introduces the model of Key Competencies in Sustainability (KCS), including the operationalization of individual sub-competencies, as a concrete approach for learning objectives in ESD. ***Tutorial:*** Content: The first tutorial introduces the goals of the tutorial (the clarification of open questions from the lecture and continuous support for working on the assignment). Furthermore, the tutors repeat and deepen the theoretical connection between ESD and related (competence-oriented) learning objectives, such as the KCS model.

04	***Flipped classroom:*** **Important questions and basic foundations** Content: Lecture four focuses on the question of how to select suitable topics and content for ESD units and introduces a relevant matrix of criteria. ***Tutorial:*** Content: The second tutorial session focuses on how teachers can find and select suitable topics and content for ESD units and aims to clarify open questions regarding the assignment and the content of the previous lectures.
05	***Flipped classroom:*** **Serious tasks and adequate approaches** Content: The desired learning objectives and suitable content call for a third step involving the selection of teaching and learning methods for ESD units. Therefore, the fifth lecture focuses on the question of how the selection of methods can be justified and introduces key principles for the didactic design of ESD units, such as constructive alignments. ***Tutorial:*** Content: The third tutorial reexamines the matrix of criteria for suitable topics and content for ESD units, the idea of a didactic triangle in education, and ESD-specific didactic principles and methods to convey the KCS. Also, the students discuss the overall dramaturgy of teaching and learning units.
06	***Flipped classroom:*** **Competence-oriented tasks** Content: The sixth lecture is focused on how to design and embed competence-oriented tasks into the procedure of a complete teaching and learning unit and introduces practical examples. ***Tutorial:*** Content: In the fourth tutorial, students can ask open questions, continue to work on their assignment, and receive feedback on their work in progress. Furthermore, the tutors present a sample teaching and learning unit to walk through the overall dramaturgy again.
07	***Flipped classroom:*** **Material and design principles of ESD** Content: The final lecture deals with summarizing the design principles for innovative teaching and learning scenarios. Existing material, selection criteria, and potential implementation scenarios are considered, and consequences for the project work in the seminar sessions of the module are discussed. ***Tutorial:*** Content: The final tutorial session offers students the opportunity to ask open questions, receive feedback, and finalize their assignments.

Table 3: Sequence of activities – ESD Seminar "Package free breakfast" 2018

Session	Topic
01	***Regular lecture:*** **ESD as an educational concept for Basic Social and Science Studies** Content: After clarifying questions about the formalities of the overall module, the first lecture introduces ESD as an educational concept and provides an overview of the historical development and establishment of ESD.
02	**The concept of ESD** Content: In the second seminar session, the key principles, building blocks, and phases of designing ESD units are discussed. Also, an overarching guiding question for the seminar and future group work during the semester is jointly formulated.
03	**Objectives of ESD and the Core Curriculum for Basic Social and Science Studies in Lower Saxony** Content: In this session, the building blocks of Lower Saxony's Core Curriculum (CC) for BSSS in elementary schools and the desired learning outcomes (KCS) are introduced.
04	**The Building blocks of the CM** Content: In the fourth session, the students deepen their CC knowledge and form working groups around the individual building blocks of the CC for the upcoming project of implementing individual teaching and learning units at the partner elementary school.
05	**Selection of learning objectives and methods** Content: In session five of the seminar, the working groups decide what KCS (learning objectives) they want to focus on in their teaching and learning unit as part of the overall project. They also discuss potential methods for implementation within the sub-groups before finally sharing their ideas with the seminar group as a whole.
06	**Further planning of the project concept (methods) + peer feedback** Content: In this session, first, the criteria for suitable teaching and learning environments in ESD are reconsidered. Second, the selected methods are revised within the working groups. Third, the students form different groups and present their ideas to members of the other sub-groups for peer feedback. Finally, the students get back to their working groups to discuss and implement the received feedback.
07	**Criteria for examination and short presentations** Content: In seminar seven, the instructor introduces the criteria for the final group presentation (Assignment 2), including (a) the theoretical foundations (concept of ESD + KCS) (b) the planning phase, and (c) reflections on the practical implementation. Then, the working groups present their intermediate project plans.
08	**Designing the project concept** (group work) Content: In session eight, the students continue working on their sub-projects. They are explicitly asked to reflect upon success factors for general group work (communication, responsibilities, shared documents etc.) and think about what conditions need to be met to ensure a successful implementation of the overall project with the partner school (physical environment, material etc.).
09	**Dry run** (group work) Content: In the ninth session, the students carry out a dry run for the overall project implementation, including the welcoming speech for the children and teachers. Finally, the students summarize what the children are expected to gain from the project (objectives) and how they plan to achieve that (methods).

10	**Implementation of teaching and learning units with the partner school** <u>Content:</u> The students implement the ESD project in the form of individual teaching and learning units with primary school children from the partner school (1st-4th grade).
11	**Reflection round** <u>Content:</u> In session 11, the students reflect in mixed groups on the implementation process of the teaching and learning units in preparation for the individual written reflections (second assignment). In several reflection rounds, the focus lies on (a) what went well, (b) what went wrong, and (c) possible improvements.
12	**Working on the final presentation** <u>Content:</u> In session 12, the students can continue working on their final presentations and receive direct feedback from the instructor and their fellow students.
13	**Final presentations** <u>Content:</u> In session 13, the project groups hold their final presentations – including a connection between their individual project ideas, learning objectives, and the concept of ESD. They are also asked to present and reflect the process of implementation.
14	**Final presentations** <u>Content:</u> In session 14, the project groups hold their final presentations, including a connection between their individual project ideas, learning objectives, and the concept of ESD. Also, they are asked to present and reflect on the process of implementation.

2.4.5 Participants

The focus of the research within the EDFCA project at Leuphana University was on the cohort enrolled in the summer term 2018.

The 2018 cohort consisted of 81 students, of whom 76 consented to participate in our research. The participants were predominantly female (88.5%) and aged 21 years on average[10]. More than two-thirds of these students had previous professional experience or had completed voluntary work in the social or ecological sector; a quarter of the students had engaged in additional educational activities, courses or certificates; and 10% had engaged in sustainability-related activities (data from the pre-course survey, Table 4)

In a pre-course survey, in addition to the basic socio-demographic data, work-related and extra-curricular experiences, we captured students' motivation to become teachers, using categories adapted from the FIT-Choice scale (Watt & Richardson, 2007) (see Table 5). This table shows that the vast majority of students are motivated by values. Motivational aspects that can be assigned to student-focused social utility values were most frequently mentioned. However, only 26% of students referred to the societal level. The second significant type of motivation was intrinsic career values, which motivated 43% of the students. While the socialization influence impacted at least one in five students, personal utility values, the perception of a task, and self-perception were rarer as motivational factors in this cohort.

To further cover students' attitudes toward sustainability and ESD, we included several scales in the surveys, such as the new ecological paradigm scale (NEP) by Dunlap et al. (2000) and the perceived relevance of ESD scale by Tomas et al. (2015). We measured students' ESD and innovation-related self-efficacy, based on scales introduced by Tomas et al. (2015) and Emmrich (2009). Table 6 shows that the students started the course with strong pro-environmental attitudes. These attitudes are notably more positive when compared with other student cohorts, such as undergraduate psychology students at the University of Utah (Amburgey & Thoman, 2012), Turkish pre-service German teachers (Alyaz, Isigicok, & Gursoy, 2016), and first-year students from five different programs at Otago University in New Zealand (Harraway et al., 2012). These results may be linked to the fact that the students had already completed a module on sustainability in their first semester. This could also explain the relatively high values for students' perceived relevance of ESD (Table 7).

[10] The relatively high number of students in this year reflects a transition of the study program to a lower number of first semester students. This change took place after the 2018 cohort was enrolled.

Table 4: ESD cohort 2018 (Leuphana)

	Percentage	***N***
Number of students (consented)	100 (93.8)	81 (76)
Gender		
Female	88.5	46
Male	11.5	6
(No reply)	(31.6)	(24)
Age		
20 years or younger	63.0	34
21-25 years	33.3	18
26 years or older	3.7	2
(No reply)	(28.9)	(22)
Previous work experience		
Started vocational training	1.7	1
Finished vocational training	6.7	4
Started a different study program	16.7	10
Completed a different study program	3.3	2
Internship of min. 6 months	10.0	6
Other professional activity for min. 6 months	10.0	6
Voluntary social year	40.0	24
Voluntary ecological year	5.0	3
None of the above	28.3	17
(No reply)	(21.1)	(16)
Extra-curricular activities		
Care service/Nursing	15.0	9
Education/Courses/Certificates	25.0	15
Organization and planning	21.7	13
Consulting	0	0
Sport	73.3	44
Sustainability	11.7	7
Music/Art/Creative work	41.7	25
Health/Yoga/Meditation	30.0	18
Gardening	16.7	10
IT/Computers	10.0	6
None of the above	0	0
(No reply)	(21.1)	(16)

Table 5: Motivation to become a teacher (Leuphana), based on the FIT-Choice Scale (Watt & Richardson, 2007)

	Percentage	***N***
	100	**58**
Values	96.6	56
Intrinsic career values	43.1	25
Personal utility values	3.4	2
Social utility values (students)	81	47
Social utility values (society)	25.9	15
Socialization influence	20.7	12
Perception of the task	6.9	4
Perception of the self	8.6	5
(No reply)	(23.7)	(18)

Table 6: NEP - New Ecological Paradigm (1-5 Likert scale) (Leuphana)—based on Dunlap et al. (2000)

	N	*M*	*SD*
Overall NEP scale	60	**3.98**	0.38
Sub-Dimensions			
Balance of nature (Items 3, 8[R] & 13)	60	**4.10**	0.52
Eco-crisis (Items 5,10[*R*] & 15)	60	**4.26**	0.66
Anti-Exemptionalism (Items 4[*R*], 9 & 14[*R*])	60	**3.71**	0.50
Limits to growth (Items 1, 6[*R*] & 11)	60	**3.60**	0.78
Anti-Anthropocentrism (Items 2[*R*], 7 & 12[*R*])	60	**4.21**	0.46

[*R*] = reverse-scored items from the scale

Table 7: Attitude scales (Leuphana)

	N	*M*	*SD*
Perceived relevance of ESD (1–4 Likert scale)	49	**3.55**	0.34
ESD-related self-efficacy (1–4 Likert scale)	49	**2.98**	0.37
Innovation-related self-efficacy (1–4 Likert scale)	48	**3.13**	0.40

3 TEACHER EDUCATION FOR SUSTAINABLE DEVELOPMENT AT ARIZONA STATE UNIVERSITY (CASE 2)

Our second case study is TESD at ASU, a course delivered at the Mary Lou Fulton Teachers College called Sustainability Science for Teachers (SSfT), a mandatory course for all students in K-8 education programs at ASU.

Context of the ASU case study

3.1 Teacher education in the USA

Teacher education programs in the United States often focus their curriculum on a set of model core teaching standards developed by the Council of Chief State School Officers (2011). These Interstate Teacher Assessment and Support Consortium (InTASC) standards articulate what effective teaching and learning should look like in order to optimize development for K-12 students. Student teachers may learn these skills in a variety of study programs. Many students pursue an undergraduate degree in education and fulfill requirements for a teaching license. In contrast, others enroll in an MA program that leads to licensure. Due to the shortage of teachers in the United States, there are also several alternative routes to licensure, which include a combination of coursework and relevant experience. American schools are considered elementary schools if they include students in pre-school through sixth, and in some cases, up to eighth grade. Some districts have middle schools, which focus on grades 6–8, while secondary schools often include grades 9–12.

Each state has a great deal of autonomy in developing a curriculum for students in K-12 and higher education. In Arizona, pre-service teachers can pursue an endorsement in early childhood education (birth to age 8), elementary education (grades K-8), middle grades education (grades 5–9) or secondary education (grades 6–12, with a focus on a specific subject such as life science)[11]. The students in this case study were undergraduates who attended the Mary Lou Futon Teachers College at ASU and were all pursuing a degree in elementary education. Some students were enrolled in a BA in Special Education with Dual Certification in Elementary Education, while others studied Bilingual Education and English as a Second Language in addition to elementary education.

[11] https://www.azed.gov/educator-certification/forms-and-information/certificates/

3.2 The ASU model of teacher education

ASU is a comprehensive public research university, "measured not by whom it excludes, but by whom it includes and how they succeed; advancing research and discovery of public value; and assuming fundamental responsibility for the economic, social, cultural and overall health of the communities it serves." (ASU Charter[12]). In 2002, ASU President Michael M. Crow unveiled his vision for a *"New American University."*[13] Since then, ASU has established more than a dozen new transdisciplinary schools and launched large-scale research initiatives. Today, the university is divided into 17 departments (schools, colleges, and institutes)[14], two of which—the School of Sustainability and the Mary Lou Fulton Teachers College, in cooperation with the Pathfinder Center (working at the interface of education, sustainability, and research)—are direct associates of the EFCA research project. Established in 2007, the School of Sustainability is the first of its kind in the United States and significantly contributes to ASU's reputation as one of the most ambitious and principled organizations for embedding sustainable practices into its operating model.[15]

The Mary Lou Fulton Teachers College, according to its website, has the mission of creating knowledge, mobilizing people, and taking action to improve education. It is subdivided into the Division of Teacher Preparation and the Division of Educational Leadership and Innovation.[16] The Division of Educational Leadership and Innovation offers Master's degree and PhD programs to those dedicated to the improvement of professional practice in pre-K–20 settings and those who wish to become full-time faculty at research institutions. In addition to a set of Master's degrees, the Division of Teacher Preparation offers a variety of undergraduate programs.[17] Here, we only list the degrees that students participating in the EFCA's teacher education case study were pursuing: Elementary Education, BAE; Elementary Education, (BLE/ESL), BAE; Elementary Education, (STEM), BAE; Special Education/Elementary Education (dual certification), BAE.

[12] https://www.asu.edu/about/charter-mission-and-values
[13] https://newamericanuniversity.asu.edu/home
[14] https://www.asu.edu/about/colleges-and-schools
[15] https://www.greenbiz.com/blog/2013/08/16/asu-sustainable-procurement-isnt-just-academic-exercise
[16] https://education.asu.edu/
[17] https://education.asu.edu/about/academic-divisions

The innovative curriculum aims to equip teachers and educational leaders with the professional knowledge, skills, competencies, and dispositions that will positively impact children, young people, communities, and schools. Students engage with eminent faculty members, conduct high-impact research, and learn from an innovative curriculum that prepares them to teach in a diverse and interconnected world. In addition to the general first-year student college admission requirements (see Table 8), each of the programs has specific entry requirements that are set out on the Mary Lou Fulton Teachers College website.[18]

Table 8: Entry requirements (ASU)

General course competency requirements
– 4 years mathematics
– 4 years mathematics
– 4 years English (non-ESL/ELL courses)
– 3 years lab sciences (1 year each from biology, chemistry, earth science, integrated sciences or physics)
– 2 years social sciences (including 1 year of American history)
– 2 years same second language
– 1 year fine arts or 1 year of career and technical education
General aptitude requirements:
- Top 25% in high school graduating class
- 3.00 GPA in competency courses (4.00 = "A")
- ACT: 22 (24 non-residents)
- SAT: 1120 (1180 non-residents)

3.3 Module: Sustainability Science for Teachers

EFCA's case study on TESD at ASU is focused on the SSfT course. This course was designed by an interdisciplinary team of scientists, educators, and design experts and launched at ASU in the fall of 2012. It is a three-credit, 15-week course that is mandatory in all elementary education programs (K-8) at ASU and usually takes place in the fifth semester of the above-listed undergraduate programs.

[18] https://education.asu.edu/degree-programs/undergraduate-degrees

Table 9: Attributes of the Sustainability Science for Teachers course (ASU)

Course Title	***Sustainability Science for Teachers (SSfT)***
Curriculum	**Fifth semester** - Mandatory in all elementary education programs (K-8) at ASU
Structure	**13 x weekly seminar sessions** (incl. practical project implementation at a partner school) **7 x lecture (online + present) + 7 x tutorial**
Students	***~120 allocated to six seminars***
Form of Assessment	**Participation** (150/1000 pts.) **Quiz** (130/1000 pts.) **Reflections & contributions on Blackboard** (online platform) (200/1000 pts.) **Assignments** (150/1000 pts.) **Group presentation—Sustainability in the news** (50/1000 pts.) **Final project outline** (60/1000 pts.) **Peer review** (Final project) (60/1000 pts.) **Final project—creating a learning unit** (200/1000 pts.)
Key Learning Objectives	• Understanding of ESD as an educational perspective in primary education • Pedagogical content knowledge in ESD • Ability to plan and implement teaching and learning activities in a given class setting

3.3.1 Learning objectives

The SSfT course aims to prepare pre-service teachers (K-8) as sustainable citizens and educators who will implement ESD with their future students (Merritt, Hale, & Archambault, 2019). The primary objective is to develop sustainability literacy among pre-service teachers (a) by providing ESD-related content knowledge and fostering students' understanding of sustainability concepts and their application (CK) and (b) by providing pedagogical content knowledge for ESD and developing students' ability to apply the ways of thinking (WOT) to explain sustainability concepts (PCK). The four WOTs—strategic, futures, values, and systems thinking, which relate back to the KCS (Wiek et al., 2011)—provide the overarching *"sustainability education framework"* (Warren, Archambault, & Foley, 2014), engaging the students with the course content.

In keeping with existing goals for general teacher education, the SSfT course is oriented toward learning standards formulated by the International Society for Technology in Education (ISTE)[19], Interstate Teacher Assessment and Support Consortium (InTASC) standards[20], and national ESD K-12 student learning standards proposed by the US Partnership for Education for Sustainable Development (USPESD).[21] Furthermore, the course planners explicitly consider recent curricular reform initiatives in the US including, for instance, the Common Core State Standards (CCSS)[22], the Next Generation Science Standards, (NGSS)[23] and the College, Career and Civic Life framework for social studies.[24]

3.3.2 Pedagogical approach (teaching and learning formats)

The SSfT course is conducted in a hybrid environment, which is divided into thirds:

- Short digital stories considering the global and national issues of sustainability (online material).
- Homework assignments that consider local sustainability issues and lesson plans on sustainability topics.
- In-person or virtual classroom discussion sections centered on the digital stories and course homework.

The course uses a flipped learning approach, where the content is shared in the online portion through *"digital storytelling"* (Robin, 2008). Students watch videos related to the weekly topics, take quizzes to check for understanding of content and work on reflective assignments. As a second course component, students come to class for 75 minutes each week to discuss concepts and learn pedagogical strategies to integrate the content into their future teaching. While the class is divided into several cohorts, all instructors use the same online content, are provided with weekly lesson plans, and meet monthly to discuss pedagogical strategies. Through the exploration of sustainability-related topics, the students learn about sustainability concepts, develop ESD competencies, and engage with various pedagogical approaches, aiming to foster their ability to effectively teach ESD in K-8 settings.

[19] https://www.iste.org/standards/for-educators
[20] https://ccsso.org/sites/default/files/2017-11/InTASC_Model_Core_Teaching_Standards_2011.pdf
[21] https://s3.amazonaws.com/usp_site_uploads/resources/123/USP_EFS_standards_V3_10_09.pdf
[22] http://www.corestandards.org/
[23] https://www.nextgenscience.org/get-to-know
[24] https://www.socialstudies.org/sites/default/files/2017/Jun/c3-framework-for-social-studies-rev0617.pdf

The in-class lessons vary each week and include specific activities, such as the *"Hot Dog"* activity—a systems thinking activity where students map out all of the inputs, outputs and components of the food system needed to produce a hot dog. The final project, the overarching assignment for the course, consists of a student-designed digital artifact that outlines a five-day learning unit on a sustainability topic of a student's choice. Table 10 shows the detailed sequence of activities in the SSfT course.

Table 10: Sequence of activities—SSfT course (as of Fall 2017)

Week	Topic	Readings, Media and Assignments	In-class Activities
1	**Sustainability** What is sustainability? Why is the field of sustainability relevant to education?	**Sustainability Myths article in Blackboard** **Sustainability Content Videos in Blackboard** 1. Big Themes video (5 min.) 2. History of Sustainability (4 min.) • Read the Sustainability Myths article and respond to the discussion board. • Review the materials in the course under the "sustainability" page. • Please thoroughly review the syllabus and email me with any questions you have. **Tasks and Assignments:** • Sustainability Myths discussion	**Sustainability Scenario Exercise** Students identify that many factors in human society and the natural environment are interdependent, by creating a concept map in cooperative learning groups.
2	**Population** How many people can the Earth support?	**Population Content Videos in Blackboard:** 1. Futures Thinking (3 min.) 2. Beginnings (15 min.) 3. Regulation (12 min.) 4. Migration (12 min.) 5. Innovation (11 min.) 6. Eco-footprint (11 min.) **Tasks and Assignments:** • Quiz • Futures Thinking Reflection Global Footprint Assignment	**Population Scenarios** Students discuss and the consequences of different population development scenarios in sub-groups and present their results to the class.

3	**Poverty** What does it take to meet everyone's basic needs?	**Poverty Content Videos in Blackboard:** 1. Values Thinking (3 min.) 2. Basic Needs (9 min.) 3. Disparity (15 min.) 4. Relief Goals (14 min.) 5. Financial Inclusion (12 min.) 6. Education (14 min.) **Tasks and Assignments:** • Quiz • Values Thinking Reflection • Kiva Letter Assignment	**Needs vs. wants activity** In groups, the students are asked sort needs and want cards (that show different objects) according to their value.
4	**Food** How sustainable is our food system?	**Food Content Videos in Blackboard:** 1. Systems Thinking (4 min.) 2. Standards (3 min.) 3. Feeding the World (14 min.) 4. Over- and Malnutrition (14 min.) 5. Agricultural Methods (12 min.) 6. Beyond Crops (15 min.) **Tasks and Assignments:** • Quiz • Systems Thinking Reflection	**Hot Dog Activity** The whole class discusses the different components and steps needed to produce a hot dog. Then, the class breaks up into sub-groups, each doing the same with the individual components of a hot dog.
5	**Water** How can we provide water to meet human needs sustainably?	**Water Content Videos in Blackboard:** 1. Strategic Thinking (3 min.) 2. Next Generation Science Standards (NGSS) (2 min.) 3. The Water Cycle (4 min.) 4. Water Systems 1 (8 min.) 5. Water Systems 2 (8 min.) 6. Human Health (10 min.) 7. Environmental Health (8 min.) 8. Phoenix (7 min.) 9. Bali (7 min.) **Tasks and Assignments:** • Quiz • Strategic Thinking Reflection	**Water Cycle and Human Water Systems Activity** In two different phases, the students are asked to develop a short input on the water cycle, based on their (a) most favorite and (b) least favorite learning style: kinesthetic (makers), visual (graphics), auditory (verbal), storytelling (writing) and musical (song).

6	**Fossil Fuels** How do fossil fuels affect people?	**Fossil Fuels Content Videos in Blackboard:** 1. Introduction (3 min.) 2. Oil (7 min.) 3. Natural Gas (8 min.) 4. Coal (7 min.) 5. Social History (9 min.) 6. Equity (7 min.) 7. Climate Change Background (6 min.) 8. Climate Change Science (14 min.) 9. Geology (4 min.) 10. Technological Solutions (6 min.) **Tasks and Assignments:** • Quiz • Fracking Reflection • Reducing your Footprint Assignment	**Renew a Bead Activity** http://sse.asu.edu/robin/index.html In pairs, the students draw ten beads from a bag with 90 black (non-renewable) and 10 white beads (renewable). While black beads are "used-up," the white ones go back to the bag. The students record the numbers of black and white beads on a data sheet and repeat drawing 10 beads (1 draw = 1 decade), until they only have white beads in one draw. Finally, the results are shared with the class.
7	**New Energy** How can new energy be generated to meet human needs sustainably?	**New Energy Content Videos in Blackboard:** 1. Introduction (12 min.) 2. Wind (14 min.) 3. Solar (14 min.) 4. Tidal (12 min.) 5. Geo-thermal (15 min.) 6. Conclusion (12 min.) **Tasks and Assignments:** • Quiz • Reflection	**Solar Amusement Park** In groups, the students build their own miniature amusement park rides powered by small solar panels. They use a variety of materials (straws, paper cups, pipe cleaners, etc.) The activity includes the three phases of planning, constructing, and testing.
8	**Final Project Overview** Technology Session	**Review Final Project Materials in Blackboard:** • In-class time to go over the final project requirements in detail.	
9	**Ecosystem Services** How strategic is our management of the biosphere?	**Ecosystem Services Content Videos in Blackboard:** 1. Introduction (5 min.) 2. Coupled Systems 1 (7 min.) 3. Coupled Systems 2 (11 min.) 4. Negative Effects 1 (9 min.) 5. Negative Effects 2 (5 min.) 6. Ecosystem Services (8 min.) 7. Trade-offs (10 min.) **Tasks and Assignments:** • Quiz • Tic Tac Tomework Assignment	**Philosophical Chairs Debate** In randomly composed groups, the students debate about the environmental, social, and economic pros and cons of the mega project "The Dakota Access Pipeline."

10	**Instructor's Choice Week** Specific research topics of interest related to sustainability and in-class activities. (Varies depending on instructor)	**Tasks and Assignments:** • Final Project Outline	**SSfT 1:** Field trip to Tempe Town Lake **SSfT 2:** Full class discussion **SSfT 3:** Instructor's presentation on energy and sustainability at ASU **SSfT 4:** Schoolyard habitat garden **SSfT 5 & 6:** Extended Sustainability in the news activity + ingredients exercise
11	**Production** How do systems of production and use affect people and places?	**Production Content Videos in Blackboard:** 1. Introduction (4 min.) 2. Clay Stove (8 min.) 3. Jeans (12 min.) 4. iPhone (12 min.) 5. Bottled Water (14 min.) 6. Conclusion (6 min.) **Tasks and Assignments:** • Quiz • Fast Fashion Assignment	**Production Cycle and Group Research Activity** In groups, the students research and evaluate the production cycle (extraction, processing, packaging, inspection, distribution, sales outlet, use, energy input, labor input) and the triple bottom line of a product they frequently use/purchase.
12	**Disposal** How is waste managed, and how does it affect people and places?	**Disposal Content Videos in Blackboard:** 1. Introduction (4 min.) 2. Landfills (14 min.) 3. Jeans (5 min.) 4. eWaste (9 min.) 5. Plastics (14 min.) **Tasks and Assignments:** • Quiz	**Candy Landfill Activity** In pairs, the students build a miniature landfill out of various types of candy (fruit roll-ups, Oreos, marshmallows, gummy bears, etc.) Test and evaluate it (did the liner leak? If so, why?) https://www.youtube.com/watch?v=uP9Tcf0CaV0&feature=related
13	**Governance** How may we enact policies that improve sustainability problems at different scales?	**Governance Content Videos in Blackboard:** 1. Introduction (5 min.) 2. School Governance (7 min.) 3. Tragedy of the Commons (11 min.) 4. Policy: AIDS (15 min.) 5. Police: Ozone (15 min.) **Tasks and Assignments:** • Quiz • Assignment	**Action Project – Letter Writing** Students are asked to write a letter to a person in power, referring to a specific law or bill related to education and/or sustainability, stating their personal opinion.

14	**Translation/Peer-Review** From theory to practice: How will you create a sustainable future?	**Translation Content Videos and Peer Review Materials in Blackboard:** 1. Infusing Sustainability (4 min.) **Tasks and Assignments:** • Discussion Board posting • Final Project Peer Review	**Peer Review** Each student reviews and provides feedback on the final project (status quo) of a fellow student.
15	**Change** Why does sustainability matter for teachers?	**Change Content Videos in Blackboard:** 1. Introduction (7 min.) 2. Change Agents (7 min.) 3. Educational Change (20 min.) 4. Interdisciplinary Teaching (15 min.) 5. Integrating Sustainability (16 min.) **Tasks and Assignments:** • Quiz	**Lesson Plan Activity** In groups, the students review existing lesson plans and discuss how to implement sustainability and the WOT in that specific lesson before sharing their thoughts with the entire class.
	Online Wrap-up	**Wrap-up Videos in Blackboard:** 1. Concluding the Course (3 min.) 2. Parting Thoughts (3 min.) **Tasks and Assignments:** • Final Project	

Since its launch in 2012, the SSfT described above, has been further refined and developed in various iterations by an interdisciplinary team of scientists, educators, and design experts. With Nobel Laureate Leland H. Hartwell as the Director of the ASU Biodesign Pathfinder Center, and other external stakeholders on board, funding was available to set up a course with high-quality production of digital storytelling videos as well as consistent in-class activities.

3.3.3 Participants

Students and instructors taking part in the research for EFCA's teacher education case study on the ASU side were those who enrolled in SSfT during the fall of 2017 and 2018. Data were collected during the Fall Semester of 2017 (August-November) following a mixed-methods approach to capture a rich picture of the students' learning processes and outcomes. Data collection was approved by the Institutional Review Board.

The fall cohort in 2017 consisted of 122 students—grouped into six sub-cohorts (SSfT-1-6)—of which 104 consented to participate in the research. The 2018 cohort at ASU consisted of 130 students—grouped into five sub-cohorts (SSfT-1-5)—of which 105 consented to participate in the research. This group was also predominantly female (95%) and, on average, a year older than the German students (22 years old).

Only 14% of these students had professional experience before entering the SSfT course, and four participants had completed a year of social service. Roughly a third (31.7%) engages in education-related hobbies, and more than 10% of the students claim to engage with sustainability issues in their free time (see Table 11). Here, it is important to note that an explicit item asking for previous work experience and extra-curricular activities was only implemented in the survey for the 2018 cohort.

Table 11: SSfT cohorts 2017 & 2018 (ASU)

	SSfT 2017		**SSfT 2018**	
	Percentage	*N*	Percentage	*N*
Number of students (consented)	100 (85.2)	122 (104)	100 (80.8)	130 (105)
Gender				
Female	91.1	72	95.3	61
Male	8.9	7	4.7	3
(No reply)	(24.0	(25)	(39.0)	(41)
Age				
20 years or younger	27.6	21	53.1	34
21–25 years	59.2	45	39.1	25
26 years or older	13.2	10	7.8	5
(No reply)	(26.9)	(28)	(39.0)	(41)
Previous work experience				
Started vocational training			0	0
Finished professional training			1.6	1
Started a different study program			23.4	15
Completed a different study program			15.6	10
Internship of min. 6 months			7.8	5
Other professional activity for min. 6 months			3.1	2
Voluntary social year			6.3	4
Voluntary ecological year			0	0
None of the above			54.7	35
(No reply))			(39.0)	(41)
Extra-curricular activities				
Care service/Nursing			10.9	7
Education/Courses/Certificates			31.3	20
Organization and planning			35.9	23
Consulting			3.1	2
Sport			43.8	28
Sustainability			10.9	7
Music/Art/Creative work			51.6	33
Health/Yoga/Meditation			46.9	30
Gardening			14.1	9
IT/Computers			6.3	4
None of the above			9.4	6
(No reply)			(39.0)	(41)

Table 12 shows that the factors motivating students to become teachers were somewhat similar across the two SSfT cohorts. As with the Leuphana cohort, motivational aspects that can be assigned to student-focused social utility values were most frequently mentioned. Only slightly more than 17%, referred to the societal level. Again, the second major factor was intrinsic career values, which motivated 30.4% of the students in the 2017 cohorts and 24.4% of the 2018 cohort. With more than one in five students, the third considerable impact factor was previous teaching and learning experiences. While the socialization influence impacted almost 10% of students in 2017, only one student of the 2018 cohort was motivated by this factor. Personal utility values, perception of a task, and self-perception were uncommon motivational factors in both cohorts.

Table 12: Motivation to become a teacher (ASU)—based on FIT-Choice Scale (Watt & Richardson, 2007)

	SSfT 2017		**SSfT 2018**	
	Percentage	*N*	Percentage	*N*
	100	**92**	**100**	**62**
Values	90.2	83	96.8	60
Intrinsic career values	30.4	28	24.2	15
Personal utility values	1.1	1	1.6	1
Social utility values (students)	62.0	57	74.2	46
Social utility values (society)	17.4	16	17.7	11
Socialization influence	8.7	8	1.6	1
Perception of the task	5.4	5	1.6	1
Perception of the self	3.3	3	1.6	1
Prior teaching and learning experiences	21.7	20	22.6	14

According to the results of the pre-course survey, the ASU students show slightly less strong pro-environmental attitudes (NEP scale) than their comparison group at Leuphana (see Table 13). Their values for the perceived relevance of ESD (Tomas et al., 2015), on the other hand, resemble the results of the Leuphana cohort. With respect to students' self-efficacy (ESD- and innovation-related) the ASU cohorts again show lower values compared to the Leuphana students (Table 14). This might partly be explained by the fact that for most ASU students, the SSfT course was the first intervention dealing with sustainability and ESD. In contrast, students at Leuphana had already completed a module on sustainability in their first semester, introducing them to the relevant concepts.

Here, it should be considered that the first pre-course survey conducted at ASU in 2017 did not include the innovation-related SE scale by Emmrich (2009) and only had the original seven items of the ESD-related SE scale by Tomas et al. (2015), while subsequently this scale was complemented by four items focusing on ESD-related pedagogical skills, as proposed by Bertschy et al. (2013).

Table 13: NEP - New Ecological Paradigm (1-5 Likert scale) (ASU)—based on (Dunlap et al., 2000)

	SSfT 2017			**SSfT 2018**		
	N	*M*	SD	*N*	*M*	*SD*
Overall NEP scale	85	**3.68**	0.43	59	**3.68**	0.40
Sub-Dimensions						
Balance of nature (Items 3, 8[R] & 13)	89	**3.78**	0.59	61	**3.77**	0.59
Eco-crisis (Items 5,10[R] & 15)	89	**4.02**	0.67	62	**4.03**	0.68
Anti-Exemptionalism (Items 4[R], 9 & 14[R])	87	**3.45**	0.51	60	**3.43**	0.52
Limits to growth (Items 1, 6[*R*] & 11)	89	**3.18**	0.73	62	**3.23**	0.64
Anti-Anthropocentrism (Items 2[*R*], 7 & 12[*R*])	90	**3.89**	0.64	62	**3.92**	0.62

[*R*] = reverse-scored items from the scale

Table 14: Attitude scales (ASU)

	SSfT 2017			**SSfT 2018**		
	N	*M*	SD	*N*	*M*	*SD*
Perceived relevance of ESD (1–4 Likert scale)	87	**3.49**	0.42	60	**3.48**	0.39
ESD-related self-efficacy (1–4 Likert scale)	87	**2.54** (7 items)	0.58	57	**2.80** (11 items)	0.47
Innovation-related self-efficacy (1–4 Likert scale)				61	**3.00**	0.40

4 CASE COMPARISON

The two cases of TESD at Leuphana and ASU, represented here by the Education for Sustainable Development (Leuphana) and SSfT (ASU) courses, show several differences and similarities that make a multiple case study of a comparative character highly interesting.

The ESD course at Leuphana can be described as subject-bound, as it is only offered to students enrolled in the BSSS branch of the teacher education program BA in Teaching and Learning. The SSfT course, on the other hand, is mandatory for all K-8 education major students (at undergraduate level). In general, both courses follow the overall concept of a hybrid course structure yet include different teaching and learning formats. The ESD course at Leuphana complements a flipped classroom style lecture with student-led tutorials and project-oriented seminar sessions, where students gain their first practical experience in a professional environment (partner school). The SSfT course at ASU combines elaborate video content, quizzes, and online assignments with in-class activities providing practical examples of how to implement ESD at the school level. Interestingly, despite the different foci in terms of the overall course structure and content, in both modules, the students create their individual ESD-related teaching and learning unit as their key assignment.

As a result of the different time slots for the two interventions in the overall schedule of the respective study programs at Leuphana and ASU, the participants differ concerning age and previous experiences with sustainability and ESD. All students at Leuphana complete modules focused on sustainable development in their very first semester. However, for most ASU students, SSfT is their first encounter with sustainability and related topics and with ESD as an educational concept.

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APPENDIX 5 – Educating Future Change Agents: Research instruments applied in case studies on Teacher Education for Sustainable Development

Educating Future Change Agents
Research instruments applied in case studies on Teacher Education for Sustainable Development

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EDITORIAL

This document provides additional information about the design of the different instruments (assessment tools, focus group guides, and code books) applied in case studies on Teacher Education for Sustainable Development – on the micro level (course-level) of the research project *"Educating Future Change Agents (EFCA)"*. Its main objective is to enhance transparency about how the research was conducted with regards to learning processes and outcomes in individual sustainability courses of teacher education programs at Leuphana and Arizona State University (ASU). This is to enable actual reproducibility, which usually exceeds the scope of regular journal articles. Fellow researchers, scholars, and practitioners are invited to comment, discuss, and contribute their thoughts and experiences.

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1 STUDENT SURVEY

The student survey was conducted at the beginning and at the end of the semester (pre-post course design) and consisted of two parts. Part 1 was to provide demographics and background information about the students participating in the courses under investigation. It asked about students' previous work experience, extra-curricular activities, and their motivation for becoming a teacher (open item). Part 2 included an open question asking for students' understanding of the term sustainability and used existing scales for their world-views, the perceived relevance of education for sustainable development (ESD), and their self-efficacy for a t-test based pre-post comparison.

Below, you can see the student survey as it was conducted at Arizona State University (ASU) in August and November with students of the SCN 400 course, Sustainability Science for Teachers (SSfT) – in the fall semester of 2018:

Preface: By participating in this survey, you agree that the results may be used for research purposes after being anonymized. In this survey, we will confront you with various scenarios and questions for decisions in the context of sustainability. Thereby, we will evaluate your understanding of sustainability in different application contexts as well as your knowledge about specific concepts from the field of education for sustainable development. Please use the table below to create your personal code. This will ensure the anonymization and allocation of data in the future. Please put a recognizable cross in the corresponding square. (In case you made a mistake, fully color the wrong square and put a cross in the correct one.)

A	B	C	D	E	F		A	B	C	D	E	F		0	1	2	3	4	5		0	1	2	3	4	5
G	H	I	J	K	L		G	H	I	J	K	L		6	7	8	9				6	7	8	9		
M	N	O	P	Q	R		M	N	O	P	Q	R														
S	T	U	V	W	X		S	T	U	V	W	X														
Y	Z	Ä	Ö	Ü			Y	Z	Ä	Ö	Ü															
1st letter of your first name							**2nd letter of your last name**							**2nd number in your date of birth**							**4th number in your date of birth**					

Example: **J**ohn D**o**e, born 1**4**.0**7**.1990 = **JO47**

Please transfer your code in the correct order and in capital letters/numbers to the following line:

____

PART 1 – PERSONAL INFORMATION

1. **Please enter your age (in years).**

2. **Please specify your gender.**

◯ female

◯ male

◯ other

3. **What did you do before you started your current study program?**

◯ started a vocational training

◯ completed a vocational training

◯ started a different study program

◯ completed a different study program

◯ completed an internship of min. 6 months

◯ other professional activity for min. 6 months

◯ completed a social year

◯ completed an ecological year

◯ none of the above

4. **What is your personal motivation to become a teacher?** (open item)

5. What hobbies do you have besides your studies? (extra-curricular activities)

◯ care service / nursing

◯ education / courses / certificates

◯ organization / planning

◯ consulting

◯ sports

◯ sustainability

◯ music / art / creative work

◯ health / Yoga / meditation

◯ gardening

◯ IT / computers

◯ none of the above

PART 2 – PERSPECTIVES ON SUSTAINABILTY, ESD & SELF-EFFICACY

6. How would you define the term *sustainability*? (open item)

7. **How much do you agree or disagree with the statements below?**
(NEP scale, by Dunlap et al. (2000))

	Strongly disagree	Disagree	Unsure	Agree	Strongly agree
We are approaching the limit of the number of people the Earth can support	○	○	○	○	○
Humans have the right to modify the natural environment to suit their needs **(recode)**	○	○	○	○	○
When humans interfere with nature it often produces disastrous consequences	○	○	○	○	○
Human ingenuity will insure that we do not make the Earth unlivable **(recode)**	○	○	○	○	○
Humans are seriously abusing the environment	○	○	○	○	○
The Earth has plenty of natural resources if we just learn how to develop them **(recode)**	○	○	○	○	○
Plants and animals have as much right as humans to exist	○	○	○	○	○
The balance of nature is strong enough to cope with the impacts of modern industrial nations **(recode)**	○	○	○	○	○
Despite our special abilities, humans are still subject to the laws of nature	○	○	○	○	○
The so-called “ecological crisis” facing humankind has been greatly exaggerated **(recode)**	○	○	○	○	○
The Earth is like a spaceship with very limited room and resources	○	○	○	○	○
Humans were meant to rule over the rest of nature **(recode)**	○	○	○	○	○
The balance of nature is very delicate and easily upset	○	○	○	○	○
Humans will eventually learn enough about how nature works to be able to control it **(recode)**	○	○	○	○	○
If things continue on their present course, we will soon experience a major ecological catastrophe	○	○	○	○	○

8. **Please indicate how much agree with the following statements.**
(Perceived relevance of ESD scale, by Tomas et al. (2015))

	Strongly disagree	Disagree	Agree	Strongly agree
Teachers can play an important role in solving social and environmental problems through education.	○	○	○	○
It is important to include education for sustainability in my future classroom practice.	○	○	○	○
It is important to teach environmental education to school students from an early age.	○	○	○	○
Education for sustainability is a fad that will pass in time.	○	○	○	○
It is important to include education for sustainability in pre-service teacher education programs	○	○	○	○
The inclusion of education for sustainability in my pre-service teacher education program will directly benefit my ability to teach students about sustainability.	○	○	○	○

9. **How easy would it be for you to perform the following tasks on your own?**
(ESD-related self-efficacy scale, by Tomas et al. (2015) – supplemented by Bertschy et al. (2013))

	I couldn't do this	I would struggle to do this on my own	I could do this with a bit of effort	I could do this easily
Identify the science that underlies a newspaper report on an environmental issue.	○	○	○	○
Explain the formation of acid rain.	○	○	○	○
Describe how human activities can impact the environment	○	○	○	○
Predict how changes to an environment will affect the survival of certain species.	○	○	○	○
Interpret the scientific information provided on a government website about climate change.	○	○	○	○
Educate others about sustainability issues.	○	○	○	○

Bring about an improvement in the environment, even if only in a small way, through my own skills and knowledge.	○	○	○	○
To choose possible teaching topics and evaluate their suitability for education for sustainability.	○	○	○	○
To make economic, ecological, social and cultural perspectives within a chosen topic graspable and accessible, by means of questions as well as the formulation of problems and tasks.	○	○	○	○
To appropriately introduce learners to conflicting goals and interests and to enable and guide their attempts at constructively coping with them.	○	○	○	○
To develop and provide efficient learning opportunities concerning the qualification for participation.	○	○	○	○

10. Please indicate how much you agree with the statements below:
(Innovation-related self-efficacy scale, by Emmrich (2009))

	Strongly disagree	Disagree	Agree	Strongly agree
I am confident that I can develop creative ideas that help to change unfavorable teaching and learning structures.	○	○	○	○
I am confident that I can motivate students to engage in new projects.	○	○	○	○
I can make innovative change happen, even when confronted with skeptical colleagues.	○	○	○	○
I know that I can introduce pedagogical innovations, even under problematic circumstances.	○	○	○	○
Even if I encounter barriers when implementing new ideas for teaching and learning, I find ways and means of getting them through.	○	○	○	○
Even if I try very hard, I will not be able to establish new teaching and learning methods in my teaching practice.	○	○	○	○
I feel secure and confident, even when implementing big and innovative projects and reforms.	○	○	○	○

1.1 Code book – students' motivation to become a teacher

To analyze students' motivation to become a teacher (Item 4), we used the following code book, inspired by the FIT-choice scale by Watt et al. (2012). However, whereas the original scale included the category or code of social utility value, we distinguished between a focus on the individual level (motivation to contribute to the development of children) and the societal level (motivation to contribute to the development of, for instance, the educational sector or entire generations). Furthermore, we added the code other, to account for replies that could not be assigned to any of the previously defined categories.

Code	**Rules for coding/*example quotes***
Social influence (A)	Statements on others' encouragement to undertake teaching: - *My family/friends/colleagues think I should become a teacher*
Prior teaching and learning experiences (B)	Statements on prior teaching and learning experiences: - *I had positive experiences when learning/going to school* - *I have had some inspiring teachers that serve as my role models* - *I had bad experiences with teachers and want to do it better myself*
Task demands (C)	Statements on expected difficulties and required expertise: - *The job of a teacher is emotionally demanding* - *The job of a teacher requires a high degree of content and expert knowledge* - *Teachers have to work hard, and I like to be challenged*
Task returns (D)	Statements on expected returns such as high status, reputation, and salary: - *The job as a teacher comes with a high reputation and status* - *Teaching is a respected profession* - *Teachers are highly valued/appreciated by society* - *The gratitude/gratefulness of students and their parents*
Teaching ability (E)	Statements on the perceptions of their own teaching abilities: - *I am good at teaching* - *I have the skills a teacher needs* - *The profession of being a teacher fits my skills/competencies*
Intrinsic career values (F)	Statements on the intrinsic value of teaching and the desire to work with children: - *I like teaching* - *I am interested in the profession of being a teacher* - *I would like to have a job where I can work with kids/children* - *I feel comfortable working at school* - *Being a teacher is a multi-faceted/diversified job* - *I want to make learning fun and effective* Also included: - *I want to see children grow* (implies less active input from the teacher)

Personal utility values (G)	Statements on expected job security, secure income, time for family and job transferability: - *I want a secure job* - *Teachers have a high income* - *As a teacher, I have comparably flexible hours and can combine job and family* - *I will have the ability to travel and teach English internationally*
Social utility values – focus on children (H)	Statements on the desire to shape the values of children and contribute to their development at a more individual level: - *I want to teach/guide/challenge/promote the children* - *I want to be a role model for the children* - *I want to be part of the children's development process* - *I want to prepare children for their future* - *As a teacher, I can convey certain values* - *I want to encourage disadvantaged children so that they can achieve more* - *I want to make children enthusiastic about learning* - *As a teacher, I want and can make an impact* (student-related) Excluded: - *I want to see children grow* (implies a less active input from the teacher)
Social utility values – focus on society (I)	Statements on the desire to shape society, contribute to the development of the educational sector, and impact entire generations: - *As a teacher, I can influence the next generation* - *I want to do something for the socially deprived* - *I want to do something useful for society* - *I want to give something back to society* - *I want to help change the educational system* - *Children are our future* - *As a teacher, I want, and I can make an impact* (society and generation related) Also included: - *I want to make a difference/a valuable contribution* (general statements)
Other (J)	Statements that could not be assigned to any category listed above: - *I don't want to become a teacher* - *I don't know yet*

1.2 Code book – sustainability definitions

To make students' *sustainability definitions* (Item 6) available for quantitative analysis, we created a code book, considering the two variables of *future orientation* (0–3 Pts.) and *sustainability dimensions* (0–2 Pts.), so that overall scores ranging from 0 to 5 Pts. can be used in a pre-post comparison (paired t-tests).

Variable: ***Future orientation***

No future orientation (0 Pts.)	Statements with no concrete reference to the future
Future orientation (1 Pt.)	Statements with a concrete reference to the future (such as developments, effects, and/or consequences): - Ideas/conceptions of *"not running out of resources,"*; *"systems staying diverse," "making things last," "keeping Earth healthy," "saving the planet," "using renewable recourses,"* etc. - Further, verbal indications of future orientation, like: *"maintain/maintenance," "preserving/preservation," "progress/progression,"* etc.
Intergenerational justice (2 Pts.)	Statements with a concrete reference to *"future generations"*: - for instance, "*ensuring future generations the same (or a better) lifestyle, access to resources,"* etc.
Inter- and Intra-generational justice (3 Pts.)	Statements with explicit reference to both today's and future generations: - for instance: *"meeting the needs of the present without compromising the ability of future generations to meet their own needs,"* etc.

Variable: ***Sustainability dimensions***

No dimension (0 Pts.)	Statements with no concrete reference to any of the sustainability dimensions
Ecological dimension (1 Pt.)	Statements referring to the ecological dimension of sustainability: - *Environmental protection* - *Living in harmony with nature* - *Environmental consciousness* - *Preservation of biological systems* - *Reducing waste and pollution* - References to the *"world/planet/Earth as our environment,"* etc. <u>Also included:</u> - the idea of "*going green"*
Social dimension (1 pt.)	Statements referring to the social dimension of sustainability: - *Societal needs* - *Sustainable lifestyle* - *Fighting poverty, hunger, etc.* - *Social justice*

Economic dimension (Resource orientation) (1Pt.)	Statements on the economic dimension of sustainability: - References to economic concepts like “Productivity” and “Efficiency” - Sustainable consumption Also included: - Preservation/conservation/protection of (natural) resource conservation and protection with regards to availability
Multi-dimensional understanding (2 Pts.)	Mentioning of at least **two** sustainability dimensions (ecological, social, and economic (resource orientation)), as well as taking different perspectives and/or referring to the interplay of the different dimensions

2 COMPETENCE ASSESSMENT:
ESD-RELATED PEDAGOGICAL CONTENT KNOWLEDGE

To assess students' pedagogical content knowledge (PCK) we measured their capability to decide how well the ESD-specific learning principles of vision orientation, connected learning, and participatory orientation (Künzli & Bertschy, 2008) can be put into practice in selected case studies (Plesse, 2007).[25] Ratings were based on two scores: First, we determined how closely the students' rating of whether the learning principles could be applied in each case study matched a rating by experts. This expert rating was determined by having every case study evaluated by four experts from the field of ESD in teacher education and averaging their scores. The difference between the experts' rating and the students' scores (an absolute number) was deducted from the potential maximum of four points, leading to a final score ranging from 0 to 4*, which was again used for pre-post comparisons (paired t-tests). Second, the researchers rated the students' rationales for their ratings (codes ranged from 0 to 2). All coding was conducted by at least two researchers to achieve inter-coder reliability (ICR). In the case of different scores, the researchers jointly re-examined the raw data to come to an agreement.

* Calculating the rating score:

Student rates *"can hardly be put into practice"*: **2**
Expert rates *"can be put into practice to a large extent"*: **4**

Difference between student and expert: **4 – 2 = 2**
Rating Score = Max Score – |Difference (Student vs. Expert)| = 4 – 2 = 2

Preface: Below, you will find different cases of classroom scenarios. Please read them carefully and answer the associated questions.

[25] The original case studies can be found under:
http://www.institutfutur.de/transfer-21/daten/materialien/gs4/HTML/archiv/teil_02.pdf
http://www.institutfutur.de/transfer-21/daten/materialien/gs4/HTML/archiv/teil_03.pdf

Case study 1: Who makes chocolate (un)happy – teaching unit on the topic of chocolate (Plesse, 2007, pp. 149–156)

A 12-week-long teaching unit for all class levels in elementary schools (as well as across levels) on the topic of chocolate

Learning objectives:

The children know the different stakeholders along the production process of chocolate as well as their individual interests and can identify interactions between them. They can critically reflect on their own role regarding the consumption of chocolate and differentiate and justify criteria for consumer decisions. They recognize the possible effects of their own actions on the stakeholders and understand that there are various alternative options for action, each of which leads to different outcomes. They can take a variety of the stakeholders' viewpoints and seek solutions according to their respective demands.

Process:

To begin the unit, the children think about what it would be like if chocolate did not cost anything. Afterward, they learn about some of the stakeholders within the field of chocolate and discuss the impact that free chocolate could have. During a trip to the supermarket and subsequent taste testing, they learn about various products, prices, labels, and the interests of the consumers. During the class, the children learn about the production process of chocolate: From the cocoa bean on the plantation to the chocolate in the supermarket. In addition, they talk about the countries growing the beans, the conditions under which they are cultivated, and the cocoa trade. By means of role-playing games, the children reflect on the demands of the different stakeholders as well as the impact of changing conditions. The class closes with a renewed debate on the initial question.

Task:

How well can the following didactical principles be put into practice in the given example? Please tick one box each and give a brief explanation for your choice.

Vision orientation

The lesson is aimed at a desired plan for the development of society and not a disaster scenario.

- ◯ Can be put into practice to a large extent
- ◯ Can partly be put into practice
- ◯ Can hardly be put into practice
- ◯ Cannot be put into practice at all
- ◯ Not clear from the information available

Please give a brief explanation of your evaluation
(where appropriate based on a concrete example)

Connected learning

Interconnectedness in the fields "local – global", "environment – economy – socio-culture" and "present-day – future" is implemented in class in a clear and instructive way.

- ◯ Can be put into practice to a large extent
- ◯ Can partly be put into practice
- ◯ Can hardly be put into practice
- ◯ Cannot be put into practice at all
- ◯ Not clear from the information available

Please give a brief explanation of your evaluation
(where appropriate based on a concrete example)

Participatory orientation

Pupils take part in selected decisions which concern the child alone or the class as a whole, and they share the consequence of these decisions.

- ◯ Can be put into practice to a large extent
- ◯ Can partly be put into practice
- ◯ Can hardly be put into practice
- ◯ Cannot be put into practice at all
- ◯ Not clear from the information available

Please give a brief explanation of your evaluation
(where appropriate based on a concrete example)

Case study 2: The herb, spice, and aromatic plant garden – a new place of learning (Plesse, 2007, pp. 189–192)

An ongoing project as part of the school garden for all age groups in elementary school on the topic of herbs, spices, and aromatic plants

Learning objectives:

The children take on responsibility for the school garden and learn to care for it. They are aware of the possible uses of herbs, spices, medicinal and aromatic plants. They find out about the different applications of these plants in their cultured and wild forms. They are capable of cultivating the plants themselves. They can present their knowledge to others.

Process:

In class, during the project, the children are introduced to a wide variety of plants, as well as the conditions under which they grow. On school trips, they learn about the different ways in which these plants are sold (e.g., frozen, fresh, processed) and how much they cost. In the school garden, the children can experience the cultivation of the plants for themselves – starting with the preparation of the beds, continuing with the planting and sowing, and, finally, the harvest. Here, they can participate directly in the decision on which plants should be cultivated. The children are taught the different ways of processing the plants (e.g., dry, pickle, freeze) and try out a variety of recipes. At a school fair, the children prepare their own samples to smell and taste and present the knowledge they acquired through the project on display boards.

Task:

How well can the following didactical principles be put into practice in the given example? Please tick one box each and give a brief explanation for your choice.

Vision orientation

The lesson is aimed at a desired plan for the development of society and not a disaster scenario.

◯ Can be put into practice to a large extent

◯ Can partly be put into practice

◯ Can hardly be put into practice

◯ Cannot be put into practice at all

◯ Not clear from the information available

Please give a brief explanation of your evaluation
(where appropriate based on a concrete example)

Connected learning

Interconnectedness in the fields "local – global", "environment – economy – socio-culture" and "present-day – future" is implemented in class in a clear and instructive way.

◯ Can be put into practice to a large extent

◯ Can partly be put into practice

◯ Can hardly be put into practice

◯ Cannot be put into practice at all

◯ Not clear from the information available

Please give a brief explanation of your evaluation
(where appropriate based on a concrete example)

Participatory orientation

Pupils take part in selected decisions which concern the child alone or the class as a whole, and they share the consequence of these decisions.

- ◯ Can be put into practice to a large extent
- ◯ Can partly be put into practice
- ◯ Can hardly be put into practice
- ◯ Cannot be put into practice at all
- ◯ Not clear from the information available

Please give a brief explanation of your evaluation
(where appropriate based on a concrete example)

Case study 3: Children explore the world – partner program with a school in Africa (Plesse, 2007, pp. 85–90)

A typical example of a school sponsorship of a German elementary school for an elementary school in Rwanda is developed into a partnership on equal terms, through which the children can exchange information about the different cultures by writing pictogram letters.

Learning objectives:
Through the continuous exchange with the partner school in Rwanda, the children learn about a culture that has, up to then, been completely foreign to them. They can identify particularities about their own culture and represent them graphically. Through the exchange with the partner school, the children can name differences and similarities between the cultures and learn to take on various perspectives. They develop empathy and solidarity for the children of another culture and can respect and appreciate differences.

Process:
First, a typical school sponsorship is put in place, in which fund-raising events at a German elementary school to collect money for a partner school in Rwanda. Pen pals are established between the children in the two schools, thereby fostering a real exchange. In their letters, the children describe their own daily life through pictograms. This allows them to exchange information on their family situation, day-to-day experiences, and their surroundings. Through this exchange, the children gain insight into a heretofore unknown world and can draw comparisons with their own situation. At a school fair, the children present an African market that reflects the topics of their letters, and, for example, build home-made Rwandan musical instruments, display traditional clothing, or describe the different ways children get to school.

Task:
How well can the following didactical principles be put into practice in the given example? Please tick one box each and give a brief explanation for your choice.

Vision orientation

The lesson is aimed at a desired plan for the development of society and not a disaster scenario.

- ◯ Can be put into practice to a large extent
- ◯ Can partly be put into practice
- ◯ Can hardly be put into practice
- ◯ Cannot be put into practice at all
- ◯ Not clear from the information available

Please give a brief explanation of your evaluation
(where appropriate based on a concrete example)

Connected learning

Interconnectedness in the fields "local – global", "environment – economy *– socio-culture" and "present-*day *– future" is implemented in class in a clear and instructive way.*

- ◯ Can be put into practice to a large extent
- ◯ Can partly be put into practice
- ◯ Can hardly be put into practice
- ◯ Cannot be put into practice at all
- ◯ Not clear from the information available

Please give a brief explanation of your evaluation
(where appropriate based on a concrete example)

Participatory orientation

Pupils take part in selected decisions which concern the child alone or the class as a whole, and they share the consequence of these decisions.

- ◯ Can be put into practice to a large extent
- ◯ Can partly be put into practice
- ◯ Can hardly be put into practice
- ◯ Cannot be put into practice at all
- ◯ Not clear from the information available

Please give a brief explanation of your evaluation
(where appropriate based on a concrete example)

Case study 4: Handling recyclable resources – sustainable protection of resources (Plesse, 2007, pp. 131–136)

In the Environmental Study Group (Umwelt-AG) of an elementary school, a project is conducted on the topic of waste, culminating in a project week for the entire school.

Learning objectives:

The children know the production process of paper as well as the different paper types and labels. They can reflect on their own consumer behavior and derive options for their own actions. The children can analyze the school's paper consumption, identify the potential for optimization, and develop and implement proposals for solutions. They can present their knowledge to others.

Process:

At the start of the projects, the children choose the topic of how they, themselves, would recycle paper. The children learn about the production process of paper, its uses, and the different paper labels. They research the offers at local retailers and reflect on their own paper consumption, at home and in school, as regards the amount and type of paper. They design informational posters for the school buildings to motivate classmates, teachers, and parents to save resources by monitoring their paper consumption. In the posters, they also raise awareness of ecological labels. Additionally, the children undertake the selling of recycled paper at the school, where they themselves are responsible for selecting, ordering, and financing the paper. In the final week of the project, all the children in the school can address the topic of "paper": making paper by hand, collecting, sorting, and disposing of trash, making crafts from garbage, or reflecting on the waste situation in their own school and developing a waste separation concept, which will then be implemented school-wide.

Task:

How well can the following didactical principles be put into practice in the given example? Please tick one box each and give a brief explanation for your choice.

Vision orientation

The lesson is aimed at a desired plan for the development of society and not a disaster scenario.

- ◯ Can be put into practice to a large extent
- ◯ Can partly be put into practice
- ◯ Can hardly be put into practice
- ◯ Cannot be put into practice at all
- ◯ Not clear from the information available

Please give a brief explanation of your evaluation
(where appropriate based on a concrete example)

Connected learning

Interconnectedness in the fields "local – global", "environment – economy – socio-culture" and "present-day – future" is implemented in class in a clear and instructive way.

- ◯ Can be put into practice to a large extent
- ◯ Can partly be put into practice
- ◯ Can hardly be put into practice
- ◯ Cannot be put into practice at all
- ◯ Not clear from the information available

Please give a brief explanation of your evaluation
(where appropriate based on a concrete example)

Participatory orientation

Pupils take part in selected decisions which concern the child alone or the class as a whole, and they share the consequence of these decisions.

- ◯ Can be put into practice to a large extent
- ◯ Can partly be put into practice
- ◯ Can hardly be put into practice
- ◯ Cannot be put into practice at all
- ◯ Not clear from the information available

Please give a brief explanation of your evaluation
(where appropriate based on a concrete example)

3 COMPETENCE ASSESSMENT:
ESD-RELATED CONTENT KNOWLEDGE

To assess students' sustainability-related content knowledge we developed closed response questions which align with the key competencies in sustainability as described by Wiek, Withycombe, and Redman (2011). In total fourteen items were included, and data was collected from the students pre and post. The students were scored based on the percentage of correct responses. This allowed paired t-tests of the scores for a pre-post comparison.

1. **Efforts to increase recycling rates are typically justified for helping to resolve environmental problems. Of those listed here, check the ways in which recycling helps to resolve social problems (if it does at all).** (More than one answer is correct)

◯ Mining for rare earth minerals which comes with health-threatening working conditions, may be reduced. (**correct**)

◯ Has a meaningful impact on land area available for conservation by reducing new landfill construction.

◯ Recycling is mostly just about helping the environment.

◯ Creates "blue-collar" jobs. (**correct**)

◯ Keeps plastic out of the ocean.

◯ Reduces costs for litter collection by local governments.

2. **You are asked to share an example of a positive feedback loop that might make climate change worse. You decide to give an example using air conditioners. Which of the following do you think would be the best to share (both in accuracy and representing a positive feedback loop)?** (Only 1 answer is correct)

◯ Technology for air conditioning continues to improve so even as temperatures increase and amount of air conditioners which are used increases, the electricity used does not and therefore the greenhouse gases emitted do not increase.

◯ Increased temperatures cause households to move to colder climates which reduces the amount of air conditioners needed, which uses less electricity which generates fewer greenhouse gases, which causes temperatures to increase less.

◯ Increased temperatures cause households to run their air conditioners more which uses more electricity, which generates more greenhouse gases, which increases temperatures more. (**correct**)

◯ Paris agreement causes nations to limit the sales of air conditioners, which makes them more expensive, which causes only the rich to be able to afford to keep their homes cool.

3. **You are reading a report which describes a vision of three years in the future with a zero-carbon energy grid. Currently 15% of the electricity on the grid in question is from renewable resources. You would evaluate this vision as being:** (Only 1 answer is correct)

◯ Desirable but not probable or plausible. (**correct**)

◯ Both probable and plausible.

◯ Based on a strong understanding of technological deployment.

◯ Not a vision because visions have to be at least 10 years in the future.

4. **Your team's vision is being attacked as "unrealistic" and utopian because it includes a 100% renewable society. You respond by saying…** (Only 1 answer is correct)

◯ Maybe that was a mistake and the vision should just include 90% renewable.

◯ Visions are meant for inspiration not to have any grounding in reality.

◯ The vision is actually realistic because we could do this tomorrow if we wanted.

◯ Visions are not meant to be realistic, rather they must be plausible. (**correct**)

5. **After you presented the assessment results, the CEO complains that "this is not a value-free assessment". You respond:** (Only 1 answer is correct)

◯ I agree and will start over with my work.

◯ Sustainability assessments are inherently value-laden, yet scientific. I have articulated the values on which the assessment is based and have made value trade-offs transparent. (**correct**)

◯ Unfortunately, sustainability assessment is more of an art than a science and there is no way to provide a rigorous assessment.

◯ The assessment might not be value-free, but I picked the right values.

6. **Economists often use something called Kaldor-Hicks criteria to judge whether an intervention should be carried out or not. Essentially, it gives the go-ahead as long as the net benefits are larger than the costs, regardless of the distribution of costs and benefits. Why is this criterion insufficient for choosing sustainability interventions?** (Only 1 answer is correct)

- ◯ There have to be no net costs to any individual for it to be a sustainability intervention.
- ◯ Economists don't take the environmental or social aspects into account, so it is not sustainability.
- ◯ The distribution of who bears the costs and who benefits matters as sustainability interventions seek to improve fairness. (**correct**)
- ◯ It is actually sufficient in a practical sense even if it is not the ideal method.

7. **The city has developed a plan to create a new, sustainable fire station. They have identified drivers and barriers and developed an evidence-supported set of instructions for how they will achieve the vision which they developed internally. Select two of the following elements which appear to still be missing from their strategy.** (More than one answer is correct)

- ◯ Process for inclusion of community stakeholders in development and implementation. (**correct**)
- ◯ Clarity between their strategy and their vision for the fire station.
- ◯ Rainwater harvesting and xeriscaping landscaping.
- ◯ Explicit tactics for managing the politics and power dynamics surrounding the fire station. (**correct**)
- ◯ Enough evidence from the expert internal resources at the city's disposal.
- ◯ Clear financial cost benefit analysis which shows it doesn't harm the taxpayers' interest.

8. As a sustainability expert you have been asked by the local government to evaluate a set of strategies which have been proposed by a private consulting firm for a new urban development project. You had previously worked with the local government to develop a systems understanding of the problem and with community members to craft a vision. How would you plan to go about your strategy evaluation? (Only 1 answer is correct)

◯ Work exclusively from the strategies to develop a list of pros and cons for each and from there create a recommendation for the government.

◯ Try to calculate the environmental, social and economic costs and benefits and provide a single 'net number' for each strategy.

◯ Ignore the strategies already developed by the consultants and use the work your students had done to develop a new strategy.

◯ Establish a set of sustainability criteria and analyze how the system changes when each strategy is carried out and how that would play out into the future against those criteria. (**correct**)

9. A new CEO is looking to re-make her widget manufacturing company into a transformational sustainability business. She has brought you on and asks for a brief overview of how you intend to solve the problem she has of running an unsustainable company. You explain that: (Only 1 answer is correct)

◯ First, you'll develop a systems understanding, collaborate with her employees and others on future scenarios and a vision and then craft strategies designed to achieve the vision. (**correct**)

◯ You'll begin by researching all the other companies which are most similar to hers and identifying all the sustainability initiatives they have and cull the best of those to implement.

◯ Rebranding themselves as the Sustainable Widget company will cause their employees and customers to think of themselves as sustainability leaders and will therefore be the key driver in transforming the company towards sustainability.

◯ You will first identify several relevant sustainability accounting frameworks such as ecological footprinting and then work to apply those to the company to achieve a suite of sustainability certificates of excellence.

10. **A large national grocery chain has brought you on to implement a pilot project focused on incentivizing customers to bring their own bags. You have been brought on to implement a pilot project in a handful of their stores. When you mention this project to a former colleague she asks if the pilot will provide sufficient evidence for a national roll-out of the intervention or whether an experiment was necessary. You respond:**
(Only 1 answer is correct)

◯ Yes of course. If it works at the scale of a couple stores than we can be confident that it will work in all of our stores.

◯ I don't think the company is really serious about rolling this out nationally and so it is not worth any extra effort to make the pilot project generalizable.

◯ With a few tweaks, such as establishing a baseline and careful monitoring and evaluation, we can convert this pilot into a solid experiment. (**correct**)

◯ A pilot project is by definition an experiment and therefore is sufficient.

11. **At the behest of major philanthropist, you brought together a team of experts to develop a strategy for a local food economy. You want to be sure that the team can work well together. Some members want to divide up the project and each work individually, integrating at the end. To make the case for why the team should work more closely together than that, which two arguments are the most relevant for the sustainability context?**
(More than one answer is correct)

◯ Collaborative teams develop more innovative solutions because they take time understand how to unleash the creative potential of team members. (**correct**)

◯ Teamwork is inherent to sustainability and therefore experts in this area are well practiced in it; teamwork thus will not require extra time and attention.

◯ Although it is a slower process than everyone working individual, teams generally develop better solutions.

◯ If you bring together experts with a shared goal of tackling a sustainability problem, teamwork will be easy and require little facilitation and planning.

◯ Teamwork is beneficial because continually through the process we challenge each other's ideas, ultimately making the solutions more robust. (**correct**)

◯ Effective teamwork assigns each individual a set of tasks, the results of which only need to be brought together infrequently.

12. **The company you worked for has agreed to launch a large sustainability initiative, and you are the lead designer. Company leadership was very excited about the vision articulated in the plan but not the implementation strategy described. Instead they are planning to follow the project management approach the company has always used for corporate initiatives. You make the following argument in response:** (Only 1 answer is correct)

◯ Sustainability projects require that projects be managed by sustainability experts with knowledge of the environmental, economic, and social aspects of the field.

◯ As long as the project team stays true to the original sustainability vision, how the plan is implemented is not materially important for its success.

◯ As the leader of the planning team, it is critical that I be the one to also lead implementation. Sustainability necessitates continuity from planning through implementation.

◯ Sustainability projects require different approaches to project management in order to cope with the uncertainty, complexity, dynamically changing situations, and transdisciplinary nature of implementing sustainability solutions. (**correct**)

13. **You have worked for three years to collaboratively develop a sustainability based re-development plan for a city neighborhood largely viewed as in decline. After finally receiving the go ahead from council, your office receives an unexpected flood of complaints from residents. As a result, city council demands you speak publicly about the plan at the next meeting. What would be the best approach to effectively communicating at this venue?** (Only 1 answer is correct)

◯ Tell the compelling vision story for the neighborhood and how it was collaboratively developed with stakeholders; leaving time to address specific concerns in a Q & A afterwards. (**correct**)

◯ Create a presentation which clearly lays out the case for the project backed up by the extensive data and analysis which your team put together during their years of work.

◯ Hire consultant to quickly put together a compelling short film on the project as this medium is most likely to engage the concerned residents and address specific concerns in a Q &A afterwards.

◯ Describe how the extensive stakeholder engagement process which your team carried out went well beyond what was required by law, pointing out how the current plan already was adjusted based on resident concerns.

14. **The city you work for has received special funding from city council to plant 10,000 trees but has only one year to complete the project. As the project leader, you are under significant pressure to begin planting them immediately. Should you make the case that a community consultation process is first needed, why or why not?** (Only 1 answer is correct)

- ◯ Yes, stakeholder engagement is a necessary part of any sustainability project both by law and from an ethical perspective. The focus should be on informing the community about the project plans.

- ◯ No, there is too little time to honestly engage with the affected communities and complete the project in the time required by the funders; stakeholder engagement that is done poorly does more harm than good.

- ◯ Yes, for sustainability projects such as this, engaging with stakeholders will improve the project plan, bring more supportive parties on board, and enhance the actual implementation. (**correct**)

- ◯ No, tree plantings are always in demand by residents and other stakeholders as it serves as climate change adaptation measure, and so nobody is going to object to more of them being planted in their neighborhoods.

4 FOCUS GROUP AND INTERVIEW GUIDES

To provide information about the learning process as well as perceived learning outcomes from the students' perspective, we conducted focus groups (4–7 participants) at the end of the semester. In 2017, the focus group guide asked students for a general reflection on their learning process with regards to the different teaching and learning formats as well as the achievement of the explicit learning objectives of the course. However, the 2018 version was enriched by a photovoice activity and remained more open in terms of students' learning outcomes. In the later version, the students were further asked to trace back their competence development (one competence each) and reflect upon drivers and barriers to their learning. The photovoice method, originally introduced by Wang and Burris (1994), was intended to support students' reflection processes. In using this method, the students took pictures of personal key learning moments over the semester, which then served as anchor points during the group reflections. Semi-structured instructor interviews were conducted to gain further insights about the teaching and learning environment as well as the learning processes and outcomes from the instructors' perspective.

4.1 Focus group guide 2017

Course: Sustainability Science for teachers – SCN 400

Location: ASU

Variables to cover: Competence development; Learning process; Teaching and Learning (T&L) environment; Participants; Context

Pre-discussion Tasks: Print consent form; Check recording device; Have a watch ready; Posters or slides (timeline of the course and its separate learning units + learning objectives); Whiteboard and markers for collecting results of final question (recommendations)

> **Preface:** The project *"Educating Future Change Agents"* investigates which key sustainability competencies enable change agents to promote the transition toward sustainability. While we also interview future sustainability professionals and entrepreneurs, here we focus on teacher education. The ultimate goal of the project is to provide evidence on promising pedagogical approaches to convey key sustainability competencies in different study programs. We would like to record this interview digitally. The data will be analyzed anonymously and used for academic reasons only. Is that okay with you? Furthermore, I would like to emphasize that your participation here is voluntary, and you have the right to leave at any time. Do you have any questions before we start?
> (A short round of introductions can help to identify the voices during the process of transcription.)

Introduction – Looking back at the SSfT course **(T&L environment / Learning process)**		
Question: Now that you have almost completed the SCN 400 course, I would be interested in your opinion on your learning process in the SSfT course. How did you perceive both the actual activities and face to face meetings in class and the online sessions, including videos, quizzes, and assignments?		
Contextual aspects	**Maintenance questions**	**Follow-up questions**
- General conclusion - Feedback on the structure of the module	- Could you name a concrete example of that? - What exactly were the difficulties? - What helped you? - What was missing?	- How did you deal with the tasks and challenges? - How was the spirit among your students? - What did you like about the course? - How did you organize yourselves to complete the different tasks? - How was the project work for you?
Concrete learning effect through the SSfT course (SCN 400) **(Learning process / Competence development)**		
Question: In the course syllabus, the ability to develop and communicate an understanding of sustainability concepts and their application, and being able to apply the WOT (Ways of Thinking) to explain sustainability concepts are the explicit learning objectives. To what extent did you actually achieve these learning objectives during this course?		
Contextual aspects	Maintenance questions	Follow-up questions
- Learning objectives - Teaching and learning formats - Competence development	- What helped you particularly in this regard? - What would be an indicator of that? - Could you name concrete examples for that? - What would it have been helpful to have?	- How do you convey that? - Do you think that you could transfer the new knowledge and skills to other contexts, courses, and the working practice as a teacher? - What else did you learn during the SSfT course (something you were not able to do before the course, but can now)?
Beneficial factors and challenges of the course work in SCN 400 **(T&L environment / Learning process)**		
Question: Finally, I would like to ask each of you to formulate a short list of recommendations regarding the future of the SSfT course. The goal is to further develop the course with your help. Therefore, please summarize what was helpful to your personal learning process and say what you would change about the course, if you could?		
Contextual aspects	Maintenance questions	Follow-up questions
- Conditions for competence development - Self-evaluation - Chances and obstacles to the collaboration	- Could you name concrete examples of that? - What exactly were the difficulties, obstacles, or disruptive factors? - Could you describe such a situation?	- How could you have been better supported? - How would you evaluate your engagement and motivation in this course? - To what extent could you bring in your personal strengths? - To what extent could others play out their individual strengths?
Thank you for participating in this focus group and for your hard work during the semester.		

4.2 Photovoice-Focus group guide 2018

Course: Sustainability Science for teachers – SCN 400

Location: ASU

Research question:

What teaching and learning processes enable student-teachers to develop the key competencies required to implement education for sustainability at the school level?

Goal:

To answer the questions

1. What competencies did the students develop over the semester? (key competencies)
2. How did the students learn in this course? (T&L processes)
3. What causal links are there between the different T&L processes and the development of key competencies?

Material:

- Print-Outs (timeline, photos, texts, individual skill tracing hand-out)
- Table and chairs
- Blank sheets and pens
- Sticky notes
- Recording devices
- Flipchart and markers

Time	Activity	Description/Questions	Rationale
30 min	Preparation	- Preparation of pictures in chronological order (*NUMBERING of pictures) - Timeline of the course * so that statements can be traced back to the respective picture	
[PV] Introduction (total: 10 min)			
10 min	Welcome and first impressions regarding key moments of learning	*"Welcome to this photovoice activity. In front of you, you see all the pictures I received over the semester, and that are meant to represent different key moments of your learning processes in this course. Please take a couple of minutes to look at them. Then pick one that resonates most with you or best represents your learning process (it doesn't have to be one of your own pictures) and explain what you see in the picture and why and to what extent it represents your personal learning process."* *Follow-Up Questions:* - *Where did you experience similar moments?* - *Have the others had different experiences?*	Reflection of the semester, exchange of experiences Share first impressions

[FG] "WHAT" - part (total: 15 min)			
8 min	Learning outcomes	*"As you know, I am interested in WHAT you have learned in this course, and HOW you have learned it. Let's start with: What do you think you have learned in this course and what competencies do you think you developed over the semester. Take a few minutes to think about it and write it on the sticky notes. [after 2min] Let's share now …"*	Learning outcomes / Key competencies
7 min	Future applicability of learning outcomes; Self-Assessment of skills and competencies	*"To what extent do you think that this course has prepared you for your future job as a teacher and for implementing education for sustainability at school level?"* *Follow-Up Questions:* - *"What are you now capable of doing that you could not do a semester ago?"* - *"Can you imagine yourself implementing EfS at school level in the future? Why/Why not? Please elaborate"* - *"Are there aspects or components that are relevant to implementing EfS that were missing in this course? "*	Relevance and applicability of learning outcomes from the perspective of students
[FG] "HOW" - part (total: 20 min)			
13 min	Individual HOW Activity: Process Tracing	*"I am also interested in HOW you learned what you said you learned. So:* 1. *Please select the one competence or skill you think you developed or strengthened most in this course.* 2. *Track your learning process by identifying WHEN and HOW the skill was developed.* 3. *Write the competence/skill on one card and use the other cards to write down everything that has contributed to your learning process with regards to the specific competence.* 4. *Put the competence at the end of the timeline and try to sort the other cards chronologically where they fit on the timeline."*	T&L processes, activities and interactions, causal links between learning processes and outcomes; decrypting the black box of WHEN and HOW
7 min	Under-standing of different roles in the T&L process	If not mentioned by the students, follow-up questions: *"What role did …* - *The instructors* - *Your peers* - *Previous experiences* *play in this teaching and learning process?"* *"From your perspective, what were the drivers and barriers to your learning process?"*	T&L processes, interactions, T&L environment, competence of instructors, *Enabling Context*: Stakeholders
[PV] Collective Meaning Making & Concluding Part (total: 5min)			
5min	Wrap-up using pictures	*"Are there any concluding remarks you would like to make? Could you put the pictures in chronological order on the timeline?"*	
Thank you for participating in this focus group and for your hard work during the semester.			

4.3 Instructor interview guide 2017:

Course: Sustainability Science for teachers – SCN 400

Location: ASU

Variables to cover: Competence development; Learning process; T&L environment; Participants; Context

Pre-discussion Tasks: Print consent form; Check recording device; Have watch ready

Preface: The project "Educating Future Change Agents" investigates how learning in sustainability-related university courses takes place and ultimately leads to the development of key sustainability competencies that enable change agents to promote the transition toward sustainability. While we also interview future sustainability professionals and entrepreneurs, here we focus on teacher education. The ultimate goal of the project is to provide evidence on promising pedagogical approaches to conveying key sustainability competencies in different study programs. I would like to record this interview digitally. The data will be analyzed anonymously and used for academic reasons only. Is that okay with you?

Questions:	
1 Please, tell me a little bit about your career and background (academic and non-academic) as well as your experience as a teacher. • (**Follow-up**) Did you have formal or informal training as a teacher? • (**Follow-up**) How did you become an instructor on the SCN 400 course?	**T&L environment** (Instructor profile, academic background, non-academic background, teaching experience, teaching competence)
2 How would you describe your individual approach to teaching and learning in general and to this course in particular? (tradition, preferred T&L formats) • (**Follow-up**) How do you personally relate to the WOT?	**T&L environment/ Learning process** (Instructor profile; actual activities, interactions, teaching and learning approaches)
3 To what extent are you satisfied with how the different activities worked out in class? • **(Follow-up)** Did situations develop differently than expected? If so, in what way and what were the consequences?	**Learning process/T&L environment** (planned activities, actual activities)
4 How would you describe the learning process of your class this semester up until now? • (**Follow-up**) Were there any special situations or moments over the semester that stuck with you? What was special about it/them?	**Learning process** (actual activities, pivotal moments of learning)
5 How would you describe how you interact with your students? • (**Follow-up**) Formal or informal? Is there a written code of conduct? • (**Follow-up**) Could you give an example of that? • (**Follow-up**) Did that change over the semester?	**Learning process** (Interactions)

6 How would you describe how the students interact with each other? • (**Follow-up**) Is there a written code of conduct? • (**Follow-up**) Could you give an example of that? • (**Follow-up**) Did that change over the semester?	**Learning process** (Interactions)
7 To what extent would you say that the students achieved the course-specific learning objectives? – or to what extent are they about to achieve them? • (**Follow-up**) How do you convey that?	**Competence development** (learning objectives, competence level)

Demographic information (separate from the actual interview)

a) Age?

b) Gender?

c) Duration of employment as teacher/instructor?

d) Education?

4.4 CODE BOOK FOR QUALITATIVE ANALYSIS

The qualitative analysis of focus group and interview transcripts was oriented toward an understanding and reconstruction of the learning processes and outcomes, inspired by the coding paradigm of grounded theory, applying the method of constant comparison (Corbin & Strauss, 2015).

However, we generally followed a two-step process of deductive and inductive coding. On the one hand, regarding the learning processes, as deductive codes, we considered the context – outside and within the university as an institution – as well as the teaching and learning environment – including the different teaching and learning formats applied in the individual courses. Here we distinguished between the pros (advantages) and cons (disadvantages) of each format as well as the specific role a format plays in the context of the overall learning process – for instance, in relation to the other formats. However, it is important to note that statements referring to the role of a teaching and learning format were often connected to those talking about its pros. Concerning the learning outcomes, we oriented toward the concept of ESD-specific professional action competence for teachers, introduced by Bertschy et al. (2013), using content knowledge (CK), pedagogical content knowledge (PCK) and motivation and attitude as deductive codes. On the other hand, we constantly allowed for inductive-codes to emerge within these deductive ones. We added, for instance, learning outcomes like raised awareness and behavior change as well as group work/discussions and informal learning to the teaching and learning formats (environment). The latter two, however, were only mentioned with regards to their advantages (pros) and their role in the overall learning. In the code book below, we only present teaching and learning formats applied in the SSfT course at ASU. The formats applied in the ESD at Leuphana University as the German case of the overall study, such as lectures (flipped classroom), tutorials, seminar sessions, and the practical implementation of an ESD unit with a partner school were coded following the same approach.

With a special focus on understanding the learning process in the courses, three researchers applied open coding to four focus groups to ensure the ICR of the code book encompassing inductive in-vivo codes. In search of significant factors impacting students' learning (drivers and barriers), first emerging categories, such as *"course structure"*, *"practical application"*, *"exchange with others"*, *"personal interest"*, and *"preconceptions about science and sustainability"*, were discussed with the broader research team to allow for different perspectives and interpretations.

Through several iterations of axial coding, *"connection"* was identified as a core category spanning across the other phenomena found in the data. Finally, we included personal connection, professional connection, social connection, structural connection as well as real-world connection as (deductive) selective concepts with several sub-codes – still open for the inductive emergence of new facets.

DEDUCTIVE CODES				
Category	**Code**		**Definition**	**Example and/or Lit Cite**
Context	**Broader context**	**-**	Statements on the broader context – outside of the university as an institution – and its impact on the learning processes and outcomes.	*“(…) the fact that nothing is being done or like strengthened is discouraging, because how are we as teachers expected to go above and beyond it and include sustainability when we're not being supported by the system?”* (S1_361)
	Institutional context	**-**	Statements on the institutional context of the university – outside of the individual course under investigation (e.g., the overall workload in the program and its impact on learning in the course)	*“Yeah, for me, because like I have to agree, I would just speed up the videos and that's it and I get off topic, I can't just sit there and do homework and then, at least for me I'm here* (at the university) *all day and I stay till late doing homework to like eleven o'clock, so like by the time I hit the videos, I'm already tired, I just want to kick this is and.”* (S1_300)
Teaching and learning environment (Mode of delivery/ teaching and learning formats)	**Hybrid course format**	**Pro**	Statements on the advantages of the hybrid course format	*“I really like how the whole thing was set up. I like having the videos to be able to watch it at home and kind of like have that as the lesson and come like rewind your options and you can understand. And then you can come to class and like come with questions and supplement what you watched in the videos with the activities that we did in class.”* (S1_329)
		Contra	Statements on the disadvantages of the hybrid course format	*“Hybrid classes just make me feel like there is two separate classes going on. I don't know. I feel like the online portion is a different class than the in-person one just because of like the environment how you're learning and it doesn't feel the same for me, so, I don't know.”* (S1_301)
	Online learning	**Role**	Statements on the role or meaning of the online portion for the overall learning process in the course	*“Yeah, I think, I feel like the online work was helpful for the information (…)”* (S1_397)
		Pro	Statements on the advantages of the online portion with regards to the learning process in the course	*“(…) every video and like the quizzes help and the like link she gives us, those all help, like learn it more.”* S1_381
		Contra	Statements on the disadvantages of the online portion with regards to the learning process in the course	*“I would change the online portion. The online just didn't help my learning, it's difficult to keep track online and like when you're in class, it's really easy to stay focused, so.”* (S1_395)
	Videos	**Role**	Statements on the role or meaning of the videos for the overall learning process in the course	*“And then just having the videos every single week, they're really time consuming and we all know that we're just doing it to answer the quiz questions (…)”* (S1_317)
		Pro	Statements on the advantages of the videos with regards to the learning process in the course	*“I personally, loved the videos, I felt like I learned the most through them (…)”* (S1_352)

		Contra	Statements on the disadvantages of the videos with regards to the learning process in the course	*"(…) the videos I feel like it was just too much information which is part of one of my anxieties, is like when too much information is being like thrown at me, I don't really know how to sort through it very well"* (S1_346)
	Quizzes	**Role**	Statements on the role or meaning of the quizzes for the overall learning process in the course	*"I hadn't thought about that, because I always say the quizzes are to make sure we're watching the videos and like we're getting the information (…)"* (S1_387)
		Pro	Statements on the advantages of the quizzes with regards to the learning process in the course	*"Well, the quizzes were like based on what we learned in the videos but I liked that they were short and sweet and it was able to like sum up what we saw on the videos."* (S1_416)
		Contra	Statements on the disadvantages of the quizzes with regards to the learning process in the course	*"I think the videos or quizzes is not always the best way to go, because like in, I think the disposal or the production, I think that was my favorite videos to watch, but I was having a hard time to really pay attention, because I was worrying about the questions that I needed to answer"* (S1_348)
	Assignments	**Role**	Statements on the role or meaning of the assignments for the overall learning process in the course	*"The assignments where we had like research a clothing store that we all go to like what was there, like how do they apply it that like made us think and relate it to ourselves."* (S1_405)
		Pro	Statements on the advantages of the assignments with regards to the learning process in the course	*"the other parts of the assignments were your own opinions. You watch, you read an article and then you talk about your opinion. I think I really learned a lot from that."* (S1_387)
		Contra	Statements on the disadvantages of the assignments with regards to the learning process in the course	*"Sometimes the secondary activities in the lessons, kind of felt disconnected. Like, there would be the video and it would be all cool and sometimes we would have this, you know, portion we had to like write, you know, some short answers on stuff and sometimes those felt like they didn't connect to it."* (S1_330)
	In-class activities	**Role**	Statements on the role or meaning of the in-class activities for the overall learning process in the course	*"I would definitely agree with that. Being able to articulate how you would show that in a classroom setting, I think you definitely get with the face-to-face, but like understanding the concept I got with videos."* (S1_311)
		Pro	Statements on the advantages of the in-class activities with regards to the learning process in the course	*"I think the best part where I learned is like, we had all these videos and our articles we had to read, but I like that when we came to class the next day or the next time we met, he* (the intructor) *kind of went over them and then he didn't just talk about it or just class discussion, we did activities, like the landfill, we also did the other one where, I think about the water system and then there was like, you had to do a poem, a song and like that was fun."* (S1_364)

		Contra	Statements on the disadvantages of the in-class activities with regards to the learning process in the course	*"when we came to class, the activities, it was kind of like, we were supposed to know or assume what like thinking we were doing and applying, I think there need to just be more emphasize like and like instruction within the classroom, like what thinking we're using and why applying."* (S1_364)
	Group work and discussions	**Role**	Statements on the role or meaning of group work and/or discussions for the overall learning process in the course	*"I thought we were just going to discuss it as a group but writing the letter didn't help me see like that's the point of view rather when like, when we sat in our groups, talking about it, it helped me understand better like what we're doing and like why we all feel the way we do about the topic."* (S1_300)
		Pro	Statements on the advantages of group work and/or discussions with regards to the learning process in the course	*"The in-class assignments and the in-class discussions, I think were a big part of it, too. The videos were great, but like getting to collaborate with our cohort and talk about it with each other was great also."* (S1_337)
	Informal learning	**Role**	Statements on the role or meaning of informal learning for the overall learning process in the course	*"When I was at the beach I just was thinking about all the sustainability things we had learned about throughout the semester and how, like, we need to be proactive about keeping things clean and plastic waste and basically everything. I was like 'Wow, it's right there' because I was there, so."* (S2_378)
		Pro	Statements on the advantages of informal learning with regards to the learning process in the course	*"When I was at the beach I just was thinking about all the sustainability things we had learned about throughout the semester and how, like, we need to be proactive about keeping things clean and plastic waste and basically everything. I was like 'Wow, it's right there' because I was there, so."* (S2_378)
Learning outcomes	**CK – content knowledge**	-	Statements on (not) having gained knowledge about sustainability concepts or related factual information	*"You know, like I think a lot of it was ignorance, we didn't know and now we know a lot more about sustainability."* (S1_416)
	PCK – pedagogical content knowledge	-	Statements on having developed skills to implement ESD at the school level, like the ability to create specific lesson plans, breaking down complex sustainability topics for children, etc.	*"I feel like I always was trying to make those connections and it helped me remember and I feel like I could teach it to children or infuse into a curriculum as a result of the instruction."* (S1_346)
	Motivation – attitude	**motivation to contribute to sustainability/ societal change**	Statements on the (lack of) motivation to contribute to sustainability in general and/or societal change	*"So, I think that is the, yeah, that is the whole point of this class. Like do not overwhelm yourself because, sure, you by yourself you cannot change the world but you can do something to be better."* (S1_413)
		motivation to implement ESD at the school level	Statements on the (lack of) motivation/willingness to implement ESD at the school level	*"Yeah. A lot of these topics though aren't in our standards. So that kind of freaks me out because I want to teach this but it's not in the standards that we're supposed to teach, so that's*

				kind of concerning to me because to address a lot of these, but I just kind of have to fit it in where you can, I guess." (S1_422)
		motivation to learn about sustainability	Statements on the (lack of) motivation to become educated on sustainability	*"This was also one of my favorite courses. I started looking at graduate degrees in sustainability yesterday."* (S1_398)
	raised awareness	-	Statements on the (lack of) raised awareness (cognitive perception) about sustainability issues and/or solutions, such as realizing non-sustainable actions or noticing sustainable solutions, such as renewable energy devices, etc.	*"I feel like everywhere and anywhere I go I see the signs or like the talk about sustainability, like I see solar panels and I'm like "That's awesome, they use solar panels." Like I don't know, I just, I never thought about things like that ever before and like she said we like walked out, we were walking around Campus, we're like, that's so not sustainable, like we're just so interested in it now and I've never, I've never thought about it before."* (S1_387)
	behavior change	-	Statements on (the lack of) actual changes in individual action patterns toward more sustainable behavior, such as consuming less meat, using public transportation more or recycling more, etc.	*"I think the biggest thing for me that I have noticed throughout the semester is that I don't leave anything plugged in anymore and that was like one of the first things that, no, maybe not one of the first things but something that I remembered early on in the classes, that like don't leave anything plugged in because if it's plugged in, it's wasting energy. And now, no matter what I'm doing, I'm always unplugging my, you know, whether it's the TV that's in my room that I use once a week or, you know my laptop charger, my phone charger (…)"* (S1_408)
	Other/unspecified	-	Statements on learning outcomes that could not be assigned to any of the previously defined codes.	*"I definitely learned a lot"* (S1_379)
SELECTIVE CODES				
Category	**Code**	**Sub-code**	**Definition**	**Example and/or Lit Cite**
Personal connection	**Personal connection**	-	Statements on how the (lack of) personal connection to the topics fostered or hindered learning (e.g., increased the motivation to learn).	*"Yeah, I think making a personal connection with each of the modules or lessons was really good for me and just to know that it won't be as hard to do that for the students, it was a good thing to learn."* (S1_383)
		Relatability	Statements referring to the (lack of) individual interest and the applicability of course content to private life and/or the relation to personal thoughts and actions.	*"Yeah, I agree with that. The knowledge that we gained from the videos didn't have a direct impact in your life until we had group discussions and we all connected together how this really influences our day to day life."* (S1_371)

		Emotions	Statements referring to emotions being triggered by course content and/or specific teaching and learning formats, such as anger, joy, excitement, surprise.	*"I just feel like all in all, like, this class really made me, like, fall in love with sustainability, like, I literally told T_010 that I was thinking about changing my major to Sustainability."* (S2_400)
		Personal engagement	Statements on the (lack of) personal engagement in the learning process, such as during hands-on activities.	*"I think the group activities and the actual projects that we did, that's where a lot of my learning and understanding came from, because those were just hands-on, really fun activities"* (S1_353)
		Agency	Statements referring to the (lack of) opportunity to decide on the WHEN, WHERE, WHAT, and HOW of learning.	*"You got to do it yourself and you could go at whatever pace you needed to understand it"* (S1_377)
Professional connection	**Professional connection**	**Applicability in future classroom**	Statements referring to the (lack of) applicability of course content in future classrooms and/or practical examples of how to implement ESD at the school level.	*"So, I guess the way that our learning took place was we did like modules online and then on Thursdays we came to class and she supported our learning by like doing hands-on activities and showing us ways that we could like incorporate it into our classrooms (...)"* (S1_388)
		Taking a teachers perspective	Statements referring to students taking the perspective of or being treated as teachers.	*"I feel like this is just more like a professional development, meaning where I'm like, I already feel like a teacher and oh, I'm going to go implement this in my classroom."* (S1_308)
Social connection	**Social connection**	**Exchange with others**	Statements referring to the exchange of thoughts and perspectives with others (instructor, fellow students, friends, and family) and how that impacted the learning process.	*"What I loved about the course was in-class discussion, I really loved being able to hear the people's opinions respectfully and to have a respectful debating and I feel like that helps with our learning because we're able to see, use values thinking to see different point of views. [...] discussion is huge"* (S1_368)
		Instructor's feedback and guidance	Statements referring to feedback and guidance the instructor provided during the semester and how that impacted their learning.	*"When we did the reflections on the videos, that would help me, because the I could go back and look at everything and then she would also give us comments of like if we were on the right track of what we learned from the video"* (S1_328)
		Role models	Statements referring to others being sustainable or passionate about teaching sustainabilita and how that has impacted the learning process.	*"Having a helpful teacher who's passionate the whole time helped, at least it helped most of those I've talked to in class. [...] her passion would make me interested in learning about the topic."* (S1_300)
Structural connection	**Structural connection**	-	Statements referring to the explicit or implicit (lack of) connection between individual T&L formats and related content and how that has impacted the learning process.	*"If you didn't do the online work, you wouldn't have been successful in the actual classroom or been able to discuss it."* (S1_340)

Real-world connection	**Real-world connection**	**Helps to understand**	Statements on how real-world connection supports the development of understanding sustainability issues and solutions and thereby works as a driver to learning	*"I think the thing about sustainability is facts and statistics and all these big numbers doesn't really give you an understanding of what's going on, you know what I mean? It's kind of hard to apply that to your real life, you know, exactly what kind of sheets or stats and have absolutely no idea what it means (...)"* (S1_389)
		Helps motivation	Statements on how real-world connection drives the motivation to learn or implement ESD	*"I think a big part is that it's like actually, like real world problems, like it's actually happening whereas it's just like in elementary schools like science that was like how far can your paper plane go and so like it's more interesting and it like drives you to want to keep learning and maybe eventually make a change when incorporating it into your classroom."* (S1_365)
		Helps to create a personal connection to the topics	Statements on how real-world connection helps to create a personal connection to sustainability topics and thereby works as a driver to learning	*"When we used like real world applications (S1_385: Yeah) is when I felt like I could relate more to the topics."* (S1_395)

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Zoom Meeting
Marie Weiss
Theres Konrad
Jan-Ole Brandt
Jodie Birdman
DEU
20:23
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