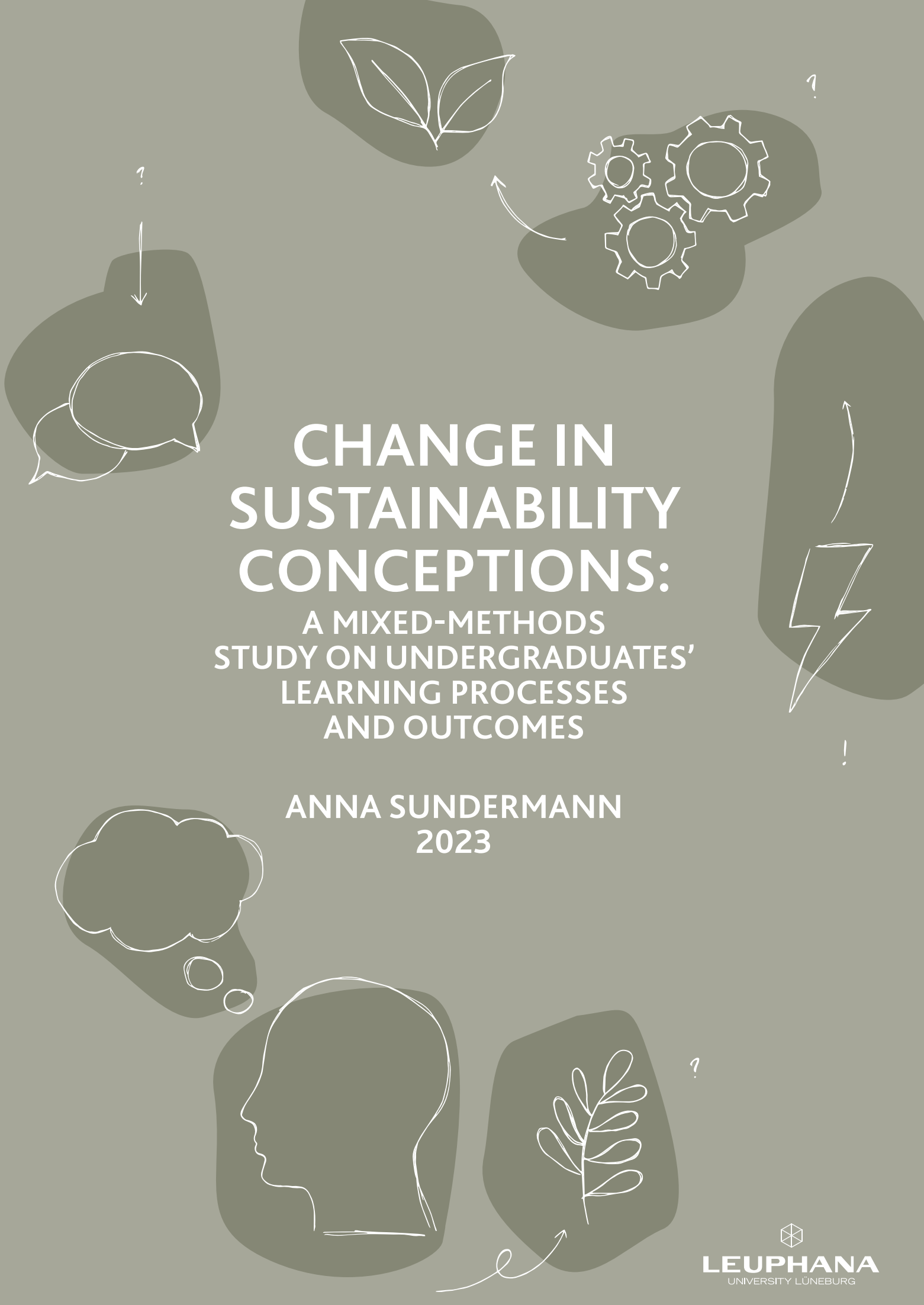

CHANGE IN SUSTAINABILITY CONCEPTIONS:

A MIXED-METHODS STUDY ON UNDERGRADUATES' LEARNING PROCESSES AND OUTCOMES

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Change in sustainability conceptions:

A mixed-methods study of undergraduates' learning processes and outcomes

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- *Article#1*: Seidel, J., Sundermann, A., Brieger, S. A., Strathoff, P., Jacob, G. H., Antonio, T., & Utami, C. W. (2018). On how business students' personal values and sustainability conceptions impact their sustainability management orientation: Evidence from Germany, Indonesia and the USA. *Journal of Global Responsibility*, 9(4), 335–354. https://doi.org/10.1108/JGR-03-2018-0010
- *Article#2*: Sundermann, A., & Fischer, D. (2019). How does sustainability become professionally relevant? Exploring the role of sustainability conceptions in first year students. *Sustainability (Switzerland),* 11(19), Article 5515, https://doi.org/10.3390/su11195155[1]
- *Chapter#3*: Sundermann, A. (2023). Die Nachhaltigkeitskonzepte Studierender im Studienverlauf: Einsichten aus einer Längsschnittstudie [Students' sustainability conceptions in the course of study: Insights from a longitudinal study]. In M. Barth, D. Fischer, & G. Michelsen (Eds.), *Bildung für nachhaltige Entwicklung in der Hochschule – Wege und Wirkungen am Beispiel der Leuphana Universität Lüneburg* (pp.137–153). Verlag Barbara Budrich
- *Article#4*: Sundermann, A., Weiser, A., & Barth, M. (2022). Meaning-making in higher education for sustainable development: Undergraduates' long-term processes of experiencing and learning. *Environmental Education Research*, 28(11), 1616–1634. http://dx.doi.org/10.1080/13504622.2022.2069679

In addition to the above core contributions of the dissertation, the following two articles are relevant in the context of this dissertation:

- Fischer, D., Haucke, F., & Sundermann, A. (2017). What does the media mean by sustainability or sustainable development? An empirical analysis of sustainability terminology in German newspapers over two decades. *Sustainable Development*, 25(6), 610–624. https://doi.org/10.1002/sd.1681
- Frank, P., Sundermann, A., & Fischer, D. (2019). How mindfulness training cultivates introspection and competence development for sustainable consumption. *International Journal of Sustainability in Higher Education*, 20(6), 1002–1021. https://doi.org/10.1108/IJSHE-12-2018-0239

[1] This paper is currently undergoing a correction process with the publisher MDPI. While reviewing the article in preparation for this framework paper, we noticed an error in the sample description of the paper and an error in reporting one of the tests checking the assumptions of the main analysis. This framework paper includes the original version of the paper and correction notice in Appendix A. Notably, the outcomes of the study are not affected by the descriptive errors.

Copyright notice

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Overview of Lists

List of Abbreviations

ESD	Education for sustainable development
HE	Higher education
HEI(s)	Higher education institution(s)
HESD	Higher education for sustainable development
RQ(s)	Research question(s)
SDG(s)	Sustainable Development Goal(s)
UNO	United Nations Organization
UNESCO	United Nations Educational, Scientific, and Cultural Organization
WGBU	Wissenschaftlicher Beirat Globale Umweltveränderungen (Scientific Advisory Board on Global Change)

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Abstract

In response to the pressing challenges posed by the current societal development trajectory, the idea of sustainability as an alternative, safe, and just development paradigm has received wide traction in different societal sectors. Higher education institutions are recognized as key players in fostering societal change by equipping students with competencies that support them in solving sustainability challenges. One essential ability of a sustainability-competent students is to assess a given problem from multiple sustainability perspectives. This ability requires elaborated conceptions of the abstract idea of sustainability. Currently, higher education institutions, however, seem to fall short in sufficiently equipping students with elaborated sustainability conceptions.

Embedded in research on higher education for sustainable development (HESD) and conceptual change, this dissertation empirically investigates how studying at such an institution affects changes in and developments of undergraduates' sustainability conceptions. An exploratory literature review identified gaps in prior research, underscoring the need for systematically investigating sustainability conceptions. Based on this, sustainability conceptions were defined as individual representations of the abstract idea of sustainability and an assessment instrument to measure changes in sustainability conceptions was developed. Further, this dissertation employs a mixed-methods approach consisting of a multi-cohort longitudinal study combined with narrative interviews that allows for long-term monitoring of changes as well as analyzing students' subjective perceptions of their learning processes.

This dissertation indicates that an undergraduate program with an initial mandatory sustainability-related first semester module in combination with further optional sustainability-related learning offers has shown certain potential in instigating changes of sustainability conceptions within all students of different subjects. The results suggest that undergraduates are gradually less likely to associate the economic and ecological dimensions with the concept of sustainable development over the course of three years. However, the changes were only subtle and often only significant in relation to students' subject affiliations. Notably, students in environmental science exhibit changes towards elaborated sustainability conceptions. This indicates that continuous engagement with sustainability throughout the entire study program is beneficial for elaborated conceptions.

The results also add evidence to the notion that effects of sustainability-related learning offers are highly intertwined with the students' subjective meaning-making processes. In line with findings from conceptual change research, this dissertation highlights the importance of emotions and values in these processes. Thus, creating relevance of the sustainability-related learning offers for all students already in the first semester seems to be a key factor for preventing loss of interest and in consequence less elaborated sustainability conceptions.

While the insights presented in this research are primarily focused on a higher education institution of medium size that has already implemented sustainability in a whole institution approach, it holds significant implications for researchers and practitioners aiming to analyze and enable conceptual change in students from different subjects.

Kurzfassung

Der Gedanke der Nachhaltigkeit findet in der derzeitigen, menschlichen Entwicklung als ein alternatives, sicheres und gerechtes Entwicklungsmodell in diversen gesellschaftlichen Bereichen breite Zustimmung. Hochschulen werden dabei als wichtige Akteure bei der Förderung eines gesellschaftlichen Wandels angesehen: Sie vermitteln Studierenden Kompetenzen, die sie zu der effektiven Lösung von Nachhaltigkeitsfragen befähigen. Eine wichtige Fähigkeit von Studierenden mit Nachhaltigkeitskompetenz ist es, aktuelle gesellschaftliche Herausforderungen aus verschiedenen Nachhaltigkeitsperspektiven beurteilen zu können. Dieser Fähigkeit liegt ein differenziertes Verständnis der abstrakten Idee der Nachhaltigkeit zugrunde. Gegenwärtig scheinen die Hochschulen jedoch nicht in der Lage zu sein, die Studierenden tatsächlich ausreichend mit differenzierten Nachhaltigkeitskonzepten auszustatten.

Eingebettet in die Forschung zu Hochschulbildung für nachhaltige Entwicklung (HBNE) und Conceptual change-Theorie, wird in dieser Dissertation empirisch untersucht, wie sich ein dreijähriges nachhaltigkeitsbezogenes Studienprogramm auf Veränderungen und Entwicklungen studentischer Nachhaltigkeitskonzepte auswirkt. Eine explorative Literaturrecherche zeigte Forschungsdesiderate auf und unterstrich damit den Bedarf einer systematischen Untersuchung der Entwicklung von Nachhaltigkeitskonzepten in der Hochschullehre. Auf dieser Grundlage wurden Nachhaltigkeitskonzepte als individuelle Vorstellungen der abstrakten Idee der Nachhaltigkeit definiert und ein Instrument zur Erfassung von Veränderungen in Nachhaltigkeitskonzepten entwickelt. Darüber hinaus wird in dieser Dissertation ein Mixed-Methods-Ansatz verwendet, der aus einer kohortenübergreifenden Längsschnittstudie in Kombination mit narrativen Interviews besteht. Dieser Ansatz ermöglicht sowohl eine langfristige Beobachtung der Veränderungen in den Nachhaltigkeitskonzepten sowie eine Analyse der subjektiven Wahrnehmung dieser Lernprozesse seitens der Studierenden.

Diese Dissertation zeigt, dass ein Bachelor-Studiengang mit einem verpflichtenden ersten Semester mit Nachhaltigkeitsbezug und darauffolgenden freiwilligen nachhaltigkeitsbezogenen Lernangeboten ein gewisses Potenzial für eine Veränderung der Nachhaltigkeitskonzepte bei Studierenden aller Fachrichtungen besitzt. Die Studie ergab, dass die Studierenden die ökonomische und ökologische Dimension im Laufe des

dreijährigen Studiums immer weniger mit dem Konzept der nachhaltigen Entwicklung in Verbindung setzen. Allerdings waren diese Veränderungen nur geringfügig und oft nur in Bezug auf die Fachzugehörigkeit der Studierenden signifikant. Auffallend ist, dass lediglich die Studierenden der Umweltwissenschaften eine Veränderung hin zu differenzierteren Nachhaltigkeitskonzepten zeigten. Das deutet an, dass eine kontinuierliche Auseinandersetzung mit dem Thema Nachhaltigkeit während des gesamten Studiums von Vorteil für die Herausbildung von differenzierten Nachhaltigkeitskonzepten ist. Die Ergebnisse erbringen darüber hinaus weitere Nachweise dafür, dass die Auswirkungen von nachhaltigkeitsbezogenen Lernangeboten eng mit der Bedeutungszuschreibung der Studierenden verwoben sind. Entsprechend den Erkenntnissen aus der Conceptual change-Forschung unterstreicht diese Dissertation die Bedeutung von Emotionen und Wertvorstellungen in diesen Prozessen. Daher scheint das Herstellen von subjektiver Relevanz in Bezug auf die nachhaltigkeitsbezogenen Lernangebote für alle Studierenden bereits im ersten Semester ein Schlüsselfaktor zu sein, um Interessensverlust und in der Folge weniger differenzierte Nachhaltigkeitskonzepte zu vermeiden.

Obwohl sich die hier vorgestellten Erkenntnisse in erster Linie auf eine mittelgroße Universität beziehen, die Nachhaltigkeit bereits im Rahmen eines gesamtinstitutionellen Ansatzes implementiert hat, bietet diese Arbeit wichtige Anhaltspunkte für Forschende und Lehrende, die die Entwicklung der Nachhaltigkeitskonzepte von Studierenden unterschiedlicher Studienfächer untersuchen und unterstützen möchten.

Framework paper

Change in sustainability conceptions: A mixed-methods study of undergraduates' learning processes and outcomes

1 Introduction

Today's students are among tomorrow's decision-makers, professionals, and consumers (Cortese, 2003; Hesselbarth & Schaltegger, 2014; Svanström et al., 2008). In the future, they will be responsible for leading educational programs, managing companies, designing products, or consulting politicians, so their professional work will have an impact on generations to come (Summers et al., 2005). For this reason, universities are seen as highly relevant in promoting sustainable development to facilitate students' acquisition of sustainability competencies[2] (Findler et al., 2019; Mochizuki & Fadeeva, 2010). Higher education for sustainable development (HESD) is seen as providing the vision to transform and rethink education to achieve sustainability (Kohl et al., 2021). The demand for students with sustainability credentials is expected to keep rising. This is driven by several factors, for instance, the growing emphasis on sustainability orientation within the private sector (Graff, 2012) or the increasing demand for climate change experts in public service (Brasseur & Gallardo, 2016). Notably, target 4.7 of the globally ratified sustainable development goals (SDGs) highlights the pivotal role of education in empowering learners to actively contribute to these crucial objectives (UNO, 2015).

Key policy documents claim that an understanding of the idea of sustainability is necessary to reach the goal of a more sustainable world (Michelsen, 2016; UNCED, 1992). Accordingly, one of the learning outcomes in HESD is how learners conceptualize sustainability. This can play a significant role in how learners frame problems in their future

[2] The terms competency and competence are often used interchangeably (Bianchi, 2020). In this dissertation the term competency is used to refer to an individual's ability to perform a task and solve-problems based on "a cluster of specific and interrelated individual dispositions comprising knowledge, skills, motives, and attitudes, i.e., combining cognitive, affective, volitional and motivational elements. Competency facilitates self-organized action, a pre-condition to achieve successful performance and a positive outcome in various complex situations, responding to the specific situation and context." (Brundiers et al., 2021, p. 17).

professional fields. Consequentially, in Wiek et al.'s (2011) influential framework for key competencies in sustainability, students' sustainability conceptions are framed as a learning outcome in normative/values-thinking competency. Based on the key competencies framework it is assumed that individuals with elaborated sustainability conceptions, encompassing multiple dimensions of societal development and interconnected aspects, are better equipped to evaluate and solve multifaceted and complex sustainability challenges (Gardner & Stern, 1996). Further, it is assumed that competent students can navigate and negotiate different concepts of the idea of sustainability. Thus, students with knowledge of and understanding of the idea of sustainability are believed to be more likely to generate robust solutions.

However, enabling the development of differentiated and elaborated sustainability conceptions is challenging task for communicators and educators (Fischer, Haucke, et al., 2017). There is no general agreement on one accepted concept of the idea of sustainability yet; instead, the existing concepts are rather vaguely defined, multidimensional, and often inherit contradictions (Jacobs, 1999; Parris & Kates, 2003; Rout et al., 2020). Theoretical concepts such as sustainable development are foremost political compromises, born out of particular normative stances and institutional perspectives (Voget-Kleschin & Meisch, 2015). Thus, learners must deal with varying value positions and the contestedness of different sustainability concepts. These characteristics suggest that learners confronted with these concepts face various challenges in developing an elaborated conception of the idea of sustainability. Conceptual change research suggests that difficulties in apprehension and elaboration of concepts can lead to internal inconsistencies, misconceptions, or inert knowledge (Vosniadou, 2012).

Unlike change in natural sciences concepts, change in social sciences concepts, such as justice or sustainable development, has not yet gained much attention (Lundholm, 2017). However, Lundholm and Davies (2013) argue that conceptual change in these conceptions deserves just as much attention as in natural science. They claim that change in social science concepts is somehow different from natural science concepts because of the difference in epistemological assumptions as well as often normative and value-laden nature of these concepts (Lundholm & Davies, 2013).

Students' sustainability conceptions have already received some attention in HESD research. For instance, a previous literature review reported that students struggle to develop elaborated conceptions of the idea of sustainability (Lipscombe, 2008b). In *article#2*[3], Lipscombe's literature review has been updated and extended. In summary, the following was observed:

- Most studies report that students associate ecological/environmental aspects most prominently with sustainability
- Many studies find popular, everyday conceptions of sustainability among the students
- The focus of students' conceptions often seems to correspond with the students' subjects
- Students' conceptions tend to be less complex in structure. That is, there are fewer connections between the dimensions within the conception in comparison with expert conceptions.

Further, the review revealed that empirical work on students' sustainability conceptions in the field of HESD is fragmented, incorporates little systematic theoretical considerations from the field of educational learning theories or competency-oriented research, and is of descriptive nature lacking systematic research on how studying is related to learning processes and outcomes regarding students' sustainability conceptions (*article#2*).

To explore the challenges to students' conceptualization of the idea of sustainability by providing a more thorough understanding of their learning processes and conditions, this dissertation focuses on analyzing long-term changes and developments in their sustainability conceptions and the relationship to internal and external learning conditions. Thus, it pursues the following over-arching exploratory research question:

How does studying sustainability affect students' sustainability conceptions?

[3] An extension of the literature review from *article#2* has been funded as part of a Writing-up Fellowship (01.11.2020 to 30.04.2021) of the Konrad Lorenz Institute for Evolution and Cognition Research in Klosterneuburg (Austria). Appendix B presents the results of the extended literature review.

The main research contribution of this dissertation is to advance the understanding of sustainability-related learning processes through a detailed and long-term analysis of changes and developments in students' sustainability conceptions. These research insights shall inform the scientific discourse on conceptual change in HESD. Practical implications of this dissertation will support higher education institutions (HEIs), curriculum designers, and lecturers in enabling change in students' sustainability conceptions.

This framework paper starts by outlining the conceptual challenges when looking at sustainability conceptions as a learning outcome and relating these challenges to existing approaches to facilitating and measuring learning outcomes and processes in HESD (section 2). This section continues by introducing the underlying learning theory to stress the assumptions about changes and development in sustainability assumptions. It ends by summarizing the research gaps and related research questions. The third section describes the mixed-methods research design and illustrates the main research context. Section 4 presents the research results in the order of publication. Finally, the synthesis section offers the theoretical and practical implications of the findings and discusses the limitations of the dissertation (section 5).

2 Theoretical Background

Section 2.1 introduces and defines the key objective of the dissertation and describes the research problem. Then, the research objective is embedded in the field of HESD research to derive the specific challenges associated with sustainability conceptions as a learning outcome (section 2.2). The final section, 2.3, connects the central arguments of the theoretical background to highlight the research gaps and questions that form the rationale for this research.

2.1 The Difficulty of Determining the Idea of Sustainability

The abstract idea of sustainability is based on the consensus that humanity lives in times of severe global transformation. These times are characterized by multiple and complex social, economic, cultural, and ecological changes, which already threaten a number of so-called planetary boundaries (Folke et al., 2021). There is growing agreement that "humanity has become a dominant force in shaping the face of Earth" (Elhacham et al., 2020, p. 442). To some extent, researchers even argue that we have reached a state of irreversible change in certain processes that govern the stability and resilience of Earth's system (Steffen et al., 2015). A notable example of how humanity is shaping the planet is that in 2020, man-made goods outnumbered all global biomass (Elhacham et al., 2020). This footprint that we leave on Earth becomes also visible when we look at the severity of biodiversity loss through habitat loss (Díaz et al., 2019) or the steep rise in global warming (Lenton et al., 2019). These threats to our living space are coupled on many levels through time and space within the socio-ecological system (W. C. Clark & Dickson, 2003). This is exemplified in the case of global migration, as evidence is showing the relationship between broader global economic, social, political, and technological change and increasing migration (S. Castles & Schierup, 2010; Goldin et al., 2011; Koser, 2011; Palumbo et al., 2022). Thus far, it has been argued that humans live in times of massive changes and that humanity and the planet exist under intensive pressure to adapt and survive.

More than 45 years ago, researchers raised awareness amongst the public and policymakers regarding the unsustainable state of society and the economy. This awareness was largely triggered by the report *Our common future* (WCED, 1987). The report introduced the concept of *sustainable development* by defining it as "development that meets the needs of

the present generation without compromising the ability of future generations to meet their own needs" (WCED, 1987, p. 54). Although the report is acknowledged as the door-opener for the concept, core aspects of the *abstract idea of sustainability*, such as "living in harmony with our planet", are deeply rooted in traditional knowledge, for instance, from European forest management and indigenous knowledge from all over the world (Mebratu, 1998, p. 498).

Concepts "are *entities* accessible intersubjectively that *may be used to classify* thoughts and expressions as content-identical, content-similar, and so forth" (Ciecierski & Grabarczyk, 2020, p. 349). According to Ciecierski and Grabarczyk (2020), concepts are vehicles in language to establish common ground in conversations or research. Thus, in this dissertation, the term concept means the abstracted perception of an idea (Figure 1). The key controversies in conceptualizing the abstract idea of sustainability concern the roles and values of the characteristics of societal development that need to be addressed for a sustainable approach towards the future (dimensions of the idea of sustainability), the importance of intergenerational justice, and the priorities regarding (economic) development against preserving the ecosystem and wellbeing of humans (Jörissen et al., 1999). Each theoretical concept based on the abstract idea of sustainability varies in its main characteristics, including varying focal topics, objectives, and ways to achieve these objectives.

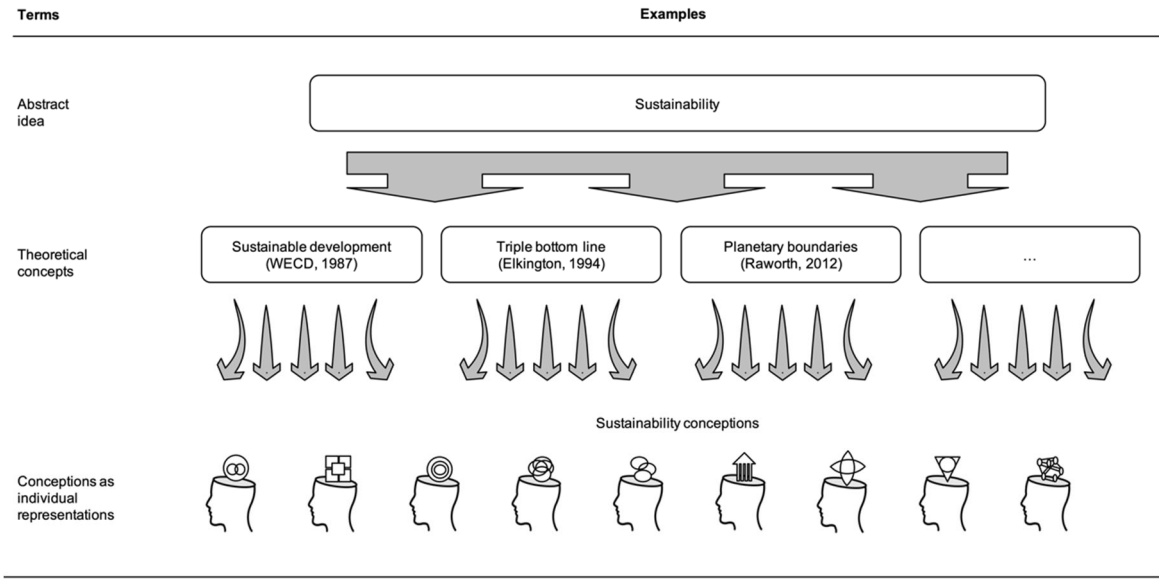

Figure 1. *Sustainability conceptions as individual representations of the abstract idea of sustainability.*

The *concept of sustainable development* is to be understood as an open-ended, interim determination of the abstract idea of sustainability (S. A. Frank, 2011). The WECD report distinguishes three dimensions that cover ecological, socio-cultural, and economic aspects of societal development processes (Farley & Zachary, 2014). The concept is suggested as a guiding principle based on the assumption that these dimensions of societal development are mutually dependent (Di Giulio, 2004). Further, the definition stipulates that problem-solving strategies must consider the interdependencies between these dimensions. The term *development* refers to the constant change in society, which is thought to ensure a good life for all people now and in the future. Furthermore, sustainable development in the sense of the United Nations definition means ensuring a good life for all while at the same time preserving the natural basis of life for human survival (Brand, 1997). Further, the concept encompasses two additional ideas: First, that the current challenges concern the social, ecological, and economic dimensions of local and global development equally. Second, a sustainable state of the socio-ecological system is described as a dynamic objective. Even though the concept of *sustainable development* is familiar worldwide, it is constantly critiqued, for example, for being too vague about the meaning of needs, for being too focused on human survival, for promoting unlimited growth, and for providing opportunities for greenwashing (Mebratu, 1998; Robinson, 2004). Moreover, it is argued that the concept lacks clarity regarding content and conceptualization (SRU, 2002).

Lipscombe (2008b) notes that in response to the constant critique, there has been an explosion of alternative concepts across sectors, disciplines, and between places. Alternative concepts include, for example, the concept of the triple bottom line (Elkington, 2013), the concept of planetary boundaries (Raworth, 2012), or the concept of social-ecological justice (Grossmann et al., 2022). These alternative concepts vary in their dimensionality, their structural complexity, and their different propositions of what is considered important in human development (Kothari, 2009). This means they differ in terms of the number and choice of the developmental dimensions they address. The concepts, for instance, include environmental/ecological, social, cultural, or institutional dimensions. Additionally, sustainability concepts can have different objectives, such as ensuring the long-term survival of enterprises and corporations, promoting sustainable management of forests, or focusing on a just development that includes humans and non-humans. Furthermore, these concepts

propose different ways of achieving sustainability, such as sufficiency, education, efficiency, or governance (Connelly, 2007; Kates et al., 2005).

This non-exhaustive list exhibits the multitude of sustainability concepts. In this dissertation it is furthermore assumed that persons, and thus also students, develop individual conceptions of the idea of sustainability (see Figure 1 above). Based on Borg et al. (2014), sustainability conceptions are defined as students' individual representations of the idea of sustainability which is reflected, for instance, in how these students relate specific fundamental elements of the three dimensions mentioned above to the concept of sustainable development (*article#2*). These individual representations are likely dependent on the timing, situation, culture, and knowledge at the time of formation and elaboration. In cognitive psychology, a mental representation of a concept is understood as part of human beings' declarative memory (Margolis & Laurence, 2007). Mental representation describes an internal, subjective, individual depiction of an abstract idea. This representation is most likely influenced by theoretical and everyday concepts of that abstract idea. The way students conceive of an idea must be differentiated from the way they understand this idea[4] and from the way they perceive it.[5] Lastly, conceptions are seen as important antecedents for all learning, as students are expected to use prior knowledge structures to construct new knowledge (Simonsmeier et al., 2022; Thompson & Zamboanga, 2003; Tobias, 1994).

This dissertation explores changes and developments in students' sustainability conceptions using the concept of sustainable development based on the United Nations' definition as a reference point. The decision to use this concept is based on the fact that it is the paradigm used in international key agreements and declarations, for example, in Agenda 21 (UNCED, 1992), Agenda 2030 (UNO, 2015), or the Treaty on European Union (EU, 2020). Consequentially, the definition of what constitutes the idea of sustainability appears to be shared globally. Thus, in this dissertation, the concept of sustainable development is

[4] *Understanding* refers to knowing how something works (de Regt & Baumberger, 2019). Students who understand would not just remember a conception. Instead, they could use their understanding to make relevant inferences about a phenomenon or solve problems (de Regt & Baumberger, 2019; Wilkenfeld, 2013). Thus, students who understand the idea of sustainability, for example, can make sense of sustainability problems by using different perspectives based on their elaborated conceptions, can think about solutions that they have not encountered before, and can anticipate how changes in one part of the socio-ecological system will typically lead (or fail to lead) to changes in other parts.

[5] The term *perception* in a physiological perspective refers to the way a student interprets sensing of information, which means that the respective student becomes aware of something through the senses (Spielman et al., 2020). In the context of this dissertation, perception is used more broadly to describe how students evaluate an object, a situation, or an idea.

considered representing the widest-reaching agreement on how the idea of sustainability is conceived.

This dissertation focuses on the challenges of individual conceptualization of the abstract idea of sustainability in HESD. As previously explained, this research interest is based on the challenges posed by the vagueness, normativity, and contestedness of sustainability concepts for education practice. These characteristics are not unique to sustainability concepts. It is suggested that social science concepts are challenged by greater controversiality and normativity than natural science concepts due to the fact that differences in underlying philosophies of science of academic disciplines make it more difficult to achieve consensus on concepts such as democracy, freedom, or justice (Gallie, 1955; Lundholm & Davies, 2013). This assumption entails, for example, that learners' preconceptions might be challenged by conceptions in the classroom that contradict their own ethical stance. Another example could be that learners might be overwhelmed by the temporary nature of sustainability concepts which cannot offer them a fixed position. In contrast, researchers suggest that contestedness, normativity, and vagueness may also be advantageous for broad social inclusiveness (Brand, 1997; McKenzie et al., 2015).

Against the background of the challenges outlined above for educators, communicators, and learners, the main interest of this dissertation is to understand how individuals conceptualize the abstract idea of sustainability and how this is affected by educational approaches, as well as how the approaches, in turn, affect students' engagement with sustainability issues.

2.2 Learning for Conceptual Change in HESD

2.2.1 Higher Education for Sustainable Development

HESD[6] is one of the strategies promoted by international policies and organizations to support the transformation of our society towards more sustainability (Kohl et al., 2021; Wu & Shen, 2016). In the global policy arena, HESD is defined as educational endeavors where individuals gain the expertise and competencies necessary to advance a sustainable

[6] There is a continuous discussion within the research community regarding the utilization of the term *education for sustainable development*. Numerous different other terms such as environmental and sustainability education or sustainability education are used, all shaped by different perspectives, and foci. In this dissertation Van Poeck and Vandenabeele's (2014) reasoning to use the term ESD as it seems to have caught on internationally and has achieved the widest dissemination in policy discourse has been followed.

development of society (UNO, 2015). In contrast, HESD scholars call it more radically an educational vision that requires fundamental changes to the current educational paradigms (Lotz-Sisitka et al., 2015; Wals, 2011).

The SD in HESD refers to the core purpose of sustainability science (Figure 2). Sustainability science is about understanding the relationships between human societal development and the natural environment and how to move the development forward in a sustainable manner (W. C. Clark & Dickson, 2003; Jerneck et al., 2011; Komiyama & Takeuchi, 2006). From the perspective of sustainability science, learning is seen as a way to shape the relationship between humans and their environment sustainably (Barth & Michelsen, 2013; Kates et al., 2001; Sterling et al., 2016; Stoltenberg & Burandt, 2014). Thus, sustainability science defines, informs, and identifies the content and learning objectives of what should be addressed by educational approaches to enhance sustainability (Mochizuki & Yarime, 2016).

The HE in HESD refers to the background of the research field in educational theory and practice (Figure 2). In general, educational science can be understood as being concerned with how people learn and how learning situations can be designed (Schreiber & Cramer, 2023). HESD is consequently ESD in the context of higher education. In this dissertation, higher education refers to all educational processes that are anchored and shaped at universities and universities of applied sciences (Brennan & Teichler, 2008). These processes include forms of optional higher education where bachelor's, master's, and doctoral degrees are obtained (UIS, 2015). According to Wright (2004), universities are important for sustainability due to their public service mission. Universities are seen as having a responsibility to prepare students in the best possible way for their lives as having a responsibility towards society by which they are often funded. Accordingly, universities are asked to orient their research and outreach activities toward the questions brought to them by society, such as solving sustainability challenges (Compagnucci & Spigarelli, 2020). These sustainability-related learning objectives align with the general learning objectives in HEIs in Germany which encompass not only subject-related education but also personal development (e.g., reflective and problem-solving skills), and the creation of employability (KMK, 2017).

Figure 2. *HESD as a field of research and practice at the interface of educational sciences and sustainability science.*

The above-mentioned general objectives of HEIs are discussed intensively in research and practice in higher education, specifically in the field of HESD (Elsholz, 2019). Researchers, including the author of this dissertation, argue that HESD should meet two general learning objectives (Michelsen & Fischer, 2016; Singer-Brodowski, 2016b; Sterling, 2010; Vare & Scott, 2007). The first objective takes on the need for individual and societal change, which includes changing personal actions (ESD-1). The second objective takes on the need for critical-emancipatory examination of the values and normative foundations of sustainability, with the self-determination of the learner as the central focus (ESD-2). This unifying complementary perspective tries to combine the best of two modes of education, instrumental and emancipatory, and thereby to address their weaknesses. Still, the extent to which the scientific-theoretical foundations of the two modes – in ESD-1 rather a positivist and in ESD-2 rather a constructivist epistemology – can be reconciled, has not been conclusively clarified (Sterling, 2010).

To sum up, HESD is understood as a field of research and practice that deals with approaches and activities that, on the one hand, have a critical-emancipatory educational impact on learners (educational impact) and, on the other hand, promote change in the sense of the idea

of sustainability (sustainability impact) (Barth & Michelsen, 2013; Rieß et al., 2018). Thus, the political initiative has given rise to a domain of practical implementation and scholarly research, with the overarching aim of fundamentally reorienting education, including higher education, toward the pursuit of sustainability (Wals et al., 2016).

2.2.2 Students' Sustainability Conceptions as a Learning Outcome

Learning in this dissertation is understood "as any process that in living organisms leads to permanent capacity change and which is not solely due to biological maturation or aging" (Illeris, 2007, p. 3). In this sense, the term learning encompasses intentional and unintentional processes, and it does not imply anything about the quality of the learning outcomes. For the purposes of this dissertation, this broad understanding of learning is particularly helpful since it allows statements about the nature and dimensions of learning as well as about the internal and external conditions. Furthermore, it is relatable to the theoretical embedding of the teaching-learning approaches in HESD.

Illeris (2018) argues that learning is related to various internal (e.g., age, personal values, beliefs) and external learning conditions (e.g., learning environment, society, objective learning situation), which are also affected by the learning process itself. The author additionally suggests that two fundamental interaction processes are at work in learning: on the one hand, an interaction process between the individual learner and the environment, but also an internal process of deep processing and appropriation (Figure 3). Both processes are described as integrated and acting together. Finally, Illeris relates learning objectives (e.g., knowledge, attitudes, skills), the learning incentives (e.g., emotion, volition, motivation, etc.), and the learning environment (e.g., action, communication, cooperation) to illustrate three dimensions involved in any learning process. These three dimensions thus determine the learning outcome.

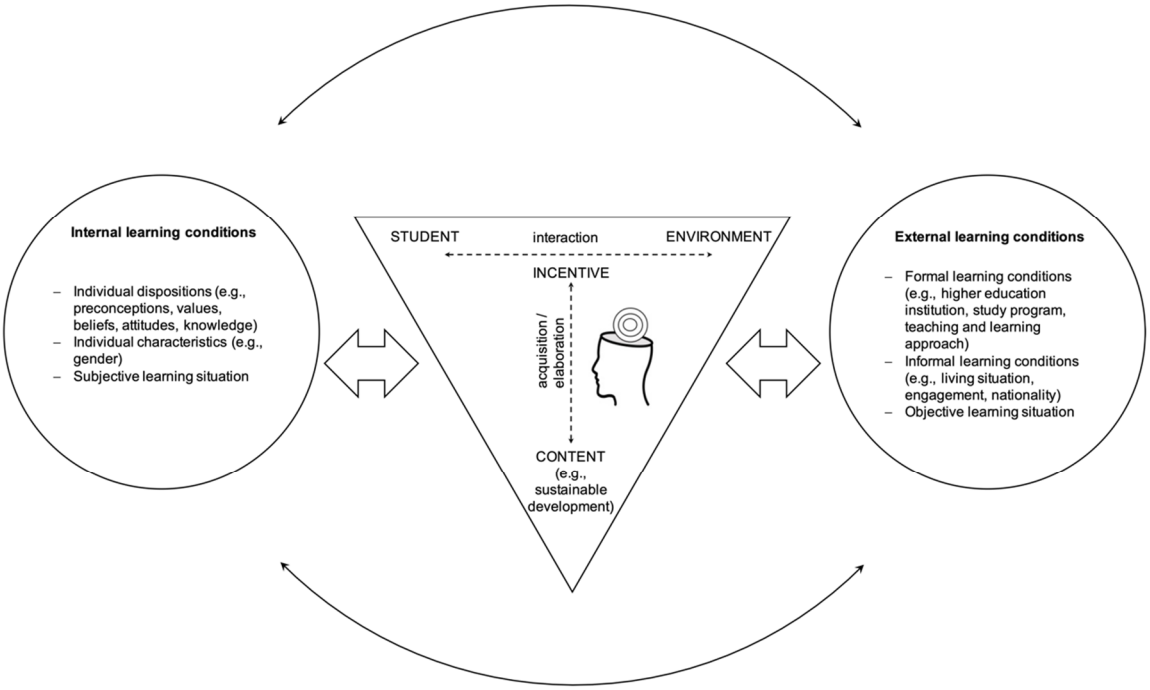

Figure 3. *Essential processes of learning.*

Adapted from "A Comprehensive Understanding of Human Learning", by K. Illeris, in K. Illeris (Ed.), *Contemporary Theories of Learning: Learning Theorists…In Their Own Words* (1ed, p. 4), 2018, Routledge. Copyright 2018 by Informa UK Limited, trading as Taylor & Taylor & Francis Group. Adapted with permission.

The term learning outcome generally describes what learners know or can do at the end of a learning process (Barth, 2015). In higher education, the term encompasses the full range of subject-related, individual, and also cross-disciplinary academic learning outcomes (Allan, 1996). The concept is grounded in constructivist learning theories which imply that learners construct individual mental representations of their reality as they learn. Therefore, a learning outcome is always a result of a student's individual learning process within the three dimensions of learning determined by the internal and external learning conditions. This dissertation investigates change and development in students' sustainability conceptions with an explanatory perspective, and thus explores both internal and external learning conditions.

Against the background of controversies around the idea of sustainability and the different modes of HESD outlined in previous sections, it is not surprising that neither researchers nor practitioners have reached a consensus on a final set of learning outcomes for HESD (Barth, 2015; Kagawa, 2007). However, in recent years, HESD scholars have strongly promoted sets of complex learning outcomes referred to as sustainability competencies (Barth et al., 2007; Brundiers et al., 2021; de Haan, 2008; Wiek, Withycombe Keeler, & Redman, 2011). The focus emerged to define learning outcomes that are of overarching importance for an individually successful life (ESD-2) as well as for a sustainable development of society as a whole (ESD-1) (see also Barth & Fischer, 2012). According to Weinert (2001, p. 45) competencies are characterized by five main features:

- focus on the individual and their self-directed learning processes,
- consist of interdependent dispositions such as knowledge and attitudes,
- manifest in situations
- gradually develop over lifetime
- usage is context dependent

Competencies encompass more than just one's knowledge and skills. They enable learners to do meaningful and successful actions in complex situations (Erpenbeck & von Rosenstiehl, 2007). Competent learners are able to analyze problems, develop solutions and reflect on the consequences of these solutions through knowledge and skills influenced by their values, attitudes, and motivational dispositions (Brundiers et al., 2021).

A broad consensus on a competency framework for sustainability has not yet been reached (Brundiers et al., 2021). Despite the ongoing debate, Wiek et al.'s (2011) comprehensive competency framework is recognized as one of the "most influential" contributions to HESD (Grosseck et al., 2019, p. 26). The *framework of key competencies for sustainability* comprises of five interrelated clusters of knowledge and skills presented in Table 1. These competencies are suggested to contribute to sustainability-related problem-solving[7] (Wiek, Withycombe Keeler, & Redman, 2011).

[7] Rychen and Salganik (2003) argued that some competencies can be considered more fundamental than others because they are cross-cutting and relevant to all individuals for solving problems in a particular field or domain. These competencies are referred to as *key competencies*.

Table 1. K*ey competencies in sustainability based on Wiek, Withycombe Keeler, and Redman (2011) and Wiek et al. (2016).*

Competency	Description
Systems thinking competency	"ability to collectively analyze complex systems across different domains (society, environment, economy, etc.) and across different scales (local to global), thereby considering cascading effects, inertia, feedback loops and other systemic features related to sustainability issues and sustainability problem-solving frameworks" (Wiek et al. 2011, p. 207)
Anticipatory/ futures thinking competency	"ability to collectively analyze, evaluate, and craft rich "pictures" of the future related to sustainability issues and sustainability problem-solving frameworks" (Wiek et al. 2011, pp. 208–209)
Normative/values -thinking competency	"ability to collectively map, specify, apply, reconcile, and negotiate sustainability values, principles, goals, and targets" (Wiek et al. 2011, p. 209)
Strategic-thinking competency	"ability to collectively design and implement interventions, transitions, and transformative governance strategies toward sustainability" (Wiek et al. 2011, p. 210)
Interpersonal/ collaborative competency	"ability to motivate, enable, and facilitate collaborative and participatory sustainability research and problem solving" (Wiek et al. 2011, p. 211)
Integrated problem-solving competency	ability "to apply different problem-solving frameworks to complex sustainability problems and develop viable solution options" to "meaningfully integrate problem analysis, sustainability assessment, visioning and strategy building" (Wiek et al. 2016, p. 251) This is a "meta-competency of meaningfully using and integrating the five key competencies for solving sustainability problems and fostering sustainable development" (Wiek et al. 2016, p. 243).

There is some criticism associated with competence-based education in HESD. This type of education is criticized for reducing universities to functions that are quantifiable (Biesta, 2009). Competency-based education is thus seen as reducing universities to places of training instead of places of critical reflection and knowledge production (Singer-Brodowski, 2016a). However, despite this criticism, the framework of key competencies in sustainability seems particularly useful as it offers an orientation for integrating the so far more subject-didactic oriented research on students' sustainability conceptions into the current competency-based research on learning outcomes in HESD. In consequence, students' sustainability conceptions and understanding of sustainability are suggested as a sub-facet of normative/values-thinking competency (Figure 4).

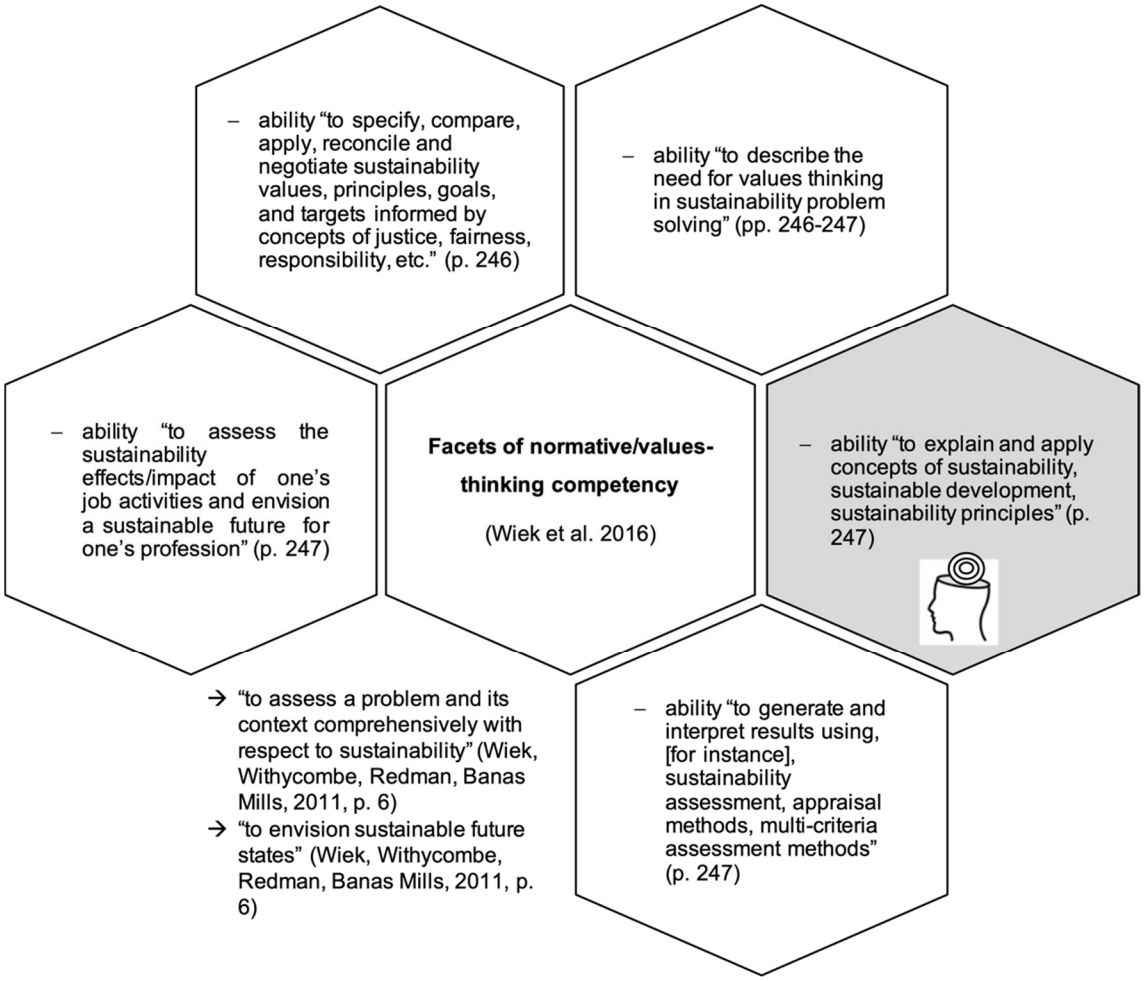

Figure 4. *Students' sustainability conceptions as part of normative/values-thinking competency.*

The framework proposes that normative/values-thinking competent students are able to comprehend, utilize, and negotiate certain core principles as related to the dimensions of a sustainable development (Brundiers et al., 2021; Wiek, Withycombe Keeler, & Redman, 2011). Thus, sustainability conceptions may, for example, work as filters in decision-making and problem-solving processes that select and adapt new information (Gouveia & Valadares, 2004). Framing sustainability conceptions as a sub-facet of normative/values-thinking competency highlights the fact that sustainability is not just a technical or scientific idea, but also an idea with normative and ethical dimensions. Furthermore, this framing emphasizes the importance of sustainability conceptions for learners as they need elaborated conceptions as an essential component for decision-making and in general as active citizens (Mansbridge, 2014; Sinatra et al., 2014; Wiek, Withycombe Keeler, Redman, et al., 2011).

2.2.3 Conceptual Change in HESD

As outlined in the previous sections, sustainability conceptions are an important prerequisite for active participation in democracy and therefore considered a key facet of normative/values-thinking competency. These conceptions, however, may change due to, for example, paradigm changes in the underlying abstract ideas or due to new learning experiences. Based on constructivist theory, conceptual change is conceived as a form of learning where naïve, conflicting, or misconceived (pre)conceptions are changed to conceptions that align with the scientific consensus (Chi et al., 1994; Heddy et al., 2018; Vosniadou, 2012). Today it is generally assumed that changes in conceptions are subject to gradual and step-by-step processes (Havu-Nuutinen, 2005; Vosniadou, 2013). Step-by-step means that individual experience-based assumptions that conflict with new experiences or instructions are gradually replaced by scientifically accepted assumptions. Furthermore, contemporary theories of conceptual change based on contemporary learning theories seem to agree on the importance of affective internal conditions as well as socio-cultural conditions in conceptual change (Heddy et al., 2018; Heddy & Sinatra, 2013; Mason, 2007; Sinatra, 2005; Sinatra & Mason, 2013).

The term conception in this dissertation is underpinned by four assumptions from conceptual change theory: (1) Students do not start as blank slates in HEIs. Already as children, they start to form conceptions about everyday experiences with sustainability, so-called preconceptions of sustainability. Thus, preconceptions are seen as starting points for conceptual change and must be considered when teaching and learning approaches are designed and concepts of sustainability are introduced. (2) Knowledge is individually constructed. Individual conceptions of abstract ideas are understood as hypothetical and tentative, meaning they can be changed in the light of new knowledge. (3) Conceptions must prove helpful to the individual. Only those conceptions that prove useful in communication with others endure. (4) Although conceptions are individually constructed, they are constructed in a certain socio-cultural context (Duit, 2015, 2016).

To date, change in conceptions in the social sciences has received little attention in conceptual change research. One reason for this blind spot is that this strand of research stands in the tradition of (natural) sciences such as physics or mathematics and related domain-specific pedagogies (Potvin et al., 2020; Vosniadou, 2020). Differences in

conceptual change processes between natural and social science concepts are suggested to be determined by ontological and epistemological differences between the natural and social sciences (Berti, 1994; Carey & Spelke, 1994; Vosniadou, 2007). When, for example, various accepted theories exist, it might be a challenge for learners to distinguish between *scientifically accepted* and *alternative* concepts (Lundholm & Davies, 2013). Another challenging characteristic of social science concepts for learners could be the existence of well-known everyday meanings which might add to the formation of naïve preconceptions (Ekström & Lundholm, 2018). Moreover, social sciences concepts often only become more relevant when learners have progressed in their education. Conceptual change research, however, rarely considers adult professionalization processes (Markauskaite, 2020) or changes in conceptions in the context of lifelong learning (Boshuizen et al., 2020). Thus, processes of change and development in specific domains of social sciences cannot be considered sufficiently understood.

Integrating sustainability into HEIs poses a challenge for learners who are expected to make sense of concepts that are at once complex and abstract, and hold controversial and uncomfortable socio-ecological implications for numerous, diverse actors. So far, these challenges in HESD have been widely neglected by conceptual change research (Lundholm & Davies, 2013). Lundholm and Davies (2013) made three key observations regarding conceptual change research in HESD: First, most research on conceptual change in HESD concentrates on the understanding of collective terms such as environment or sustainability. Second, drawing conclusions from the results is difficult because research methods are too diverse. Third, the research does not integrate theories of learning from psychology or education in general, nor theories of conceptual change in particular. However, understanding how students develop sustainability conceptions and modify existing sustainability-related preconceptions could help lecturers design effective teaching and learning approaches that enable the acquisition of normative/values-thinking competency. In summary, understanding how individual sustainability conceptions change and develop is important for developing HESD practice and theory, from improving educational practices to fostering personal growth and societal progress.

2.2.4 Enabling Conceptual Change and Learning in HESD

To date, there has not been agreement on how to effectively address sustainability conceptions in HESD. Scholars, researchers, and practitioners debate and differ not only on the character of curricula, study programs, or teaching and learning approaches, but also on the depth of sustainability integration into whole institutional structures (i.e., *bolt-on* versus *build-in* approaches) (Sterling, 2010).

Integration of sustainability in HEIs can be established on the macro-level of study programs, the meso-level of modules and the micro-level of courses (Figure 5).

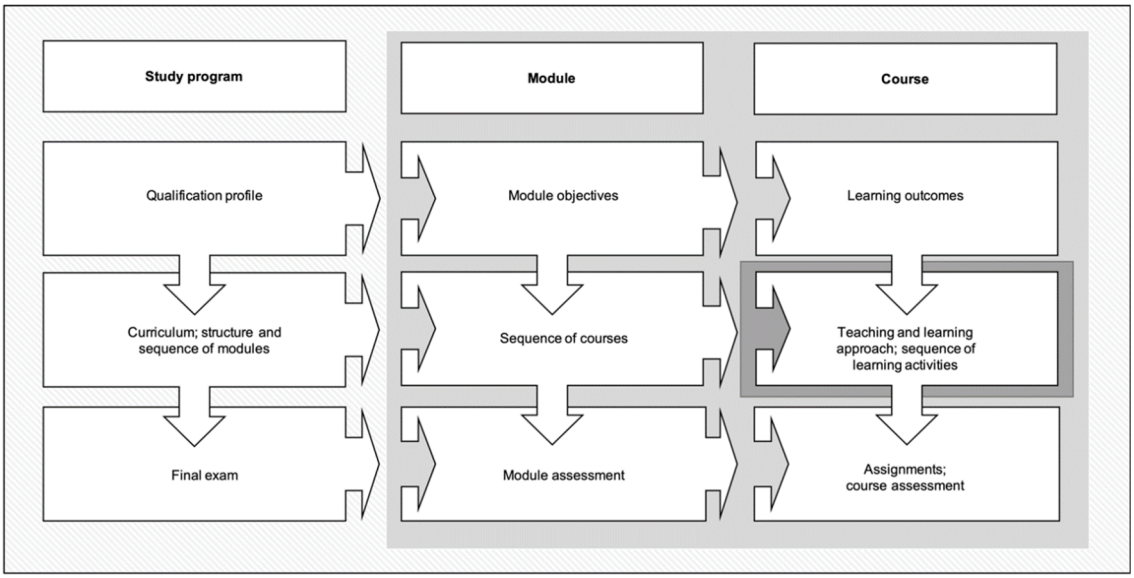

Figure 5. *Approaches to sustainability integration and alignment at all levels and components of a program.*

Adapted from "Transdisciplinary Learning for Sustainable Development–Sharing Experience in Course and Curriculum Design" (p. 8), by K. Herweg, T. Tribelhorn, A. L. Lewis, I. Providoli, L. J. Trechsel, and C. Steinböck, 2021, University of Bern (CDE) (https://boris.unibe.ch/id/eprint/157343). CC-BY-NC.

In general, coherence and alignment between educational offers across all levels of study programs is assumed to support learning most effectively (Biggs, 1996; Biggs & Tang, 2015; Drake & Burns, 2004; Drake & Reid, 2018; Lozano et al., 2022; Shiel et al., 2020). Alignment means that core elements such as learning outcomes, teaching and learning approaches, and the type of assessment are harmonized (Biggs, 1996). In a superficial type of integration, sustainability is, for instance, integrated in a stand-alone course via sustainability-related learning activities (bolt-on; in Figure 5 in dark grey). A deeper

integration of sustainability can be achieved, for example, when sustainability-related learning objectives on the module level are aligned with all course offers and assessment elements in this respective module (build-in; in Figure 5 in light grey). The most intensive form of integration can be achieved when sustainability is used as a guiding principle in the development of entire study programs or whole institutions. In a so-called *whole institution approach,* sustainability is integrated beyond teaching and learning, for example, in campus development, administration, and all outreach activities of the institution (Kohl et al., 2021). Based on contemporary learning theories, it is assumed that changes in students' learning outcomes are potentially related to all these (sustainability-related) external learning offers throughout a study program (Illeris, 2018).

In addition to the before mentioned *formal* sustainability-related learning offers on the macro-, meso- and micro-level of study programs, some researchers argue that *informal* learning experiences are important for students' individual sustainability-related learning (Barth et al., 2012; Gramatakos & Lavau, 2019; Hopkinson et al., 2008). In the context of this dissertation, informal learning experiences are understood as learning experiences unrelated to credits, assessment, and lecturers, with a voluntary and student-driven characteristic (Hopkinson et al., 2008). Informal experiences can occur in a wide range of situations, such as work experiences, internships, or student-led leisure time activities. In fact, all daily-life experiences are potential informal learning experiences related to sustainability (Gramatakos & Lavau, 2019). A few empirical studies imply that informal learning experiences are relevant for sustainability competency acquisition because they offer diverse contexts and situations that facilitate the learning process and are potentially effective in motivating non-sustainability affine students (Barth, 2015; Gramatakos & Lavau, 2019; Lipscombe, 2008a; Singer-Brodowski, 2023).

Evidence on the before described learning offers being related to students' sustainability-related learning outcomes is mixed (e.g., Barth & Rieckmann, 2016; Lozano et al., 2017; Weiß & Barth, 2019). On the micro-level, for instance, short-term positive effects of specific teaching and learning approaches with sustainability-related learning outcomes are observed (Birdman, Barth, et al., 2022; Birdman, Redman, et al., 2020; Birdman, Wiek, et al., 2022; Brandt et al., 2019, 2021, 2022; Konrad et al., 2020, 2021a, 2021b). Only a few studies investigate long-term change on the macro-level of study programs. An Australian study, for example, focused on the effects of curriculum change on business students'

sustainability-related learning outcomes (Hay et al., 2019). This longitudinal study indicates that integrating sustainability in the curriculum was effective in terms of changes in some sustainability-related learning outcomes. However, the results showed that not all intended changes, for example, whether students perceived sustainability as relevant, could be achieved. Additionally, Shephard et al. (2015) investigated long-term changes in the pro-environmental attitudes of students with different subject affiliations. The study did not find changes in pro-environmental attitudes over time. It did find that students' subject affiliation was related to the degree of their pro-environmental attitudes, without, however, specifically examining the integration of sustainability into these subjects.

The literature review on students' sustainability conceptions found mixed results regarding the relationship between teaching and learning approaches and changes in students' sustainability conceptions (*article#2,* Appendix B). Some studies could be identified that report relationships between students' sustainability conceptions and internal and external conditions beyond teaching and learning approaches. Demographic characteristics such as gender, subject affiliation, or awareness of students' knowledge level are often among the internal learning conditions studied.

These findings illustrate the recognition towards evaluating sustainability integration and sustainability-related learning in HESD. Furthermore, the studies indicate that change in students' sustainability conceptions over time is likely. To understand the underlying learning processes in relation to the learning offers, internal and external learning conditions on the meso- and macro-level of study programs should be investigated. Thus, there is still a need to understand how external formal and informal (sustainability-related) learning conditions relate to changes in students' sustainability conceptions.

2.2.5 Measuring Conceptual Change in HESD

A growing number of studies is concerned with operationalizing and measuring students' learning outcomes and competencies in HESD (Cebrián & Hernández, 2019; Kuehl et al., 2023; Redman et al., 2021). In general, defining and operationalizing learning outcomes is seen as contributing to the theoretical development of HESD research and the quality assurance of HESD teaching and learning activities.

Operationalization means making an individual characteristic that is not directly observable, such as a learning outcome, measurable and thus observable (Bühner, 2011). This requires translating the characteristics of a construct into scale contents and suitable response formats in relation to the theoretical perspective (Renner et al., 2012). An essential prerequisite of operationalization is an excellent theoretical foundation and definition of the behavior or characteristic. In this dissertation, measurement is understood in the sense of assessment *of* learning, which includes all methods that can be used to systematically collect evidence of student learning, including conceptual change, in contrast to more formative and student-centered types such as assessment *for* or *as* learning (Earl, 2013).

To better understand learning processes in the context of HESD, it is essential to consider the temporality of these processes in measurement and study designs (Siegler & Svetina, 2013). This can be done from two different perspectives. First, one can monitor the difference in students' conceptions from time a to time b (change); and, secondly, one can look at how students' conceptions develop from time a to time b (development). For example, in the context of a longitudinal study, Shephard (2016) captures learning as change and views the learning outcome as "changes in personal characteristics" (p. 261). In this sense, change is the quantifiable product of the learning processes (Lachman, 1997). Consequently, the term *learning outcome* is used in this study to describe the difference in students' conceptions from time a to b. In contrast, the term *learning processes* describes the long-term development as a sequence of learning experiences that extends over a certain period of time (i.e., a three-year undergraduate program) and gradually influences individual learning outcomes. These changes and developments are assumed to be related to both internal learning conditions as well as formal and informal external learning conditions (Zelezny, 1999). At the same time, Shephard (2016) points out that there are particular challenges in longitudinally monitoring change in learning outcomes in HESD: First, changes are dynamic entities whose analysis can require considerable effort. Second, participation in longitudinal surveys is subject to unpredictability. Third, it may be difficult to attribute changes to one course or the study program or teaching method because there may be many confounding internal and external learning conditions related to change in the learning outcome. Further, it has been suggested to measure single learning outcomes or facets of competencies in the absence of comprehensive options to operationalize sustainability competencies (Mulder, 2014; Shephard, 2016).

Article#2 revealed that most current studies on students' sustainability conceptions aim to describe differences in sustainability conceptions among different groups of students. Consistent with this aim, the studies use descriptive case study designs (Appendix B; *article#2*). Exceptions are studies that aim to analyze relationships between teaching and learning approaches and students' sustainability conceptions (Hales & Jennings, 2017; Jollands & Parthasarathy, 2013; Pruett & Weigel, 2020; Segalàs et al., 2010; Sherman & Burns, 2015; Watson & Barrella, 2017). These studies tend to use pre-post or action research designs to explore the relation between teaching-learning approaches and students' sustainability conceptions. In order to reach these goals, questionnaires with open-ended and/or closed-ended questions are employed. With regard to data analysis, most often content analysis, or descriptive analysis of questionnaire data are used. The exceptions are studies where phenomenographic approaches (Kilinc & Aydin, 2013), discourse analysis (Hales & Jennings, 2017), grounded theory approach (Sherman & Burns, 2015), or structural equation modeling (Pestana & Parreira, 2016) are applied. Overall, the literature review reinforces the notion that current operationalization and measurement approaches devoted little systematic attention to capturing how students' sustainability conceptions change in relation to studying.

2.3 Research Gaps and Research Questions

Following from the theoretical background laid out in the preceding sections, this section is dedicated to the four research gaps which this dissertation attempts to tackle.

Gap 1: HESD is seen as an important strategy to increase the likelihood of sustainable societal development. Implementing sustainability into higher education means pursuing two goals simultaneously: achieving an impact towards a change for sustainability as well as fostering competencies in learners that enable them to act in a self-determined way. However, one challenge in dealing with the idea of sustainability in higher education is the contestedness of the idea of sustainability itself (see section 2.1). From the learners' and lecturers' point of view, the ambiguity and contestedness of the idea of sustainability poses a challenge in sustainability-related learning. A baseline for understanding learning processes such as change and development in sustainability conceptions is to define the learning outcome

thoroughly (see section 2.2.2). Up to now, sustainability conceptions as learning outcomes have been understood disparately and have been defined little or not at all. Thus, it remains unclear how students' sustainability conceptions are understood in the field of HESD. This makes it difficult to integrate research findings from the field of conceptual change and to further develop teaching-learning approaches in HESD (see section 2.2.4). To contribute to closing this research gap, there is a need for a systematic overview of research on students' sustainability conceptions in HESD, a systematization and synthesis of terminology, and an integrative definition distinct from related terms such as perceptions and understanding.

Gap 2: In the context of HESD, there seems to be broad agreement on the need to identify whether sustainability-related learning offers meet the sustainability-related learning objectives. The review of the literature has revealed that prior research concerned with students' sustainability conceptions pursued descriptive objectives by employing qualitative methods (see 2.2.2). While qualitative studies provide in-depth, descriptive insights into students' thought processes and characteristics of sustainability conceptions, longitudinal research could help identifying patterns of change over time to provide evidence for the relationship between studying and learning outcomes. Thus, to deepen and complement the knowledge on change and development of students' sustainability conceptions, it is argued that valid instruments for measuring these conceptions are needed (see 2.2.5). Quantitative approaches to measurement would not only facilitate the evaluation of the effectiveness of current HESD approaches but also allow for comparison between HEIs. This information can thus guide curriculum development and inform the choice of teaching and learning approaches.

Gap 3: As claimed in section 2.2.4, a central idea of HESD teaching and learning approaches is that the aligned and integrated implementation of sustainability into learning objectives, teaching and learning approaches, and assessment is related to change and development in sustainability-related learning outcomes. Conceptual change theory presumes that conceptions develop gradually over time. This leads to the assumption that students' sustainability

conceptions change and develop over the course of study programs (see 2.2.3). Although much has been written about the benefits of integrating sustainability into university curricula and study programs, empirical evidence on even short-term change and development of students' sustainability conceptions in HESD is mixed (Ssossé et al., 2021). Thus, it is still unclear whether students' sustainability conceptions change over the course of study programs in HESD.

Gap 4: Theories of learning suggest that individual learning and conceptual change is related to manifold internal (e.g., characteristics of students, preconceptions) and external learning conditions (e.g., curricula design, overall assessment, institutional structure) (see section 2.2.2) Moreover, to better understand learning processes, it seems crucial to understand not only the objective learning situation but also how the students themselves make meaning of their subjective sustainability-related learning experiences (Mejeh et al., 2023). However, there have been no systematic approaches relating students' changes and developments in sustainability conceptions with internal and external learning conditions. Identifying nuances in learning processes is crucial for tailoring educational approaches to specific groups of students, addressing cultural nuances, and ensuring relevance and inclusivity in HESD.

In conclusion, this dissertation aims to (1) *define* the learning outcome sustainability conceptions, (2) develop an instrument to *measure* change in sustainability conceptions in order to better understand whether (3) students' sustainability conceptions *change* over the course of study, and (4a, 4b) identify which internal and external learning conditions are related to sustainability conceptions (*learning processes*). In consideration of these aims, the empirical work of this dissertation focuses on the following exploratory research question:

How does studying sustainability affect students' sustainability conceptions?

In order to manage the exploratory research question, four sub-questions were designed:

- RQ1: How can students' sustainability conceptions be conceptualized (definition)?
- RQ2: How can students' sustainability conceptions be measured (measurement)?
- RQ3: What changes occur in students' sustainability conceptions throughout their studies (changes)?
- RQ4: What internal (RQ4a) and external (RQ4b) learning conditions are related to students' sustainability conceptions (learning processes)?

The four sub-questions first serve to gain theoretical insights into students' learning processes in HESD within a particular teaching-learning context. Secondly, they allow for practical implications, which then contribute to the design of teaching-learning approaches with regard to addressing conceptual change in students' sustainability conceptions.

3 Research Design

This section presents at first the epistemological foundation that guided this research project. Then it describes the implications of this chosen foundation for the research design and selection of the research methods as well as their application.

3.1 Epistemological Foundation

Epistemologically, the dissertation is informed by pragmatist philosophy as a guiding school of thought. Pragmatist philosophy adopts a problem-solving perspective to address real-world challenges instead of reflecting on or explaining the status quo in the world (Caniglia et al., 2021). According to pragmatist ontology, reality can never be determined (Kaushik & Walsh, 2019). Individuals are assumed to construct their own reality within objective social conditions, such as living conditions or study programs (Morgan, 2014). Dewey (1923) proposes that humans gain knowledge about the world through experience and that only propositional truth is gained by this experience. Additionally, he proposes that certain worldviews and experiences are shared, which means that worldviews or conceptions can be both unique and, to a certain extent, socially shared (Morgan, 2014). Based on this view, it is suggested that sustainability concepts and conceptions are warranted beliefs (section 2.1), that there is not a true understanding of sustainability, and that individual conceptions of the idea of sustainability have socially shared aspects.

There are two core ideas of pragmatist epistemology that resonate well with research at the interface of sustainability and educational science: First, according to pragmatist epistemology, knowledge is a tool that needs to prove useful to solve real-world problems (Feilzer, 2010). This assumption that knowledge and theories need to be useful in practice resonates well with the research aim of this dissertation at the interface of sustainability science and educational sciences because both research fields are geared towards practice and solution-oriented knowledge (Biesta & Burbules, 2003; Jerneck et al., 2011; Merriam & Tisdell, 2015; Spangenberg, 2011). Second, pragmatism acknowledges the importance of reflexivity in inquiry processes (Elkjaer, 2018; Morgan, 2014). From the perspective of sustainability science research, the normative assumptions underlying the idea of sustainability need to be carefully reflected in inquiry processes (Caniglia et al., 2021; Miller et al., 2014; Nastar, 2023). From the angle of HESD research, a research attitude of reflexivity and transparency accommodates the critical voices of educational science

scholars, who fear that learners could become overwhelmed by normative concepts (Jickling & Spork, 1998; Sterling, 2010; Wals & Corcoran, 2006).

Taking a pragmatist epistemologist perspective has three main implications for the design of this dissertation: adopting reflexivity as the main research attitude, choosing an integrative understanding of learning, and using a mixed-methods research design. First, pragmatist philosophy's demand for transparency and reflexivity has determined the extent to which the research problem has been grounded in social realities, how extensively the underlying understandings have been explicated, and the comprehensiveness with which the limitations of the research design and methods are discussed. Additionally, the reflexive pragmatist attitude led to an openness towards emerging questions when interpreting data instead of being fixed on pre-defined research interests.

Second, pragmatist thought values the holistic understanding of social phenomena through knowledge integration and experimentation (Kivinen & Ristela, 2003). Based on this thought, a variety of sources based on different epistemological and ontological assumptions as well as practical knowledge can be used to find solutions to a real-world problem. This seems particularly relevant when seeking to understand the complexities of change in students' sustainability conceptions. Integrating established theories from educational sciences and psychology, such as the latest insights from learning theories and conceptual change research, is supposed to offer a comprehensive understanding of this complex topic. Therefore, an integrative understanding to learning has been adopted (Illeris, 2018).

Third, pragmatist epistemology suggests using the research methods that are most effective in solving the underlying research problem (Teddlie & Tashakkori, 2012). This call for appropriateness and usefulness is often associated with using mixed-methods (Creswell & Plano Clark, 2011; Onwuegbuzie, Johnson, et al., 2009; Onwuegbuzie & Leech, 2005). Mixed-methods research combines elements of qualitative and quantitative research approaches for – in this case – utility purposes, diversity of views, and to add context (Schoonenboom & Johnson, 2017). Against this background, this dissertation adapts a sequential and explanatory mixed-methods design as a means of "solving problems and answering questions that cannot be satisfactorily addressed using single methods or approaches" (Klein, 1990, p. 196). Consequently, the cumulative dissertation employs a mixed-methods approach incorporating classic test theory, online surveys, multilevel

modeling, and regression analysis. Additionally, qualitative data collection and analysis methods such as semi-structured narrative interviews, process analysis, and concept maps are utilized. This mixed-methods approach focuses on answering the research questions rather than adhering to a particular methodology. Thus, by following pragmatist philosophy, this comprehensive methodology offers a robust and nuanced design for the dissertation.

3.2 Research Context

Building on the epistemological foundation presented in the preceding section, this section briefly introduces the research context of the undergraduate program offered by Leuphana University Lüneburg. This research context has been chosen based on the argument that a real-world setting is particularly helpful in exploring complex phenomena. As discussed in the previous section, from a pragmatist standpoint, knowledge production is always influenced by social, cultural, and objective conditions. Therefore, by delving into the changes in students' sustainability conceptions within a real-world setting, it is hoped to gain a more comprehensive understanding of the intricate external learning conditions that may be involved in these learning processes.

This research context of the undergraduate program at Leuphana University presents itself as an example of a whole-institution approach (Kohl et al., 2021). Leuphana University is an HEI located in a mid-sized German city close to a metropolitan area. Twenty years ago, the university started to re-orient its organizational structure, study programs, teaching, campus development, and management towards the principles of sustainability (Adomssent et al., 2009). This orientation towards sustainability is, for instance, reflected in the humanistic, action-oriented, and sustainable action areas described in the university's mission statement as well as in dedicating a whole department to sustainability research. In fact, the institution is one of the few in the world where environmental and sustainability science can be studied from the bachelor's up to doctoral levels (Birdman, Barth, et al., 2020). Additionally, the sustainability integration approach extends beyond curricula offers and even beyond the campus (e.g., a variety of student initiatives, local entrepreneurial business partnerships and even a sustainable music festival). All studies in this project use data from Leuphana's study programs, with *article#2*, *chapter#3*, *article#4* using data from three cohorts of the undergraduate program and *article#1* using data from a master's program on entrepreneurship and marketing from the same university. For more detailed

information on the undergraduate program at Leuphana and the sustainability integration approach, see Michelsen (2013) and *article#4*.

3.3 Article Overview and Methodology

This section first describes how the three research articles and the chapter building this dissertation's main body of work contribute to the four sub-questions (Table 2). Next, there is an explanation of how the contributions align with the overall mixed-methods research design (Figure 6). The section ends by displaying each contribution's main design characteristics (Table 3).

Table 2. *Overview of articles, the chapter and their publication status.*

No.	Article and publication status
#1	Seidel, J., Sundermann, A., Brieger, S. A., Strathoff, P., Jacob, G. H., Antonio, T., & Utami, C. W. (2018). On how business students' personal values and sustainability conceptions impact their sustainability management orientation: Evidence from Germany, Indonesia and the USA. *Journal of Global Responsibility*, 9(4), 335–354. https://doi.org/10.1108/JGR-03-2018-0010
#2	Sundermann, A., & Fischer, D. (2019). How does sustainability become professionally relevant? Exploring the role of sustainability conceptions in first year students. *Sustainability (Switzerland*), 11(19), Article 5155. https://doi.org/10.3390/su11195155
#3	Sundermann, A. (2023). *Die Nachhaltigkeitskonzepte Studierender im Studienverlauf: Einsichten aus einer Längsschnittstudie* [Students' sustainability conceptions in the course of their studies: Insights from a longitudinal study]. In M. Barth, D. Fischer, & G. Michelsen (Eds.), *Bildung für nachhaltige Entwicklung in der Hochschule – Wege und Wirkungen am Beispiel der Leuphana Universität Lüneburg* (pp.137–153*).* Verlag Babara Budrich.
#4	Sundermann, A., Weiser, A., & Barth, M. (2022). Meaning-making in higher education for sustainable development: Undergraduates' long-term processes of experiencing and learning. *Environmental Education Research*, 28(11), 1616–1634. http://dx.doi.org/10.1080/13504622.2022.2069679

To address RQ1 (How can students' sustainability conceptions be conceptualized (*definition*)?), a systematic review of the literature on sustainability conceptions and understanding in HESD was necessary (Figure 6). A first version of the exploratory review was published in *article#2*, and an updated version is presented in Appendix B. The purpose of this review was to examine empirical studies regarding students' conceptions in HESD across four different aspects: (1) the terminology used, (2) the study design, (3) the character

of students' sustainability conceptions, and (4) identifying related learning conditions connected with the conceptions.

Key answers regarding RQ2 (How can students' sustainability conceptions be measured (*measurement*)?) were published in *article#2*. After reviewing the literature, the sustainability conceptions scale was developed, employing a classic test development approach. An initial version of the scale was used in *article#1*. The scale measures which sustainability dimensions students associate with the concept of sustainable development. This scale can be used to describe and visualize the shared aspects of individual change. Additionally, conceptual maps have been used in *article#4* to visualize students' sustainability conceptions. The conceptual maps were combined with content analysis to identify the structural and content complexity of students' sustainability conceptions in a selected sample (Appendix C).

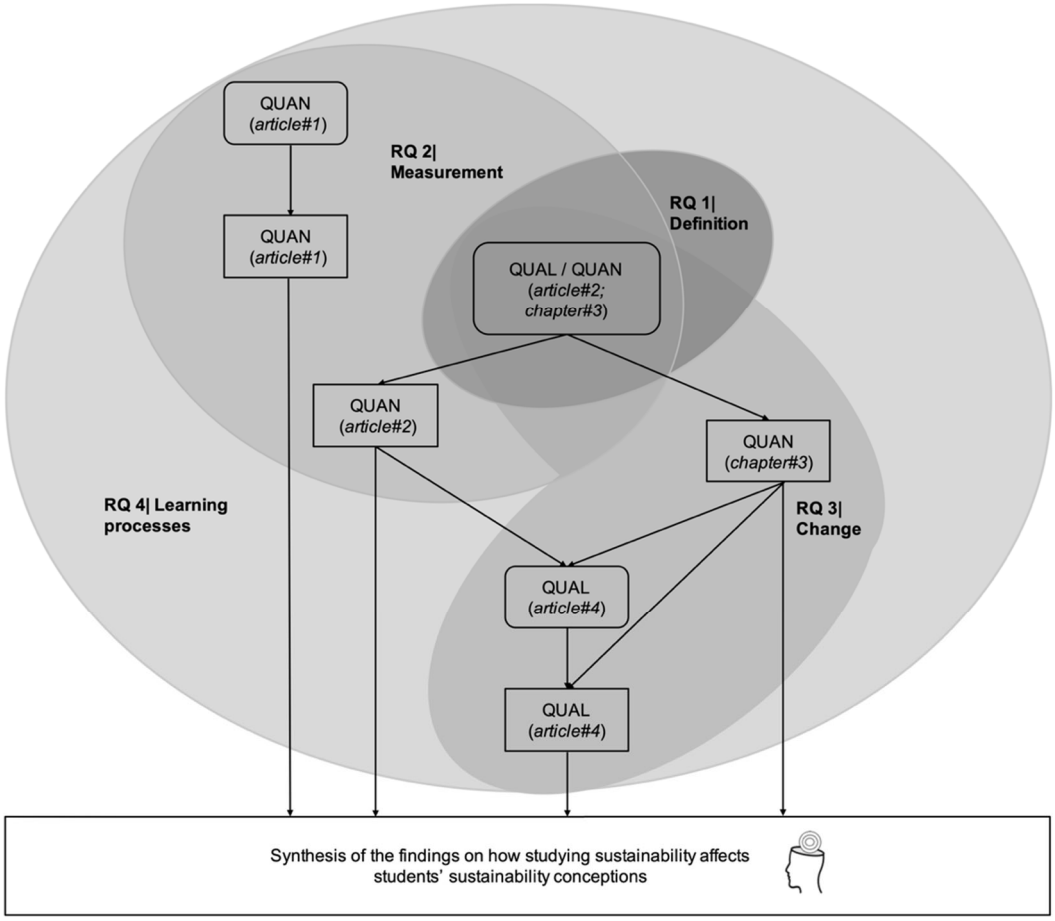

Figure 6. *Overview of the mixed-methods research design.*

Findings from *chapter#3* are the key contribution to RQ3 (What changes occur in students' sustainability conceptions throughout their studies (*changes*)?). This chapter utilized a logic that involved measuring preconceptions before the beginning of the undergraduate program, followed by a measurement after the first mandatory semester of studying sustainability for all undergraduate students. Two additional follow-up measurements were taken in the second and third years of the undergraduate program. This approach aligns with Barth's (2016) idea of study program evaluation in HESD, which involves "finding out where the students start", "tracking how it goes", and "checking how they got it" (p. 110). The data analysis method used was multilevel modeling, which allowed for describing change patterns.

All studies in this dissertation supply answers to RQ4, which involved examining the internal (RQ4a) and external learning conditions (RQ4b) that are related to students' sustainability conceptions (*learning processes*). *Article#1* used a paper and pencil questionnaire and mediation analysis to investigate the relationship between self-transcendence values, students' sustainability conceptions, and sustainability management orientation as internal learning conditions. Additional internal learning conditions were also controlled for, for example, political orientation, religiosity, life satisfaction, and personal characteristics such as gender and age. Similarly, *article#2* analyzed the relationship between students' perceived relevance of sustainability and their sustainability preconceptions, along with internal learning conditions like gender and age, and external learning conditions such as subject affiliation and prior formal and informal educational experiences. This study used questionnaire data from a longitudinal study in combination with logistic regression analysis. To analyze the change patterns in students' sustainability conceptions, multilevel linear modeling was used in *chapter#3*. These findings are complemented by *article#4* which collected subjective experiences of students in their final year of the same undergraduate program. In this article prior formal sustainability-related learning experiences as well as informal learning experiences have been identified as crucial for preventing loss of interest and are found to be related to differences in students' sustainability conceptions. Additionally, various internal learning conditions such as feelings of ambiguity, negative emotions, or individual interest are identified as important in different sustainability-related learning processes. This study utilized narrative interviews in combination with process analysis to analyze students' subjective experiences and to identify internal and external learning conditions involved in learning processes.

The purpose of the design choices in this dissertation was to obtain detailed and large-scale insights into how studying affects students' sustainability conceptions to improve the understanding of learning processes in HESD and contribute to the design of more effective HESD approaches. Based on this purpose and guided by pragmatist philosophy, the four empirical contributions of this dissertation are part of a sequential and explanatory mixed-methods design (Foscht et al., 2007). The qualitative data collection follows the longitudinal assessment of students' sustainability conceptions to retrospectively shed light on the students' subjective experiences during their undergraduate studies (Van Ness et al., 2011).

One of the critical quality criteria for mixed-methods studies is the value added by integrating different qualitative and quantitative research methods on the various levels of the research process (Fetters & Freshwater, 2015). Most importantly, the identification of internal and external learning conditions related to students' sustainability conceptions played a role in all empirical contributions (*article#1; article#2; chapter#3; article#4*). While the emphasis in this dissertation was the quantitative part on change and development of students' sustainability conceptions, the qualitative study served to elaborate on the learning processes (*article#4*). Finally, the qualitative research added students' perspectives of their learning experiences, which is a desideratum of the longitudinal study. On the data level, the qualitative interview guideline and the process analysis were informed by the results of *article#2* and *chapter#3*. In addition, the results from both contributions guided the generation of inductive categories in *article#4*. This sequential approach was particularly suited for identifying internal and external learning conditions, for example, by combining the fixed effects model, which included external learning conditions derived from the empirical literature, with the strengths of narrative interviews and process analysis. The latter mainly aims to trace individual experience patterns and thus seems suitable to explore the relationship between internal and external learning conditions and different sustainability-related learning processes. The synthesis of results within this framework paper then reintegrates the findings into the four main research objectives: definition, measurement, conceptual change, and internal and external learning conditions.

Thus, the mixed-methods design, based on pragmatist epistemology, is integrative in the following levels of the research process: first, the integration of research from the field of HESD and conceptual change research as well as knowledge from educational sciences and

psychology. Second, the design is integrative on the level of data collection by using the findings of *article#2* to inform the sampling of *article#4*. Third, in this framework paper, contributions to the four cross-sectional research questions based on the idea of constructive alignment are used to synthesize the contributions of the articles to the overall research questions of how studying sustainability affects students' sustainability conceptions. Consequentially, the focal points and methods in these aforementioned empirical contributions complement each other, and each article responds to one or several research questions (Table 3). Thus, following Creswell and Plano Clark (2011) this design "allows more than just collecting and analyzing both kinds of data. it also involves the use of both approaches in tandem so that the overall strength of a study is greater than either qualitative or quantitative research" (p. 5).

Table 3. *Characteristics of the empirical contributions.*

Characteristic	Article#1	Article#2	Chapter#3	Article#4
Title	On how business students' personal values and sustainability conceptions impact their sustainability management orientation: Evidence from Germany, Indonesia and the USA.	How does sustainability become professionally relevant? Exploring the role of sustainability conceptions in first year students.	Students' sustainability conceptions in the course of their studies: Insights from a longitudinal study	Meaning-making in higher education for sustainable development: Undergraduates' long-term processes of experiencing and learning
Article Research questions	– What role do business students' personal values and sustainability conceptions play in their preferences for sustainable management practices?	– What relevance do first year students ascribe to sustainability for their current and future professional career? – What is the nature of first year students' sustainability conceptions? – Which roles do sustainability conceptions play in comparison to socio-demographic and prior experience-related factors for first year students' perception of the professional relevance of sustainability?	– How do students' sustainability conceptions change in an undergraduate study program with multiple opportunities to engage with sustainable development over a three-year period?	– How do students make meaning from their formal and informal sustainability-related learning opportunities in a three-year undergraduate program? – Why do students consider sustainability-related learning experiences significant?

Table 3. *Characteristics of the empirical contributions.*

Characteristic	Article#1	Article#2	Chapter#3	Article#4
Design	Cross-sectional; multi-country study	Cross-sectional	Longitudinal; multi-cohort	Cross-sectional; temporarily oriented
Dissertation research questions (RQ)	RQ2; RQ4a, 4b	RQ1; RQ2; RQ4a, 4b	RQ3; RQ4a, 4b	RQ3; RQ4a, 4b
Data collection methods	Paper-pencil survey	Literature review; rationale scale development; online survey	Online survey	Narrative semi-structured interviews; conceptual maps

Table 3. *Characteristics of the empirical contributions.*

Characteristic	Article#1	Article#2	Chapter#3	Article#4
RQ1: Defining sustainability conceptions		– Identified four gaps in HESD research on students' sustainability conceptions Developed a definition for students' sustainability conceptions		
RQ2: Measuring sustainability conceptions	Cross-cultural validation of the preliminary version of the sustainability conceptions scales	Development and validation of the sustainability conceptions scale		
RQ3: Change in students' sustainability conceptions			– Decrease over time in associating the ecological and economic dimensions with sustainable development Identified strong intraindividual variations in students' sustainability conceptions	Showed individual differences in students' sustainability conceptions after three years of studying in the undergraduate program

Table 3. *Characteristics of the empirical contributions.*

Characteristic	Article#1	Article#2	Chapter#3	Article#4
RQ4: Internal and external learning conditions	– Sustainability conceptions mediate the relationship between self-transcendent values and sustainable management orientation – Sustainability conceptions are related to students' sustainability management orientation – Students' cultural background is related with their sustainability conceptions	– The socio-cultural dimension of sustainability preconceptions is significantly positively related to students' perceived professional relevance of sustainability – Ecological and economic dimension of students' sustainability preconceptions are not related to students' perceived professional relevance of sustainability	– Subject affiliation is significantly related to differences in dimensions of students' sustainability conceptions	– Describes three distinct learning processes related with differences in students' sustainability conceptions – Identified external learning condition (i.e., prior sustainability-related learning experiences participatory, active, and experiential teaching approaches; role of the lecturer) – internal learning conditions (i.e., emotions, personal interest; perceived relevance)
Implications for this dissertation	– Validates preliminary version of the scale from *article#1* with different sample	– Identifies further research needs – Provides scale for long-term monitoring of change in sustainability conceptions – Informs sampling and guides process analysis in *article#4*	– Informs sampling and guides process analysis in *article#4*	– Explores intraindividual differences in sustainability-related learning processes reported in *chapter#3*

4 Results

The following section contains the findings of this dissertation project, which have been disseminated through three research articles and a book chapter. All articles are presented as author post-print versions.

4.1 Article#1: On how business students' personal values and sustainability conceptions impact their sustainability management orientation: Evidence from Germany, Indonesia and the USA.

Author accepted manuscript

Seidel, J., Sundermann, A., Brieger, S. A., Strathoff, P., Jacob, G. H., Antonio, T., & Utami, C. W. (2018). On how business students' personal values and sustainability conceptions impact their sustainability management orientation: Evidence from Germany, Indonesia and the USA. *Journal of Global Responsibility*, 9(4), 335–354. https://doi.org/10.1108/JGR-03-2018-0010.

Abstract

Purpose – This paper aims to develop and empirically test a framework on how personal values and sustainability conceptions affect students' sustainability management orientation (SMO). An understanding of this connection gives insight into the question whether students are likely to engage in sustainable business practices in their future work.

Design/methodology/approach – A cross-sectional and comparative research design is used, using survey data of business students from Germany, Indonesia and the USA ($N = 475$). The proposed mediation models are tested by bootstrap procedures using Hayes's (2013) PROCESS macro for SPSS.

Findings – Self-transcendence values translate into more nuanced sustainability conceptions since individuals with self-transcendence values are more likely to conceptualize sustainability beyond their own (narrow) self-interests. In turn, the stronger individuals' sustainability conceptions, the higher the likelihood that they prefer sustainable management practices in their future professional working field.

Research limitations/implications – Implications arise for researchers to investigate the engagement of future managers with different personal value types in sustainability practices and to gain insights into values and sustainability conceptions as a learning outcome. Limitations of this research – for instance, arising from potential common method bias – are discussed.

Practical implications – The findings point to the need to (re-)design appointment processes for management positions in a way that allows taking into account individuals' personal values and sustainability conceptions. This research may also help firms and higher education institutions to empower their workforce/students to develop more integrated perspectives on sustainability challenges as well as teaching methods that address students' effective learning outcomes, e.g. their values.

Originality/value – The paper offers a new framework and a cross-country perspective on psychological antecedents of individuals' SMO as an important prerequisite for responsible behavior in the business context.

Keywords Sustainability, Personal values, Cross-country study, Management orientation, Sustainability conceptions

Paper type Research paper

1. Introduction

Responsible management seen from the perspective of sustainable development includes dealing with the well-being of humankind and the biosphere, from generation to generation and collaborative efforts across all sectors of society. Responsible management aims to achieve sustainable business by influencing its triple bottom line (Elkington, 1997). The idea of sustainability and especially its application to management is a way to manage responsibly between what has been described as the social foundations of human life and the ecological planetary boundaries to create a just and safe space for humanity (Rockström et al., 2009; Leach et al., 2013). Fuelled by the declaration of the UN Decade of Education for Sustainable Development (2005-2014) and the finalization of the Principles for Responsible Management Education (PRME) in 2007, a vivid debate among policy makers, business leaders and the academic community has evolved around the question of how individuals can be empowered to deal with the complex and interrelated phenomena associated with a transformation toward sustainability at local, national and global levels (see, for instance, PRME 10th Anniversary Special Issue in the *International Journal of Management Education*, edited by Parkes et al., 2017; see also Louw, 2015; Adomßent et al., 2014). Contributors to this debate widely agree that it is not enough to teach students about responsible management. Instead, it is important to enable them to master responsible management (McDonald, 2013).

Given the prominence of the concept of sustainability management, i.e. "the formulation, implementation, and evaluation of both environmental and socioeconomic sustainability-related decisions and actions" (Starik and Kanashiro, 2013, p. 12), in the current debate, there is surprisingly little research on sustainability management orientations (SMO) as a psychological antecedent of sustainable management practices. SMO is defined as individuals' inclination to direct their attention to management practices which allow the achievement of economic growth through "the demonstration of environmental integrity and social responsiveness" (Louche et al., 2010, p. 97). As sustainability is a highly normative lens to use when making management decisions (Beckmann and Pies, 2008), SMO can be assumed to be strongly influenced by psychological antecedents such as personal values (Alonso-Almeida et al., 2015; Crane and Matten, 2016). So far, only a few contributions in the field address the relationship between people's values and preferences of sustainability management (Shafer et al., 2007; Adams et al., 2011; Simmons et al., 2013; Lehnert et al., 2016). Moreover, recent research highlights a lack of conceptual frameworks linking various individual-level antecedents in different socio-cultural settings (Krambia-Kapardis and Zopiatis, 2008). In

consequence, Aguinis and Glavas (2012) called for more studies that examine chains of impact (mediation models) and conditions under which certain impacts unfold (moderation models).

This study seeks to respond to this call. It argues that two components – personal values and sustainability conceptions – are key to understand people's preferences for sustainability management better. This research suggests that an individual's sustainability conceptions play a mediating role in the relationship between personal values and SMO. More precisely, it is hypothesized that personal values affect the way how people understand and interpret the idea of sustainability. In turn, these individual sustainability conceptions impact a person's SMO. To ascertain the validity of the proposed model, this study uses a comparative research design, based on survey data from business students in three countries: Germany, Indonesia and the USA. Business students represent an important group to study as they are likely to be confronted with sustainability issues in their future professional roles in the business world, maybe even holding leading positions.

The remainder of this paper is structured as follows: Section 2 presents the framework identifying the relationships between personal values, sustainability conceptions and SMO. In this part of the article, the hypotheses are also introduced and grounded in the literature. Then, Section 3 reports data collection and analysis methods. The results of the empirical analysis are synthesized in Section 4. In the following discussion in Section 5, the theoretical implications for responsible management and practical implications for the selection and training of future leaders are explored. Having also pointed to limitations, the article ends with a short conclusion in Section 6.

2. Conceptual framework and hypotheses

The conceptual framework is built on three relationships that give insights into how personal values influence SMO, both directly and indirectly via sustainability conceptions:

- a values-orientation relation;
- a values-conceptions relation; and
- a conceptions-orientation relation.

2.1 The influence of personal values on sustainability management orientation

Organizational activities and sense-making with regard to sustainability are formed by the individual mental processes and behavior of the organization's workforce. Research finds evidence that personal values are the foundation of ethical attitudes, intentions and behavior (Fritzsche and Oz, 2007; O'Fallon and Butterfield, 2005).

The broad field of personal values has been structured in different ways (Parsons, 1956; Allport et al., 1960; Rokeach, 1973; Inglehart et al., 2004). One particularly coherent and wellreceived approach to measure values has been put forward by Bardi and Schwartz (2003). Schwartz and Bardi (2001, p. 269) define values as "desirable, trans-situational goals, varying in importance, that serve as guiding principles in people's lives." Their approach represents ten value types that are aggregated into two dimensions. This paper focuses on the dimension that is described by the two poles of *self-enhancement* and *self-transcendence* (Schwartz, 1994). The former encompasses the pursuit of self-interest, whereas the latter includes the welfare of society and nature.

The Schwartz classification has been applied in some studies in the business ethics discourse (Joyner and Payne, 2002; Hemingway and Maclagan, 2004; Vitell and Hidalgo, 2006; Fisher and Lovell, 2009). These studies suggest that values do not influence socially or environmentally oriented behavior in a direct manner. However, values have been found to influence beliefs, norms and orientations. Consequently, they influence behavior indirectly (Dietz et al., 2005). Although these studies do not explicitly discuss the relationship between values and SMO, their findings provide interesting insights into the relationship between personal values and responsible management behavior. For example, Wang and Juslin (2011, p. 251) observe that self-transcendence values, which they call altruistic values (universalism and benevolence values), "make a significant positive contribution to ethical decision-making and CSR. They are associated with higher levels of moral awareness." Kausch (2013) discovers that self-transcendent individuals have more favorable attitudes toward environmental corporate sustainability and less favorable attitudes toward economic corporate sustainability.

Synthesizing these empirical results, the existing research suggests a positive link between self-transcendence values and preferences for sustainability management practices among students. Therefore, this study suggests that students with values that transcend their self-interest show stronger SMO, leading us to the first hypothesis:

H1. Self-transcendence values are positively linked with SMO.

2.2 The mediating role of sustainability conceptions

In line with the notion that values are guiding principles about what individuals find desirable, they have been found to be involved in an individual's opinions and beliefs and give direction and priorities for certain interpretations and evaluations of reality (Beyer, 1981; Wright and Wright, 2000). Values extend or restrict an individual's cognition by shaping what they see as preferable end-states, thus determining the degree to which something is selectively,

holistically, or not understood (Russell, 2001; Campbell, 2007). Against this background, it is argued that individuals' personal values influence their sustainability conceptions.

Sustainability conceptions are defined as the degree to which individuals associate a particular set of economic, socio-cultural and ecological elements as integral parts of sustainability (cf. Borg et al., 2014). Following Borg et al. (2014), it is noted that individuals can link economic (e.g. efficiency, economic growth, technological performance), sociocultural (e.g. human rights, social security, justice between rich and poor) and ecological elements (e.g. green technologies, protecting ecosystems) with sustainability. Linnenluecke et al. (2009) find that organizational subcultures, in particular shared values and beliefs, had a significant influence on how employees understand and conceptualize sustainable management practices. Giddings et al. (2002, p. 188) remark that "the existing worldviews of people and organizations flow into their conception of sustainability".

Against this background, it is suggested that self-transcendence values shape the way individuals construct knowledge concerning sustainability and influence interpretations and evaluations of the idea of sustainability. More specifically, the degree to which individuals link economic, socio-cultural or ecological elements with sustainability should be grounded in self-transcendence values. Those individuals with self-transcendence values are expected to have broader sustainability conceptions, as the values these conceptions are built on explicitly transcend the maximization of individual utility emphasizing the welfare of society and nature.

In turn, it is assumed that individuals with broader sustainability conceptions will see the necessity to create value for various stakeholders connected to society and nature, like for instance government, (local) communities, the natural environment or suppliers and employees (Lydenberg et al., 2010). In other words, broader conceptions encompassing economic, sociocultural and ecological elements of sustainable development should make individuals more sensitive for the long-term economic (e.g. strengthening local and regional economic development), socio-cultural (e.g. fostering inter- and intragenerational justice) and environmental consequences (e.g. protecting the biodiversity of nature) of their strategies and actions (Burmeister and Eilks, 2013) and should facilitate a focus on good governance (e.g. ethical-moral business operations). Accordingly, the framework proposes a relation between sustainability conceptions and SMO. More specifically, it is hypothesized that sustainability conceptions take the role of amediator between self-transcendence values and SMO:

H2. Sustainability conceptions in terms of economic, socio-cultural and ecological components mediate the relationship between self-transcendence values and SMO.

2.3 Cross-country validation

To understand how values and SMO relate, this study uses a cross-country approach that captures between-country variances in the model components. This research examines the hypothesized relationships in Germany, Indonesia and the USA. Yau et al. (2007) point to the need for researching company's orientation towards stakeholders in non-Western settings. By including Indonesia, the study comprises an important non-western country (Oeyono et al., 2011) and addresses the need for more insights from these regions of the world. The three countries were chosen since previous studies found significant differences in terms of socio-economic development, values and civic entitlements between them (Hofstede, 2001).

All three countries are the trading block leaders in their respective regional trade organizations (EU, ASEAN, NAFTA; Table I). Germany and the USA are highly developed countries. High human development index (HDI) values indicate that their populations benefit from a long and healthy life, easy access to knowledge and a decent standard of living. By contrast, Indonesia showed a comparably modest HDI value and was positioned at rank 110 of 188 countries in 2014 (UNDP, 2015). In comparison to Indonesia, individuals from Germany and the USA have large ecological footprints. In consequence, results of the Happy Planet Index indicate that people from Germany and the USA use more environmental resources to achieve a long and happy life (Abdallah et al., 2012). More specifically, the Happy Planet Index measures how efficient countries are in using natural resources to achieve life expectancy, well-being and equal distribution of outcomes for their citizens. With regard to cultural value differences, Hofstede (2001) finds significant differences between Germany, Indonesia and the USA on his cultural dimensions. Table I provides a comprehensive overview of cultural values and socio-economic indicators of the three countries.

Table 1: Cross-country comparison.

	Hofstede's cultural dimensions					Trade organi-zation	HDI (2014)	HPI (2012)	EF (2012)
	IDV	PDI	MAS	UAI	LTO				
Germany	67	35	66	65	83	EU	0.916	29.8 (49^{th*})	5.3 (114^{th*})
Indonesia	14	78	46	48	62	ASEAN	0.684	35.7 (16^{th*})	1.6 (41^{st*})
United States	91	40	62	46	26	NAFTA	0.915	20.7 (108^{th*})	8.2 (137^{th*})

Note: IDV = Individualism versus Collectivism, PDI = Power Distance Index, MAS = Masculinity versus Femininity, UAI = Uncertainty Avoidance Index, LTO = Long-Term versus Short-Term Normative Orientation. HDI = Human Development Index. HPI = Happy Planet Index. EF = Ecological Footprint. * From a total of 140 countries.

Studying the chosen countries appears instructive because, being quite different on a number of relevant dimensions, they put the model to a tough check of external validity. This variation on cultural dimensions ultimately helps to increase representativeness (Seawright and Gerring, 2008). Despite the country differences, this paper suggests a stable pattern of the model relationships, as the mechanism we have introduced pertains to fundamental mental processes:

H3. The hypothesized model holds for Germany, Indonesia and the USA.

Figure 1 illustrates the conceptual framework. The bottom arrow represents the direct relation between self-transcendence values and SMO. The dashed line represents the mediation effect. In addition, Figure 1 also locates the hypotheses within the conceptual framework.

3. Methods

3.1 Sample and empirical setting

The paper-pencil questionnaire was administered to business students at a German, an Indonesian and a US-American university. The universities were selected based on, first, general institutional characteristics and, second, specific characteristics of the respective business programs. In terms of general institutional characteristics, the institutions' missions and values and the location of the business school campus were considered. The three schools, which were all based in medium-sized cities or townships at the outskirts of metropolitan areas, addressed sustainability issues in their mission statements, and they engaged in sustainability-

related external activities, for instance local and regional development through entrepreneurship education.

The business programs our sample was drawn from were similar regarding their focus, which was on management and entrepreneurship. All curricula included some courses on ethics, diversity or sustainable business. The German sample was drawn from (early-stage) master-level students, and the samples from Indonesia and the USA consisted of undergraduate students. To sum up, three universities and business programs with similarities regarding their mission, location and study contents were selected. Culturally, very different countries were chosen to rigorously test the validity of the proposed framework.

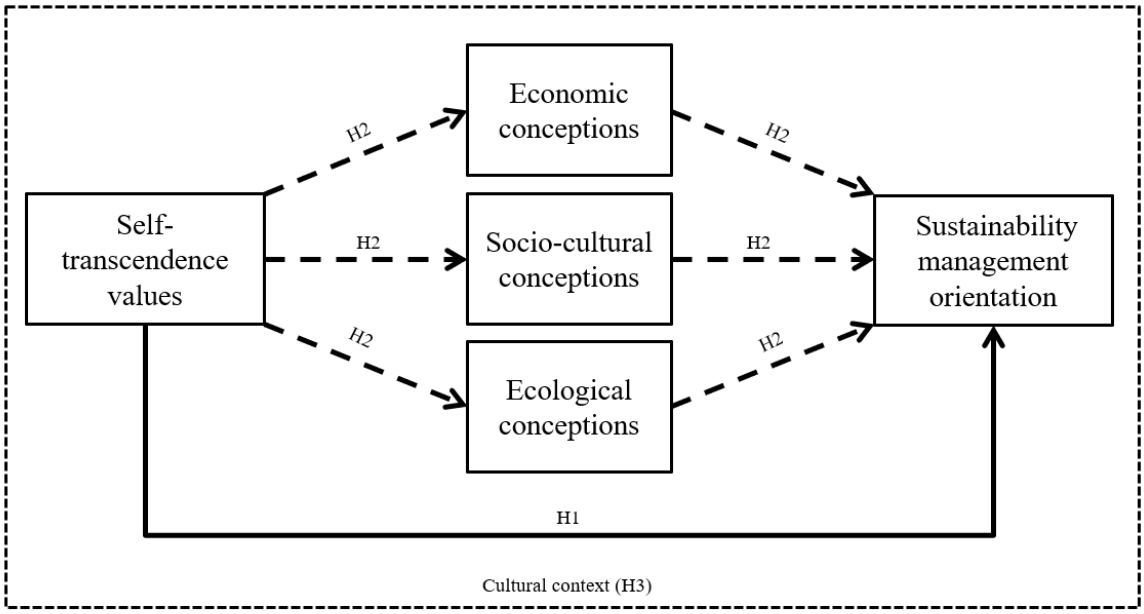

Figure 1: Overview of the conceptual framework for the relationships between self-transcendence values, sustainability conceptions and SMO

Cases with missing data were excluded listwise during the analyses, resulting in a sample of $N = 475$ cases for the final mediation analysis ($n_{\text{Germany}} = 150$, $n_{\text{Indonesia}} = 191$, $n_{\text{USA}} = 134$). In total, the sample consisted of 205 females and 270 males. The data were collected between April and November 2015. No course credit or any other incentive was offered for respondents' participation. Age ranged from18 to 36 years ($M = 21.9$, $SD = 2.63$). The questionnaire used for data collection included well-established as well as new measures. The respondents were asked about their SMO, personal values and their sustainability conceptions. Moreover, the questionnaire included questions concerning respondents' demographics and study backgrounds. The questionnaire was pre-tested qualitatively with

think-aloud technique and quantitatively ($N = 37$). The results of the pretests showed that no major questionnaire modifications were necessary. The questionnaires were issued in German to the German sample, in Bahasa Indonesia to the Indonesian sample and in English to the US-American sample. Bilingual native speakers translated all versions of the instrument.

3.2 Measures

To measure participants' SMO, they were asked to take the role of a manager and to state which managerial practices they would adopt or not, using a seven-point scale indicating their inclination to engage in the described behavior. From a total of 28 items, many of which were previously used by Wang and Juslin (2011) and Kausch (2013), the items wereselected along environmental, social and governance (ESG) dimensions (Principles for Responsible Investment, 2018; Velte, 2017) and considering various aspects related to local communities, employees, suppliers, governance, the environment and customers (Lydenberg et al., 2010, p. 19). The final version of the scale (see Table AI in the appendix) comprised 11 items and showed a good degree of internal consistency ($a = 0.839$).

Participants' *personal values* were assessed using a shortened version of the Schwartz Value Inventory (SVI) from the World Values Survey, consisting of ten statements. In this shortened version, each item corresponded to one of the ten Schwartz values (Held et al., 2009). A fictional person was described by the ten statements. Then, the respondents were asked to indicate for each description to which degree the described person is similar to themselves by using the answer categories "not at all like me" (coded as 1), "not like me" (coded as 2), "somewhat like me" (coded as 3), "a little like me" (coded as 4), "like me" (coded as 5) and "very much like me" (coded as 6). For the analysis, the score of the value category of self-transcendence is used that includes the value types of universalism ("Looking after the environment is important to this person; to care for nature") and benevolence ("It is important to this person to help the people nearby; to care for their well-being").

Sustainability conceptions were measured using a scale developed by Sundermann and Fischer (2016). The scale consisted of 24 items designed to capture a broad variety of potential facets of individuals' conceptions ranging from economic, social and cultural to ecological ones. To analyze the factor structure, a principal fact or analysis was performed on the 24 items with promax oblique rotation. All items with factor loadings over 0.4 were considered (Stevens, 2012). With the cut-off set at 0.4, one item out of 24 did not load on any factor. One item loaded on two factors almost equally strongly and was thus not considered. A Kaiser–Meyer–Olkin

value of 0.891 verified the sampling adequacy for the analysis (Hutcheson and Sofroniou, 1999, p. 225).

The factors explained 58.09 per cent of the variance. The items that clustered on the same factor suggested that Factor 1 represented ecological conceptions (a = 0.855), Factor 2 sociocultural elements *(a* = 0.859) and Factor 3 economic elements (a = 0.689) (see also Table AII in the appendix). For each factor, separate indices were built by averaging the factor items. In addition, several control variables were considered, such as gender (male = 1; female = 0), age (in years), political orientation (1 = left, 10 = right), religiosity (1 = not religious at all, 10 = very religious) and life satisfaction (1 = very dissatisfied, 10 = very satisfied).

3.3 Data analysis

The analysis was conducted in SPSS using the PROCESS macro (Hayes, 2013, p. 85). The proposed mediation models were tested applying a bootstrap procedure (Efron and Tibshirani, 1993). Bias-corrected 95 per cent-confidence intervals were obtained using 10,000 bootstrap (re)samples. An F-test was used to compare the full model against a base model excluding the mediators to test whether integrating sustainability conceptions significantly increased the variance explained by the model.

4. Results

4.1 Descriptive statistics

Table II provides descriptive statistics on the dependent, independent and control variables. Lowest self-transcendence scores were observed in the German sample (M = 3.55; SD = 1.03). The means of the Indonesian sample (M = 4.36, SD = 0.96) and the US-American sample (M = 4.41; SD = 0.85) were higher. SMO was also the lowest in the German sample (M = 4.53; SD = 0.79) and the highest in the Indonesian sample (M = 5.63; SD = 0.72). Table AIII (see Appendix) provides correlations between the variables.

Table 2: Mean values and standard deviations (in parentheses)

	Total (*N* = 475)	**Germany (*n* = 150)**	**Indonesia (*n* = 191)**	**US (*n* = 134)**
Self-transcendence values	4.12 (1.03)	3.55 (1.03)	4.36 (0.96)	4.41 (0.85)
Economic conceptions	5.60 (1.00)	4.87 (1.02)	6.00 (0.73)	5.85 (0.85)
Socio-cultural conceptions	4.89 (1.14)	4.19 (1.07)	5.57 (0.79)	4.69 (1.11)
Ecological conceptions	5.80 (0.84)	6.07 (0.77)	5.75 (0.74)	5.55 (0.96)
Sustainability management orientation	5.18 (0.88)	4.53 (0.79)	5.63 (0.72)	5.29 (0.73)
Political orientation	6.00 (1.84)	4.93 (1.29)	6.96 (1.58)	5.84 (2.01)
Religiosity	5.32 (2.92)	3.13 (2.22)	7.35 (1.99)	4.88 (2.77)
Life satisfaction	7.71 (1.65)	7.53 (1.60)	7.60 (1.78)	8.06 (1.45)
Male	0.57 (0.50)	0.43 (0.50)	0.64 (0.48)	0.62 (0.49)
Age	21.9 (2.63)	25.2 (2.29)	20.6 (0.75)	20.1 (0.48)

4.2 Regression analysis

Considering the entire sample (Table III), self-transcendence positively influenced SMO ($b = 0.139$, $b = 0.163$, $SE = 032$, $p < 0.001$). This finding holds for all three countries (Figure 2). Thus, H1 can be confirmed.

Empirical support was also found for the mediation hypothesis, i.e. the mediating role of individuals' sustainability conceptions in the relationship between self-transcendence values and SMO. More specifically, economic conceptions were found to mediate the relationship between self-transcendence values and SMO (Indirect effect: $b = 0.023$, $SE = 0.009$, $CI = 0.008$ to 0.045, $p_{\text{Sobel}} = 0.005$). Further, a significant indirect effect of self-transcendence on SMO via socio-cultural conceptions (Indirect effect: $b = 0.042$, $SE = 0.014$, $CI = 0.018$ to 0.073, $p_{\text{Sobel}} < 0.001$) was found. Also, ecological conceptions were found to mediate the relationship between self-transcendence values and SMO (Indirect effect: $b = 0.087$, $SE = 0.016$, $CI = 0.058$ to 0.123, $p_{\text{Sobel}} < 0.001$) (see Table AIV in the appendix). Therefore, H2 is confirmed.

Table 3: Regression results (unstandardized coefficients)

Dependent variables	Sustainability conceptions			Sustainability management orientation	
	Economic	Socio-cultural	Ecological	Base model	Full model
Independent variable					
Self-transcendence values	.168**	.317**	.292**	.291**	.139**
Mediators					
Economic conceptions	-	-	-	-	.136**
Socio-cultural conceptions	-	-	-	-	.132**
Ecological conceptions	-	-	-	-	.297**
Country dummies					
Germany	Reference	Reference	Reference	Reference	Reference
Indonesia	.513**	1.157**	-.512**	1.028**	.957**
United States	.318	.241	-.840**	.659**	.833**
Controls					
Male	.232**	-.128	-.172*	-.266**	-.230**
Age	-.083**	.004	-.025	.028	.046*
Political orientation	.024	.012	-.051*	.008	.018
Religiosity	.000	-.002	-.005	.000	.002
Life satisfaction	.066**	.053*	.059**	.067**	.034*
Constant	5.637**	2.568**	5.571**	2.362**	-.396
R^2	.307	.357	.226	.443	.583
MSE	.701	.856	.558	.437	.329
F	25.86**	32.29**	17.00**	46.26**	58.84**

Note: *$p < .05$; **$p < .01$.

The results of individual analyses for each sub-sample will be summarized in the following paragraph. Based on the entire sample, the result of an F-test showed that adding sustainability conceptions to the model as a mediator significantly increased the variance explained in individuals' SMO ($R^2_{\text{Full Model}} = 0.583$, $R^2_{\text{Base Model}} = 0.443$, $F(3, 475) = 51.81$, $p < 0.001$). In the Indonesian sample, the effect of self-transcendence values was fully mediated by people's sustainability conceptions, underlining the importance of this mediator.

Taking a closer look at the three sub-samples, several differences are observed in the levels of the examined constructs (see Table II for mean values and Table AV in the appendix for results of Kruskal–Wallis tests), but only a few differences regarding the proposed relations between the constructs. As Figure 2 shows, five of the seven hypothesized relationships were identified in all three sub-samples. While in the Indonesian and the German sample all proposed effects turned out to be significant, with some marginally significant results in the German sample, for the US-American sample, two of the hypothesized relations could not be found. More specifically, no influence of self-transcendence on economic sustainability conceptions and no effect of socio-cultural conceptions on SMO were identified. R^2 ranged from 0.375 in the US sample and 0.384 in the German sample to 0.624 in the Indonesian sample. In summary, the results mostly support H3, which posited that the research model holds for Germany, Indonesia and the USA.

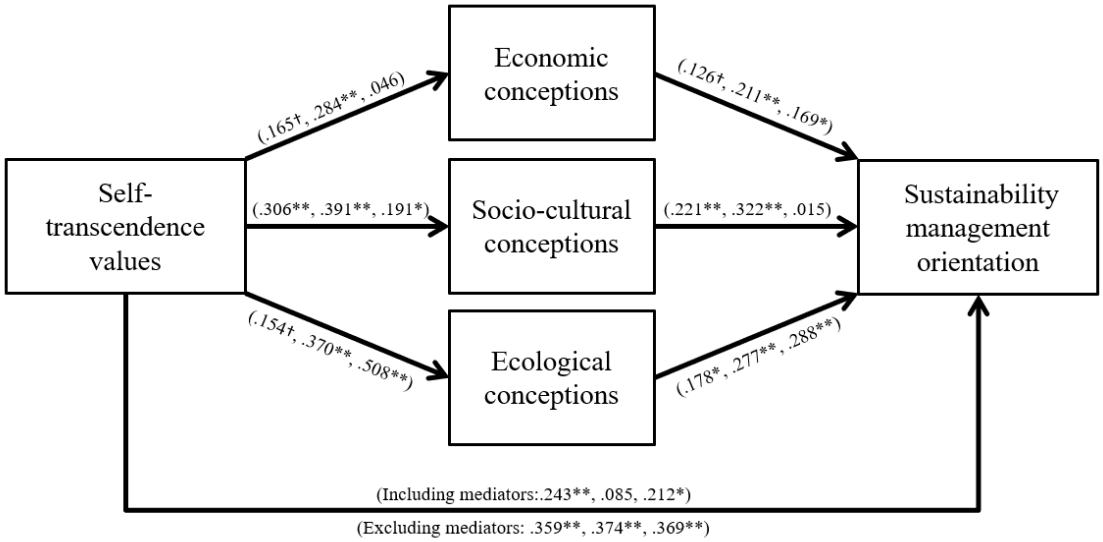

Figure 2: Standardized regression coefficients for the German, Indonesian, and US sub-samples ($^{\dagger}p < .10$, $*p < .05$, $**p < .01$).

5. Discussion and implications

5.1 Findings

The present study gives insight into business students' antecedents of SMO in three countries. Although research on sustainable activities of firms is in the phase of mainstreaming, Wang et al. (2016) highlight in their review that the antecedents of sustainable practices are still unclear. In the framework put forward in this paper, it is shown that students' SMO is related to personal self-transcendence values. An individual's sustainability conceptions mediate this relationship.

Empirical evidence for the hypothesized model is found. More specifically, these findings highlight the importance of sustainability conceptions by showing that the more students interpret certain aspects as integral parts of sustainability, the stronger their orientation towards sustainable management practices. All three dimensions of sustainability (economic, socio-cultural and ecological) have been found to have a positive effect on SMO. In this regard, these results extend findings of previous studies, which either did not specifically address the relationship between self-transcendence values and the economic dimension of sustainability (Hanson-Rasmussen and Lauver, 2018) or provided mixed results concerning the association of these constructs (Wang and Juslin, 2011; Kausch, 2013). We show that having self-transcendence values does not necessarily contradict conceptualizing aspects such as economic growth, efficiency and technological progress as integral parts of sustainability. These economic conceptions, in turn, have a positive impact on individuals' SMO.

Notably, the study has shown that more pronounced self-transcendence values and sustainability conceptions that comprise a variety of associations are related to stronger SMO, but with some differences with respect to the cultural background of the individuals. Hanson-Rasmussen and Lauver (2018) report, for example, that globally business students are interested in environmental sustainability. Contrary to the expectations derived from other studies, in the present research, students from Indonesia and the USA show more nuanced sustainability conceptions than those from the German sample. Although this research finds differences in the three model components, the mechanism has been confirmed in Germany, Indonesia and the USA. This implies that the basic mechanism holds true irrespective of cultural contingencies. In doing so, this paper identifies antecedents of SMO which might contribute to dealing with sustainability management challenges in different countries.

Furthermore, we find that the German sample has the lowest self-transcendence values and also the lowest SMO. Besides values, the high uncertainty avoidance orientation among individuals from Germany might play a role in explaining the low degree of SMO in this sample. According to Hofstede (2001), cultures with high uncertainty avoidance avoid uncertain and unknown situations. The author (2001, p. 148) notes that people in these cultures "look for structure in their organizations, institutions and relationships, which makes events clearly interpretable and predictable." A strong SMO is rare and its consequences are thus not very well-known. Therefore, a strong SMO might be seen as an unfamiliar risk for a company. As individuals with higher levels of uncertainty avoidance shun situations that are not predictable, they will probably more frequently show a lower willingness to enter into such unknown and unfamiliar ventures.

The strong collectivism and long-term orientation could have affected the strong SMO in Indonesia. If individuals focus on cooperation and group harmony and take into account long-term consequences of their actions taken today, they will probably develop long-term strategies to achieve their aspirations (Ashkanasy et al., 2004; Parboteeah et al., 2012). Hörisch et al. (2014) argue that sustainability has to be a core value to comprehensibly include durability and environmental concern in sustainability management. The study contributes to this view in showing that values and nuanced sustainability conceptions enhance students' SMO. Hence, amplifying the conceptions of business students could be a way to create mutual interests and benefits for all stakeholders.

5.*2 Implications*

Already about 30 years ago, Bunge (1989, p. 393) concluded that:

> if the survival of humankind is at risk because some of us – mainly our leaders and habit makers – have espoused the wrong values and consequently the wrong morals [. . .] we must transvaluate the dominant value system.

Against this background, it is crucial to further investigate the role of self-transcendence values in responsible management.

Future research could gain valuable insights into teaching and learning in business ethics and values as a learning outcome by including assessments of curriculum and teaching approaches as control variables. This study finds similarities and differences in sustainability conceptions and SMO among students within a university and across countries. Future investigations could extend the study to see whether findings are also applicable to other countries and other universities, as cross-cultural results on responsible and sustainable business practices remain unclear (Ho, 2010). In similar vein, future research might further enquire into the conditions under which responsible management education is likely to contribute to the achievement of the sustainable development goals (Weybrecht, 2017).

Implications for researchers to investigate the engagement of present managers with different personal value types in sustainability practices beyond only satisfying the most salient stakeholders. This study also reveals the need for further investigations at the organizational level and with actual managers to find out if shared self-transcendence values in an organization and growing SMO translate into corresponding managerial behavior. As Peters and Waterman (1982) have already stated, superior performance in responsible management also arises from well-defined sets of shared values in an organization.

Moreover, this study has practical implications for teaching approaches in higher education. Previous research has stated that values are relatively stable, but through new

constructivist teaching approaches, conceptual change and even value change seems accessible. For instance, Geiger et al. (2018) showed that a mindfulness intervention is linked to decreasing material values in students and at the same time increases their subjective well-being. This may require the integration of unusual educational methods such as contemplative practices, service learning or storytelling activities into the teaching of responsible management (Laasch and Conaway, 2015; Laasch, 2014). Education for sustainability has been identified as a key to more responsible and sustainable business practices (Lourenço, 2013; Hesselbarth and Schaltegger, 2014), and there have been calls for a stronger integration of all dimensions of sustainability in university curricula to enable students to develop more nuanced and integrated sustainability conceptions (Brito et al., 2018). This research points to the relevance of sustainability conceptions as important antecedents of SMO. To enhance sustainability competencies in business students, for instance SMO, as one facet of system thinking competence, approaches like values-based teaching and leadership development (May et al., 2014; Arce and Gentile, 2015; Gentile, 2017) or transgressive teaching (Lotz-Sisitka et al., 2015) need to be considered. Moreover, students' perspectives on teaching concepts shall play a more important role in curriculum development (Warwick et al., 2017).

In line with Bunge's (1989) call for a change in leaders' value systems, assessment and appointment processes for management positions should be (re-)designed in a way that allows taking into account candidates' personal values. In doing so, individuals can be chosen who are more likely to make sustainable management decisions (Holtbrügge et al., 2015). Such assessment could, for instance, use the "value knowledge grid method," which is a tool to analyze value knowledge in organizations (Meynhardt, 2004). The value knowledge grid is a method to identify individuals' and organizations' value knowledge (Meynhardt, 2004, p. 231). Management appointment processes should also take account of a potential self-selection issue, whereby individuals with self-transcendence values might be less likely to seek management positions than their colleagues with more pronounced self-enhancement values. One relatively simple suggestion that can be made based on the present research is that leadership positions should be advertised and described in a way that appeals to individuals with self-transcendence individuals (Fritzsche and Oz, 2007).

The implications are also interesting for firms that seek to empower their workforce to develop more nuanced and integrated sustainability conceptions to enhance their commitment to sustainability. In line with Hartman and Werhane's (2010) findings concerning management education at business schools, it is argued that to create an enduring change in people's sustainability conceptions, their attitudes, and sustainability-related behaviors, firms need to

make sure to expose their employees and leaders to sustainability topics continuously. However, the overall lesson is that offering individuals occasions to reflect upon their implicit and explicit assumptions about sustainability is very important, and this paper shows that these assumptions impact individuals' SMO.

5.3 Limitations

This section addresses limitations regarding common method bias, sample structure, and cultural setting bias. To begin with, all variables in this cross-sectional study were measured with the same survey instrument. Therefore, the potential for common method bias cannot be discounted. However, common method bias is not expected to be a significant problem in this study, as several strategies to reduce this bias were used: First, following Podsakoff et al.'s (2003) advice, full anonymity was ensured to the respondents, and they were told that there were no "right" or "wrong" answers. Second, the measurement of the independent and dependent variables was psychologically separated by placing them on different pages of the questionnaire and by including introductory paragraphs to separate the item batteries and "prime" respondents for the respective questions. Third, to avoid monotonic response patterns, two item batteries with different scale formats (ipsative measures), which are not part of the investigation, were introduced between the dependent variable construct and the independent variable constructs. Fourth, we used questionnaire items that were clear, precise, and easy to understand for the respondents. To check the validity of the survey instruments and the adequacy of the survey length, a quantitative and a qualitative pretest were employed. Fifth, we used a relatively complex model. Thus, it can be proven that variance in the response pattern exists. Finally, Harman's (1976) single-factor test was conducted to examine whether a single factor could explain the majority of the variance. All items of the independent variable, the mediator and the dependent variable were entered into an unrotated principal component analysis. It was found that there were 12 factors with eigenvalues greater one which accounted for 61.8 per cent of the total variance. The largest single factor only explained 22.7 per cent of the variance. In conclusion, it seems that common method bias was not a serious concern in the study. Nonetheless, future research could focus on longitudinal studies to avoid some of the shortcomings of cross-sectional research.

Second, another limitation concerns the sample. While it might be argued that using student samples is not recommendable in addressing research questions in the area of management, this study argues that investigating into the values and conceptions of future decision makers makes sense, as this generation will take various responsibilities in years to come. Furthermore, business students are interesting as a sample because previous research has

shown that their sustainability conceptions differ from those of students from other disciplines (Sharma and Kelly, 2014; Zeegers and Clark, 2014). Moreover, they are more likely to be employed in a business context than students enrolled in other majors.

Third, a limitation lies in the study design, which is based on concepts developed in Western cultural settings. Some terms might be understood differently in Indonesia. However, the instrument comprised very clear and precise items and bilingual speakers translated the questionnaire. Furthermore, the Schwartz values instrument is used which is highly valid and has often been employed in cross-country research. Moreover, the differences observed in the study with regard to mean values might partially stem from cultural differences in response behavior, as analyzed by Harzing (2006). Yet, as the focus of the research was not on the comparison of mean values, but on analyzing the validity of the research framework in terms of proposed relations between the constructs, cultural response biases should not represent a serious threat to the results, as they can be expected to affect all constructs in a similar way. This study may also face limitations regarding the transferability of the findings to other cultural and institutional contexts since we carried out the study in only three countries. However, owing to the comparably big (especially cultural) differences between the three examined countries, the results are expected to be rather robust, i.e. they might also hold in other countries. Nevertheless, carrying out similar studies in other countries and at other institutions would further strengthen the external validity of the findings.

6. Conclusion

Sustainability is one of the major challenges of the Anthropocene. For the successful implementation of sustainability and responsible management in business, government and society, individuals who assume responsibility for the necessary change processes are required. This research shows that individual characteristics, in the case of this study personal values, shape SMO. Individuals' sustainability conceptions mediate the effect. Future research should further examine the role of SMO for responsible management. May the discovery of the important role of sustainability conceptions open a way to future conceptual and empirical research including this construct.

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Appendix

Table 4: Items of the SMO scale

Item	ESG dimension
Sustainable use of natural resources	Environmental
Cooperation with environmental organizations	Environmental
Product safety	Environmental
Strengthening local and regional economic development	Social (external)
Relationships with the social environment and local communities	Social (external)
Cooperation with organizations serving civil society	Social (external)
Cooperation with schools, universities and institutions	Social (external)
Taking responsibility for employees	Social (internal)
Company health policy / Safety at work	Social (internal)
Ethical-moral business operations	Governance
Controlling suppliers relating to ethical standards	Governance

Cronbach's α = .839.

Table 5: Pattern matrix (Sustainability conceptions)

Items	Factor loadings		
	1	2	3
Conservation of natural resources	.857		
Protecting ecosystems for future generations	.775		
Green technologies	.701		
Environmental program	.642		
Relationship between the ecological, economic, and social	.638		
Responsible behavior	.636		
Durability/longevity	.590		
Fair trade products and services	.429	.411	
Societal learning process			
Human rights		.852	
Justice between developed and developing countries		.769	
Social security		.754	
Justice between rich and poor		.680	
Protection of different cultures in the world		.674	
Participation of all people in decision-making processes		.459	
Traditional knowledge		.443	
Economic growth			.792
Efficiency			.646
Technological progress			.545
Cronbach's α	.855	.859	.689

Note: Principal factor analysis, Promax rotation with Kaiser normalization, rotation converged in six iterations. Only factor loadings > .4 are displayed. A fourth factor comprising three items related to skepticism is not displayed, since we do not seek to analyze this facet of individuals' conceptions.

Table 6: Correlations (Pearson's *r*)

	1	2	3	4	5	6	7	8	9
(1) Self-transcendence values	1								
(2) Economic conceptions	**.309**	1							
(3) Socio-cultural conceptions	**.403**	**.489**	1						
(4) Ecological conceptions	**.253**	.028	**.287**	1					
(5) Sustainability management orientation	**.510**	**.474**	**.587**	**.328**	1				
(6) Political orientation	.007	**.244**	**.225**	**-.194**	**.213**	1			
(7) Religiosity	**.283**	**.304**	**.361**	-.044	**.374**	**.381**	1		
(8) Life satisfaction	**.096**	**.154**	**.093**	**.102**	**.173**	**.114**	**.119**	1	
(9) Male	-.077	**.167**	-.010	**-.208**	**-.094**	**.142**	.028	-.041	1
(10) Age	**-.276**	**-.467**	**-.320**	**.178**	**-.393**	**-.318**	**-.420**	**-.104**	**-.103**

Note: Correlations significant at a level of $p < .05$ displayed in bold, $N = 475$.

Table 7: Indirect effects of self-transcendence on SMO

Mediator	Effect	Boot SE	Boot LLCI	Boot ULCI
Total	.151	.023	.110	.201
Economic conceptions	.023	.009	.008	.045
Socio-cultural conceptions	.042	.014	.018	.073
Ecological conceptions	.087	.016	.058	.123

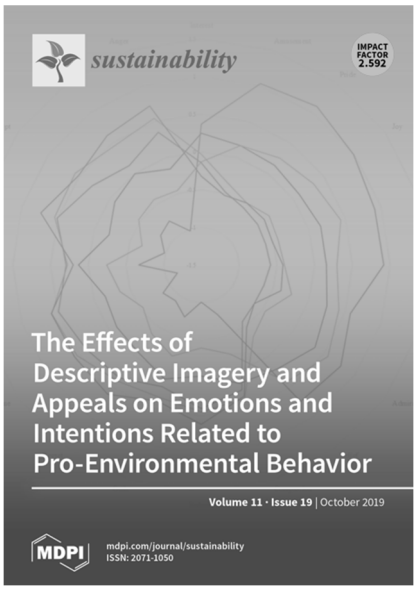
Table 8: Comparison of central tendencies across countries (Kruskal-Wallis tests)

	Self-transcen-dence values	Economic conceptions	Socio-cultural conceptions	Ecological conceptions	Sustainability management orientation
	60.8	118.6	149.5	32.4	135.8

Note: All results significant at a level of $p < .001$, $df = 2$, $N = 475$.

4.2 Article#2: How does sustainability become professionally relevant? Exploring the role of sustainability conceptions

Published version



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Article

How Does Sustainability Become Professionally Relevant? Exploring the Role of Sustainability Conceptions in First Year Students

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Abstract: One of the main objectives of higher education for sustainable development is to nurture holistic conceptions of sustainability in students, so that they can use sustainability as an approach to analyze and solve complex problems in their future professional fields. Existing studies have shown that students differ substantially in how relevant they consider the concept of sustainable development to their future careers. Previous studies have identified socio-demographic characteristics, disciplinary background and past experiences with sustainability education as potential influencing factors. To date, the relationships between one's own "understanding" of sustainability (sustainability conception) and the importance students attach to sustainability has hardly been investigated. This case study offers a first systematic examination of how the perceived professional relevance of sustainability is influenced by different individual characteristics and sustainability conceptions. Based on data from a recent survey of n = 1364 first year undergraduate students from 14 different major subjects, our findings indicate that in addition to the previously reported individual characteristics like sex and academic affiliation, sociocultural sustainability conceptions are an important influential factor for the perceived importance of sustainability for their professional contexts. However, the regression analysis shows that the model based on predictors found in the literature lacks incremental power. This paper unveils that further research is needed on the underlying factors that explain the strength of perceived relevance of sustainability in students and that these influences need to be taken more into account in curriculum development.

Keywords: higher education for sustainable development; learning outcomes; conceptions; understanding; perceptions; professional practice

1. Introduction

Universities and other higher education institutions (HEIs) have been shown to play a critical role in engaging future professionals and decision-makers with sustainability in order to educate a new generation of change agents for sustainable development (SD) [1]. After early periods of experimentation, orientation and pilot development, efforts to implement and mainstream sustainability as a guiding idea for the design of teaching, research, operation and community outreach have intensified over the period of the UN Decade of Education for Sustainable Development and the follow-up Global Action Program [2] (p. 51). The growing importance of sustainability in the private sector [3], the emergence of associations for sustainability professionals [4], and the increased profile of sustainability on the international political agenda through the Sustainable Development Goals (SDGs) [5] suggest that the demand for students with sustainability credentials is likely to increase further.

Although sustainability is increasingly recognized as an important principle for the design of higher education, the actual large-scale implementation of Higher Education for Sustainable Development (HESD) is still largely lacking. Effective mainstreaming is complicated not least by the fact that there are very different ideas about how HESD could and should be implemented. There are different proposals, for example, on the questions of the learning outcomes to be aimed for and the pedagogies and educational philosophies to be used for them [6], the intensity of the integration of sustainability (from additive "bolt-on" to integrative "built-in" approaches) [7] (p. 58), as well as the contents and understandings of sustainability itself to be conveyed [8]. Despite the diversity of approaches it seems valid to say that a shared goal of different HESD approaches is to support students in developing an understanding of sustainability that they can then use to analyze specific problems and act on.

However, being *able* to act as a change agent for sustainability and actually *acting* like one are two separate outcomes of HESD. Shephard, Rieckmann and Barth [9] rightfully point out that it is critical to distinguish between cognitive (e.g., knowledge and its application) and affective learning outcomes (e.g., motivational factors and values). In this perspective it seems critical to not just understand how students can be enabled to engage with sustainability challenges (that are often times not just known problems in narrowly defined fields of action, but comprise a variety of ill-defined problems in different domains of life), but also explore what makes learners want to use what they have learned when confronted with such challenges. The explicit focus of sustainability education programs on acing on and solving problems "along the lines of sustainable development" [10] (p. 22) suggests that how learners understand sustainability plays a significant role in how they can and want to respond to domain-specific problems and demands. The extent to which learners regard their conceptions of sustainability as relevant when confronted with concrete domain-specific problems and demands, can thus be considered a potentially promising intermediate step from understanding to using sustainability as a concept that is informing professional action. Surprisingly, however, the interdependencies between students' conceptions of sustainability and their perceived relevance of sustainability for coping with the demands they are facing in their current and future professional contexts have not yet been systematically investigated.

This paper addresses this research gap. It empirically analyses the relationship between students' sustainability conceptions and their perceived professional relevance (PPR). Following Borg, Gericke, Höglund and Bergman [11] (p. 546), we refer to *sustainability conceptions* as "the degree to which individuals associate a particular set of ecological, sociocultural, and economic aspects as integral parts of the concept of sustainable development". Empirical data was collected as part of the LISHE (Longitudinal study on the Integration of Sustainability in Higher Education) case study at a midsize university in Northern Germany. It was obtained from a survey of two cohorts (commencing in the academic years of 2014 and 2015) of first-year students from 14 major subjects from four professional fields that was administered before classes began. LISHE pursued three aims: first, to shed light on how relevant first-year university students consider sustainability to be, both for their current studies ($PPR_{CURRENT}$) and, in future, as professionals in their jobs (PPR_{FUTURE}); second, to explore which sustainability conceptions and other characteristics first-year students already bring to campus when they begin their undergraduate studies; and third, to describe how sustainability conceptions and other factors interrelate with the current and future relevance that students attribute to sustainability. Thus, three research questions (RQs) are examined:

1. Which relevance do first year students ascribe to sustainability for their current and future professional career?
2. What is the nature of first year students' sustainability conceptions?
3. Which roles do these sustainability conceptions play in comparison to socio-demographic and prior experience-related factors for first year students' perception of the professional relevance of sustainability?

The paper is structured as follows: In the first two sections, we give an overview on research of our two main constructs PPR of sustainability and sustainability conceptions. In the next sections, we clarify our methodological approach, present our findings and discuss them in relation to existing literature. We conclude by providing theoretical as well as practical implications for future work on approaches to address and further advance students perceived professional relevance of SD and their relationship towards professional contexts and teaching approaches in HESD.

2. Theoretical Background

2.1. Research on Perceived Professional Relevance (PPR)

The turn towards competence-based learning outcomes in HESD has been noted to emphasize that teaching and learning programs in higher education should be designed "to equip graduates with the knowledge, skills and values that enable business, government and society as a whole to progress towards more sustainable ways of living and working" [12] (p. 285). A prominent line of inquiry in (H)ESD research focuses on pedagogies that are conducive to these objectives (see e.g., [6]). Several ESD scholars distinguish between instrumental or transmissive and transformative or transgressive approaches [13,14]. While the former set of approaches has been described as operating on the assumption that information, concepts, and ideas need to be transferred to learners (instructive mode), the latter is more concerned with the process of inquiry and deliberation (constructive mode) [15]. While it has been acknowledged that both approaches are not in fundamental opposition but can actually complement each other [16]. ESD scholars like Arjen Wals and Bob Jickling [17] have called for greater emphasis to be placed on the construction of meaning around sustainability in classrooms. We know from other fields, such as research on constructivist learning theories, that pedagogical approaches need to account for and adapt to existing experiences and conceptions of learners as they represent a crucial starting point for any transformative learning [18]. For instance, learners' formal and informal educational experiences with ESD in school is suggested as the foundation for later learning at HEIs and to influence the quality of their learning processes [19]. There is evidence that these existing conceptions can remain unaffected by education and pedagogical approaches when the design of these learning settings fails to adequately address what students bring to the classroom [20]. Thus, we argue that the question of what students perceive as useful and important at the beginning of their academic learning process should be reflected in the design of HESD programs. To not consider students' views on the usefulness and relevance of sustainability bears the risk of counteracting and undermining the accumulation of inert knowledge. Surprisingly, though, only few studies have investigated explicitly what we call PPR of sustainability at all. Most studies also frame the importance students ascribe to sustainability during their education as perceptions or perceived importance of or interest in sustainability. One of the pioneering works exploring PPR of sustainability was Davis et al. [21]'s qualitative case study at two campuses in the US. The researchers conducted qualitative interviews with 31 students and asked them about the experiences they had made in engaging with the concept of sustainable development in their studies. The students stated that their engagement had raised their awareness of social and environmental benefits as well as for sustainability trade-offs that they had found useful to consider in their fields of study and future work contexts. Two comprehensive quantitative surveys come to a similar conclusion. First, results from a worldwide study on engineering students suggested that despite a lack of general knowledge of sustainability and understanding, students were in favor of the concept [22]. Bone and Agombar [23] found in an online survey of n = 5.763 first-year students in the UK that most students perceived sustainability to be relevant at least to some extent for their studies and future working contexts, irrespective of their study backgrounds. According to their results, the generally perceived importance of the topic seems to be stable even after graduation. For instance, research on post-graduates in the UK (n = 98) revealed that students generally acknowledge the relevance of sustainability for their career but have reservations about existing approaches to deliver ESD in HEIs [24]. A number of studies suggest

different individual characteristics that might influence students' PPR of sustainability. These include academic affiliation (major subject) [25,26], sex [26,27], age or year of studies [22,25], as well as formal and informal educational experiences [25,28]. Moreover, researchers argue that increasing students' understanding of sustainability concepts increases their PPR [21,29,30].

In sum, existing studies yield empirical insights into how students assess the professional relevance of sustainability and provide some first cautious indications of possible influencing factors. So far, however, there is no comprehensive study available that allows conclusions to be drawn about how the perception of the relevance of the concept of sustainable development for professional contexts among students is influenced by the aforementioned individual factors or their own sustainability conceptions.

2.2. Research on Sustainability Conceptions

The most widely used definition of SD is that provided by the Brundtland commission, describing it as "meeting the needs of the present without compromising the ability of future generations to meet their needs" [31] (p. 43). Despite its prominence, the definition has been met with severe criticism, e.g., for its anthropocentric focus, its uncritical affirmation of environmental conservation and economic growth or for its indetermination with regard to specific goals and approaches to achieve SD [32]. Consequently, more than 100 alternative definitions of SD have been proposed, highlighting e.g., ethical [33], social [34,35], or cultural [36,37] aspects of the concept. So far, no consensus has been reached in the scholarly debate [38]. There has been a lot of confusion in the literature over the definition of SD, over the way it is used and how it is conceptualized [39]. Different conceptualizations are mirrored for instance by the different shapes of the models, which take the form of pillars, nested circles, triangles [40] (p. 7ff) or even doughnuts [41]. Thus, individual conceptualizations of the term vary widely [42]. Another complexity of this discussion concerns the question whether the notions of sustainability and sustainable development can or should be used interchangeably [43]. Three arguments to distinguish the two terms are commonly found in the literature:

1. Idea vs. political program: Sustainability is seen as a historically evolved idea that describes certain principles of justice and ideals for the future. Sustainable development, on the other hand, is located more strongly in a political context that is particularly influenced by the work initiated by the Brundtland definition and carried out by the United Nations since the 1980s;
2. State vs. process: In line with the previous distinction, sustainability is used as a term expressing a desirable future state, while sustainable development is used to refer to the process leading to that terminal condition;
3. North vs. South: A third distinction stems from the criticism, mainly from the Global South, that the concept of SD is intended to promote Western development models. In line with this, critics from the post-growth or degrowth community have advocated that sustainability strategies should aim to overcome the growth logics inherent in the concept of development.

Against the background of the controversies described above, the interest of this study relates to how students represent sustainability on a general level: The focus is not on theoretical concepts such as strong/weak sustainability, or concrete strategies to achieve a more sustainable future, but rather on semantic connotations of the root term. Since the connotation profiles of the terms "sustainability" and "sustainable development" are very similar among the German population [44], we use both terms synonymously in this study. In order to express that we are more interested in general associations with the idea of sustainability than in concrete sustainability strategies, we speak of sustainability conceptions in the following.

In addition to different definitions of sustainability, there are also different ways to conceptualize the construct. Traditionally, three dimensions of sustainability are distinguished: economic, environmental and social [40]. These three dimensions and similar terms can also be found in UNESCO's ESD Implementation Scheme [45]. This document identifies a number of key sustainability issues underlying the three dimensions of SD. Sub-themes of the environmental dimension are natural resources (water,

energy, agriculture and biodiversity), climate change, rural development, sustainable urbanization, disaster prevention and mitigation. Those reflecting the social dimension are human rights, peace and human security, gender equality, cultural diversity and intercultural understanding, health, HIV/AIDS and governance. Part of the economic dimension are poverty reduction, corporate responsibility and accountability, and market economy [45] (pp. 18–22). National target agreements with universities in Germany and funding guidelines for higher education policy have been developed on the basis of UNESCO's ESD Implementation Scheme, which consequently had a substantive on how the idea of sustainability was conceived in teaching and research at universities. The Implementation Scheme has also been successfully used as a guiding framework for the assessment of school students' views on ESD [46]. For these reasons, we are using the above-mentioned key issues as the basis for assessing sustainability conceptions in this study.

A related strand of inquiry focuses on investigating how students deal, perceive, and make sense of these differing and vague sustainability conceptions. Constructivists conceive learning as a process of creating new insights by validating existing conceptions and adapting emerging conceptions [47]. These (pre-)conceptions can be activated when a problem is framed and presented in a sustainability perspective and may act as a filter that selects and adapts any new information [48]. Sustainability conceptions have been researched and discussed in the HESD literature for some time. We focused our review of existing works on sustainable conceptions on articles published from 2008 to 2019 in order to continue the seminal work by Lipscombe [39], who gave an overview of studies between 2002 and 2007. We centered on studies from the field of HESD (excluding other fields, e.g., school education). Accounting for differences in the terminology, we used the terms *understanding*, *perceptions* and *conceptions*. Subjects of the empirical studies had to be university students. We included $n = 17$ studies with the following disciplinary backgrounds: management and business education [49–52], engineering education [24,53–55], teacher training [56–58], tourism [29,59], as well as five studies with the overall aim of integrating ESD into HEIs [25,60,61].

Three questions were of particular interest in the literature review: (1) Which terminology is used, (2) which study design is employed and (3) which results on dimensionality are reported. The following synopsis of the review is structured along these questions.

First, with regard to terminology, we found that the terms are often used interchangeably and inconsistently. Moreover, most articles use the term understanding, less conceptions and perceptions. As we noticed so far, only three authors provide explicit definitions of sustainability conceptions. Reid et al. [49] (p. 664) define conceptions as the outcome of a phenomenographic study, which is described as an "hierarchical set of qualitatively different but logically related categories." This definition is only useful in the narrow context of this research method and therefore not useful for large scale assessment. Cotterel et al. [29] (p. 2) use conceptualization and describe it as the "formation of an idea about something". Conceptions need to be distinguished from understanding which incorporates the application of knowledge in decision-making situations according to Carew and Mitchell [62]. Based on our critical reading of the literature, we decided to understand sustainability conceptions as "the degree to which students associate ecological, sociocultural, and economic aspects as integral part of sustainability" [11] (p. 546). This definition seems helpful as it encompasses the three core dimensions previously described, contains the possibility of measurement, and allows to show individual points of gravity in students' conceptions.

Second, the dominant research method is a survey with open-ended and closed questions followed by qualitative interviews and mixed method approaches where interviews and surveys are combined. One study used conceptual maps as a way to measure the complexity of the conceptions [53]. Another study analyzed students' reflective journals in order to gain insight into students' conceptual changes over time [51]. Most studies are case studies which describe differences between student groups within a confined setting. However, two studies use pre-post designs to show effects of ESD courses on students' conceptions and conceptual changes [51–53].

Third, the majority of studies draws on the traditional conception with three or four dimensions of sustainability. Some studies, however, distinguish between up to seven different sustainability dimensions [25,55–57,59]. A common distinction is made between naïve, simple or pre-structural conceptions on the one hand, and broader, more sophisticated, multi-structural or interconnected conceptions on the other. Almost all previous studies indicate a tendency among students to associate primarily environmental or ecological aspects with sustainability on the expense of sociocultural aspects or economic aspects. An exception is the study by Carmargo and Gretzel [59] report 15% holistic views among their tourism students in Latin America. Further, freshmen's conceptions seem to be more simplistic, in particular prior to their studies or without being exposed to interdisciplinary sustainability courses [51,52,55].

Taken together, these results suggest that students start their higher education career with pre- or unistructural conceptions that might then influence their perception of the relevance of sustainability for them and their professional future.

3. Materials and Methods

The empirical case study presented in this paper addresses two shortcomings that have been identified in the review of the literature on key concepts (Section 2): (1) The fragmented knowledge about students' sustainability conceptions and (2) the influences of these conceptions on PPRs of sustainability as antecedents of competence acquisition in comparison to other influencing factors (i.e., socio-demographic and prior experience-related factors). We used a cross-sectional and correlational design to examine the relationship between the variables. The study was carried out at a medium-sized university with a strong focus on sustainability in northern Germany (2012–2016). In this article, we use data that have been collected before the students started their first semester in a so-called starting week. The university pursues a whole-institution approach to HESD, thus incorporating HESD into its four core activities (education, research, operations, and community outreach).

3.1. Measures

The questionnaire consisted of six independent (IV) and two dependent (DV) variables. The first part of the questionnaire asked the respondents to provide information on socio-demographics that previous studies have shown to be influential (sex, age, major subject) as well as previous informal educational experiences and prior formal engagement with sustainability (see Section 2.1). The second part comprised measures of individual characteristics like students' sustainability conceptions and PPR for their major subject ($PPR_{CURRENT}$) and their future professional work contexts (PPR_{FUTURE}) (for an overview see Table 1).

Table 1. Summary of independent (IV) and dependent (DV) variables and response types.

	Variable		Question	Response Type
IV	SEX	Sex	Please indicate your sex.	Categorical item with three options: Female/male/no answer
	MAJ	Major subject	Which major subject did you choose?	Categorical item with 15 options
	AGE	Age	How old are you?	Open ended item
	IEE	Informal educational experience	What did you do between the end of the school and the start of your current study at the university?	Multiple response, 15 items (e.g., voluntary work, internship, vacation longer than 2 month)
	FEE	Formal educational experience	Do you have ever encountered the concept 'sustainability' or 'sustainable development' in the classroom?	Dichotomous categorical item (YES/NO)
	CSD	Sustainability Conceptions	Here we would like to know to what extent you associate the following aspects with the concept of sustainable development.	Seven-point Likert scale, 12 items (e.g., 'conservation of natural resources, efficiency').
DV	$PPR_{CURRENT}$	Current Perceived Professional Relevance	Do you perceive sustainable development as related to your major subject?	Dichotomous categorical item (YES/NO)
	PPR_{FUTURE}	Future Perceived Professional Relevance	Do you perceive sustainable development as related to your future professional career?	Dichotomous categorical item (YES/NO)

3.1.1. Independent Measures

Sociodemographic variables and formal and informal educational experience were assessed through single items (see Table 1 for details). Due to the unavailability of an elaborated measure of student sustainability conceptions (see Section 2.2), a new scale was developed for this study following Borg et al.'s definition of sustainability conceptions [11]. As this study presents only cross-sectional data from first-year students entering university, we use the term *(pre-)conceptions* to refer to the aspects students relate to sustainability prior to entering the university system.

The development of the conceptions of sustainable development (CSD) scale is based on a threefold model of sustainability that comprises environmental, sociocultural and economic dimensions that has been used in prior research on students' sustainability conceptions (e.g., [58]). Each of the dimensions includes a set of independent, rather conservative objectives and principles of sustainability. The items in our questionnaire were developed and categorized to represent most commonly addressed sub-themes of these three dimensions. Participants were asked to indicate how much they associate certain aspects (e.g., 'conserving natural resources') with the term sustainability on a six-point Likert scale from 6 ('*I strongly associate this aspect with sustainability*') to 1 ('*I do not associate this aspect with sustainability*'). The related comprehensive item pool is based on Barth and Timm's [25] measurement of understandings and follows a rational scale development resulting in a list of 23 items (see Table 2). Initially, the item pool was tested in a pilot study with (n = 832) students as recommended by De Vellis [63] (p. 144–146). Additionally, students could add aspects they missed in the scale and comment on the scale. These items were then analyzed according to their psychometric aptitude and also revised and expanded based on the pre-study (see Table 2 for the scale summary and factor loadings across studies). Next, a revised pool of 23 items was created and the number of answer categories was

changed from six to seven, because a) the quality of the measurement increases when the number of answer categories increases and b) a central category to avoid forced, systematic answer biases has been added [64]. Now, the answer categories are ranging from 7 (*'I strongly associate this aspect with sustainability'*) to 1 (*'I do not associate this aspect with sustainability'*).

The revised 23 items were again tested for capturing the three dimensions of sustainability conceptions. In order to analyze the factor structure, a principal factor analysis was performed on the 23 items with promax oblique rotation. All items with factor loadings over 0.4 were included. With the cut-off set at 0.4, we considered the items with high loadings and content validity to keep the scale balanced [65]. A Kaiser-Meyer-Olkin value of 0.89 verified the sampling adequacy for the analysis.

The resulting instrument consists of 12 Likert-type items. Table 2 provides a full overview of the items used in the present study and Table 1 gives an example how the questionnaire was designed. Eleven items had to be deleted as they were redundant, had no content validity or were covered by another measure. Some have been rephrased. For theoretical reasons, we fixed the number of factors to three in a follow-up analysis, with the three factors representing an environmental (env_con), a sociocultural (soccul_con) and an economic (econ_con) dimension of sustainability conceptions. This factor solution explains 43% of the variance. This supports construct validity. Regarding scale reliability, Cronbach's alpha for 12 items is $\alpha = 0.74$, indicating that a heterogeneous attribute is measured, which is reasonable against the background of existing definitions. Alpha coefficients for subscales between $\alpha = 0.70$ and $\alpha = 0.76$ (see Table 2) demonstrate that the developed instrument has an acceptable consistency and results can be considered reliable [66]. The mean inter-item correlations are between $r = 0.38$ and $r = 0.45$, which can be considered optimal [67]. For each factor, we built separate indices by averaging the factor items.

3.1.2. Dependent Measures

The conception of relevance underpinning this study has its focus on the vocational dimension, in which academic qualification (in the major subject), career orientation and preparation for future working demands are of pivotal interest [68]. PPR is operationalized in two measures: with regard to their current professional contexts ($PPR_{CURRENT}$), students were asked whether they see a relationship between their major subject and sustainability; regarding their future professional contexts (PPR_{FUTURE}), students were asked about a corresponding relationship between their future professional work and sustainability (see Table 1).

Table 2. CSD-Scale summary (factor loadings across studies).

Item	Pilot Study	Study
Factor 1: Sociocultural conception	**c = 4.00**	**c = 4.43**
Human rights	0.77	0.74
Justice between industry and developed countries	0.77	0.71
Life quality for all people around the world	0.65	0.60
Participation of all people in decision making	0.58	0.59
Social security	0.55	0.61
Protection of different cultures in the world	0.53	0.45
Deceleration	0.47	0.39
Bad compromise	0.30	-
Justice between rich and poor	-	0.82
Factor 2: Environmental conception	**c = 2.07**	**c = 2.13**
Responsible behavior	0.66	0.60
Conservation of natural resources	0.57	0.74
Environmental program	0.52	0.56
Protecting ecosystems for future generations	0.53	0.75
Relationship between the Ecological, economic, and Social	0.34	0.39
Durability/longevity	0.48	0.54
Societal learning process	-	0.33
Factor 3: Economic-technical conception	**c = 1.13**	**c = 1.07**
Economic performance	0.90	0.75
Economic growth	0.85	0.75
Technological progress	0.622	0.55
Efficiency	-	0.40
Factor 4: Skeptical conception	**c = 0.83**	
Buzz word	0.71	-
Empty phrase	0.57	-
Utopia	0.53	-

Note: Entries calculated with SPSS24. Rotated factor loadings. Rotation: oblique promax (Kaiser on). c = eigenvalues.

3.2. Data Collection and Data Analysis

The online questionnaire based on LimeSurvey™ was administered over a period of three weeks in October 2013 and 2014, before semester beginning. The sampling approach was convenience-based. Participation was anonymous, voluntary and based on informed consent. This means that the questionnaire was not part of the formal assessment of the students and that students have been invited via an online link to take part in the study. Students have been informed about their right not to answer the questionnaire and that their answers are pseudonymized. We used the LimeSurvey™ settings in a way that no link between answers and participants was possible. Items in item batteries were presented in randomized order to avoid primacy and recency effects [64]. Two independent logistic regression analyses between the independent variables and the dependent variables $PPR_{CURRENT}$ and PPR_{FUTURE} was conducted as we expected that the relationships between the personal characteristics could be different for the two outcomes. The likelihood of perceiving sustainability as relevant for their major subject or for their future professional work is represented in the form of odds ratios (*ORs*). The approximate *OR*s were calculated by exponentiating the logistic regression coefficients. *OR*s > 1 indicate that respondents have a greater likelihood of perceiving sustainability as relevant relative to the reference group employed. Conversely, an *OR* < 1 has the opposite interpretation.

Regression models were tested using a bootstrapping procedure [69]. Bias corrected 95% confidence intervals were conducted using 1.000 bootstrap samples. Furthermore, interaction terms of continuous predictors and their log-transformation were analyzed for collinearity, but no significant interaction terms were found ($p > 0.05$). The observed tolerance values for predictors are between 0.89 and 0.95 and VIF values are between 1.16 and 1.27 and therefore indicate no causes of concern [70].

No cases with concerning leverage, Cook's distances or standardized DFBetas were found. Residuals were analyzed for outliers above the limits of ± 3, with no cases found.

3.3. Sample

The online questionnaire was disseminated to all first-year students in 2013 and 2014 (N = 2730). The overall response rate of our study was 50% (see Table 3). In total, n = 1364 students responded (n_{2013} = 756 and n_{2014} = 608). We could not distinguish any external factors resulting in this rather high response rate, but not all respondents answered all questions. Due to lower response rates on some instruments in the survey, cases were excluded listwise before logistic regression analysis, resulting in $n_{\text{PPRCURRENT}}$ = 784 and $n_{\text{PPRFUTURE}}$ = 814 complete data sets in regression analysis. The share of women in the sample is 62%, which can be regarded as representative of the university surveyed. The number of female students there has remained relatively unchanged for years, with a total share of women of 60%. Students' ages ranged from 17 to 51 (M = 21.23; SD = 3.50; n = 1244). All 14 different major subjects offered at the university were represented (n = 1294).

Table 3. Sample distributions.

	Pilot Study		**Present Study**	
	N	**%**	**N**	**%**
Total Sample	1740	100.00	2730	100.00
Response (Rate)	913	52.00	1364	49.90
Sex				
Female	558	61.11	477	34.97
Male	304	33.29	258	18.91
Not indicated	51	0.06	73	5.35
Age	-	-	1244	91.20
Study program				
B.A. Teaching and Learning	111	12.16	242	17.74
B.A. Social Education	32	3.50	57	4.18
B.A. Business Education	27	2.96	48	3.52
Major subject				
Business Administration	156	17.09	214	15.69
Business Information systems	23	2.52	58	4.25
Cultural Science	202	22.12	198	14.52
Digital Media	-	0.00	25	1.83
Economics	20	2.19	34	2.49
Environmental Science*	105	11.50	179	13.12
Studium Individuale	16	1.75	33	2.42
Industrial Engineering	42	4.60	43	3.15
Business Law	70	7.67	43	3.15
Political Science	18	1.97	32	2.35
(Organizational) Psychology	73	8.00	88	6.45
Total	895	98.30	1289	94.50

Note: Age was not included in the pilot study. The major subject Digital Media has been introduced in 2014. Environmental Science including the students from Global Environmental and Sustainability Science.

4. Results

In this chapter, we first give an overview of descriptive statistics on all variables (4.1) and expand on the results regarding the role of individual characteristics on PPRs focusing in particular on the role of students' sustainability conceptions.

4.1. Descriptive Statistics for Independent Variables

Descriptive statistics on independent and dependent variables are displayed in Tables 4–6. In total, more than 46% of the sample (n = 633) indicated that they had prior encounters with sustainability in school (FEE). In addition, students experienced between zero and five informal educational experiences (n = 1287; IEE) before they entered university. Most of the students (74%) reported zero or one, and less than 1.50% had four or five informal experiences. Multiple answers were possible on this scale, so that the relative frequencies cannot be added together. If they had such encounters, most students did some casual work (26%) or completed a vocational training (23%) and/or they travelled longer than two months (21%), including Au-Pair services). Some also completed an internship (14%) after school. Often students did voluntary work (19%) and fewer participated in voluntary social, ecological or cultural services for about a year (11%). Around 12% of the undergraduates studied already before they started again at the university.

We then analyzed to what extent students associate different dimensions with sustainability. We found that the environmental dimension (Mdn = 6.5, n = 1156, IV: env_con) was most strongly associated with the concept of sustainable development, followed by the sociocultural (Mdn = 5.50; n = 1155; IV: soccul_con) and the economic dimension (Mdn = 5.00, n = 1154; IV: econ_con). Median values have been compared with Wilcoxon ranked sign test for paired samples because the scores for environmental (D (1.154) = 0.20, $p < 0.001$), sociocultural (D (1.154) = 0.11, $p < 0.001$) and economic dimensions of sustainability conceptions (D (1.154) = 0.10, $p < 0.001$) were deviating significantly from normal. All median values were significantly different ($p < 0.001$) and effect sizes varied from r = 0.57 to r = 0.36. The value for the environmental dimension indicated the possibility of a ceiling effect, which might reduce the variance.

4.2. Descriptive Statistics for Dependent Variables

We cross-checked QQ-plots and skewness and kurtosis to control for large sample size effects. As for the dependent variable, a total of 46% of n = 1364 students perceive sustainable development as relevant for their major subject ($PPR_{CURRENT}$). More than 52% think that sustainable development will be relevant for their future professional work (PPR_{FUTURE}). The drop out for $PPR_{CURRENT}$ is n = 563 and the drop-out for PPR_{FUTURE} is n = 530. In total, only n = 763 students answered both questions. The reason for the high dropout rates in the dependent variables might result from their position at the end of the questionnaire. Due to the relatively high drop-out rate in the dependent variables, we carried out a detailed analysis of the dropouts on $PPR_{CURRENT}$ and PPR_{FUTURE} as well as on all independent variables in order to find out whether values are missing at random and can be excluded listwise in the following steps of analysis. The MCAR-Test indicates that the pattern of missing values in quantitative variables is random (χ^2 = 9.43, p = 0.08) [71].

However, separate t-tests showed that missing values in the independent variable age and the dependent variable $PPR_{CURRENT}$ and PPR_{FUTURE} were significantly related. To control for possible effects on the generalizability of the data, age will be excluded from the logistic regression analysis.

Table 4. Frequencies for categorical IVs and DVs.

Variable	Name	Category	Frequencies	% (n = 1364)
IV	SEX	Female	477	34.97
		Male	258	18.91
		No answer	73	5.35
IV	FEE	ESD in School	633	46.40
		No ESD in School	254	18.60
DV	$PPR_{CURRENT}$	Yes	631	46.30
		No	170	12.50
DV	PPR_{FUTURE}	Yes	712	52.20
		No	122	8.90

Note: Entries calculated with SPSS 24.

Table 5. Descriptive statistics (means, standard deviations, minimum and maximum) for continuous IVs.

Variable	*M*	*SD*	Min	Max	*n*
AGE	21.23	3.50	17	51	1244
Econ_con	4.77	1.06	1	7	1154
Env_con	6.41	0.65	1	7	1156
Soccul_con	5.50	1.03	1	7	1155
IEE	1	-	0	5	1287

Note: Entries calculated with SPSS 24. For the ordinal scaled variable IEE we calculated the median.

Table 6. Spearman pairwise correlations for ordinal and interval scaled IVs.

Variables		AGE	Eco_con	Env_con	Soccul_con	IEE
AGE	*r*	1				
	p					
Eco_con	*r*	0.038	1			
	p	0.193	.			
Env_con	*r*	−0.030	0.128 **	1		
	p	0.306	< 0.001	.		
Soccul_con	*r*	−0.032	0.202 **	0.296 **	1	
	p	0.278	< 0.001	< 0.001	.	
IEE	*r*	0.200 ***	−0.062 *	0.041	0.104 **	1
	p	< 0.001	0.036	0.166	< 0.001	.

Note. * $p \leq 0.05$. ** $p \leq 0.01$. Econ_con = economic CSD. Env_con = environmental CSD. Soccul_con = sociocultural CSD. n = 1153.

4.3. The Role of Individual Characteristics for PPRs

In the first step of binary logistic regressions, we added independent variables in three different models in order to choose the most parsimonious for further analysis [72] (pp. 767–768). The logistic regression model was performed to describe the relationships between individual characteristics with undergraduate first year students' PPRs of sustainability. We added variables in three blocks with hierarchical analysis of each block. First, we tested a model only with sex and academic affiliation (major subject). Second, we tested a model with sex, major subject and the three dimensions of sustainability conceptions. In the third block, we added formal and informal educational experience. The models were tested independently for both DVs ($PPR_{CURRENT}$ and PPR_{FUTURE}). In what follows, we will first report the model test for $PPR_{CURRENT}$, and then for PPR_{FUTURE} (see Figure 1).

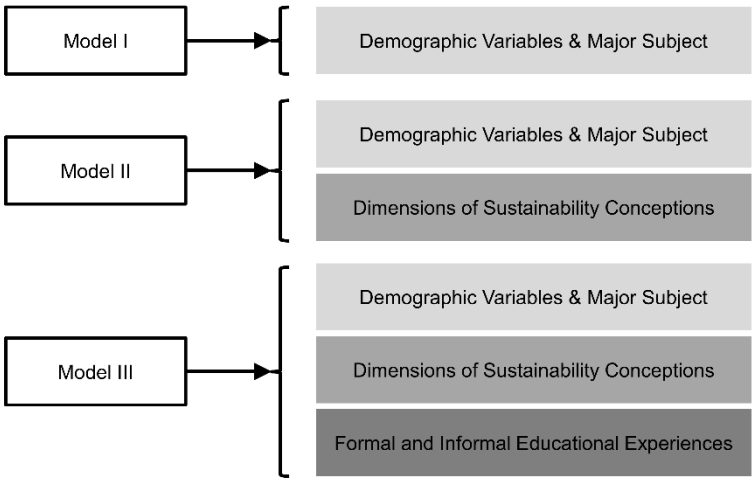

Figure 1. The three models tested in the first step of binary logistic regression to find the most parsimonious model for the prediction of current and future perceived professional relevance of sustainability.

4.4. Results for $PPR_{CURRENT}$

The logistic regression model II for $PPR_{CURRENT}$ was statistically significant, χ^2 (19) = 122.37, $p < 0.000$, and bootstrapping based on 1000 samples was applied. The final model III explained 22% (Nagelkerke R^2) of the variance in $PPR_{CURRENT}$ and correctly classified 80% of the cases.

Tables 7 and 8 show the results regarding the measures of relations of sustainability to students' major subject. Odds ratio (*OR*) for the outcome variable $PPR_{CURRENT}$ yielded several significant results. Four (sex, major subject, sociocultural dimension of sustainability and informal educational experiences) of the eight predicator variables had significant relationships with $PPR_{CURRENT}$. Planned simple contrasts were calculated to compare all major subjects to the biggest group of students: B.A. Teaching and Learning a teacher training program for primary, lower secondary and intermediate school. Next relationships will be explained in greater detail.

First, the odds of male students perceiving sustainability as relevant for their major subject were 1.73 times higher than for female students. This means that in our study the probability of perceiving sustainability as relevant for one's own academic affiliation was 73% higher for men than for women. Second, students of Environmental Science (*OR* = 19.30), B.A. Social Education (*OR* = 4.07) and Engineering (*OR* = 3.72) were more likely to perceive sustainability as relevant for their major subject than students who study the B.A. Teaching and Learning. Also, students of Studium Individuale (*OR* = 3.55), Cultural Science students (*OR* = 2.42), and Business Administration (*OR* = 2.02) perceived sustainability as more relevant for their major subject than teacher training students. In contrast, students enrolled in digital media (*OR* = 0.17) perceived sustainability less likely as important than B.A. Teaching and Learning students. Listwise deletion resulted in small samples for students from B.A. Social Education (*n* = 36), Digital Media (*n* = 17), Engineering (*n* = 23) and Studium Individuale (*n* = 23). These results should be interpreted with caution. Third, a stronger association of sociocultural aspects with sustainability resulted in a 1.53 greater likelihood of perceiving sustainability as relevant for their major subject ($PPR_{CURRENT}$). Fourth, odds ratio of the predictor IEE indicated that the more informal educational experiences students had gained before they start their studies, the greater the likelihood that they perceive sustainability as relevant for their major subject (*OR* = 1.37).

Finally, the economic and environmental dimensions of sustainability conceptions as well as formal learning experiences were not associated with $PPR_{CURRENT}$.

Table 7. Logistic regression predicting likelihood of current perceived professional relevance of sustainability ($PPR_{CURRENT}$) based on students' individual characteristics.

	Model I						Model II						Model III					
				95%CI for OR						95%CI for OR						95%CI for OR		
	B		*SE*	*LR*	*OR*	*UR*	*B*		*SE*	*LR*	*OR*	*UR*	*B*		*SE*	*LR*	*OR*	*UR*
Sex (reference = female)	0.31		0.23	0.88	1.36	2.12	0.54	*	0.24	1.07	1.72	2.76	0.55	*	0.26	1.07	1.73	2.80
Major subject (reference = B.A. Teaching and Learning)																		
B.A. Social Education	1.29	*	0.56	1.21	3.64	10.96	1.27	*	0.57	1.17	3.57	10.91	1.40	*	0.58	1.31	4.07	12.65
B.A. Business Education	0.06		0.44	0.45	1.06	2.52	0.03		0.45	0.43	1.03	2.50	0.12		0.46	0.46	1.13	2.76
Business Administration	0.40		0.29	0.85	1.49	2.62	0.60	*	0.30	1.01	1.82	3.26	0.70	*	0.30	1.11	2.02	3.67
Digital Media	−1.73	**	0.57	0.06	0.18	0.54	−1.67	**	0.58	0.06	0.19	0.59	−1.77	**	0.59	0.05	0.17	0.54
Industrial Engineering	0.99		0.66	0.74	2.69	9.81	1.22	*	0.68	0.90	3.38	12.75	1.31	*	0.68	0.98	3.72	14.06
Cultural Science	0.84	*	0.31	1.26	2.32	4.29	0.89	**	0.32	1.29	2.43	4.57	0.88	**	0.33	1.28	2.42	4.58
Political Science	0.95		0.65	0.72	2.59	9.31	0.91		0.68	0.66	2.47	9.28	0.85		0.68	0.61	2.34	8.91
Business Law	−0.51		0.46	0.25	0.60	1.48	−0.48		0.47	0.25	0.62	1.55	−0.43		0.48	0.26	0.65	1.65
Studium Individuale	1.08		0.65	0.83	2.95	10.49	1.29	*	0.67	0.98	3.62	13.35	1.27	*	0.67	0.96	3.55	13.15
Economics	−0.10		0.51	0.34	0.90	2.43	0.06		0.52	0.39	1.07	2.92	0.14		0.52	0.42	1.15	3.19
Business Information Systems	0.32		0.52	0.50	1.38	3.83	0.47		0.54	0.56	1.60	4.58	0.50		0.55	0.56	1.64	4.78
Organizational Psychology	0.04		0.36	0.51	1.04	2.12	0.20		0.37	0.59	1.22	2.54	0.25		0.38	0.61	1.28	2.67
Environmental Science	2.97	**	0.61	5.87	19.51	64.86	2.99	**	0.62	5.89	19.78	66.48	2.96	***	0.62	5.74	19.30	64.94
Dimensions of sustainability conceptions																		
Economic dimension							−0.03		0.10	0.80	0.97	1.18	−0.02		0.10	0.81	0.98	1.19
Environmental dimension							0.17		0.15	0.89	1.19	1.59	0.19		0.15	0.90	1.20	1.61
Sociocultural dimension							0.45	**	0.10	1.29	1.56	1.89	0.43	**	0.10	1.26	1.53	1.86
Educational Experience																		
Formal (reference = no FEE)													−0.18		0.21	0.83	0.83	1.25
Informal													0.31	*	0.12	1.37	1.37	1.74
Constant	0.72	***	0.19		2.05		−2.79	*	1.04		0.06		−2.88	**	1.10		0.06	
Observations	784						784						784					
(-2LL)	722.63						694.96						687.58					
Nagelkerke R^2	0.16						0.21						0.22					
Classification accuracy	79.70%						80.10%						80.00%					

Note: * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$. OR = Odds ratio. CI = Confidence interval. LR = Lower. UR = Upper.

Table 8. Logistic regression predicting likelihood of perceived professional relevance of sustainability (PPR_{FUTURE}) for future professional work based on students' individual characteristics.

	Model I						Model II						Model III					
				95%CI for OR						95%CI for OR						95%CI for OR		
	B		*SE*	*LR*	*OR*	*UR*	*B*		*SE*	*LR*	*OR*	*UR*	*B*		*SE*	*LR*	*OR*	*UR*
Sex (reference = female)	0.02		0.24	0.63		1.64	0.23		0.26	0.76	1.26	2.09	0.24		0.26	0.77	128	2.12
Major subject (reference = B.A. Teaching and Learning)																		
B.A. Social Education	1.09		0.76	0.67	2.99	13.35	1.02		0.77	0.61	2.76	12.42	0.98		0.77	0.59	2.68	12.08
B.A. Business Education	1.00		0.77	0.61	2.72	12.22	0.96		0.77	0.57	2.60	11.81	0.97		0.77	0.58	2.64	11.99
Business Administration	0.20		0.33	0.43	0.82	1.56	−0.05		0.34	0.49	0.95	1.84	−0.02		0.34	0.50	0.98	1.92
Digital Media	−1.14	*	0.56	0.11	0.32	0.97	−1.05	**	0.57	0.12	0.35	1.07	−1.02		0.57	0.12	0.36	1.11
Industrial Engineering	−1.12	*	0.52	0.12	0.33	0.90	−0.96		0.53	0.14	0.38	1.08	−0.96		0.53	0.14	0.38	1.09
Cultural Science	−0.02		0.35	0.50	0.98	1.92	−0.07		0.35	0.47	0.93	1.86	-0.07		0.35	0.47	0.93	1.86
Political Science	0.05		0.67	0.28	1.05	3.89	−0.08		0.68	0.24	0.93	3.54	−0.05		0.69	0.25	0.95	3.64
Business Law	0.15		0.67	0.32	1.17	4.30	0.23		0.67	0.34	1.26	4.68	0.25		0.67	0.34	1.29	4.82
Studium Individuale	0.16		0.66	0.32	1.17	4.29	0.24		0.67	0.34	1.27	4.74	0.19		0.67	0.32	1.21	4.53
Economics	−0.86		0.52	0.15	0.42	1.18	−0.73		0.53	0.17	0.48	1.36	−0.70		0.53	0.18	0.50	1.42
Business Information Systems	−0.75		0.53	0.17	0.47	1.33	−0.68		0.54	0.18	0.51	1.45	−0.67		0.54	0.18	0.51	1.47
Organizational Psychology	−0.51		0.40	0.27	0.60	1.32	−0.41		0.41	0.30	0.67	1.49	−0.39		0.41	0.30	0.68	1.52
Environmental Science	2.05	**	0.63	2.26	7.73	26.49	1.98	**	0.63	2.09	7.21	24.87	1.98	**	0.63	2.10	7.24	24.97
Dimensions of sustainability conceptions																		
Economic dimension							−0.12		0.11	0.72	0.89	1.09	−0.12		0.11	0.72	0.89	1.09
Environmental dimension							0.21		0.16	0.91	1.24	1.68	0.22		0.16	0.91	1.24	1.69
Sociocultural dimension							0.34	**	0.10	1.15	1.41	1.72	0.36	**	0.10	1.16	1.43	1.75
Educational experience																		
Formal (reference = no FEE)													0.27		0.24	0.81	1.30	2.09
informal													0.04		0.12	0.82	1.04	1.33
Constant	1.74	***	0.23		5.67		−1.00		1.08		0.37		−1.49		1.08		0.23	
Observations	814						814						814					
(-2LL)	631.56						616.04						614.68					
Nagelkerke R^2	0.10						0.14						0.14					
Classification accuracy	85.30%						85.50%						85.50%					

Note. * $p \leq 0.05$; ** $p \leq 0.01$; *** $p \leq 0.001$. OR = Odds ratio. CI = Confidence interval. LR = Lower. UR = Upper.

4.5. Results for PPR_{FUTURE}

In Table 8, the effects of the predictor variables (IV) and the second outcome variable PPR_{FUTURE} are displayed. In case of PPR_{FUTURE}, adding formal and informal educational experiences in model III did not result in a significant change in the χ^2-statistics. Therefore, we stayed with model II. In comparison to the model for $PPR_{CURRENT}$, only two of the hypothesized predictor variables had a significant relationship with the outcome. The logistic regression model was statistically highly significant, $\chi^2(17) = 65.12$, $p < 0.001$, and bootstrapping based on 1,000 samples was applied. The model explained 14% (Nagelkerke R^2) of the variance in PPR_{FUTURE} and correctly classified 86% of the cases.

We found, that academic affiliation and the sociocultural dimension of sustainability conceptions showed a significant relationship with PPR_{FUTURE}. Environmental Science students expressed a 7.21 greater likelihood to attach relevance of sustainability to their future professional work than B.A. Teaching and Learning students. Surprisingly, no further contrasts were found for other academic affiliations. In addition, a stronger association of sociocultural aspects with sustainability was correlated with increasing likelihood of perceiving relevance of sustainability for future professional work contexts ($OR = 1.41$). Finally, sex, the economic and environmental dimension as well as formal and informal education were not associated with PPR_{FUTURE}.

5. Discussion

This study explored how relevant first year students at a German university with an explicit sustainability profile consider sustainability to be for their current and future professional career (RQ1), what different sustainability conceptions they hold (RQ2), and in how far these conceptions inform their perceived professional relevance compared to other influencing factors (RQ3).

5.1. Findings

Regarding RQ1, our findings corroborate earlier works and show that almost half of all students considered sustainability as relevant for their major subject ($PPR_{CURRENT}$), and more than half for their future professional work contexts (PPR_{FUTURE}) prior to commencing their undergraduate studies. Already Azapagic et al. [22] and Bone and Agombar [23] have shown that undergraduate students conceive of sustainability as being important for their future career trajectory. Interestingly, Barth and Timm [25] showed that second and fourth semester students from the same university analyzed in our LISHE case study scored lower when they were asked to look back at how relevant they had perceived sustainability in the first semester (29%). However, the authors report that when they were asked how relevant sustainability is to them presently, this perception increased substantially, in particular for students in sustainability-related programs.

Regarding RQ2, this study found that although every dimension of sustainability was recognized by the students, differences were observed regarding the extent to which they associate economic, environmental and sociocultural aspects. Differences in median values reveal that students associate the environmental dimension to a greater extent with sustainability than other dimensions. Here, too, our findings support previous works highlighting environmental biases in sustainability conceptions (e.g., [25,51–53,55,57,59]). An important extension of previous works is that although students associate sustainability most strongly with the environmental dimension, this dimension is not significant as a predictor.

Regarding RQ3, our study has identified the sociocultural dimension of sustainability conceptions as a relevant factor influencing in how far students perceive sustainability to be relevant for the current major subject and future professional work. This is somewhat surprising as existing research found that the sociocultural dimension of sustainability is often disregarded by undergraduate and pre-university students [58,73] or neglected as an important dimension of sustainability conceptions at all [11]. More so, our study showed that it was not just considered by students, but also significantly correlated with the environmental dimension. A possible explanation for this is that students respond with more

positive emotions to sociocultural aspects of sustainability, as emotions and values have been shown to play a strong role in the ways that students make meaning of sustainability [74]. If this was the case, then this may provide an explanation for the predictive effect of sociocultural sustainability conceptions on both $PPR_{CURRENT}$ and PPR_{FUTURE} of sustainability among students. Another explanation could be that the share of students interested in social studies is high in this sample and has led to a stronger relation of this dimension to perceived relevance. However, these tentative explanations would require further exploration and substantiation.

Our study also confirms that students' academic affiliation and sex was associated with a greater likelihood of perceiving sustainability as relevant for current study contexts. Other findings confirming previously reported results are that environmental science students are more likely to consider sustainability relevant for their studies and their career than teacher training students. This finding is not surprising, given that sustainability is a key concept in environmental science students' major subject ($PPR_{CURRENT}$). Equally plausible is greater likelihood of PPR_{FUTURE} as it can be assumed that the students are already aiming for a sustainability-related position at the beginning of their studies. For teacher training students, the connection between their professional future and sustainability is probably less clear in this early stage of their studies.

Teacher training is one of several academic programs that our data showed to have some interesting nuances. In teacher training, students with a focus on vocational social education perceive sustainability to be more relevant to their studies than students for primary, lower secondary and intermediate schools. A possible explanation for that is that the B.A. Program for Social Education attracts students with a greater predisposition for social responsibility. Other noteworthy differences between major subjects can be identified for Engineering and Business Administration students who have higher scores in PPR than teacher training students. A possible explanation for this is that the fields of engineering sciences and economics at the case university have embraced sustainability more explicitly, which may have attracted students. However, this does not seem to extend to Digital Media students as they do not seem to be able to establish a link between their major subject and sustainability. However, it may also be that the field appears clearly defined and technically positioned that it is difficult to establish a relationship between the key topics of the academic affiliation and SD.

One unanticipated finding was that those students who identified themselves as being male had a greater likelihood to view sustainability as relevant for their major subject ($PPR_{CURRENT}$). This was surprising, as several other studies have shown that female students tend to display greater environmental concern [75], which we would have expected to result in stronger connections between their perceived relevance of sustainability and their major subject. A possible explanation is that in smaller samples, variance of answers can be reduced. This takes into account that probably only interested and motivated male individuals might have participated in the survey.

Finally, it is generally noteworthy that the explained variance in $PPR_{CURRENT}$ and especially for PPR_{FUTURE} was rather low. Obviously, the suggested predictors lacked incremental power, especially for describing the relationship of the factors and PPR_{FUTURE}. We see three possible explanations:

1. **Lack of studies looking into antecedents of relevance:** Most studies on relevance and conceptions in the field of HESD describe students' conceptions rather than analyzing the determinants and antecedents of these constructs. Overall, our results show that the predictors drawn from the literature lack incremental power and seem to be rather unspecific. Thus, we suggest looking into values [46] and more specific aspects why students might relate sustainability to their particular major subject, given that previous research has shown that the perceived importance of peoples' goals is strongly related to their values [76];
2. **Lack of quality in previous sustainability-related education:** Recent evidence from a representative study of German youths and young adults suggests that ESD is widely treated as an add-on topic ("teaching about sustainability") rather than an integrative perspective ("ESD as a teaching approach") [77] pp. 121–123. While this may help to improve students' familiarity with the term sustainability, it may be limited in its ability to significantly improve students' perceived

relevance of sustainability [78]. In this vein, future work may seek to include a more qualitative predictor to better account for the quality of previous formal and informal ESD experience;

3. **Lack of sophisticated sustainability conceptions in media-induced learning:** Recent findings show that while German newspapers have increasingly used sustainability terminology, they still refer to it mostly in an everyday language meaning of something being long-lasting or very intense [79]. The exposure to mass media may have contributed to an overall high familiarity with the term on the one hand but could have also given rise unspecific and unsophisticated understandings of it that may impede the perception of the concept as being relevant on the other hand.

5.2. Limitations

There are certain limitations of this study that need to be considered. In both regression analyses, we were able to show relationships only for two or three independent variables. This might suggest that PPRs are not related with other variables. It is more plausible, however, that the lack of connections, especially for sex, was a methodological inconsistency or an artefact of the unbalanced sample ratio between men and women. Furthermore, items with ceiling effects such as 'protecting ecosystems for future generations' or 'conservation of natural resources' (as aspects of sustainability conceptions) and different group sample sizes could be responsible for the lack of connections of the independent variables.

We make no claims that the survey sample is representative for the cohorts. The study was conducted with limited knowledge about sociocultural background, years of education or further information on students' individual characteristics and how these might influence students' responses. Finally, despite the large number of the survey respondents, the scope of the study was limited to a comparatively uniform group - first year students in one university in one European country in a 2-year time frame. In view of these limitations, an essential contribution of our study is to have developed and tested an empirically based approach that can be used to empirically clarify the connections between different established influential factors and PPRs. The model developed is necessarily limited in its external validity and generalizability. A promising direction for further research in this field could be to apply the approach tested here to other national, historical, cultural and institutional settings and to examine the differences and similarities that emerge.

5.3. Implications for Future HESD Research and Theory-Building

We see theoretical implications for further theory-building on PPR of sustainability as a construct in the conceptualization of learning outcomes and as a covariate especially in the detected lack of powerful predictors. As the predictors included in this study do not have a lot of incremental power and seem to be rather unspecific, further research is needed to probe the contribution of other variables. These could be, for example, individual values or practical relevance in a course or the way in which a teaching approach is designed. Furthermore, more research is needed on specific constructs or aspects that investigate what perceived relevance could mean more specifically in the context of major subjects (e.g., educating future change agents as a teacher, designing less resource-consuming products as an engineer) or different universities. Overall, our research shows that there is a need for greater consistency in the application of concepts and terms in research on student conceptions and perceptions of sustainability. Our review of existing works revealed that the terms *perception* or *view* are more often used in the context of how students perceive the implementation of sustainability in their professional contexts or how they perceive ESD, whereas the term *conception* refers to the mental representation of (aspects of) a concept. Future research should ensure greater consistency in the usage of these terms and the definitions underpinning them in order to allow for more comparable results and a consolidation of research. A further limitation for the generalization of results and models on conceptions and PPRs lies in the study designs, which are based on concepts developed in Western cultural settings and restricted to data collected in a case study context. While this study did not aim

to produce generalizable results, it seems worthwhile to build on our findings to explore how similar research in different contexts would yield differences and similarities that could then inform further theory building.

5.4. Practical Implications for Teaching Approaches in HESD

Which recommendations can be derived from these findings for the development of teaching approaches in HESD as to increase PPRs and sophistication of students' sustainability conceptions? We see three possible implications: first, given the variations in sustainability conceptions that students bring to the classroom, the instrument can inform the design of learning settings, which should provide adequate room for a critical and non-affirmative engagement with divergent sustainability conceptions. In light of the important role that prior experiences seem to play for the formation of these conceptions, learning settings should provide sufficient opportunities for students to reflect on previous informal and formal experience in their learning process [80]. Two practical implications can be drawn from this result. Universities need to offer support—especially for first year students with less informal experiences—in developing PPRs of sustainability. One possible way to leverage students' perceptions of sustainability as being professionally relevant could be to more explicitly communicate the advantages of integrating sustainability issues into curricula to and with students.

Additionally, university teachers dealing with sustainability issues should be aware of the importance of prior informal learning experiences of their first semester students and provide opportunities for transfer of this informal knowledge especially in the first semesters. Second, curriculum designers in HESD may work to strengthen the sociocultural aspects of sustainability, as these seem to be the most important factors when it comes PPRs of sustainability. For example, explicit efforts could be made to complement the presentation of environmental and/or economic-technical issues with a discussion of sociocultural conditions or implications of sustainability. Third, HESD teaching approaches should more explicitly enable students to actively engage with different understandings of sustainability. Teaching approaches including for instance mindfulness practices [81] may enable students to reflect on different understandings and provide opportunities for conceptual change.

6. Conclusions

With the SDGs, sustainability is today a key idea and concept in politics, the private and corporate sector, as well as civil society worldwide. Universities play a key role in engaging students with different concepts of sustainability so that they can develop their own understanding and use it as a framework to decide and act in different contexts. The findings of this study reveal significant differences between first year students' sustainability conceptions and the relevance that they ascribe to sustainability for their current studies and future professional contexts. These findings highlight a twofold challenge that HESD is facing to increase its effectiveness: first, to more adequately address the wide range of undergraduates' sustainability conceptions; and second, to make their academic engagement with sustainability more relevant for their current and future professional work. Our research suggests that possible curricular innovations could highlight sociocultural aspects of sustainability in order to enhance the perceived relevance of sustainability in professional contexts. This study provided a first exploration of the link between different individual characteristics, sustainability conceptions, and the relevance that students ascribe to sustainability for their professional lives that future studies in HESD research can build up on.

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4.3 Chapter#3: Students' sustainability conceptions in the course of study: Insights from a longitudinal study

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9 Das Nachhaltigkeitskonzept Studierender im Studienverlauf: Einsichten aus einer Längsschnittstudie

Anna Sundermann

9.1 Idee und Hintergrund der Studie

Hochschulbildung für nachhaltige Entwicklung (HBNE) zielt einerseits darauf ab, Lernenden den Erwerb von notwendigen Fähigkeiten und Fertigkeiten zu ermöglichen, um Lösungsansätze für Nachhaltigkeitsprobleme entwickeln, umsetzen und kritisch betrachten zu können, und andererseits, die individuelle Entwicklung der Studierenden zu unterstützen (Michelsen & Fischer, 2016). Innerhalb dieser zwei übergeordneten Zielsetzungen formulieren Wiek et al. (2016, S. 248) als ein konkretes Lernziel nachhaltigkeitsbezogener Lehre, dass Studierende ein Verständnis davon entwickeln, inwiefern Konzepte wie Gerechtigkeit, Verantwortung oder Umweltschutz mit dem übergeordneten Konzept einer nachhaltigen Entwicklung zusammenhängen. Basierend auf dieser Grundlage wird in diesem Beitrag die individuelle und subjektive Auslegung der Idee einer nachhaltigen Entwicklung, im Weiteren *Nachhaltigkeitskonzept*, als ein manifester Aspekt von normativer Kompetenz verstanden. Normative Kompetenz bildet mit fünf anderen vorgeschlagenen Kompetenzen einen viel beachteten Vorschlag dazu, welche konkreten Kompetenzen Studierende in nachhaltigkeitsbezogener Lehre entwickeln (Wiek et al., 2016).

In den vergangenen 25 Jahren hat sich ein reger akademischer Diskurs über diese Lernziele in der HBNE entwickelt (Brundiers et al., 2021). Ebenso liegt inzwischen eine Vielzahl von Fallbeispielen vor, die aufzeigen, wie entsprechende Lernziele in hochschulischen Lehr-Lern-Formaten adressiert werden (Weiss & Barth, 2019). Unklar ist hingegen, *ob* und wenn ja, *wie* die entwickelten nachhaltigkeitsbezogenen Lehr-Lern-Formate und Studienprogramme die Studierenden beim Erwerb von Kompetenzen unterstützen (Lozano et al., 2017).

Daher werden in diesem Beitrag Teilergebnisse einer Studie vorgestellt, die der Frage nachgegangen ist: *Wie verändert sich das Nachhaltigkeitskonzept der Studierenden eines Bachelorstudiums mit vielfältigen Möglichkeiten zur Auseinandersetzung mit nachhaltiger Entwicklung innerhalb eines dreijährigen Zeitraums?*

Diese Fragestellung basiert auf der Annahme, dass Lernen innerhalb von nachhaltigkeitsbezogenen Studienprogrammen nicht vollumfänglich verstanden werden kann, ohne die Zeitlichkeit von Lernprozessen zu beachten (Brake, 2016). Unter dem Begriff *Lernen* werden in dieser Studie alle intraindividuellen Veränderungen des Nachhaltigkeitskonzepts der Studierenden in einem festgelegten Zeitraum gefasst. Diese Veränderungen können sowohl durch inhaltlich-formelle Erfahrungen im Studium, aber auch informell entstehen, z.B. durch außer- oder inneruniversitäres Engagement (Zelezny, 1999).

Bisherige Studien zu studentischen Lernprozessen in nachhaltigkeitsbezogener Lehre untersuchen entweder Teilaspekte von Kompetenzen und decken dabei ein Spektrum an kognitiven, affektiven und verhaltensbezogenen Lernergebnissen ab (z.B. Mintz & Tal, 2014) oder betrachten die Entwicklung einer Kompetenz (z. B. Konrad et al., 2020). Dabei werden gleichermaßen qualitative wie quantitative Erhebungs- und Analysemethoden eingesetzt, jedoch handelt es sich meist um Studien mit einem Querschnittdesign (z.B. Sidiropoulos, 2018) oder Studien, die einzelne Lehrveranstaltungen in den Blick nehmen (z.B. Sandri, 2020). Auf Basis dieser Studien wird angenommen, dass ein positiver Zusammenhang zwischen Hochschulbildung und z.B. umweltrelevanten Ein- stellungen besteht (Cotton & Alcock, 2013).

Es gibt wenige empirische Studien, die sich über einen längeren Zeitraum mit dem Zusammenhang zwischen nachhaltigkeitsbezogenen Studienangeboten und studentischen Lernergebnissen beschäftigen. Die existierenden Untersuchungen kommen zu unterschiedlichen Ergebnissen: von keinem Einfluss der Studienprogramme auf umweltbezogene Normen oder Einstellun- gen (Harring et al., 2019; Shephard et al., 2014) bis zu geringen positiven Einflüssen auf das Umwelt- und Nachhaltigkeitsbewusstsein und entsprechender Verhaltensveränderungen (Hay & Eagle, 2020).

Im Rahmen dieser Längsschnittuntersuchung mit vier Befragungszeitpunkten wurden deshalb die Veränderungen in den Nachhaltigkeitskonzepten für zwei Jahrgänge Studierender über den Zeitraum eines Bachelorstudiums miteinander verglichen. Die Ergebnisse dieser Untersuchung zielen darauf ab, Lernprozesse innerhalb eines bestimmten Kontexts und in der Abfolge von Ereignissen nachzuvollziehen, um besser zu verstehen, wie Lernerfahrungen und Lernergebnisse zusammenhängen.

In den folgenden Abschnitten des Beitrags werden Ansatz, Vorgehen und Ergebnisse dieser Studie dargestellt, um so Wirksamkeit von Lehr-Lern-Formaten zu verbessern und die organisationale Entwicklung zu unterstützen.

9.2 Methodisches Vorgehen

9.2.1 Das nachhaltigkeitsbezogene Studienangebot der Leuphana Universität Lüneburg

Zur Zeit der Erhebungen im Zeitraum 2013 bis 2017 verstand sich die Leuphana Universität als humanistische, handlungsorientierte und nachhaltige Bildungseinrichtung. Insbesondere der Gedanke einer nachhaltigen Entwicklung sollte sich in den Wirkungsfeldern Bildung (z.B. nachhaltigkeitsbezogene Lehre), Campusbetrieb (z.B. Bio-Mensa), Gesellschaft (z.B. vielfältige studentische Initiativen) und Forschung (z.B. Fakultät Nachhaltigkeit) widerspiegeln. Das Bachelorstudium an der Leuphana, insbesondere das erste Semester, wurde daher unter Bezugnahme auf Lehr-Lern-Prinzipien einer HBNE gestaltet: Inter- und transdisziplinäres Problemlösen, Umgang mit Komplexität, selbstorganisiertes und kollaboratives Lernen sowie Kompetenzentwicklung (Barth & Timm, 2011).

Das Studienprogramm bestand für alle Studierenden aus einem Haupt- und einem Nebenfach. Alle Studierenden des Programms erhielten im ersten Semester (*Leuphana Semester*) eine verpflichtende Einführung in Nachhaltigkeitsfragen, die aus einer Vorlesung, einem projekt- und forschungsbasierten Seminar und begleitenden Tutorien bestand. Nach dieser verpflichtenden Auseinandersetzung mit Nachhaltigkeitsfragen konnten die Studierenden die Auseinandersetzung mit der Idee einer nachhaltigen Entwicklung mit der Wahl des Haupt- oder Nebenfaches Umweltwissenschaften ab dem zweiten Semester vertiefen (siehe die Beiträge von Matthias Barth, wie auch von Daniel Fischer, Berta Martín-López und Gesche Keding im zweiten Teil dieses Bandes). Zudem stand es allen Studierenden unabhängig von der gewählten Studienrichtung frei, im fachübergreifenden, studienbegleitenden Komplementärstudium nachhaltigkeitsbezogene Lehrveranstaltungen zu belegen (siehe den Beitrag von Sven Prien-Ribcke und Maik Adoßment in diesem Band)[1].

1 Die Studierenden des Lehramts (Lehrerbildung für Grund- Haupt, und Real- sowie Berufsschulen) absolvieren das Leuphana Semester in geringerem Umfang und haben danach nicht die Möglichkeit, ihr Studium mit dem Nebenfach Nachhaltigkeitswissenschaften zu kombinieren. Auch am Komplementärstudium nehmen diese Studierenden in geringerem Umfang teil.

9.2.2 Aufbau der Studie

Zur Beantwortung der Forschungsfrage wurden Studierende zweier Jahrgänge der Leuphana Universität Lüneburg mit Studienbeginn 2013 bzw. 2014 (J1 = Jahrgang 2013/14, J2 = Jahrgang 2014/15) mit Hilfe von Onlinefragebögen befragt. Die Studierenden belegten einen Bachelorstudiengang mit 12 unterschiedlichen Hauptfächern oder einen der drei Lehramtsstudiengänge (B.A. Lehren und Lernen, B.A. Sozialpädagogik für Berufsschulen, B.A. Wirtschaftspädagogik). Erhebungen wurden an vier Messzeitpunkten (Studienbeginn (t0), im zweiten Semester (t1), im vierten Semester (t2) und im sechsten Semester (t3)) vorgenommen. Der Abstand zwischen den ersten beiden Messzeitpunkten betrug sechs Monate; der zwischen den weiteren Messzeitpunkten jeweils 12 Monate. Zwischen dem ersten und dem zweiten Messzeitpunkt lag das Leuphana Semester (siehe 9.2.1). Die Teilnahme an den Erhebungen war freiwillig und anonym. Die Studierenden erhielten keinerlei Aufwandsentschädigung. Der erhobene Versuchspersonencode lässt eine Verbindung der Datensätze zu, ohne die Anonymität der Befragten aufzuheben. Die Befragungsdauer betrug im Durchschnitt 30 Minuten.

Bei der Stichprobe für die Onlineerhebung handelt es sich um eine Gelegenheitsstichprobe (Cozby & Bates, 2012). Diese Art der Stichprobenziehung wird häufig dort verwendet, wo es aus organisatorischen Gründen nicht möglich ist, Versuchspersonen durch verpflichtende Teilnahme oder durch Aufwandsentschädigungen zu rekrutieren und Versuchspersonen mit bestimmten Eigenschaften gezielt aufzufüllen. Eine Schwierigkeit dieser Art der Stichprobenziehung ist, dass Studierende, die ein größeres Interesse an den Themen der Umfrage haben, eher an der Umfrage teilnehmen als nicht interessierte Studierende. Jedoch kann in dieser Untersuchung davon ausgegangen werden, dass durch die Erhebungen in zwei Jahrgängen und die große Zahl an Teilnehmenden mögliche Verzerrungen in der Stichprobe minimiert wurden.

9.2.3 Gestaltung des Fragebogens

Der Online-Fragebogen teilt sich in vier Bereiche und orientiert sich an vorherigen Untersuchungen zu Lernergebnissen und Lernprozessen in der HBNE (Barth & Timm, 2011; Shephard et al., 2015). Der erste Bereich umfasst die demografischen Angaben und Erwartungen an das Studium an der Hochschule (nur zum Zeitpunkt der ersten Erhebung t0). Der zweite Bereich deckt die allgemeinen und nachhaltigkeitsspezifischen Einstellungen, Überzeugungen und Konzepte ab. Im dritten Teil des Fragebogens werden die Studierenden zu ihren Einschätzungen in Bezug auf verschiedene Elemente des Studiums befragt.

Der vierte Bereich des Fragebogens beinhaltet Instrumente zur Messung von Absichten und individuellem nachhaltigem Verhalten, die nicht Gegenstand dieses Beitrages sind (Tabelle 9.1).

Variable	Frage	Items	Antwortoptionen
Geschlecht	Bitte geben Sie ihr Geschlecht an.	n = 1	weiblich/männlich/keine Antwort[2]
Alter	Bitte geben Sie ihr Alter in Jahren an.	n = 1	Alter in Jahren
Studiengang	Welchen Studiengang haben Sie gewählt?	n = 1	15 verschiede Antwortmöglichkeiten (z.B. Kulturwissenschaften)
Nachhaltigkeitskonzept	Hier würden wir gerne von Ihnen wissen mit welchem Ausmaß Sie die folgenden Aspekte mit einer nachhaltigen Entwicklung verbinden?	n = 12	Siebenstufige Likerttype-Items (z.B. Umweltprogramm; soziale Gerechtigkeit), zusammengefasst zu drei Dimensionen mit je vier Items: ökologische, soziokulturelle und ökonomische Dimension

Tabelle 9.1. Items und Antwortmöglichkeiten des Onlinefragebogens

9.2.4 Stichprobe

Die Ursprungsstichprobe besteht aus n = 3.035 Studierenden der Jahrgänge 2013/14 (Jahrgang 1; J1) und 2014/15 (Jahrgang 2; J2). Die Rücklaufquoten beziehen sich deshalb auf die per Universitätsstatistik ermittelten zum Messzeitpunkt eingeschriebenen Studierenden. Der Rücklauf bei Messzeitpunkt t0 beträgt 41% (n = 1.238), bei t1 30% (n = 875), bei t2 noch 16% (n = 442) und bei t3 lediglich 11% (n = 293). Insgesamt besteht die finale Stichprobe aus n = 2.274 Studierenden, von denen jedoch 81% nur an einzelnen Erhebungszeitpunkten teilgenommen haben (n_{J1} = 1.036, n_{J2} = 801). Übereinstimmungen zwischen den Personencodes ließen sich bei n = 321 Studierende für zwei Messzeitpunkte, bei n = 95 für drei und nur bei n = 21 für vier Messzeitpunkte ermitteln. Tabelle 9.2 gibt die Merkmale der Stichprobe nach Jahrgängen an. Die Ausdünnung der Stichprobe über die Messzeitpunkte und die geringe Anzahl der verbundenen Fälle sind in längsschnittlichen Erhebungen keine Seltenheit. Ein Vergleich der in der Stichprobe verbliebenen Studierenden ergab keine systematischen Abweichungen in der Wiederbeteiligung bezogen auf einen Jahrgang. Es gibt einen signifikanten Zusammenhang zwischen dem Geschlecht der Studierenden und der Wiederbeteiligung an der Studie,

2 Die Datenerhebung dieser Studie erfolgte von 2013 bis 2015. Zu dieser Zeit existierte eine geringe Aufmerksamkeit für non-binäre Geschlechter. Aus diesem Grund wurde keine vierte Kategorie für non-binäre Personen angeführt.

χ^2 (1) = 22,60, p < 0,000. Die Chance, dass eine Studentin mehrmals an der Studie teilnimmt, ist demnach 1,8-mal höher als dass ein Student sich wiederholt beteiligt. Außerdem gibt es einen signifikanten Zusammenhang zwischen der Wiederbeteiligung an der Studie und dem Studiengang, χ^2 (4) = 30,78, p < 0,000. Während sich 28% bzw. 22% der Studierenden der Umwelt- und Kulturwissenschaften mindestens ein weiteres Mal an der Studie beteiligen, tun dies nur 16% der Studierenden des Studienprograms B.A. Lehren und Lernen und 13% der Studierenden der Betriebswirtschaftswissenschaften.

Merkmale	**J1**				**J2**			
	t0	**t1**	**t2**	**t3**	**t0**	**t1**	**t2**	**t3**
Geschlecht								
weiblich	459	361	169	106	357	253	155	103
männlich	245	129	62	36	166	113	42	36
fehlend	3	14	9	7	8	5	5	5
	Studiengänge							
B.A. Lehren und Lernen	159	129	59	35	70	49	25	16
	Leuphana Bachelor (Major)							
Betriebswirtschaftswissenschaften	105	72	22	13	104	72	25	21
Kulturwissenschaften	108	85	48	30	83	55	34	27
Umweltwissenschaften[a]	94	72	47	30	81	63	50	34
Referenzgruppe (alle übrigen Studierenden)	241	146	64	41	193	132	68	46
Alter (in Jahren)	Mittelwerte (Standardabweichungen)							
	21,16 (3,30)	21,49 (3,32)	22,58 (2,54)	23,15 (2,53)	21,29 (3,89)	22,02 (4,42)	22,55 (4,19)	23,70 (4,54)

Anmerkung: J1 = Jahrgang 2013/2014; J2 = Jahrgang 2014/15. a: inklusive Environmental and Sustainability Studies

Tabelle 9.2. Merkmale der Stichprobe in absoluten Häufigkeiten

9.3 Veränderungen im Nachhaltigkeitskonzept als Lernprozess

An vier Zeitpunkten während ihres Studiums wurde erhoben, wie sehr Studierende bestimmte sozio-kulturelle, ökologische und ökonomische Kernaspekte mit der Idee der nachhaltigen Entwicklung verbinden. Diese Antworten werden als subjektive Repräsentationen (individuelles Nachhaltigkeitskonzept) der von den Vereinten Nationen geprägten Kernaspekte der Idee einer nachhaltigen Entwicklung aufgefasst (UNESCO, 2006).

Bei einer Längsschnittstudie sind zwei Besonderheiten zu beachten: Erstens müssen alle Beobachtungen von verschiedenen Zeitpunkten ein- und derselben Person als abhängige Beobachtungen betrachtet werden, sodass man individuelle Veränderungen über die Zeit hinweg nachzeichnen kann. Zweitens sind diese individuellen Beobachtungen einer Person eingebettet in die Zusammenhänge von Studiengängen und Jahrgängen, sodass eine hierarchische Struktur entsteht (z.B. Ebene 1: vier Messungen „innerhalb" einzelner Studierender, Ebene 2: Unterschiede zwischen den Studierenden). Um beide Ebenen abbilden zu können, bedient man sich in der Analyse der Daten gemischter linearer Modelle (Field, 2013). Wie bei Shephard et al. (2015) vorgeschlagen, werden in dieser Studie neben dem Studienverlauf (z.B. 0 = t0, Studienbeginn) der Studiengang als 5-stufige kategoriale Einflussgröße (z.B. 1 = B.A. Lehren und Lernen) sowie der Jahrgang als binäre Einflussgröße (z.B. 0 = J1) in die Analyse einbezogen. Die Studienprogramme wurden zusammengefasst, um die Gruppengrößen möglichst homogen zu gestalten und die vier größten Studierendengruppen gezielt vergleichen zu können.

Es wird angenommen, dass sich diese Einflussgrößen auf das *Nachhaltigkeitskonzept* mit den drei Dimensionen *soziokulturell* (*KNK_sozkul*), *ökologisch* (*KNK_öko*) und *ökonomisch* (*KNK_ökon*) (Sundermann & Fischer, 2019) auswirken und dass sich die Ausprägungen mit der Zeit verändern. Da vor dieser Untersuchung keine spezifischen Erkenntnisse zu den Wechselbeziehungen zwischen den Einflussgrößen vorlagen und um eine große Modellpassung zu erreichen, wurden mehrere mathematische Modelle getestet. Das einfachste Modell 1 beinhaltete die Einflussgrößen, die sich über die Zeit nicht (z.B. Jahrgang) oder konstant verändern (z.B. Studienverlauf in Monaten) und Unterschiede zwischen den Studierenden erklären (fixed effects). In Modell 2 wurden die Zufallseffekte innerhalb der Studierenden in die Modelle aufgenommen. Mit Hilfe dieser Zufallseffekte (random effects) können Einflüsse der Messwiederholung innerhalb der Studierenden geschätzt werden. Zuletzt wurden bei den Schätzungen in Modell 3a-d sukzessive Wechselwirkungen

(z.B. Studiengang*Studienverlauf) der festen Effekte aufgenommen, um zu sehen, ob sich jeweils die Passgenauigkeit des Modells für die Einflüsse zwischen den Studierenden erhöht. Um herauszufinden, welches dieser Modelle die Daten am besten beschreibt, wurden diese anhand der Log-Likelihood-Funktion und des AIC-Koeffizienten miteinander verglichen. Je kleiner die Koeffizienten, desto größer die Passgenauigkeit des Modells.

Im Modell 1 betrugen die AIC-Werte $AIC_{KNK\_sozkul} = 7538{,}38$, $AIC_{KNK\_öko} = 5053{,}54$ und $AIC_{KNK\_ökon} = 7658{,}67$. Es zeigt sich, dass für die Veränderungen in den drei Dimensionen des Nachhaltigkeitskonzepts das Modell 2 oder das Modell 3a mit Wechselwirkungen jeweils die größte Modellpassung aufwiesen: $AIC_{KNK\_sozkul} = 7399{,}83$, $AIC_{KNK\_öko} = 5008{,}29$ und $AIC_{KNK\_ökon} = 7568{,}39$. Bei $n = 277$ Fällen (9,7%) fehlen die Antworten bei den drei abhängigen Variablen, diese Fälle wurden bei der Berechnung der linearen Modelle nicht berücksichtigt.

Abbildung 9.1 vermittelt einen ersten Eindruck der Veränderungen in den drei Dimensionen des Nachhaltigkeitskonzepts (sozio-kulturell, ökologisch und ökonomisch) über den Studienverlauf hinweg. Beispielsweise deuten die gefetteten Linien, die sich in jedem der Kästen im Achsenabschnitt und Neigung unterscheiden, an, dass der Studiengang einen starken Zusammenhang mit den Ausprägungen der Dimensionen des Nachhaltigkeitskonzepts hat. Dies würde bedeuten, dass beispielsweise Studierende der Kulturwissenschaften in ihrem Nachhaltigkeitskonzept eher soziokulturelle Aspekte akzentuieren, während Studierende der Betriebswirtschaftswissenschaften in einem größeren Maß ökonomische Aspekte mit ihrer Vorstellung von der Idee einer nachhaltigen Entwicklung verbinden. Die studiengangsbedingten Akzentuierungen in den Ausprägungen scheinen sich auch im Studienverlauf kaum zu verändern. Auf der anderen Seite deuten die grauen Linien im Hintergrund eine starke Variabilität innerhalb der einzelnen Studierenden von Zeitpunkt zu Zeitpunkt an. Zudem verweist die Abbildung darauf, dass unabhängig vom Studiengang die ökologische und die soziokulturelle Dimension stärker ausgeprägt sind. Im nächsten Abschnitt sollen nun diese ersten augenscheinlichen Vermutungen mit den statistischen Antworten verglichen werden, um ein genaueres Bild der Einflüsse und Wechselwirkungen zu bekommen.

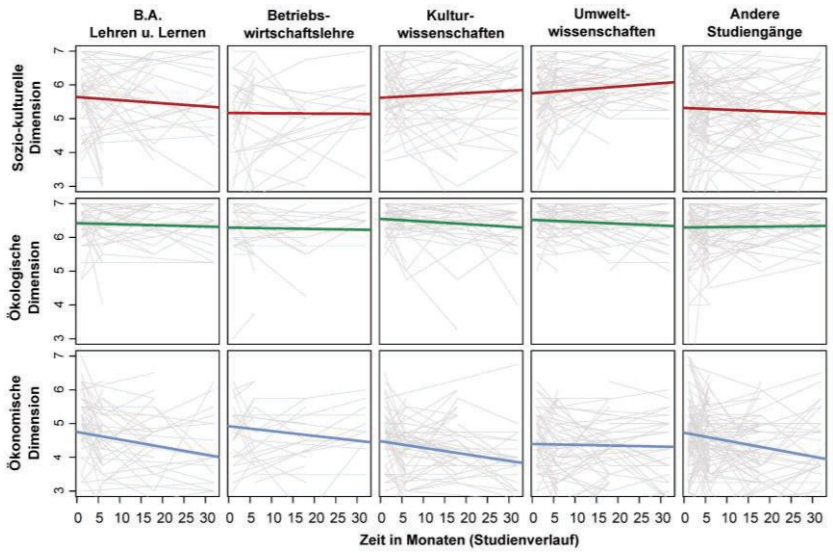

Abbildung 9.1. Individuelle Veränderungen über drei Jahre eines Bachelorstudiums in den drei Nachhaltigkeitskonzept-Dimensionen sozio-kulturell (n = 2.076), ökologisch (n = 2.077) und ökonomisch (n = 2.075)

In das finale Modell für die Ausprägungen der soziokulturellen Dimension wurden die Einflussgrößen Studiengang, Studienverlauf und deren Wechselwirkung aufgenommen, um die Unterschiede zwischen den Studierenden zu erklären (siehe Tabelle 9.3). Zusätzlich verbesserten individuelle Zufallseffekte die Modelpassung. Für die Ausprägung der soziokulturellen Dimension bei den Studierenden zeigte sich ein signifikanter wechselseitiger Zusammenhang des Studienverlaufs in Verbindung mit dem Studienfach, $F(4, 602) = 3{,}47$, $p = 0{,}008$. Das heißt: Studierende der Umweltwissenschaften entwickeln im Studienverlauf eine stärkere Ausprägung dieser Dimension. Es zeigte sich zudem ein signifikanter Zusammenhang des Studiengangs mit der Ausprägung dieser Dimension, $F(4, 2023) = 17{,}20$, $p < 0{,}001$. Dies bedeutet das diese Dimension bei Studierenden des B.A. Lehren und Lernen sowie der Kultur- und Umweltwis- senschaften stärker ausgeprägt ist als bei den übrigen Studierenden.

						95%-KI	
Feste Effekte	***β***	***SE***	***df***	***t***	***p***	**UG**	**OG**
konstanter Term	5,30	0,05	2492	117,77	<0,001	5,22	5,39
Zeit in Monaten (Studienverlauf)	-0,004	0,00	1890	-1,07	0,286	-0,01	0,00
B.A. Lehren und Lernen [a]	0,33	0,07	2512	4,34	<0,001	0,18	0,47
Betriebswirtschafts-wissenschaften [a]	-0,16	0,08	2512	-1,97	0,049*	-0,31	0,00
Kulturwissenschaften [a]	0,33	0,08	2533	4,14	<0,001	0,17	0,48
Umweltwissenschaften[a,b]	0,44	0,08	2524	5,42	<0,001	0,28	0,60
B.A. Lehren und Lernen*Zeit	-0,01	0,01	1978	-1,15	0,251	-0,02	0,00
Betriebswirtschafts-wissenschaften*Zeit	0,01	0,01	1984	0,98	0,328	-0,01	0,02
Kulturwissenschaften*Zeit	0,01	0,01	1766	1,75	0,081	0,00	0,02
Umweltwissenschaften*Zeit	0,01	0,01	1689	2,48	0,031*	0,00	0,02

					95%-KI	
Zufallseffekte [c]	**Schätzer**	**SE**	**Z**	***p***	**UG**	**OG**
$\sigma^2_{\text{Zeit in Monaten}}$ [c]	0,57	0,04	16,15	<0,001	0,50	0,64
$\text{Cov}_{\text{Zeit in Monaten}}$ [c]	0,53	0,04	12,22	<0,001	0,44	0,61

Notiz: KI = Konfidenzintervall. *p < 0,05; **p < 0,01

a: Referenzkategorie sind alle anderen 9 Studienfächer im B.A. General und 2 Lehramtsstudienprogramme

b: Inklusive Environmental and Sustainability Studies

c: Kovarianzstruktur zusammengesetzte Symmetrie

Tabelle 9.3. Schätzungen der festen (oben) und zufälligen (unten) Einflussgrößen für Ausprägungen der soziokulturellen Dimension des Nachhaltigkeitskonzepts (n = 2.076)

Das Modell für die Ausprägungen der ökologischen Dimension beinhaltet die Einflussgrößen Studiengang und Studienverlauf auf Ebene 2 sowie individuelle Zufallseffekte (siehe Tabelle 9.4). Es zeigte sich, dass der Studienverlauf einen negativen Zusammenhang mit den Ausprägungen dieser Dimension hat, $F(1, 718) = 7{,}26$, $p = 0{,}007$. Für die Ausprägungen dieser Dimension zeigte sich ebenfalls ein Zusammenhang mit dem Studiengang, $F(4, 1999) = 9{,}21$, $p < 0{,}001$. Bei Studierenden des B.A. Lehren und Lernen sowie bei Studierenden der Kultur- und Umweltwissenschaften ist die ökologische Dimension stärker ausgeprägt als bei den übrigen Studierenden.

						95%-KI	
Feste Effekte	**β**	**SE**	**df**	**t**	**p**	**UG**	**OG**
Konstanter Term	6,33	0,03	2002,77	252,39	<0,001	6,28	6,38
Zeit in Monaten (Studienverlauf)	-0,004	0,00	718,26	-2,69	0,007**	-0,01	0,00
B.A. Lehren und Lernen [a]	0,08	0,04	2053,32	2,14	0,033*	0,01	0,16
Betriebswirtschafts-wissenschaften [a]	-0,03	0,04	2119,91	-0,84	0,401	-0,12	0,05
Kulturwissenschaften [a]	0,18	0,04	1999,09	4,46	<0,001	0,10	0,26
Umweltwissenschaften [a,b]	0,16	0,04	1833,98	3,94	<0,001	0,08	0,24

					95%-KI	
Zufallseffekte [c]	**Schätzer**	**SE**	**Z**	**p**	**UG**	**OG**
σ^2_{t0}	0,42	0,02	24,03	<0,001	0,39	0,46
σ^2_{t1}	0,40	0,02	19,76	<0,001	0,36	0,44
σ^2_{t2}	0,45	0,03	14,06	<0,001	0,39	0,51
σ^2_{t3}	0,40	0,04	11,18	<0,001	0,34	0,48
ρ Zeit in Monaten	0,37	0,04	8,97	<0,001	0,29	0,45

Notiz: KI = Konfidenzintervall. *p < 0,05; **p < 0,01

a: Referenzkategorie sind alle anderen 9 Studienfächer im B.A. General und 2 Lehramtsstudienprogramme

b: Inklusive Environmental and Sustainability Studies

c: Autoregressive Kovarianzstruktur erster Ordnung mit heterogenen Varianzen

Tabelle 9.4. Schätzungen der festen (oben) und zufälligen (unten) Einflussgrößen für Ausprägungen der ökologischen Dimension des Nachhaltigkeitskonzepts (n = 2.077)

In das Modell für die Ausprägungen der ökonomischen Dimension wurden die Einflussgrößen Studienverlauf, Studiengang, Jahrgang, die Wechselwirkung zwischen Studienverlauf und Studiengang sowie individuelle Zufallseffekte aufgenommen (siehe Tabelle 9.5). Der Studienverlauf zeigte in Verbindung mit dem Studiengang einen signifikanten Zusammenhang mit den Ausprägungen dieser Dimension, $F(4, 1940) = 2{,}80$, $p = 0{,}025$. Überraschenderweise bedeutet dies, dass der Studienverlauf sich positiv auf die Ausprägung dieser Dimension bei den Studierenden der Umweltwissenschaften auswirkt. Außerdem zeigte sich insgesamt ein negativer Zusammenhang des Studienverlaufs mit den Ausprägungen der ökonomischen Dimension: je länger das Studium dauert, desto niedriger die Ausprägungen $F(1, 1964) = 42{,}09$, $p < 0{,}001$. Es zeigte sich aber auch, dass die ökonomische Dimension bei Studierenden der Kulturwissenschaften und Umweltwissenschaften geringer ausgeprägt ist als bei den übrigen Studierenden, und stärker bei den Studierenden der Betriebswirtschafts-

wissenschaften, $F(4, 2516) = 9{,}20$, $p < 0{,}001$. Schließlich zeigten die Ergebnisse, dass Studierende des Jahrgangs 2013/14 ökonomische Aspekte stärker mit dem Nachhaltigkeitskonzept verbinden als Studierende des Jahrgangs 2014/15, $F(1, 1971) = 16{,}06$, $p < 0{,}001$.

						95%-KI	
Feste Effekte	**β**	**SE**	**df**	**t**	**p**	**UG**	**OG**
Konstanter Term	4,62	0,05	2384,32	87,54	<0,001	4,52	4,73
Zeit in Monaten (Studienverlauf)	-0,02	0,00	1998,91	-5,41	<0,001	-0,03	-0,01
B.A. Lehren und Lernen	-0,03	0,08	2503,35	-0,36	0,719	-0,18	0,12
Betriebswirtschafts-wissenschaften [a]	0,18	0,08	2507,78	2,24	0,025*	0,02	0,34
Kulturwissenschaften [a]	-0,28	0,08	2523,46	-3,43	0,001**	-0,44	-0,12
Umweltwissenschaften [a,b]	-0,29	0,08	2508,82	-3,49	<0,001	-0,45	-0,13
Jahrgang	0,18	0,05	1971,06	4,01	<0,001	0,09	0,27
B.A. Lehren und Lernen*Zeit	0,00	0,01	2086,02	-0,18	0,858	-0,01	0,01
Betriebswirtschafts-wissenschaften*Zeit	0,01	0,01	2092,56	1,47	0,143	0,00	0,02
Kulturwissenschaften*Zeit	0,00	0,01	1877,02	0,41	0,685	-0,01	0,01
Umweltwissenschaften*Zeit	0,02	0,01	1795,52	2,88	0,004**	0,01	0,03
						95%-KI	
Zufallseffekte d	**Parameter**	**SE**		**Z**	**p**	**UG**	**OG**
$\sigma^2_{\text{Zeit in Monaten}}$ [c]	0,67	0,04		15,89	<0,001	0,59	0,76
$\text{Cov}_{\text{Zeit in Monaten}}$ [c]	0,48	0,05		9,76	<0,001	0,38	0,57

Notiz: KI = Konfidenzintervall. *$p < 0{,}05$; **$p < 0{,}01$

a: Referenzkategorie sind alle anderen 9 Studienfächer im B.A. General und 2 Lehramtsstudienprogramme b: Inklusive Environmental and Sustainability Studies

c: Referenzkategorie ist der Jahrgang 2

d: Kovarianzstruktur zusammengesetzte Symmetrie.

Tabelle 9.5. Schätzungen der festen (oben) und zufälligen (unten) Einflussgrößen für Ausprägungen der ökonomischen Dimension des Nachhaltigkeitskonzepts ($n = 2.075$)

Zuletzt soll hier noch auf die individuelle Ebene innerhalb der Studierenden eingegangen werden. Gegenüber einem Modell mit ausschließlich festen Effekten erhöhte die Aufnahme dieser individuellen Zufallseffekte die Passgenauigkeit aller Modelle signifikant. Das bedeutet, dass die Ausprägungen *einzelner* Studierender (Ebene 1) zu unterschiedlichen Messzeitpunkten nicht vollständig durch die Einflussgrößen für die Unterschiede *zwischen* den Studierenden (Ebene 2) erklärt werden können. Vielmehr zeigen sich in den Ausprägungen einzelner Studierender für die soziokulturelle und die ökonomische Dimension *gleichbleibende* Abweichungen von den Vorhersagen auf Ebene 2. Für die Ausprägungen der ökologischen Dimension zeigen die individuellen

Abweichungen hingegen zu jedem Messzeitpunkt *unterschiedliche* Abweichungen von den Vorhersagen auf Ebene 2. Einen weiteren Hinweis zu Abweichungen der individuellen Ausprägungen gibt der Zusammenhang zwischen den Abweichungen eines Studierenden zwischen zwei Messzeitpunkten. Dieser Zusammenhang ist für die individuelle Abweichungen der Ausprägungen der soziokulturellen Dimension gleichbleibend. Gleiches gilt für die Abweichungen auf der ökonomischen Dimension. Für die Ausprägungen der ökologischen Dimension hingegen nimmt dieser Zusammenhang zwischen den Antworten von Messzeitpunkt zu Messzeitpunkt ab. Das heißt, die Abweichungen der Ausprägung zu Studienbeginn hängt stärker mit der Abweichung nach dem Leuphana Semester zusammen als beispielsweise mit den Abweichungen am Ende des Studiums.

9.4 Fazit

Diese Studie ging der Frage nach, inwiefern sich das Nachhaltigkeitskonzept der Studierenden in einem dreijährigen Bachelorstudienprogramm verändert. Dabei sollte insbesondere die Zeitlichkeit der Veränderungen in den Blick genommen werden.

Insgesamt lässt sich festhalten: Die Akzentuierungen in den Nachhaltigkeitskonzepten verändern sich im Zeitverlauf nur teilweise, in Verbindung mit einzelnen Studiengängen und eher in geringem Maße. Am umfangreichsten scheint sich der Studiengang – unabhängig oder in Verbindung mit dem Studienverlauf – auf die drei Dimensionen des Nachhaltigkeitskonzepts auszuwirken. Wenig überraschend deuten sich hier Ausprägungen gemäß der Studieninteressen ab: Die Ausprägungen der soziokulturellen und der ökologischen Dimension sind für Studierende von eher sozial- und geisteswissenschaftlichen Studiengängen stärker. Im Gegensatz dazu liegt der Fokus bei Studierenden der Betriebswirtschaftswissenschaften eher bei den ökonomischen Aspekten. Für die Studierenden der Umweltwissenschaften zeigt sich eine Ausnahme: Während der allgemeine Einfluss des Studienverlaufs auf die Ausprägungen der ökonomischen Dimension negativ ist, zeigt sich bei dieser Studierendengruppe im Laufe der Zeit ein kleiner positiver Einfluss. Die Einflussgröße Jahrgang wirkt sich überraschenderweise, wenn auch nur in geringem Maße, auf die Ausprägung der ökonomischen Dimension aus.

Ein ähnliches Bild zeigte sich bereits bei Studierenden in Australien (Shephard et al., 2015). Dort konnten die Forschenden keine Einflüsse des Studienverlaufs, aber einen starken Zusammenhang des Studiengangs mit den Umwelteinstellungen von Studierenden feststellen. Derweil nehmen Harring et al. (2019) auf Basis einer Längsschnittbefragung in Schweden an, dass der Zusammenhang zwischen nachhaltigkeitsbezogenen Lernerfahrungen und Einstellungen

eher indirekt ist. Insgesamt zeigt auch eine Längsschnittstudie zum Einfluss von Bildung für nachhaltige Entwicklung in schwedischen Schulen, dass der Zusammenhang zwischen Lernerfahrungen und -ergebnissen schwierig herauszuarbeiten ist (Ignell et al., 2019).

Möglicherweise lassen sich die geringen Effekte des Studienverlaufs in diesem Beitrag mit der verringerten inter- und transdisziplinären Ausrichtung nach dem ersten Semester in einigen Hauptfächern des Studienprogramms erklären. Zwar gibt es etwa über das Komplementärstudium weiterhin fächerübergreifende Lernangebote, jedoch sind die Studierenden in ihrer Wahl flexibler und können auch Veranstaltungen wählen, die keinen expliziten Bezug zur Idee einer nachhaltigen Entwicklung herstellen.

Das Ergebnis, dass eher soziokulturelle und ökologische als ökonomische Aspekte in den individuellen Konzepten akzentuiert werden, deckt sich auch mit Erkenntnissen vorhergehender Studien (Sharma & Kelly, 2014; Zeegers & Clark, 2014). Eine mögliche Erklärung für den negativen Effekt der Studienzeit auf die Ausprägung der ökonomischen Aspekte ist, dass Lehrende selbst Schwierigkeiten damit haben, ökonomische Aspekte mit ihrem Nachhaltigkeitskonzept zu vereinen (Borg et al., 2014). Gleichzeitig erfolgte in den vergangenen Jahrzehnten eine stark kritische Auseinandersetzung mit ökonomischen Aspekten in den traditionellen Konzepten einer nachhaltigen Entwicklung, sodass auch diese wissenschaftliche und gesellschaftliche Debatte einen Einfluss auf die Ausprägungen dieser Dimension bei den Studierenden haben könnte (Robinson, 2004). Zudem könnte der Unterschied in der Akzentuierung dieser Dimension zwischen beiden Jahrgängen durch veränderte schulische Auseinandersetzung mit der Idee einer nachhaltigen Entwicklung bedingt sein (Michelsen et al., 2015).

Insgesamt weist jedoch die hohe Abweichung der individuellen Ausprägungen darauf hin, dass es lohnenswert sein könnte, in zukünftiger Forschung empirisch belegte individuelle Einflussgrößen auf Lernprozesse wie studentisches Verständnis von Lehre, studentische Wahrnehmungen oder Überzeugungen in die Vorhersage von Lernergebnissen mit einzubeziehen, um die Vorhersagekraft der Modelle zu erhöhen (Price, 2013).

Abschließend soll nun diskutiert werden, welche Rückschlüsse sich aus den Ergebnissen für die Verbesserung der nachhaltigkeitsbezogenen Lehre ziehen lassen und welche möglichen Konsequenzen sich für die weitere Forschung ergeben. Die Ergebnisse in diesem Beitrag deuten an, dass die Studierenden die Tendenz zeigen, diejenigen Aspekte in ihrem Nachhaltigkeitskonzept zu akzentuieren, die ihren Studienfächern entsprechen. Dieser Spezialisierung scheint das gemeinsame Lernen und Forschen sowie die fachübergreifende Perspektive im ersten Semester nicht entgegenwirken zu können. Ein möglicher Ansatz zur Verbesserung des Studienmodells wäre daher, die disziplinären Unterschiede im Nachhaltigkeitskonzept aufzugreifen und die fachliche Auseinandersetzung mit dem Konzept einer nachhaltigen Entwicklung

im weiteren Verlauf des Studiums zu intensivieren. So könnte insgesamt in allen Studienfächern im Studienverlauf systematischer daran gearbeitet werden, Nachhaltigkeitsprobleme aus unterschiedlichen Perspektiven zu beleuchten, Trade-offs und Synergien zu erkennen und zu lernen, mit diesen umzugehen.

Auf diese Weise ließe sich eine kontinuierliche Auseinandersetzung mit der Idee einer nachhaltigen Entwicklung erreichen, welche die Vorkonzepte der Studierenden stärker herausfordert als es möglicherweise die intensive Thematisierung im ersten Semester zu tun vermag.

In zukünftigen Untersuchungen zur Wirkung von ganzheitlichen nachhaltigkeitsbezogenen Lehrangeboten wäre es lohnend, die Wahrnehmung der Studierenden auf ihre eigenen Lernprozesse über den Studienverlauf hinweg zu untersuchen. Auch wären vergleichende Studien wünschenswert, um die Einflüsse verschiedener universitärer Umgebungen vergleichen zu können. Nicht zuletzt und sehr grundsätzlich besteht weiterer Forschungsbedarf in Bezug auf die Frage, welche Faktoren in welcher Form und zu welchem Zeitpunkt Einfluss auf die Lernergebnisse Studierender in der HBNE nehmen. Prozessorientierte Forschung, die auf der Grundlage theoretischer Lernmodelle die Zeitlichkeit des Lernens in den Blick nimmt, stellt ebenso ein Desiderat wie ein lohnendes Betätigungsfeld für weitere Forschung im Bereich der HBNE dar.

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4.4 Article#4: Meaning-making in higher education for sustainable development: Undergraduates' long-term processes of experiencing and learning

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Meaning-making in higher education for sustainable development: undergraduates' long-term processes of experiencing and learning

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ABSTRACT

Despite the increase in teaching approaches designed to integrate sustainability into higher education, the connection between students' learning experiences and their learning outcomes remains incompletely understood. The present multi-case study complements the discussion by investigating undergraduates' long-term meaning-making processes using the theoretical lens of significant learning and process analysis of students' learning experience. Based on in-depth narrative interviews with 10 students at the end of a three-year study program, we analyzed how and why learning experiences become significant, differentiating perceived personal impact and the subjective value assigned to these experiences. We identified three types of sustainability-related meaning-making processes, ranging from *no sustainability-related meaning-making* to *meaning-making as self-realization*. The differentiated view on how meaning-making mediates students' sustainability-related learning experiences and their learning outcomes enhances our understanding of the specific dynamics that may shape the how and why of significant learning. It thus supports the tailored curriculum design for integrating sustainability into higher education.

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1. Introduction

Higher education for sustainable development (HESD) aims to support students' competence development to become future change agents who can critically and responsibly contribute to a more sustainable society. Educators design learning opportunities in higher education for students to gain awareness of sustainability-related challenges and to develop sustainability competencies (Jones, Selby, and Sterling 2010). At the same time, these formal learning opportunities (curriculum-as-planned) pair with informal ones, forming an experiential space (curriculum-as-lived) where students' learning experiences cannot be fully predicted (Aoki 1993). The curriculum-as-lived allows students to have intended and unintended learning experiences by engaging with these learning opportunities. Therefore, the challenge for educators is that

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learning opportunities do not necessarily result in anticipated learning outcomes (Lundholm, Hopwood, and Rickinson 2013).

Consequently, it seems crucial to uncover whether students learn and how the impact of sustainability-related learning experiences is perceived and why students assign subjective value to their experiences. In the context of this work, we denote these processes as meaning-making—the way of interpreting learning experiences (Mezirow 1997). Learning experiences shape these meaning-making processes, and these meanings, in turn, shape what we perceive as significant and what we ultimately learn (Heimlich, Mony, and Yocco 2013). In addition, we base our research on the assumption that certain sustainability-related learning experiences may be perceived more significant than others and that individuals vary in their responses to identical sustainability-related learning opportunities (Merriam and Clark 1993). Understanding the human patterns of subjectivity can play an important role in developing context-specific and significant ways of integrating sustainability into curricula and study programs (Bruhn 2021).

This multi-case study aims to better understand meaning-making processes that link sustainability-related learning experiences and learning outcomes throughout a higher-education curriculum. The following research questions drove the analysis:

1. Concerning the dimension of perceived impact of significant sustainability-related learning experiences: How do students make meaning from their formal and informal sustainability-related learning opportunities in a three-year undergraduate program?
2. Concerning the dimension of assigning value to this perceived impact: Why do students consider sustainability-related learning experiences significant?

To answer these questions, we interviewed 10 students from a three-year undergraduate study program in their third year who had participated in a mandatory sustainability-related module during their first semester. We expected them to have had the full range of possible sustainability-related learning experiences at this point in their studies. Thus, by asking them about their experiences as learners and actively engaging with their reflections, we intended to gain insights on how such experiences could be further integrated into curriculum design processes. Our analysis used process analysis of narrative interviews and conceptual maps to uncover possible types of meaning-making processes that could inform further research and curriculum development.

This article starts by summarizing the theoretical background, which integrates key ideas on meaning-making from socio-constructivist learning theories. Next, previous results and related research gaps on students' meaning-making in HESD are summarized. The third section provides an overview of the multi-case study approach that allowed comparative process analysis. The results section presents three types of students' meaning-making using the dimensions of personal impact (how) and subjective value (why). This article ends by discussing the findings against the background of research on meaning-making in HESD and the design of significant sustainability-related learning opportunities.

2. Theoretical framework

2.1. Meaning-making as learning

Central to our understanding of learning is that it always involves an interaction with the world (learning experience) and a transformation of this experience via assignment of significance and meaning. The transformation is suggested to require mental energy that drives the meaning-making process via feelings, emotions, and motivations (Illeris 2018, 4).

According to socio-constructivist learning theories, these learning experiences are individually constructed (Chaiklin 2003; Garrison 1998). Hence, in learning processes, each individual makes meaning from experiences based on prior knowledge, beliefs, values, and experiences while

drawing on cultural and societal influences (Zittoun and Brinkmann 2012). In transformative learning theory, these propositions serve as a frame of reference for new experiences (Mezirow 1997, 7). Experiences and critical reflection may transform the frame of reference, thereby rendering learning meaningful. From Mezirow's point of view, reflection, contemplation, and discourse with authorities and peers are integral to the process of meaning-making (Mezirow 1997). Two recent extensions expanded the understanding of meaning-making underpinning this research: the critical idea that meaning-making processes are not only individual but also socio-contextual (Merriam and Heuer 1996) and the emphasis on the affective dispositions of the learner such as emotions and value judgments (Jarvis 2018; Merriam and Kim 2011) as well as expectations and motivations (Illeris 2018).

These theoretical considerations do not yet explain at what point and which kind of learning experiences can develop transformative potential. Jarvis suggested that no learning will occur if a learning experience is too congruent or incongruent with the frame of reference (Jarvis 1987). Merriam and Clark (1993, 136) emphasized that a learning experience must be "subjectively valued by the learner and have an impact on the learner involving an expansion of skills, sense of self or life perspective or a transformation" to be significant. Subjective value refers to assigning individual importance to this change or development.

We acknowledge that this framework for meaning-making processes and significant learning does not account for the full complexity of individual learning processes. Nevertheless, the framework offers great potential for our study to deliver valuable insights into learning experiences and outcomes.

2.2. Previous research on meaning-making in HESD

Previous research on meaning-making in environmental and (higher) education for sustainable development has thus far focused on meaning-making in formal, individual seminars and courses (Lundholm 2004, 2005) or on school students in environmentally-themed classes (Caiman and Lundegård 2014, 2018; Lundegård and Wickman 2007; Manni, Sporre, and Ottander 2017). Most fundamentally, Öhman and Östman (2007) found evidence for the importance of prior experiences in meaning-making. Many studies that are building on this body of research point to the relevance of values, emotions, and value judgements for meaning-making regarding environmental learning opportunities. In a synthesis of their work, Rickinson and Lundholm (2008, 345) identified three significant challenges of students' meaning-making processes in environmental formal learning experiences: "different emotional responses to the content, different opinions about the content as compared with the teacher, and different views of what should be studied in a subject". However, these studies cover relatively short-term and formal learning experiences and do not consider the experiences students have in the dynamic curriculum-as-lived over an extended period. Longitudinal biographical studies identified processes of emancipation over time in some students and dependence of others on external authorities, supporting the notion of highly individualized meaning-making over time (Barber, King, and Baxter Magolda 2013). Finally, studies covering more informal learning experiences in higher education have shown that adults also make meaning from extracurricular experiences (Gramatakos and Lavau 2019). Against this background, it seems fruitful to further illuminate students' long-term individual meaning-making processes to gain a more holistic picture in a curriculum-as-lived.

3. Empirical design

3.1. Comparing and analyzing individual meaning-making processes

In an exploratory study, we investigated processes of students' meaning-making using detailed descriptions of students' sustainability-related learning experiences that took place during a three-year undergraduate study program. A multi-case study approach was adopted to perform,

on the one hand, a deep analysis of individual meaning-making processes, and on the other, to support contrasting the commonalities of these processes (Stake 2005). We decided to use a multi-case study design—due to the individual combinations of major and minor subjects and complementary studies. Additionally, the epistemological assumptions of the multi-case approach align well with the underlying understanding of meaning-making in this study (Yazan 2015). Above all, multi-case studies are suggested to provide more robust results because cases from diverse study backgrounds are directly compared as part of the analysis (West and Oldfather 1995). Thus, the case study is characterized by the units of analysis (students from diverse major and minor subjects) and not by the focus of the analysis (their meaning-making processes).

3.2. Multi-case study context

The present study was conducted at a mid-sized German university (approximately 10,000 students) whose undergraduate study program stands in the tradition of a *liberal education* approach. The three-year study program is characterized by a high proportion of interdisciplinary teaching in the first semester and the complementary studies accompanying major and minor subjects. After a first compulsory general first semester, students choose a major subject (e.g. Business Administration, Cultural Science, Industrial Engineering, and Sustainability Science) and combine it with a minor subject (e.g. Philosophy, Business Law, E-business, Educational Sciences, and Sustainability Science) (see Figure 1).

The compulsory first semester consists of four modules: The most extensive module[1] aims to familiarize students with the concept of sustainability and the discourse on sustainability transformation. Figure 2 presents a detailed overview of the sustainability-related learning opportunities in the sustainability and responsibility module that accounts for one-third of the semester's workload. The module design follows sustainability learning objectives: inter- and transdisciplinary problem-solving, dealing with complexity, self-organized and collaborative learning, and competence development (Barth and Timm 2011). In addition to this module, there are two further interdisciplinary modules: one that introduces students to humanities perspectives and one that provides a general introduction to research methods. There is also an introductory major-specific module. The primary learning objectives in the first semester are

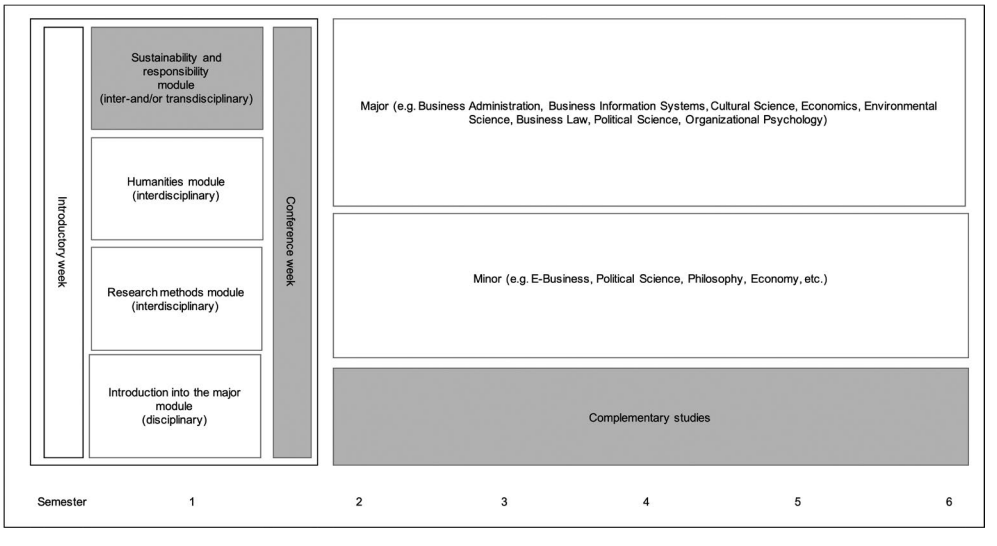

Figure 1. Structure of the three-year undergraduate program (explicitly sustainability-related elements in light grey).

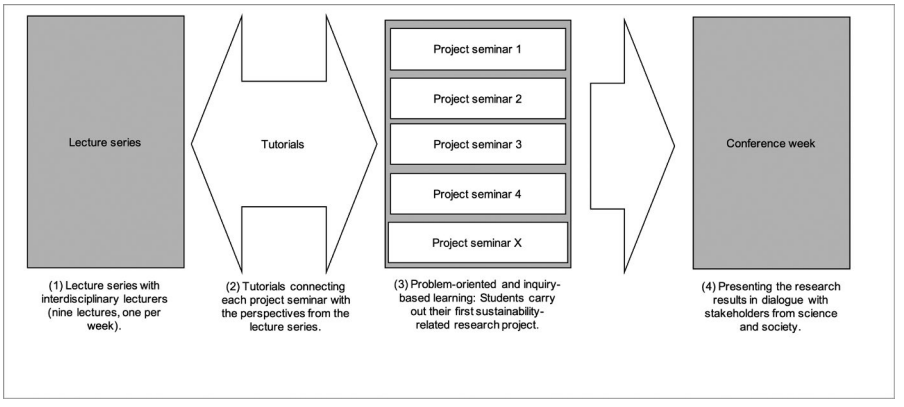

Figure 2. Sustainability-related formal learning opportunities in the sustainability and responsibility module in the first semester (explicitly sustainability-related elements in light grey).

- understanding complex real-world challenges against the background of their origins
- critically reflect different scientific perspectives in their cultural conditionality
- testing the basics of (contemporary) scientific work
- enabling interdisciplinary competence development

The mandatory sustainability-related module is mainly structured by three formal learning opportunities: a project-based seminar,[2] a lecture series on the basics of sustainability,[3] and connecting tutorials.[4] The students can choose one out of 60 different seminars that focus on issues such as *Unconditional Basic Income: A program for more social sustainability?*, *Use of Biomass for Energy Production – A Critical View* or *Economy 2.0,* or *Growth, Products, and Profit in Transition!?*. The teaching and learning approaches of the seminars are based on the idea of inquiry-based learning (Mieg 2019). The students independently conduct a first research project concerning sustainability challenges in small groups. The lecture series provides insights on 'acting responsibly in the 21st century' from lecturers with different disciplinary backgrounds, including business ethics, environmental psychology, or governance. After this semester, students present and discuss their research results in a joint three-day conference in a festival-like atmosphere with their peers and guests from science, politics, and society. The conference's goal is to engage the students in a critical dialogue about the opportunities and challenges of societal change. Two assignments assess the students' performance at the end of the first semester: a collaborative presentation during the final conference and a written group report on the research project.

From the second semester onward, further sustainability-related learning experiences are optional. Students may choose a major or minor subject in Environmental and Sustainability Sciences or attend seminars in the complementary studies that deal with sustainability. It is also possible for students—either intentionally or unintentionally—to not have any other formal learning experiences with sustainability (Michelsen 2013). In addition to the formal learning opportunities, campus management supports informal sustainability-related learning experiences by, for example, a sustainable music festival on campus, student initiatives, and close partnerships with the city's administration, civil society actors, and local businesses (Birdman, Barth, and Lang 2020).

3.3. Participants

We conducted interviews throughout one university semester in fall 2015. Participants were selected from a cohort that started studying in winter 2012 ($n = 1{,}773$) and was in their final year of the three-year undergraduate program in summer 2015 ($n = 1{,}424$). The recruiting process

took place in two stages: First, students were asked to answer a short questionnaire in the seminars of the cohort in their third year. Forty-two students answered the questionnaire on their perceived (current and future) professional relevance of sustainability, age, and their study program (see Appendix A for results of the survey). All participants consented to the collection and processing of data by signing a data-processing and publishing contract prior to participation. Second, the goal of the subsequent stage of case selection was not to achieve possible representativeness but to strive for balance and diversity in the sample, which should guarantee that we can learn as much as possible from the cases (Stake 2005, 451).

In qualitative case studies, conducting few interviews always has the potential for bias. Concerning the two research questions guiding our study, the two-staged sample selection aimed to interview the possible range of meaning-making processes from students with diverse study backgrounds. The limitation to a few interviews focused on the depth and thickness of the individual narrative (Perey 2015). Nevertheless, this type of selection may still allow not to identify other types of meaning-making processes. Keeping these limitations in mind, we paid particular attention to the comprehensibility of the data analysis and the plausibility of the conclusions (Merriam 1995) by strictly following Stake's (2005) advice to use protocols.

Finally, 10 students were selected one after another based on their answers to the survey questions on a) perceived professional relevance of sustainability for their study program and their future professional life in the questionnaire and, b) variation in study programs and genders to be able to assess a variety of meaning-making processes (Table 1). However, we did not interview students indicating that sustainability was relevant for their major subject but not for their future professional life. The share of female students was representative of the university (approx. 60%). The final sample included students from all four university departments.

3.4. Data collection

Data was collected via narrative interviews and conceptual maps. We used narrative interviews to ascertain students' perceptions of sustainability-related learning opportunities (Almers 2009; Manni, Sporre, and Ottander 2017). The interview guidelines were constructed to encourage storytelling (Rosenthal 2004). The interviews took place toward the end of the third year of the undergraduate study program, allowing students to look back at experiences and envision their future plans. Interviews began by instructing the students to reflect on

Table 1. Case characteristics of the multi-case study.

					Perceived professional relevance of sustainability for		
Student	Gender	Age (years)	Major subject	Minor subject	Study program	Future professional life	Interview length (minutes)
1	Male	24	Environmental Science	Spatial Studies	Very high relevance	yes	60
2	Male	24	Cultural Science	Digital Media	Rather low relevance	yes	70
3	Female	26	Organizational Psychology	E-business	Rather low relevance	yes	105
4	Male	26	Environmental Science	Philosophy	Very high relevance	yes	60
5	Female	21	Organizational Psychology	E-business	Rather low relevance	yes	63
6	Female	23	Organizational Psychology	E-business	Low relevance	yes	65
7	Female	22	Business Law	Business Administration	Rather low relevance	no	80
8	Female	25	Cultural Science	Educational Science	Low relevance	yes	75
9	Female	24	Environmental Science	Educational Science	Very high relevance	yes	76
10	Female	23	Business Administration	E-business	Rather low relevance	yes	72

sustainability-related learning experiences throughout their studies (see Appendix B for the interview guideline). We used semi-structured questions to focus, for instance, on the most significant changes in students' sustainability conceptions (Davies and Dart 2005). Before the interview, students were given the opportunity to recall their sustainability conceptions using a conceptual-map approach (Novak and Cañas 2008). However, the conceptual maps do not play a central role in this article. The maps were primarily intended as a reflective task introducing the students to the interviews and only secondarily to explore their sustainability conceptions as a learning outcome. The transcripts, conceptual maps, and the coding schemes that support the findings of this study are available in pseudonymous form in German on request from the corresponding author [AS]. The data are not publicly available due to restrictions (e.g. containing information that could compromise the privacy of research participants).

3.5. Data analysis

Our interest in *how* and *why* students make meaning from their sustainability-related learning experiences served as the guiding principle behind the analysis. As an overall framework for data analysis, we used process analysis to understand better how students experienced the impact of dealing with sustainability and why they subjectively valued these experiences as being significant (Schütze 2016). The transcripts were analyzed in three phases (Figure 3). In the first phase, we determined the structure of the main learning narrative from the interview transcript. We further abstracted the narrative in the second phase by organizing the learning experiences chronologically and identifying the four main analytical themes. Finally, in the third phase, we contrasted the four themes identified in each case.

The analysis of the conceptual maps drawn at the beginning of the interviews took place in a process that was eventually largely separate from the results presented in this article. However, we compared the perceived impact of the learning experiences and sustainability conceptions prevalent in each of the three types of meaning-making processes with the structural and content-related complexity of the maps, which further complemented our results.

4. Findings

Our analysis revealed three different types of processes in which students assign meaning to learning experiences throughout their undergraduate studies, which differ concerning *how* and *why* they assign value to their sustainability-related learning experiences. In Figure 4, we present the main characteristics derived from the process analysis that distinguish the different processes, forming three distinct types of meaning-making. The three types of meaning-making processes (which are not necessarily fully exclusive) were identified as *no sustainability-related meaning-making* (type 1*), meaning-making as professionalization* (type 2*),* and *meaning-making as self-realization* (type 3). They differ in their key learning experiences, their type of trajectory, perceived impact, subjective value, and variations in sustainability conceptions.

The following sections illustrate the three process types following the characteristics as outlined in Figure 4: key learning experiences and trajectories, perceived impact (how) and subjective value (why), and finally, determined by describing their sustainability conceptions as a learning outcome.

4.1. Type 1: No sustainability-related meaning-making

Type 1 meaning-making processes are characterized by only *institutionally-driven* sustainability-related learning experiences and a loss of interest in sustainability after the first

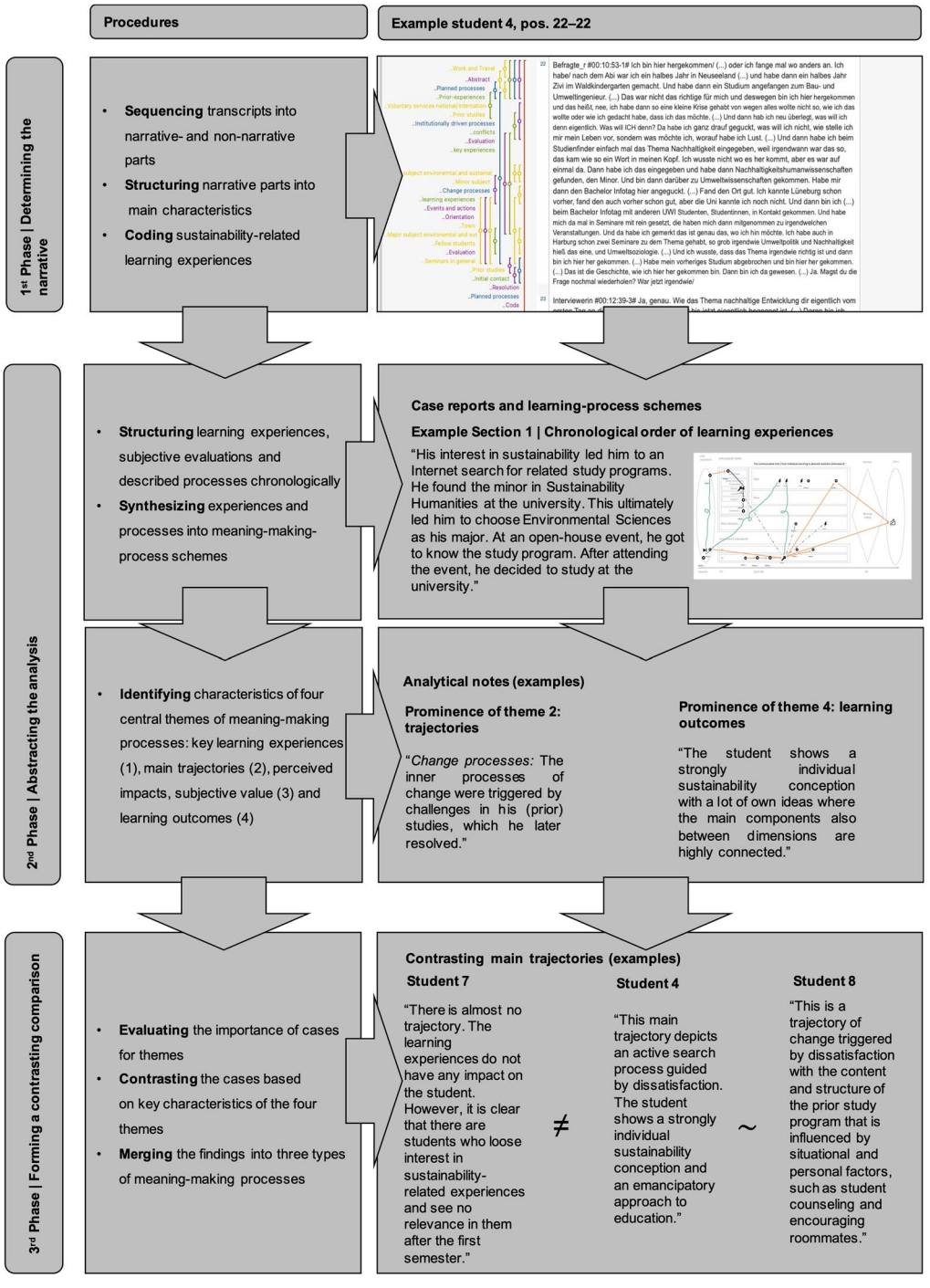

Figure 3. Data-analysis flowchart showing how one paragraph (student 4, pos. 22–22) is processed in three phases following a process analysis approach.

semester. This type of trajectory can be seen, for example, in the fact that students of type 1 identified no or few significant sustainability-related learning experiences during their studies (student 6 and 7). After the first semester, students of type 1 described only those learning experiences as significant that match their disciplinary career goals and are not related to

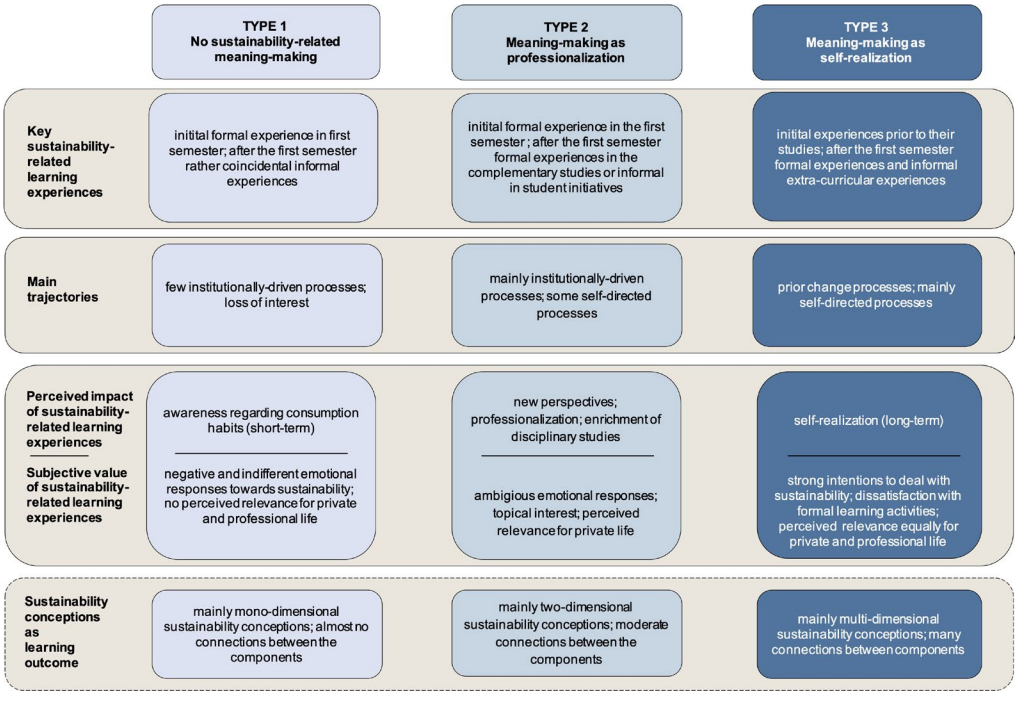

Figure 4. Main characteristics distinguishing the three types of meaning-making processes.

sustainability. Thus, students of type 1 experienced sustainability-related learning exclusively in formal contexts in the first semester, without any further interest in the issue during their subsequent study programs (*loss of interest trajectories*).

Concerning their perceived impact of their learning experiences, students of type 1 perceived that sustainability-related learning experiences raised *awareness* about their consumption habits, in parts leading to arguments about unsustainable habits with friends and family (student 6). This is briefly mentioned by student 7. While the student admitted being negatively impressed by her own carbon footprint, she ultimately did not change her consumption habits. It seems that students of type 1 commonly perceived the impact of their sustainability learning experiences as detached from what they consider valuable.

Concerning the subjective value (why) of the perceived impact, students of this type only attached *negative* and/or *indifferent emotional responses* to their sustainability-related learning experiences in the first semester. In one case, student 6 experienced sustainability as strongly value-laden and instrumental, potentially causing overload and rejection expressed as the need "to puke" (pos. 11), whereas student 7 could not remember her first-semester experiences with sustainability. She remembered: "That was actually mainly in the first semester. […] So, you hear the term very often, but I could not say now (…) in certain courses we have implemented so and so." (student 7, pos. 20). All in all, although the students seemed to welcome the opportunities to develop awareness for sustainability issues in their first semester, they did not consider the perceived impact as relevant for their major subject, their future careers, or their private life. Additionally, the students' statements indicated a *solid expectation* to focus on their major subjects during their undergraduate studies. This expectation is well reflected in one student's statement: "But (…) in the end, I came here to study Business Psychology" (student 6, pos. 11). Similarly, student 7 expressed strong domain-specific epistemological beliefs about what a significant learning outcome of the first semester should have looked like. She said with regret: "Unfortunately, I can't really define it [sustainable development]. So, nothing has really stuck"

(student 7, pos. 88). This individual perception of student 7 is reflected in the conceptual maps of the two students of this type, which indicate mono-dimensional, economically-focused sustainability conceptions with few connections between components.

4.2. Type 2: Meaning-making as professionalization

Compared to the loss of interest in type 1 processes, type 2 meaning-making processes feature several significant sustainability-related learning experiences in the first semester and beyond. After the first semester, students of type 2 remained partially engaged in more informal learning opportunities, such as students' initiatives, voluntary work abroad, and/or formal learning opportunities in the complementary studies. Thus, type 2 meaning-making processes are mainly institutionally-driven. However, in contrast to type 1 processes, the type 2 trajectories feature some *self-directed learning processes* after the first semester.

Concerning the perceived impact of these experiences, students of type 2 perceived that their key sustainability-related learning experiences changed their *perspectives*. Student 2, for instance, prominently reflected on how the seminar experience helped him gain a more holistic perspective of sustainability. He noted on organizing the conference week:

> "That was interesting for me. It was a lot about sustainability [and] you were confronted with it somehow. If you didn't really know sustainability before, […] of course what one always gets from advertising [on sustainability], is ecology or the environment, and from that, you don't easily get the idea that you can or should and must also design a festival or large cultural events sustainably." (student 2, pos. 10)

Other students perceived gaining new perspectives on sustainability issues through learning experiences that connected the issues with gender and developmental services (student 3), economy and social entrepreneurship (student 5), or organizing musical events (student 10). Additionally, it appears that students of type 2, similar to students of type 1, perceived awareness for personal unsustainable consumption habits as an impact of their learning experiences in the first semester. An indication for this perceived impact was statements of almost all students of this type about noticing increased conflicts over consumption habits with their peers and family.

Referring to the subjective value, students of type 2 explained how the sustainability-related learning experiences of the first semester sparked their *personal interests,* such as in social entrepreneurship or female empowerment, and thus motivated them to engage with issues after the first semester. Student 3 declared: "I was always afraid of becoming such a blinkered specialist through my studies, in the sense that you know a lot about your own discipline, but you no longer look to the left or the right" (pos. 213). In contrast to students of type 1, students of type 2 appreciated acquired skills and knowledge from sustainability-related learning experiences as relevant in the light of their *professionalizatio*n (students 2, 3, 5, and 10). Student 2 explained, for instance, how organizing a part of the conference week sustainably impacted his "soft skills" and gave him a professional attitude for managing a festival (pos. 51).

Yet, students of type 2 showed *ambiguous emotional responses* regarding their sustainability-related learning experiences. This ambiguous response is well reflected in student 3's summary of her first-semester experience: "I perceived it as positive […] however, sometimes the word brainwashing also comes up among students" (pos. 225). Nevertheless, the complexity of sustainability issues also seemed to overwhelm students of this type. Student 2 conveyed:

> "I think, […] when it comes to sustainable development, then you have the images of the cleared rainforest in your head somehow, I think (…) But I mean it is just at the same time also society, or I find it just difficult because it is just so complex." (student 2, pos. 61).

Thus, despite their personal interests in specific sustainability issues, the complexity of the coupled sustainability dimensions and/or confrontations concerning theirs' or others' unsustainable consumption behavior challenged them.

After the first semester, students of this type valued formal sustainability-related learning opportunities as an *enrichment* to follow their interests and enjoy interdisciplinary perspectives or feel less pressure to perform. Still, almost all students of this type rated their sustainability-related learning experiences as irrelevant in light of their major and minor subjects. Student 10 objected, for example:

> "It is of course, a bit difficult for business students. […] Because that's [sustainability] not really a topic in the lectures. (laughs) So you are shaped so beautifully in the first semester […] from time to time it could be integrated again, I think. Especially since it is the university's claim." (student 10, pos. 18).

Similar to the ambivalence in the emotions and valuations of their learning experiences, no clear picture of their sustainability conceptions emerges from the analysis of their conceptual maps. This ambivalence is expressed by student 3, who said "it's definitely still a squishy term and I rather feel like it's getting bigger, and squishier because you're just discovering more and more" (pos. 135). Overall, the conceptual maps reflected disciplinarily colored conceptions, which in some students already revealed the first beginnings of recognizing the dependency of the dimensions.

4.3. Type 3: Meaning-making as self-realization

Unlike the previous process types, type 3 processes are characterized by initial formal and informal sustainability-related learning experiences prior to commencing at the university. Students mentioned experiences such as previous study programs (Students 1 and 4), volunteering, traveling (students 4, 8, and 9), or growing up in a family with a strong sustainability orientation (students 4 and 8). Students' narratives indicated that these experiences led to *change processes* that had guided the students to their application to this particular study program. Students 1, 4, and 9 illustrated this point by claiming that their primary studies were too strongly focused on natural sciences, engineering, or organizational psychology instead of sustainability issues. Moreover, after the first semester, type 3 meaning-making processes were mainly characterized by conscious, self-directed plans to engage with sustainability, mostly in informal contexts (students 4 and 8), or active use of formal institutional sustainability-related experiences (students 1 and 9).

In contrast to type 1 and type 2 processes, gaining awareness does not seem to be an important impact of sustainability-related learning experiences for students of type 3. Instead, the characterizing perceived impact is *self-realization*. Self-realization captures the students' perception that engaging with sustainability issues changes their ability to enhance their self—in terms of knowledge, attitudes, or behavior. Students of type 3 appeared to understand the development of self-knowledge and autonomy in addressing sustainability issues as a perceived impact of their experiences. Student 4, for example, reflected on his perceived impact from an extracurricular seminar:

> "HOW are processes accompanied, how are processes guided, what is the cooperation at all? (…) What does it take for cooperation to produce results that are really meaningful [in terms of sustainability transformations]? And I found myself in that very much, and I'm still deepening that in my bachelor's thesis" (student 4, pos. 30)

At the same time, student 8 (pos. 23) even changed her major subject from Organizational Psychology to Cultural Science as she recognized how she wants to deal with issues in her further studies due to her exposure to sustainability-related learning experiences. She explained:

> "[I felt] that I actually have no desire for this (…) rational and predictable view of a topic. […] And I think that happened to a large extent because I shared a flat with Cultural Science students only, but also because I already noticed in this [sustainability and] responsibility module how it can also be to look at things and analyze them." (student 8, pos. 23)

Concerning the subjective value, students of type 3 showed from the beginning onwards *intentions* to deal with sustainability issues regardless of whether they study Sustainability

Science: "But then I realized pretty quickly in the first semester that (…) if I want to study here, then I have to be able to identify with it somehow" (student 8, pos. 23). At the same time, statements such as "What I didn't find at university, I did at home" (student, 4, pos. 74) indicate an intention to delve even deeper into sustainability issues. Consequently, students of type 3 often expressed *dissatisfaction* with formal sustainability learning opportunities they experienced as superficial. This dissatisfaction was accompanied by a strong *need for reflection* that supports valuing self-realization as an impact of their experiences. Student 8, for instance, concluded:

> "And (…) that/so at the end of the studies it definitely shaped me, everything in the complementary studies so that I also (…) know for myself that I see the whole concept [Education for Sustainable Development] critically, totally critically." (student 8, pos. 27)

Another characteristic of type 3 meaning-making processes seems to be that the perceived impact of new sustainability-related learning experiences is constantly evaluated and reflected against the background of *prior sustainability-related experiences*. Student 4, for example, spent a great deal of time in his interview on his individual process of change and the role his prior experiences played in it, "I had a little crisis because everything didn't work out the way I wanted it to or the way I thought I wanted it to" (ibid, pos. 22). In his interview, he revealed his struggle when he noticed that his first study program did not cover his interest in environmental communication. Finally, he interpreted his application to study at this university as a solution to his "crisis". However, he then reflected and criticized during the interview that the experiences in this study program were also not sufficient for him and that he, therefore, took more extensive informal experiences outside of the university to develop himself. Thus, such reflections of prior experiences often indicate initial change processes in type 3 meaning-making. It seems to shape why students of this type assign significance to the perceived possibility for self-realization through sustainability-related experiences. This could mean, if formal and informal sustainability-related learning processes lead to self-realization, students of type 3 assign perceptions of relevance: For example, some students claimed to perceive that sustainability had a high degree of professional relevance for their future career goals (students 1 and 9) or relevance for both their private lives and their disciplinary studies as well as for their future career plans (students 4 and 8).

Finally, the vital need for dealing critically with sustainability issues and for self-realization is reflected in the holistic, multidimensional sustainability conceptions with highly interconnected components of students of type 3. Student 9, for example, verbalizes this reflexivity in her sustainability conceptions by explaining: "I would still emphasize ecology and socio-cultural aspects stronger than economics. Simply, […] because that is somehow more important to me personally and somehow everything ultimately has its origin in it" (student 9, pos. 72).

5. General discussion

This study examined the questions of *how* and *why* sustainability-related formal and informal learning experiences became meaningful in a three-year undergraduate program for students with different disciplinary backgrounds. We contribute to the literature in HESD by providing further evidence for variations in students' meaning-making processes, and by adding a long-term and differentiated perspective to support curriculum design and the development of effective teaching and learning approaches.

5.1. A differentiated view on meaning-making: Integrating how and why

Our results provide further evidence on the notion that meaning-making in HESD is highly individual. More importantly, this study integrates the *how* and *why* of meaning-making, thereby offering a differentiated perspective on the characteristics of different meaning-making processes.

For example, this perspective allowed us to differentiate that while students of type 1 lose interest in sustainability issues after the first semester, students of type 3 attribute significance to sustainability-related learning experiences in complementary studies and informal contexts just from the second semester onward, even though for students of both types the first-semester learning experiences had not been significant.

Regarding *how* students perceive the impact of dealing with sustainability, we found that the extent of the perceived impacts is a distinguishing characteristic of different types of meaning-making processes. The different perceived impacts of sustainability-related learning experiences are similar to those found in other studies. For example, previous studies showed that sustainability-related learning experiences are perceived as beneficial for sustainability awareness (Davis et al. 2003), employability (Azapagic, Perdan, and Shallcross 2005; Bone and Agombar 2011; Opoku and Egbu 2018), professional relevance (Abbonizio and Ho 2020), or professional specialization (Wyness and Dalton 2018). Interestingly, we were able to show that within one cohort with different study backgrounds, similar learning experiences in the first semester are attributed varying extents of impact. One possible explanation is that learners perceive only impacts congruent with their beliefs, attitudes, values, and knowledge. Other impacts, such as self-realization, that are probably incongruent with their beliefs and values (frame of reference) might be blocked entirely or not perceived at all (Ardoin and Heimlich 2021; Jarvis 1987).

Regarding the question of *why* (i.e. the subjective value that students did or did not assign to the perceived impact of their key sustainability-related learning experiences), the study emphasizes the role of emotional and motivational responses as a sign of assigned value. Similar to previous studies on meaning-making in environmental education/education for sustainable development (Dillon, Heimlich, and Kelsey 2013; Lundholm, Hopwood, and Rickinson 2013; Manni, Sporre, and Ottander 2017; Öhman and Östman 2007), our results show that students engaging with sustainability form diverse emotional responses. The present findings especially support Lundholm, Hopwood, and Rickinson's (2013) results, i.e. that sustainability-related subject matter often seems to challenge learners. In the case of type 1 and type 2 meaning-making processes, negative emotional responses seem to signify a barrier for assigning value to the perceived impact of sustainability-related learning experiences. However, the more negative emotional responses were more evident among sustainability novices. This result may be explained by the fact that these students' specific worldviews and values, such as conservatism, are threatened by the sustainability-related learning experiences (Ojala 2013; Park 2017). Consequently, students might defend their values and worldviews by losing interest in sustainability rather than reflecting on them and expanding their learning experiences. In contrast to negative responses, ambivalent emotional responses appear to indicate slight incongruence of the experiences and the frame of reference that still leaves room for some meaning-making (type 2 processes). Probably, they are experienced as stimulating and thus enhance meaning-making.

Further, our findings emphasize the role of prior sustainability-related experiences for facilitating type 3 meaning-making processes. These findings are in line with previous studies that found students assigning low significance to environmental subject matter if they expected it to be irrelevant for their major subject and their professional future (Rickinson and Lundholm 2008) or found that preconceptions regarding science and sustainability can be challenging for learning (Wyness and Dalton 2018). To some extent, this prominent role of prior experiences for type 3 processes could be explained by the notion that strong expectations can become self-fulfilling prophecies (Mezirow 2018). Evidently, by integrating the how and why of meaning-making, we found evidence that the two dimensions are essential for understanding the complexity of individual meaning-making processes in students with diverse backgrounds.

Additionally, the results support the assumption that problem- and inquiry-based learning approaches applied in the first semester can facilitate type 2 meaning-making processes. There is already a large body of literature showing that participatory, active, and experiential learning is essential in fostering students' personal interest or engagement in sustainability issues (Birdman,

Redman, and Lang 2021; Brandt et al. 2021; Konrad, Wiek, and Barth 2021). However, our results indicate that these teaching-learning approaches do not support meaning-making for all students in the same way. To prevent loss of interest (type 1 meaning-making processes) or dissatisfaction (type 3 meaning-making processes) with the formal institutionally-driven sustainability-related learning experiences, there should be more support for addressing diverse emotional responses. Although dealing with affective learning outcomes has already been described as an important element of HESD (Manni, Sporre, and Ottander 2017; Shephard et al. 2015), it is possible, for example, that not all teachers in the first semester are prepared for or comfortable with emotional responses and affective learning outcomes (Shephard 2008; Winter and Cotton 2012). Moreover, education for sustainable development is understood differently by different teachers (Wals and Jickling 2002). To address the different types of meaning-making processes, it could help to deal with diversity in emotional responses, already from the first semester on.

When taken together, these findings raise intriguing questions for future research, for instance on the extent to which the two dimensions of meaning-making become evident in other educational contexts and, on a larger scale, on the specific characteristics of key significant formal and informal sustainability-related learning experiences, or on the diversity of meaning-making processes three or five years after graduation. Although there is a need for further research in this area, we came up with practical implications for future design of curricula design based on the different processes, which are illustrated in the next section.

5.2. Implications for sustainability-related curriculum design

This study offers insights for curriculum designers, lecturers, and higher education institutions interested in expanding their efforts to engage students with different backgrounds in interdisciplinary sustainability-related learning. As suggested by our results, the sustainability-related learning opportunities in the first semester of the study program do not seem to lead to meaning-making processes for all students. The findings, in particular, have two important practical implications: Training the lecturers in the first semester to become more responsive to the students' emotional responses and adapting the study program even more to the different needs.

First, students' needs and challenges should be more strongly addressed and reflected upon in the first semester. Tutorials should function as an open and protected space for reflection on personal challenges with sustainability-related learning experiences. This reflective space would be beneficial in avoiding type 1 meaning-making processes and facilitating type 3 meaning-making. The tutorials would address the dissatisfaction with perceived superficiality and, at the same time, negative emotional responses by, for example, role playing or engaging with role models (Shephard 2008). The implication follows suggestions of a few students who valued the opportunity for reflection in the interview, and by recent studies suggesting integrating reflective tasks into the curriculum to cope with explicit challenges (e.g. negative emotions toward sustainability-related learning experiences) (Frank, Sundermann, and Fischer 2019; Lundholm, Hopwood, and Rickinson 2013). Second, an attempt could be made to create more learning opportunities in the first semester that explicitly frame the sustainability issues from disciplinary perspectives instead. The implication is supported by the findings of Sandri (2021), who recommends creating so-called entry points to sustainability issues tailored to the disciplinary backgrounds of the students. However, there is a risk of losing the interdisciplinary and problem-oriented approach of the first semester which, in turn, were presented by most students of types 2 and 3 as helpful for meaning-making.

The study program in its current form seems to offer the most significant potential to facilitate type 2 processes. Hence, our results provide further evidence that the combination of informal and formal learning experiences offers the opportunity for meaning-making for students with diverse backgrounds (Ballantyne and Packer 2005) but with a certain openness and curiosity towards issues outside their disciplinary major subject. The first semester seems to generate an

initial interest ("opening the door") through subjectively valued professionalization in students of type 2. The electives in the complementary studies could further facilitate engagement with sustainability by offering a sustainability-oriented track of seminars for students who did not choose the minor Sustainability Science in the first semester ("keeping the door open").

Weaving sustainability-related learning opportunities in disciplinary major and minor subject content could further support type 2 and 3 meaning-making processes. Students of type 2 themselves expressed this desire for more coherence throughout their studies. Of course, weaving sustainability issues more closely with disciplinary content could be supportive for all students (Kohl et al. 2022). Based on our results: type 1 processes could probably be turned into type 2 processes if specific, major-related sustainability content gave students the impression of professional relevance in the first semester. However, our results suggest that more institutionally-driven learning opportunities would probably not facilitate type 3 meaning-making processes. It appears that type 3 processes are facilitated by prior change processes and independent, self-directed experiences. The mandatory introductory learning opportunities could thus have a rather deterrent effect on this type of meaning-making process. Our research reconfirms the findings of Gramatakos and Lavau (2019) that informal and elective learning experiences are precious if students already bring the intention to delve more deeply into specific sustainability-related challenges. For these students, freedom for informal learning experiences and elective options within the study program structure seem particularly helpful and supportive for their meaning-making processes. To support these students in the best possible way, it seems advisable to expand informal and extracurricular learning opportunities to create more spaces for experiential learning.

In summary, we responded to the call for deeper insights into the role of learning in empowering people to think and act reflectively, critically, and sustainably (Dillon, Heimlich, and Kelsey 2013). In light of the intense individual learning and meaning-making processes in a curriculum-as-lived, our findings enhance understanding of the specific dynamics that may shape *how* and *why* sustainability-related experiences are perceived as meaningful, which mediates the relation between (formal and informal) learning experiences and learning outcomes. A combination of mandatory and elective, formal and informal learning opportunities has shown potential in engaging students from diverse study backgrounds. However, it seems important to incorporate reflective and tailored learning opportunities in the first semester to facilitate meaning-making for all students equally. Looking into meaning-making processes from students' perspectives throughout a three-year undergraduate study program may thus serve as a starting point to further support the development of significant pedagogical means to improve competence development in sustainability.

Notes

1. A module in the three-year study program has the function of an organizational unit that combines individual courses, in this case a lecture, tutorials, and a project seminar from the subject area of sustainability.
2. In this study, a seminar is a learning activity in a smaller group (up to 30 people), which serves the more interactive acquisition and/or production of knowledge. Learning objectives of seminars often go beyond the mere transfer of knowledge and tend to focus on competence acquisition.
3. Lectures are understood as learning activities in which lecturers aim to transmit knowledge to students by means of speaking in front of an audience in a transmissive manner. These lectures are sometimes, but not always, supported by interactive elements such as questions to the plenum, discussion rounds or assignments.
4. A tutorial is a supporting and accompanying course to a lecture or seminar, which serves to deepen and repeat content from the lecture and seminars with hands-on exercises. The tutors are students, who are more advanced in their studies.

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Appendices

Appendix A. Preselection survey (n = 42)

Preselection characteristics	Absolute frequency
Gender (response option: female)	27
Major subject	
Teaching and Learning	4
Vocational Education in Social Pedagogy	1
Business Education	4
Business Administration	2
Environmental Science (incl. Environmental and Sustainability Studies)	9
Engineering	2
Cultural Science	9
Business Law	2
Economics	3
Business Psychology	7
Perceived professional relevance for the future (response option: yes)	38
	Mean
Perceived professional relevance for future professional life (response options from very high relevance to no relevance)	3.83
Age	24.69

Appendix B. Key questions from the interview guideline

Question block	Key questions	Example follow-up questions
1	How do you understand the concept of sustainable development? We will now give you a sheet of paper with "sustainable development" written in the middle. We ask you to take 10 min and draw/present your understanding of sustainable development in the form of a mind map.	
2	How did you experience the issues of sustainable development at the university from the beginning of studies onwards? What experiences did you have with issues of sustainable development up to the present day in the study program?	You talked about experience XY, please describe your experience again in a little more detail. What was it like for you?
3	Let us take a look at your mind map again: How do you think of your understanding of sustainable development?	What does this concept exactly mean to you? Could you describe this concept in more detail?
4	Thinking about your course of study, what was the most significant change in your understanding of sustainable development?	Why did you choose this particular change? What was the main reason for this change?
5	To what extent do you perceive relations between your major/minor subject and issues of sustainable development?	Imagine you were allowed to further develop the study program: How would you create links between your major/minor subject and issues of sustainable development?
6	How do you envision your professional/private future?	To what extent will issues of sustainable development play a role in your future?
7	Is there anything that comes to your mind that you would like to mention, add, or emphasize regarding what you have already said?	

5 Synthesis

This synthesis section integrates the findings of the four individual research contributions to address the four major themes of the research questions: (1) defining students' sustainability conceptions, (2) measuring students' sustainability conceptions, (3) analyzing change in students' sustainability conceptions, and (4) identifying related internal and external learning conditions to better understand how studying affects students' sustainability conceptions (learning processes). Table 4 gives an overview of the synthesized theoretical implications by research question. The theoretical implications are further discussed in section 5.1. Then, section 5.2 offers a reflection on the mixed-methods approach, and critically examines the limitations of this dissertation's contributions. Furthermore, the practical implications for the development of sustainability-related teaching and learning are discussed in section 5.3. These are geared to be benefiting for curriculum developers and lecturers seeking effective sustainability-related teaching and learning approaches.

Table 4. *Overview of the theoretical implications by research question.*

Research questions	Theoretical implications
RQ1: Definition	– Revealed the need for (1) terminological clarification, (2) reliable assessment instruments, and (3) need for further systematic exploration of the learning processes – Terminological clarification allows comparability and integrability of the findings on change of students' sustainability conceptions within the field of HESD and in the field of conceptual change research
RQ2: Measurement	– Enables comparative and large-scale measurement of change in students' sustainability conceptions
RQ3: Change	– Provides evidence for moderate change in students' sustainability conceptions – Similarities in change patterns between natural science and social science concepts
RQ4: Internal and external learning conditions	– Findings regarding the importance of affective and cognitive internal learning conditions in line with conceptual change research – Sustainability conceptions as mediators between affective internal learning conditions and antecedents of engagement – Underlines the importance of subjective meaning-making processes for the effectiveness of learning offers

5.1 Theoretical Implications

5.1.1 Defining Sustainability Conceptions

Regarding RQ1, this dissertation contributed by exceeding a previous literature review and identifying three research gaps, but also by providing a definition for students' sustainability conceptions (cf. Lipscombe, 2008b). From this, implications can be derived for future research.

First, the literature review identified a lack of consensus in defining students' sustainability conceptions. Regarding this first gap, this dissertation provides conceptual and terminological clarity by defining students' sustainability conceptions as individual representations of the idea of sustainability in HESD which manifests itself, for instance, in associating core aspects with the concept of sustainable development (*article#2*). By using an existing definition from Borg et al. (2014) and framing sustainability conceptions within the framework of key competencies in sustainability as a learning outcome, this demarcation supports forming a common understanding of sustainability conceptions. By providing this definition, this dissertation avoided ambiguity and may facilitate further collaboration in the field. Furthermore, sustainability conceptions are delineated from neighboring terms. This clarity contributes to making sustainability conceptions measurable and findings comparable across cohorts, institutions, or countries.

Second, the review exposed a gap in research on sustainability conceptions regarding the assessment periods of change and development in students' sustainability conceptions (*article#2*). As conceptual change research suggests, conceptions develop slowly over time. Thus, changes and developments in students' sustainability conceptions are only to be expected to unfold over the course of entire study programs. However, none of the studies included in the review cover such a period: they either use cross-sectional designs or, in a few cases, pre-post study designs. Against this background, longitudinal studies and an expansion of research at the intersection of conceptual change and HESD are required to determine the effectiveness of studying sustainability in changing students' conceptions of sustainability. Another methodological gap connected to the aforementioned vague definitions of sustainability conceptions is the lack of assessment instruments. To shed light on the relationship between sustainability-related teaching and learning and change in

sustainability conceptions, it is essential that reliable and validated instruments are developed.

Third, the review revealed a missing theoretical foundation of the empirical research in conceptual change research and contemporary learning theories (*article#2*). Contemporary learning theories suggest, for example, that various internal and external learning conditions are involved in learning and conceptual change. Against this background, future research should seek to utilize mixed-methods approaches, not only to investigate whether students' conceptions change but also to explore and identify internal and external learning conditions involved in these processes. Thus, the findings regarding RQ1 contributed to the theoretical foundation of students' sustainability conceptions by providing a comprehensive overview of existing empirical research and highlighting areas of consensus as well as areas where further research is needed to resolve discrepancies.

In the future, the definition of students' sustainability conceptions can serve as a foundational element for integrating knowledge from conceptual change research and research on normative/values-thinking competency. Furthermore, the definition gives researchers a starting point to develop definitions for other concepts of the idea of sustainability to compare students' conceptions of different sustainability concepts. However, the used definition limits sustainability conceptions to the characteristic of dimensionality and the concept of sustainable development. According to Watson and Barrella (2017), textual and structural complexity are also important characteristics of sustainability conceptions. Future research could develop extended definitions that account for these characteristics to identify changes in conceptions more comprehensively. Subsequently, it seems worth exploring how students' sustainability conceptions relate to other facets of normative/values-thinking competency. This dissertation, for instance, presents some initial evidence about the relationships of sustainability conceptions with perceived professional relevance and personal values (*article#1; article#2*). Additionally, *article#4* revealed relationships with other internal learning conditions, that seem to be close to facets of the competency. Nevertheless, it is essential to examine their interrelationships for the development of instruments to systematically assess normative/values-thinking competency. In summary, defining conceptual change and reviewing the literature in the field of HESD has contributed by identifying and enhancing conceptual clarity, providing a

foundation for developing theoretical frameworks, identifying research gaps, and synthesizing existing knowledge.

5.1.2 Measuring Sustainability Conceptions

This dissertation contributes to the question of how studying affects students' sustainability conceptions by developing an assessment instrument – the sustainability conceptions scale – for exploring the long-term changes in the dimensionality of students' sustainability conceptions in higher education (RQ2). There are three key reasons why a comprehensive scale complements the existing research instruments: First, a valid and reliable tool for tracking changes across multiple time points is necessary to investigate the relationship between sustainability integration approaches and changes in students' sustainability conceptions. Second, a comprehensive scale allows for valid cross-cultural comparisons which promote a better understanding of commonalities and differences in sustainability conceptions across institutions or cultural backgrounds. This might help to identify strengths and weaknesses in sustainability-related teaching and learning approaches in addressing sustainability conceptions. Third, on a meta-level, data from the scale can help to inform policy-makers and curriculum developers on the level of conceptualization of sustainability among cohorts of students. These insights can guide allocation of resources to promote HESD.

Previous studies on students' sustainability conceptions aimed to learn how undergraduate and graduate students experience the concept of sustainable development or tend to describe and categorize conceptions and understandings of sustainability (*article#2*; Appendix B). At the same time, various challenges arise with numerous planned observations in longitudinal interview or conceptual map studies. For example, conceptual map assessment requires all students to be equally proficient in the graphical visualization method (Daley, 2004). Qualitative longitudinal studies not only result in complex datasets but subsequent interviews also may affect the interpretation of the data by the researcher as well as the memory of the participants (Elliott et al., 2008). It thus appears that few studies use these methods to investigate long-term changes of sustainability conceptions. To demonstrate that HESD approaches effectively address sustainability conceptions, longitudinal designs are imperative. Few of the assessment instruments used prior to this study have been applied in more than one national context or with more than one sample. Therefore, the instrument

developed in this dissertation proves to be a useful complement to previously used assessment and data collection methods. *Chapter#3*, for example, shows that the instrument combined with multilevel modeling is suitable for gaining a first impression of change patterns in sustainability conceptions. In addition, individual variability has been detected. Thus, the approach developed in this dissertation explicitly meets the practice-oriented need to be able to monitor changes in students' sustainability conceptions. Thus, the scale development responds to the general call for developing instruments to monitor students' learning outcome development in HESD (Cebrián & Junyent, 2015).

The target group of this scale development were students in higher education in mainly western and developed country contexts. On the one hand, these personal characteristics build the foundation for the validation of the scale to tailor it closely to the research aim of this dissertation. On the other hand, this focus on scale development needs to be considered when transferring the scale to other samples or environments. Furthermore, the scale is constructed based on a specific understanding of conceptions that translates the United Nations definition of the concept of sustainable development into a measurable learning outcome. The approach captures the changes in associating certain core aspects of sustainability with the concept of sustainable development (Borg et al., 2014). This conceptual framework for the operationalization of students' sustainability conceptions has advantages as it is transparent and draws on one of the globally highly cited concepts of the idea of sustainability.

For an even more comprehensive assessment of students' sustainability conceptions, measures are needed that cover the textual complexity and interrelations between and within the dimensions of sustainable development. However, as a basis for this further development of the scale, an expanded definition of sustainability conceptions would be needed. Additionally, only a previous version of this scale has been used with business students from Indonesia and the USA. To validate the current version of the scale, it would be useful to test it with students from different backgrounds, study programs, and educational levels. However, it can be argued that given the similarities in dimensionality of the prior scale presented in *article#1,* the current version of the scale can be considered robust in other contexts as well. Research is needed to rectify this proposition.

In terms of analysis of the scale, future research could go one step further in the direction of latent transition analysis. This quantitative method of data analysis has been used so far in studies with school students and for natural science concepts such as rational number development and the concept of sinking and floating of different objects (Kainulainen et al., 2017; McMullen et al., 2015; Schneider & Hardy, 2013). Compared to the multilevel modeling used in *chapter#3*, latent transition analysis has the advantage of distinguishing types of understandings and being able to map inter- and intraindividual differences in heterogeneous groups (Hickendorff et al., 2018). Employing latent transition analysis, Flaig et al. (2018), for instance, examined changes in the concept of human memory in psychology students. However, this analysis method requires a distinction between misconceptions, experience-based everyday conceptions, and scientifically accepted conceptions at the outset of the investigation. Hence, before the method can be employed in HESD, future studies should agree on termini and work on the theoretical grounding of sustainability concepts. Future studies using a similar measurement approach and a more advanced analysis method could thus contribute to an even more nuanced understanding of conceptual change in HESD.

5.1.3 Change in Sustainability Conceptions

A key contribution of this dissertation is that it addresses the need for systematic research on how studying affects students' sustainability conceptions: first, by providing empirical evidence for change in students' sustainability conceptions over time, and second, by providing descriptions of the patterns of change in the dimensionality of students' sustainability conceptions. In this section, both contributions are discussed against the background of studies on learning outcomes in HESD and conceptual change research. Finally, implications for research on change in students' sustainability conceptions are presented.

The most important contribution of this dissertation is the empirical evidence of decreasing association of the ecological and economic dimension with the concept of sustainable development over time across all students (*chapter#3*). These changes, however, are small which means that a significant change only manifests itself over years. General evidence for change over time in HESD learning outcomes has been reported in, for instance, school students' action competency in relation to holistic teaching about sustainability (Olsson et

al., 2022). Furthermore, a pre-post study on sustainability-related learning outcomes of teacher training students revealed increasing complexity in students' understandings of sustainability in relation to sustainability-related teaching and learning approaches Brandt et al. (2021, 2022). Adopting the analysis perspective of Brandt et al. (2022), the changes found in *chapter#3* could be interpreted as change towards more holistic and balanced sustainability conceptions. Additionally, these results suggest more elaborated conceptions of sustainable development over time. Overall, however, the findings suggest that the changes towards a balanced dimensionality of students' sustainability conceptions related to studying are only minor (*chapter#3*). This seems to be supported by *article#4* where final year students' conceptual maps show both mono-dimensional as well as multi-dimensional sustainability conceptions (Appendix C). Similarly, Segalàs et al. (2010) found that on average, the dimensionality and the structural complexity of undergraduate engineering students' sustainability conceptions hardly changed after participating in sustainability-related courses. Thus, evidence for change over time in learning outcomes and especially in students' sustainability conceptions in HESD over time remains scarce – and if it is detected, results are mixed (Collado et al., 2021; Harring et al., 2020; Shephard et al., 2015). These findings align with findings from conceptual change research. Scholars from this field conclude that changes in (science) preconceptions are possible but challenging to achieve by pure instruction-based teaching and learning approaches (Coştu et al., 2010; Kainulainen et al., 2017; Rebich & Gautier, 2005; Reinfried & Tempelmann, 2014).

Notably, significant intraindividual differences at each point in time in the sustainability conceptions were observed in *chapter#3*. These intraindividual differences appear to occur in conceptual change studies with school students and natural science concepts as well (Edelsbrunner et al., 2018; Kainulainen et al., 2017; Merenluoto & Lehtinen, 2004). To date, longitudinal intraindividual changes have not been reported in studies on changes of learning outcomes in HESD, although scholars point to the individuality of learning based on synthesized findings from qualitative research (Lundholm et al., 2013). Qualitative data from *article#4* add to this notion by revealing three different learning processes related to varying sustainability conceptions and by identifying several internal learning conditions shaping these learning processes. In sum, these results do not suggest a strong institutional effect over time for changes in sustainability conceptions.

Regarding the dimensionality of students' sustainability preconceptions, this dissertation's findings support previous studies showing that students associate aspects of the ecological dimension strongly with the concept of sustainable development (*article#1*; *article#2*; *chapter#3*). However, this dissertation's contributions differ from previous findings. Firstly, the majority of students, including freshmen, associate aspects of more than one dimension with the concept of sustainable development (*article#2*). Secondly, most students show not only high scores on the ecological but also on the socio-cultural dimension (*article#1*; *article#2*). There are two possible explanations for these differences: First, it is possible that students in situations such as an interview or a conceptual map study, in which they have to freely associate, remember less diverse aspects than when they are presented with a scale with different aspects. To avoid this common method bias, future studies could do both: assess students' conceptions with the sustainability conceptions scale and by means of conceptual maps. Second, the differences might be caused by cohort effects. Previous studies are older, so it could be assumed that these students had less exposure to sustainability issues in school or in the media.

Notably, students of environmental science associated the concept of sustainable development more strongly with economic and socio-cultural aspects over time while overall a decrease in associating the economic and ecological dimension with the concept was found (*chapter#3*). Findings from *article#4* suggest that especially students studying environmental science reflected increasingly critical on the concept of sustainable development. These students were also critical of the formal sustainability-related learning opportunities in the first semester which they perceived to be too superficial (*article#4*). It might additionally be the case that students from other disciplines are not able to recognize the differences between the concept of sustainable development and other sustainability concepts at the end of their studies, and might instead just have internalized the ongoing criticism against current economic practices. Therefore, they would associate sustainable development with eco-social aspects. These findings align with a study by Kruger et al. (2020) which found that students with elaborated sustainability conceptions were enrolled in environmentally-oriented study programs. In contrast, other studies note that students showed ecologically focused sustainability conceptions even after taking sustainability-related courses (I. F. Clark & Zeegers, 2015; Segalàs et al., 2010; Zeegers & Clark, 2014). Additionally, Segalàs et al.'s (2010) results indicate a relationship between multidimensional post-course conceptions and *activating teaching* approaches. Similarly,

some students in *article#4* retrospectively reported changes in their understandings in relation to significant sustainability-related learning experiences that were often informal and happened prior to their studies. However, *article#4* identified that students with these kinds of learning outcomes were often studying environmental sciences. This qualitative observation is supported by the notion that the dimensionality of sustainability conceptions is related to the respective students' subject affiliation (*chapter#3*). These contributions seem to imply that specific teaching-learning settings in individual study programs, specific characteristics, and subjective or informal experiences of students are connected with changes in students' sustainability conceptions.

The implications of these contributions are threefold: First, the overall results suggest that sustainability conceptions somewhat change in relation to the undergraduate program and often in interaction with the students' subject affiliation. In combination with previous results, this provides further evidence of the proposition that time spent studying is related to change in students' sustainability conceptions. However, these effects could be affected by aging effects or related to multiple internal and external learning conditions. Now that there is first evidence for conceptual change, future research should conceptualize systematically the integration of sustainability in study programs, modules, and courses in order to specifically analyze the relationships of sustainability-related learning offers with change in conceptions.

Secondly, these results imply that most students, except for the environmental science students, make little distinction between the concept of sustainable development and other sustainability concepts. Future studies should pick up at this point and compare students' conceptions of different sustainability concepts across different sustainability-related teaching and learning approaches. These studies could reveal whether students can differentiate between the dimensional focal points of different concepts of the idea of sustainability.

Third, it appears that a continuous engagement with sustainability throughout the undergraduate program leads to more elaborate sustainability conceptions. A stand-alone sustainability-related first semester combined with formal optional sustainability-related course offers in the complementary studies does not seem to have long-term effects for all students. Thus, future research should compare this study program with study programs in

which sustainability is fully integrated into the subjects from the beginning to the end to reveal the influence of this integration on change patterns.

5.1.4 Learning Processes related to Sustainability Conceptions

In response to the call for a better understanding of learning processes in HESD (Gap 4, RQ4a, 4b), this dissertation identifies internal and external learning conditions related to students' sustainability conceptions beyond subject affiliation and time spent studying. Furthermore, it explores the role of sustainability conceptions concerning students' sustainability-related engagement. Figure 7 jointly displays these internal and external learning conditions.

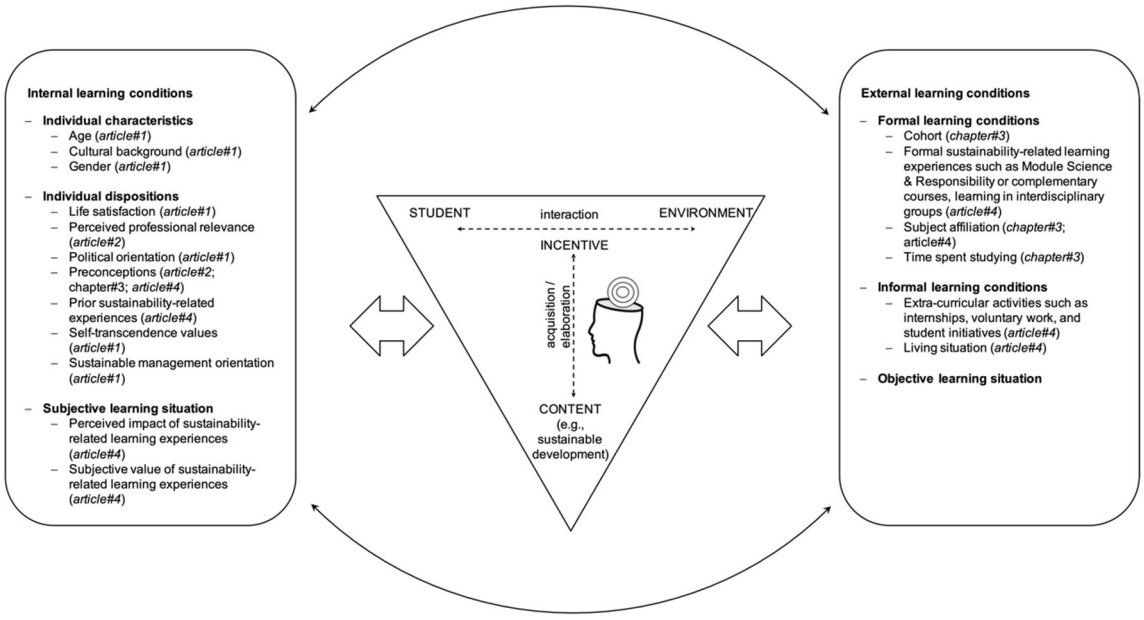

Figure 7. *Joint display of internal and external learning conditions related to sustainability conceptions identified in the quantitative and qualitative parts of this dissertation.*

Adapted from "A Comprehensive Understanding of Human Learning", by K. Illeris, in K. Illeris (Eds.), *Contemporary Theories of Learning: Learning Theorists…In Their Own Words* (1ed, p.4), 2018, Routledge. Copyright 2018 by Informa UK Limited, trading as Taylor & Taylor & Francis Group. Adapted with permission.

Most importantly, this dissertation provides evidence for the roles internal learning conditions play with regard to differences in students' sustainability conceptions. First, the findings support the already strong evidence in conceptual change research for the importance of preconceptions and prior knowledge in these learning conditions (*article#2,*

article#3, article#4). Reinfried and Tempelmann (2014) found that preconceptions are related to intraindividual variations in learning processes. These findings align well with *article#4*, where change processes before the start of the studies have been identified as influential for learning processes associated with elaborated sustainability conceptions. Overall, this further supports the assumption that pre-conceptions function as a gatekeeper for the mere possibility of change (Reinfried & Tempelmann, 2014; Vosniadou, 2012; Vosniadou et al., 2001). Second, as previously stated, HESD and conceptual change scholars assume that affective internal learning conditions are important in learning processes. The findings from this dissertation on the relationship between several affective internal learning conditions such as personal values, emotions, or interest and motivation in relation to differences in students' sustainability conceptions add further evidence to this assumption (*article#1, article#4*). Recent studies in HESD show that emotional difficulties in dealing with sustainability issues, perceived expectations of instructors, or perceptions of relevance are necessary internal learning conditions related to the development of sustainability competencies (Birdman, Barth, et al., 2022; Birdman, Redman, et al., 2020; Birdman, Wiek, et al., 2022; Brandt et al., 2022; Konrad et al., 2020, 2021a, 2021b). These findings align with findings from conceptual change research (Linnenbrink & Pintrich, 2002; Moriggi et al., 2020; Pintrich, 1999; Pintrich et al., 1993). In fact, this dissertation provides evidence for the interrelationship between cognitive and affective internal learning conditions. Findings in *article#*1 indicate a significant positive relationship between all dimensions of students' sustainability conceptions, self-transcendence values, and sustainable management orientation (*article#1*). While this finding needs further exploration, it provides evidence for the notion that knowledge is not irrelevant with regard to sustainability-related attitudes and behaviors (Geiger et al., 2018, 2019). Furthermore, together with the finding that only the social dimension of students' sustainability conceptions was related to their perceived relevance of sustainability (*article#2*), it more specifically adds to the assumption that the relationship between sustainability-related attitudes and behavior might depend on the framing of sustainability (Fischer et al., 2021; Maibach et al., 2010; Nisbet, 2009).

Regarding the relationship between external learning conditions beyond time spent studying and subject affiliation and differences in students' sustainability conceptions, this study provides fewer detailed results. Findings from *article#4* showed in particular the following: The project-based seminars in the first-semester appear to be only useful for raising interest in students if the respective approach of a seminar matches their personal interest and

professionalization needs and thus is able to raise perceived professional relevance. Exactly for these students, the study program with further optional sustainability-related courses seems to unfold its full potential as these students tend to report stable self-directed engagement with sustainability in the complementary studies later on. In addition, they also tend to hold more elaborated sustainability conceptions in their final year as compared to the beginning of their studies. However, if the first semester courses fail to increase the relevance for their current studies, students with high professionalization needs soon lose their interest in sustainability. This seems as well to be related with mono-dimensional sustainability conceptions in the final year of the undergraduate program. So far, it has within HESD been widely argued that interactive and experiential, student-centered teaching and learning approaches are appropriate for sustainability-related learning (Elliott, 1991; Sterling, 2011). However, these findings imply that not all students seem to benefit in the same way from these learning approaches, especially with regard to their sustainability conceptions.

In summary, these findings show that a wide range of internal and external learning conditions must be considered to understand change and development in students' sustainability conceptions. Merely investigating time spent studying and academic affiliation as well as personal characteristics does not fully explain the complex change and development patterns in students' sustainability conceptions. As stated above, the effects of learning offers are highly interrelated with the subjective meaning-making of students. This overall finding has implications for the design of longitudinal research on specific learning outcomes in HESD. So far, existing longitudinal studies are investigating specific learning outcomes without operationalizing specific external and internal learning conditions at all levels of a course, module, or study program and seldomly consider investigating affective learning conditions. Future studies should therefore use educational frameworks such as Price's (2013) to thoroughly operationalize these learning conditions. A more complex theoretical operationalization of studying could contribute to more nuanced statements about the inter- and intraindividual differences in learning processes.

5.2 Methodological Reflection and Limitations

This section offers in its first part a reflection on the mixed-methods approach. This provides insights into the advantages and challenges of the sequential mixed-methods design in order to provide further insights on how far this approach contributes to an understanding of how studying affects students' sustainability conceptions. The second part examines the limitations of this dissertation that need to be considered to understand the constrains of the overall contribution.

5.2.1 Reflection on the Mixed-methods Design

Mixed-methods research designs can take many forms, depending on the research objective and types of integration of qualitative and quantitative research approaches within the research design (Foscht et al., 2007). In practice, mixed-methods studies can differ in what is considered the ideal design. This reflection section delves into three characteristics of the employed design, namely: (1) simultaneous theory development and testing, (2) combination of a longitudinal study within a sequential explanatory design, and (3) the theme-based synthesis of results. It outlines the advantages of these characteristics for analyzing how HESD affects learning outcomes and addresses encountered challenges, accompanied by potential solutions.

Simultaneous theory building and testing. The key objective of this dissertation was to analyze how studying affects students' sustainability conceptions. The complexity of the social phenomenon was translated into a comprehensive and inclusive framework of learning that has been combined with knowledge from conceptual change research. This object-specific development of a framework was necessary as so far in HESD, limited frameworks for conceptual change were available (Lundholm, 2017; Lundholm & Davies, 2013). Jäger-Erben et al. (2012) rationalize the use of mixed-methods designs exactly for the purpose of addressing new research questions in evolving research fields, where these questioned cannot be solved by using established frameworks. An advantage of the mixed-methods design is its ability to not only provide standardized findings on changes in students' sustainability conceptions but also on students' subjective experiences and learning processes. It thus contributes to theory development in HESD research (Mejeh et al., 2023). Almalki (2016) expects more socially robust explanations for research objectives

from these kind of mixed-methods designs. One challenge related to the simultaneous theory development and theory testing was that the relatively simple quantitative study design provided little flexibility for reanalyzing the data based on the results of the qualitative study and the adapted framework (Vogl, 2023). So far, it is an unresolved question in the mixed-methods literature how the iterative nature of theory development can be balanced with rigorous and structured theory testing. One strategy to avoid bias in the interpretation of the quantitative data, however, was to use a sequential mixed-methods design, where the qualitative analysis follows the quantitative and combining it with at least a prior study to test the scale in a different research context. Another helpful strategy employed in this project was using a typology to describe the specific characteristics of this design and paying attention to determine the features of the design according to most important characteristics of a mixed-method design (Foscht et al., 2007). This strategy ensured both, the priority of the research objective at any time of the research process and the quality of the mixed-methods research (Collins & O'Cathain, 2009; Onwuegbuzie, Slate, et al., 2009)

Combination of a longitudinal study with a reconstructive qualitative study. This dissertation used a mixed-methods design including a longitudinal study based on previous suggestions from Shephard et al. (2015) extended by a qualitative interview study. Shephard et al. (2015) report that the lack of changes in students' pro-environmental attitudes could not be explained sufficiently by their longitudinal design. A longitudinal, reconstructive mixed-methods design compensates this by addressing the following dimensions of learning and meaning-making: *what changes in students' sustainability conceptions, how do the conceptions change* and *why are they changing*. This design has the advantage that it especially in the qualitative part gathers data that is relevant to the context and subjective experience of the students and that the findings from both phases of research are building on to each other (Almalki, 2016). However, according to Vogl (2023), this specific combination of a longitudinal designs in combination with a qualitative interview study with a reconstructive nature are relatively seldomly used and quality standards are not yet developed. Thus, this specific design combination revealed several challenges. Integrating qualitative and quantitative data necessitated meticulous coordination, and ensuring that qualitative insights genuinely illuminated quantitative findings proved intricate. A longitudinal study with two cohorts of undergraduate students needs a fair amount of time because of the amount and complexity of the data (Vogl, 2023). For example, there has not been enough time in this dissertation project to analyze the data of the qualitative interview

study before the second cohort was investigated. This limited the possibility to change the questionnaire design by including more contextual factors or to change the focus of the analysis of the longitudinal data. To mitigate these challenges, meticulous planning and resource allocation were pivotal. Future longitudinal mixed-methods studies should reflect on the interrelatedness of findings and develop a strategy of substantiating findings from the qualitative strand with the second-wave of the quantitative strand to make full use of the potential of the mixed-methods design.

Theme-based synthesis of results. The integration of findings from diverse strands of inquiry within a mixed-methods design demands transparency to maintain rigor (Ivankova et al., 2006). All integration steps must be traceable to ensure the replicability of the findings (Creswell, 2009). The most important integration step for a mixed-methods study is that of synthesizing the different parts of the study. This synthesis then generates the meta-inferences. The different findings of the dissertation are synthesized based on the four research objectives. However, the synthesis has been challenging. To maintain participant anonymity and assuring voluntary participation, the data of both strands did not allow for full integration of the data collection methods, which affected the synthesis (Subedi, 2016; Vogl, 2023). Additionally, common research practicalities of longitudinal studies, such as panel mortality and lack of self-generated identification codes, prevented an extension of the qualitative strand to students of the cohorts of the longitudinal study. In consequence, a theme-based synthesis was used to gain some explanatory insights based on the shared research context of the two parts of the study. However, Plano Clark et al. (2015) suggests optimizing the synthesis of longitudinal mixed-methods designs by jointly showing comparisons of results of different strands at different points in time.

Reflecting on the benefits and challenges of the sequential mixed-methods design highlights its inherent value for the broader use in educational research (Mejeh et al., 2023). While challenges did surface, the design's advantages far outweighed the difficulties, underscoring its suitability for investigating change in learning outcomes in HESD.

5.2.2 Limitations

Despite its achievements in providing evidence for conceptual change in HESD, the findings in this dissertation have limitations, too. While the limitations of each article and chapter

have already been discussed in the respective contributions, three overarching limitations of the research approach will be reflected on in this section: First, limitations arise from the context dependency of the main samples in this research; second, there are limitations from the adopted perspective of assessment; and third, limitations stem from the underlying conceptual framework of learning and conceptual change.

First, this research has been performed mainly in the context of one German university and within one undergraduate program with several major and minor subjects. The dissertation thus studied students from the western hemisphere and of a certain age. Furthermore, samples in the quantitative parts of the study were convenience samples that might be biased by, for instance, the interest in the topic of the study. The bias in responses could be exacerbated by panel mortality in the longitudinal study, in that there is a relation between relevance of or interest in sustainability with participation over time. Still, the research focused on comparing large sample sizes from students of different major and minor subjects to ensure external validity. Furthermore, the potential bias does not apply to the sample selection of *article#4,* as the students were selected based on the bandwidth of their perceived professional relevance of sustainability. Against the background of pragmatist thought, however, context dependency makes knowledge useful for solving and improving practical problems in a certain situation (Elkjaer, 2018). From this standpoint, context dependency does not exclude theory building. Based on Dewey (1963), it is suggested that further studies should be developed to cumulate and converge the findings. However, this limitation comes at the expense of directly generalizing the findings to other contexts with, for example, samples from non-western or non-industrialized societies, or other types of sustainability-related curricula, institutions, and study programs. Nonetheless, based on the findings from *article#1*, it can be assumed that at least the connections between personal values, sustainability concepts, and management orientations are also valid in non-German samples and beyond undergraduate contexts.

Second, a limitation of this research arises from the adopted perspective of assessment. This dissertation took the approach of assessment *of* learning. This more summative assessment approach was specifically chosen to capture changes in students' learning outcomes over time. However, there is evidence that the type of assessment influences cognitive processing of learning outcomes (Cilliers et al., 2012). This finding suggests that the repetitive summative assessment of the concept of sustainability potentially influences students'

conceptualizations and intervenes on the learning processes. This assumption is supported by Endres et al. (2020), who report that this type of recall assessment is related to differences in retrieval and learning. If we understand conceptual maps as a free recall assessment and the sustainability conceptions scale as a cued recall assessment, it remains unclear in how far the findings of *chapter#3* are related to the assessment approach itself. In HESD, assessment *as* learning is often suggested as the gold standard of student-centered teaching, as it aligns well with activating and transformative teaching approaches in HESD (Schellekens et al., 2021). In *article#4,* for example, students mentioned that reflection processes were initiated by the conceptual maps approach. In conclusion, assessment *as* learning, might lead to continuous critical reflective engagement with the learning outcome and thus support the development of conceptions. In future research, the sustainability conceptions scale in combination with a continuous conceptual map assessment might be used in the context of reflective teaching and learning in the sense of assessment *as* learning to facilitate students' continuous engagement with their sustainability conceptions and to actively promote learning.

Finally, the findings of this dissertation have limitations due to the focus of the employed conceptual framework on internal learning processes at the expense of including the interrelations between levels of the institutional context and the learning offers. The longitudinal study (*article#2; chapter#3*) thus lacked a more comprehensive operationalization of external learning conditions on the three levels of the undergraduate study program. This could have been particularly important in order to better align the qualitative findings and to explain the intraindividual variances in students' sustainability conceptions. Frameworks describing learning offers in schools, for example, emphasize the interaction between the different levels of the institution with the learning outcomes at the expense of describing the internal learning process (Helmke, 2014). In contemporary educational research in schools, it is believed that learning outcomes are a product of the subjective learning experiences and interrelated effects of learning opportunities on all levels of an institution. It has so far not been clarified if these school frameworks can be adapted for the context of higher education for sustainable development.

To overcome the lack of suitable frameworks, transdisciplinary research approaches or design science research could be used to extend the framework of this dissertation regarding external learning conditions. Both approaches would include integrating practitioners and

participants into the research process for two reasons: On the one hand, they could improve the context specificity of the framework and on the other hand validate the practical implications of the findings. Future research could thus benefit from using frameworks that focus on the relationship between levels of learning offers and from including stakeholders of HEIs.

5.3 Practical Implications

Now that the articles and the book chapter of this dissertation have been synthesized and the contributions and their boundaries are clarified, the questions remain: What does this dissertation contribute to sustainability-related teaching and learning approaches in practice? What are its practical implications for the integration of sustainability at HEIs?

This section elaborates on these practical implications for the level of courses and the level of the undergraduate program (Table 5). It provides suggestions to improve the undergraduate program regarding students' sustainability conceptions. The following implications are based on the concept of constructive alignment (see section 2.2.4).

Table 5. *Practical implications of this dissertation at the course and the undergraduate program level.*

Level	Practical implications
Course level	– Employing a problem-based approach in the first semester – Extending reflective activities and the use of narrative learning activities – Using the sustainability conceptions scale and conceptual maps to stimulate assessment *as* learning
Undergraduate program level	– Continuous engagement with sustainability in all major subjects and study programs – Increasing the recognition of informal and extra-curricular sustainability-related learning experiences to tailor study programs – Implementing constant reflective guidance in form of a spiral curriculum

5.3.1 At the Course Level

At the micro-level of sustainability-related teaching and learning approaches and course design, the findings imply that the teaching and learning approaches should be designed to (1) tailor teaching approaches to different types of learning processes, (2) enable recognition

and reflection on internal learning conditions such as preconceptions, prior experiences, or values in conjunction with (3) more directly discussing different concepts of the idea of sustainability. More specific pedagogical approaches to enhance the development of normative/values-thinking competency, in particular, are rarely developed (Remington-Doucette & Musgrove, 2015). The implications for teaching and learning at the course level are threefold: (1) using a problem-based approach; (2) addressing sustainability conceptions directly via narrative learning activities; and (3) extending the number of reflective activities in the courses.

In order to address students' sustainability conceptions indirectly, student-centered, active learning approaches such as transformative learning or experience-based learning are suggested to enhance sustainability competency development (Brundiers et al., 2010; Caniglia et al., 2016; Mezirow, 1997; Sipos et al., 2008). However, an implication from this dissertation is that project- and experienced-based teaching and learning approaches not necessarily suit all students equally and seem not to affect sustainability conceptions strongly (*chapter#3*; *article#4)*.

Against the background of these findings, the project-based approach in the first semester could be replaced by a solely problem-based teaching and learning approach. Reducing the complexity for first year students would probably help reducing overload and loss of interest (*article#4*). For example, Remington-Doucette et al. (2013) show that a problem-based approach in which students analyze prepared real-world cases in groups via case vignettes could improve normative competencies. Using case studies with a problem-based teaching and learning approach would reduce the pressure on the students to learn research techniques as well as the content-related fundamentals of sustainability science and collaborative working skills at the same time. It could also release pressure from teaching staff. This freed time could then be used to support students by coaching and giving guidance to help them reflect on challenging learning experiences in their group work on the sustainability issues (*article#4*). It is easy to imagine that, while teaching content and supporting students, teachers might neglect the equally important systematic reflection activities.

In contrast to only indirectly addressing sustainability (pre-)conceptions, lecturers should develop more targeted learning opportunities towards changing sustainability conceptions. A fruitful possible teaching and learning activity based on the results of conceptual change

research would be the triggering of inner conflicts, for example, through the juxtaposition of different narrative texts that are based on different concepts of sustainability. According to Moltan Hill and Fischer (2022), narratives appear to be particularly useful for reflecting on social aspects of sustainability, which have been found to be related to students' perceived professional relevance of sustainability-related learning offers.

In addition, according to findings from *article#1* and *article#4* and findings from conceptual change research, values and emotions seem to be important in change of sustainability conceptions. To foster dealing with these affective internal learning conditions, reflective learning activities seem particularly suitable (P. Frank et al., 2019). These reflective teaching activities could be accompanied by assessment *as* learning activities using the sustainability conceptions scale and conceptual maps in order to gear the reflection processes towards differences and similarities in sustainability conceptions. In fact, researchers in the field of HESD have argued that practice-oriented learning should always be accompanied by reflective assignments for coping with sustainability-related learning experiences (Birdman, Barth, et al., 2022; Erskine & Johnson, 2012; Vare & Scott, 2007).

5.3.2 At the Undergraduate Program Level

Regarding the macro-level of implementing sustainability into university curricula and study programs, this research has shown that the current design of the undergraduate study program did not sufficiently support the development of elaborated sustainability conceptions in all students. Following this, there are three practical implications.

First, it was observed that students of environmental science show in general more elaborate sustainability conceptions than their counterparts from all other major subjects. This might be due to these students being exposed to discussing different sustainability concepts throughout their studies. To tackle this gap, there could be continuous engagement with sustainability anchored in all programs and courses and over the entire study time.

Second, a more flexible curriculum could be adopted that allows for sustainability-related learning experiences in informal settings such as internships, scholarships, museum visits, or field trips as regular parts of the programs (Gramatakos & Lavau, 2019). This might help

to tailor the curriculum to both types of students: the students who are already relatively committed to sustainability to upkeep their interest and for others to meet their professionalization needs (*article#4*). Incidentally, it could help if sustainability-related informal and extra-curricular activities were recognized in the transcripts of records of all students. This would increase the relevance of sustainability-related learning experiences beyond the first semester.

Third, based on the findings in this dissertation, the continuous engagement with sustainability could be accompanied by constant reflective guidance not only in the first semester, but throughout the entire undergraduate program. Regardless of which sustainability-related competencies are to be acquired, continuous reflection on learning processes is an essential prerequisite for learners' development (Huber & Reinmann, 2019). Following the reflection model of Korthagen and Vasalos (2005), the reflection would start after the problem-based sustainability-related learning course in the first semester. Each new project-based learning in the subsequent semesters would be accompanied by another reflection based on the former feedback loop.

6 Conclusion

Against the background of the current global challenges, HESD serves as a fundamental pillar of the transformation of society. As humanity is confronted with complex issues that transcend borders and disciplines, it becomes increasingly evident that a comprehensive understanding of the abstract idea of sustainability and the various related concepts is not just beneficial but imperative for students.

The main objective of this dissertation was to explore how studying affects students' sustainability conceptions. Therefore, a literature review together with a mixed-methods approach was employed to demarcate students' sustainability conceptions, to contribute to the assessment of sustainability conceptions, to analyze changes in sustainability conceptions, and to identify external and internal learning conditions involved in these learning processes.

The dissertation identified gaps in the empirical research on students' sustainability conceptions. These gaps point out needs for systematic research on students' sustainability conceptions, underlining the importance of terminological clarification grounded in contemporary knowledge of learning and conceptual change. In response to these gaps, the assessment tool developed and applied, in conjunction with conceptual maps, not only facilitates large-scale comparability of change patterns but also promises to be useful as a reflection tool. From a methodological point of view, this dissertation demonstrates that the employed sequential longitudinal mixed-methods design can provide large-scale as well as detailed complementary insights into the multifaceted nature of students' learning processes.

This research shows that sustainability conceptions of students with different subject affiliations can change when these students engage in an undergraduate program with a mandatory sustainability-related first semester in combination with additional optional sustainability-related courses later on. Overall, undergraduates were gradually less likely to associate economic and ecological dimensions with the concept of sustainable development over the course of the undergraduate program, though these changes are often only significant in relation to students' subject affiliations. In fact, however, only students in environmental science exhibit changes towards more elaborated sustainability conceptions.

This feeds the assumption that constant engagement with sustainability throughout the entire study program is beneficial for elaborated conceptions. In addition, effects of sustainability-related learning offers seem to be deeply interwoven with the students' subjective meaning-making processes, and individual emotions and values appear to play a significant role in these processes. This is in accordance with findings from conceptual change research. If a loss of interest and thus less elaborated sustainability conceptions are to be avoided, lecturers should therefore aim to create relevance of the sustainability-related courses for all students already in the first semester.

In light of these nuanced findings, it is evident that the approach of a mandatory, sustainability-related first semester in combination with merely optional sustainability-related learning offers later on falls short in addressing all students equally. Rather, this dissertation underlines that shifting students' conceptions is a multifaceted process and implies that continuous engagement and reflection throughout all subjects of a study program is most likely to be effective in equipping all students with elaborated sustainability conceptions. This would recognize that learners' unique characteristics, their perceived relevance of sustainability, and their subjective perceptions of the learning offers are related with differences in sustainability conceptions.

The journey towards comprehensive sustainability conceptions is not a rapid journey. It extends beyond a three-year undergraduate study program and starts already before the program even begins. This dissertation shows this – and provides strategies to enable change and development of students' sustainability conceptions. Future research should be undertaken to provide more evidence on the relationship between change in students' sustainability conceptions and the suggested alterations in study program design.

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Appendices

Appendix A.

Correction notice

Dear Editors of the Journal Sustainability,

We are writing to inform you about two corrections that need to be made to our published article "How does sustainability become professionally relevant? Exploring the role of sustainability conceptions in first year students".

Journal Name:	Sustainability
Year	2019
Manuscript ID:	576042
Manuscript Title:	How does sustainability become professionally relevant? Exploring the role of sustainability conceptions in first year students
Authors:	Sundermann, A.; Fischer, D.
Corresponding Author(s):	Anna Sundermann
DOI	https://doi.org/10.3390/su11195155
Article number	5155

1) The sample description in Table 3 does not match the sample sizes stated in the main analysis within the manuscript (p.10, Table 3). The error in Table 3 reappears in Table 4 because the sample sizes are repeated in Table 4 (p. 12., Table 4). The following sentence "*All 14 different major subjects offered at the university were represented (n = 1,294)*" refers to Table 3 and repeats the inaccuracy from Table 3 (p. 10, section 3.3, line 10).

We have corrected the sample description in Table 3 and Table 4 to match the sample sizes that were reported correctly in the main analysis. The corrected Tables 3 and 4 below more accurately reflect the different degree programs and the total sample size.

Replacement version for Table 3:

Table 3. Sample distributions.

	Pilot Study		**Present study**	
	N	**%**	**N**	**%**
Total Sample	1740	100.00	2730	100.00
Response (Rate)	913	52.**47**	1364	49.**96**
Sex				
Female	558	61.11	**851**	**62.39**
Male	304	33.29	**440**	**32.26**
Not indicated	51	**5.60**	73	5.35
Age	-	-	1244	91.20
Teacher Training Study Programs				
B.A. Teaching and Learning	111	12.16	242	17.74
B.A. Social Education	32	3.50	57	4.18
B.A. Business Education	27	2.96	48	3.52
B.A. General (Major Subject)				
Business Administration	156	17.09	214	15.69
Business Information systems	23	2.52	58	4.25
Cultural Science	202	22.12	198	14.52
Digital Media	-	0.00	25	1.83
Economics	20	2.19	34	2.49
Environmental Science*	105	11.50	179	13.12
Studium Individuale	16	1.75	33	2.42
Industrial Engineering	42	4.60	43	3.15
Law (Corporate and Business Law)	70	7.67	43	3.15
Political Science	18	1.97	32	2.35
(Organizational) Psychology	73	8.00	88	6.45
Missing	**18**	**1.97**	**70**	**5.14**
Total	**913**	**100.00**	**1364**	**100.00**

Age was not included in the pilot study. The major subject Digital Media has been introduced in 2014. Environmental Science including the students from Global Environmental and Sustainability Science.

Replacement version for Table 4:

Table 4. Frequencies for categorical IVs and DVs.

Variable	Name	Category	Frequencies	% (*n* = 1364)
IV	SEX	Female	**851**	**62.39**
		Male	**440**	**32.26**
		No answer	73	5.35
IV	FEE	ESD in School	633	46.40
		No ESD in School	254	18.60
DV	$PPR_{CURRENT}$	Yes	631	46.30
		No	170	12.50
DV	PPR_{FUTURE}	Yes	712	52.20
		No	122	8.90

The corrected sentence on p. 10, section 3.3 in line 10 reads as follows "*All 11 major subjects from one B.A. study program and three teacher training study programs offered at the university were represented (n = 1,294)*".

2) In Section 4.1., p. 11, line 21 reports the outcome of the preparatory analysis the Wilcoxon ranked sign that checks whether the prerequisites for the main analysis are met. This segment contained D values: "*Median values have been compared with Wilcoxon ranked sign test for paired samples because the scores for environmental (D (1.154) = 0.20, p < .001), sociocultural (D (1.154) = 0.11, p < .001) and economic dimensions of sustainability conceptions (D (1.154) = 0.10, p < .001) were deviating significantly from normal.*" This test should be reported by using Z and r values.

We have corrected the statistics we reported for the Wilcoxon ranked sign test and updated them with the correct values. The correction on p. 11, line 21 reads as follows "*Median values have been compared with Wilcoxon ranked sign test for paired samples because the scores for environmental, sociocultural and economic dimensions of sustainability conceptions were deviating significantly from normal as indicated by the Shapiro Wilk test (all p < 0.001). The Wilcoxon ranked sign test indicated that the medians were significantly different ($Z_{Econ/Env} = -27.76$, $r = -0.82$; $Z_{Evn/Soccul} = -24.09$, $r = -0.71$; $Z_{Econ/Soccul} = -17.31$, $r = -0.51$; $p < 0.001$).*". The statement and the result of the Wilcoxon ranked sign test are not changed by the correct values.

We want to emphasize that these corrections are purely formal in nature and have no impact on the conclusions. We intend to provide future readers with an entirely accurate and formally correct version of our open-access article.

Thank you for your understanding and assistance in this matter.

Appendix B.

Description of the Literature Review

This qualitative narrative analysis presents data extracted from studies published within 10 years (2009 - 2020) after Lipscombe's (2008b) initial review of research on students' sustainability conceptions. A more exploratory was published in *article#2*. For this framework paper, the review has been updated to cover the most recent publications and extended to describe related constructs and internal and external conditions such as certain courses of study or the design of teaching. This last aspect did not find its way into the published paper, but appeared to be of importance against the background of the overall research findings of the dissertation. Aims and methodology of the updated review are reported in this appendix. In its current state the literature review provides a description of the final sample ($n = 32$) and an extended analysis of how conceptions are understood, monitored, characterized and finally, an identification of internal and external conditions related to change in sustainability conceptions.

The $n = 32$ studies included in the updated review are mostly located in countries in the Global North, particularly the United States, Australia, and Northwest European countries. Exceptions include one study describing results from samples of eight different countries in Latin America (Camargo & Gretzel, 2017) and another comparing sustainability conceptions of Chinese and UK nursing students (Chen & Price, 2020). Sustainability conceptions were also examined particularly frequently among undergraduates and especially among students of business and economics, engineering science, and of teacher training. Many of these studies in which the age of the students was specified examined the conceptions in people aged 20 to 30. However, especially in the USA and Australia, there are also students who are more often 40 years old or older. The sample sizes of the individual studies varied widely from ten to 1462 students due to the different research designs and methods of data collection and analysis.

Design

The purpose of the extended literature review is the systematic description of empirical studies both quantitative and qualitative, conducting research on students' sustainability conceptions in higher education. Based on the identified literature, the review aimed to answer the following questions:

- Which terminology is used to describe students' sustainability conceptions?
- Which study design is employed? How are students' conceptions assessed and monitored in the field of HESD?
- Which results on content and structural complexity are reported?
- Which internal and external conditions are related to changes and development in students' sustainability conceptions?

The term students' sustainability conceptions refers to students' individual representations of the abstract idea of sustainability which manifests itself in the extent to which these students associate certain core aspects of the three dimensions with the term sustainable development (*article#2*). From the first exploratory search it was known that not only the term conceptions have been used to refer to this construct. Therefore, the term's *view, perception, understanding, conception(s)* and *sustainability literacy* were included in the search string to identify as many relevant research articles as possible. The research followed a literature review protocol and analysis adapted from Fischer, Stanszus et al. (2017) and Schuster et al. (2019). SCOPUS has been chosen as a database for peer reviewed social sciences empirical research.

Data Collection

The initial data set of scientific articles performed on November 25, 2020 from the Scopus database including $n = 256$ unique publications in English was based on the following search string:

TITLE-ABS-KEY (*"student*"* AND (*"sustain* concept*"* OR *"sustain* view*"* OR *"sustain* perception*"* OR *"sustain* understanding*"* OR *"conception* of sustain*"* OR *"understanding* of sustain*"* OR *"perception* of sustain*"* OR *"view* of sustain*"* AND NOT *"sustain* literacy"* OR *"literacy of sustain*"*)) AND DOCTYPE (*ar*) AND (LIMIT-TO (SRCTYPE , *"j"*) OR LIMIT-TO (SRCTYPE , *"ar" LIMIT-TO DOCTYPE"*) OR LIMIT-TO (SRCTYPE , *"t LIMIT-TO LANGUAGE"*)) AND (LIMIT-TO (LANGUAGE , *"English"*))

This initial sample (n = 256) has been merged with the old search results and resulted in a merged sample of 264 articles. The three steps of selecting the final sample of articles are illustrated in Figure B1. The original literature review built on an initial review by Lipscombe (2008b); literature already listed in this review was excluded. In a second step of screening with the aim of selecting articles relevant to answer the research questions four inclusion and exclusion criteria have been applied to the preliminary sample (n = 65). Each abstract of each article retrieved underwent a screening process looking for formal criteria, as well as content related criteria in the title and abstract (Table B1). An article has been included if the study met the formal criteria, e.g., full text availability, presents an empirical study, the understanding of sustainability conceptions matched the above-mentioned definition, and sample criteria are also met. In a third step of eligibility screening, all full-texts of the remaining articles are screened a second time with the criteria in Table B2. This third step resulted in a final sample consisting of n = 32 articles.

Table B1. *Inclusion and example of exclusion for the abstract screening.*

Criteria	Description	Examples of exclusion
Formal	Studies are included when they have an abstract, their full text has to be available, they are published in English and the article is listed in the search database Scopus. Studies are included if they were part of the review in Sundermann & Fischer (2019). Studies were excluded if they were already part of the review in Lipscombe (2008) and not of Sundermann & Fischer (2019).	Doublets are excluded from the sample. Example: Record 13 = Record 14 No. 233: Only abstract in English, article written in Spanish No 187, No. 186: Same title, different journal, both articles do not exist as full texts. No. 111: This study is excluded as it was part of the review in Lipscombe (2008). No. 264: Is part of the review in Sundermann and Fischer (2019) but was not in the initial sample.
Empirical	Studies are included if they are based on empirical data excluding systematic reviews. Empirical means that the results of the study presented in the paper are based on systematic measurement, observation or experience.	No. 8: The survey results play a minor role in the article, there is no description of how they were collected or analyzed. No 130: There are only a few test cases to validate the developed method.

Table B1. *Inclusion and example of exclusion for the abstract screening.*

Criteria	Description	Examples of exclusion
Sustainability conceptions	Studies are included that deal with the research objective of students' sustainability conceptions. The following underlying definition of conceptions of sustainable development / sustainability occasionally termed as (mis)-conception(s), understanding(s), views, or perception(s) of sustainable development / sustainability or sustainability literacy has been used: By students' sustainability conceptions I mean students' subjective, cognitive representations of the abstract idea of sustainability which manifests itself in the extent to which these students associate certain core aspects with the term sustainable development. One or more of these terms must be included in the abstract.	Studies that dealt with students' knowledge of sustainable development or sustainability, attitudes toward sustainable development/ sustainability or students sustainability literacy. No 256: This assessment represents an initial effort to quantify knowledge of the broad and abstract concept of sustainability. The authors plan to continue refining these questions to better differentiate between students with higher levels of knowledge and to replace those with answers that may change over time. No. 268: Students' responses were classified into observations and realization, needs and suggestions, and future plans. All students confirmed interest to apply SD in their lives. No 4: Participants felt that universities and urban planning schools need to address sustainability issues and education on campus.
Students	Studies are included when the sample are undergraduate students in higher education.	Mixed samples excluded: exp. 53 Examples of excluded studies: No. 238/239 "This paper presents findings from a longitudinal study investigating one class of 14- and 15-year-old Geography students in England understandings of sustainability and their attitudes towards sustainable development."

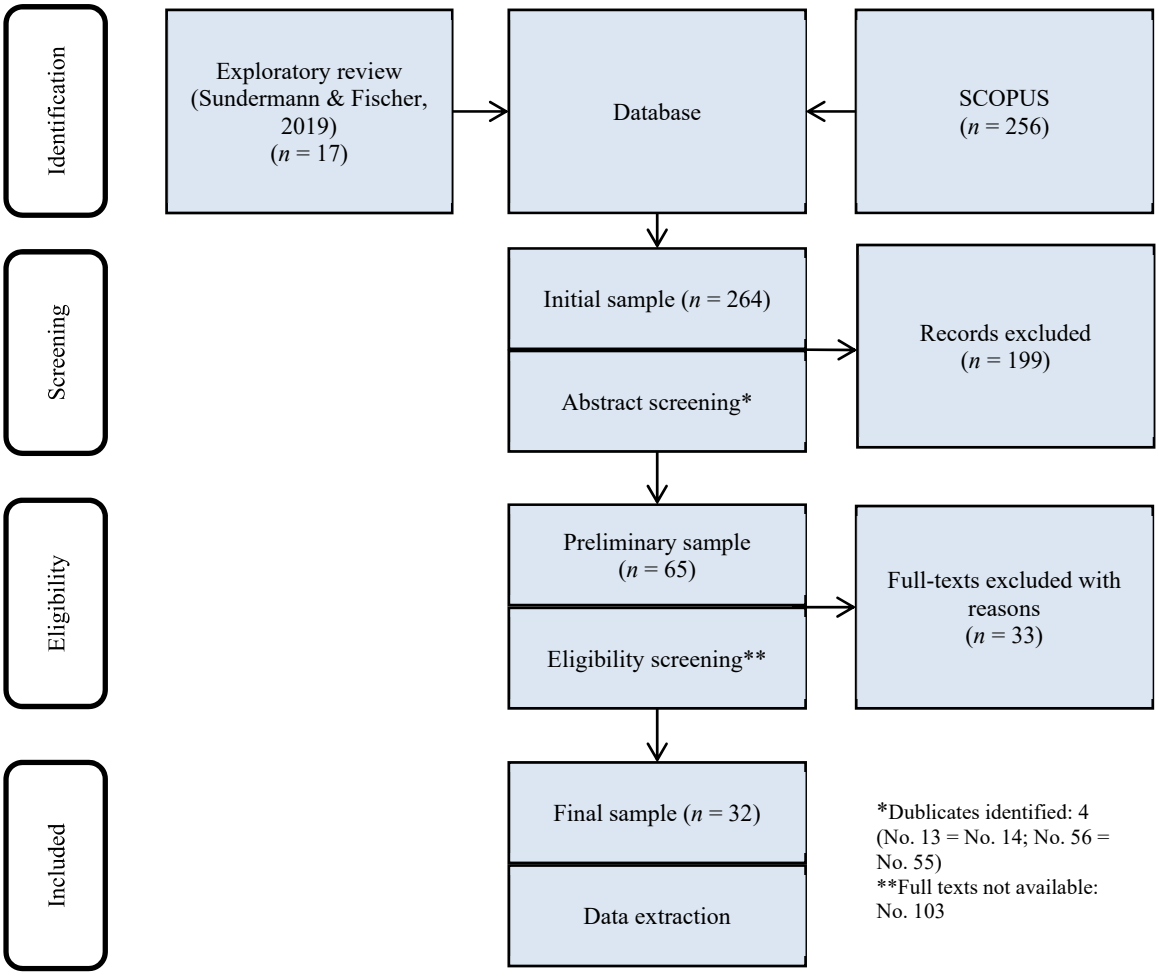

Figure B1. *PRISMA Flowchart of the search and screening and analysis process.*

Data analysis

The information has been extracted for the analysis from the *n* = 32 articles (Table B3). An overview of the extracted information and the coding of this information is given in Table B2. This table displays the data extraction scheme, code descriptions, definitions and extraction rules as well as anchor examples. The main focus of the coding scheme was the detailed description of identified articles: by describing the definition and demarcation of students' sustainability conceptions (RQ1), systemizing research approaches (RQ2) and to identifying internal and external conditions (RQ3). An overview of the articles of the final sample is given in Table B3.

Table B2. *Extraction criteria for data extraction.*

Information	Description	Coding and rules	Example
Terms	The code term(s) includes all terms used in the article to describe students' sustainability conceptions.	Is used for all terms included in the paper referring to students' sustainability conceptions. To be included in the list, the term needs to be used frequently in the article and needs to be linked to the description of the data of the respective study. It is also coded whether the term refers to sustainability or sustainable development.	No 27, p. 7: "These findings imply that students' perception of sustainability has not yet reached the full shift to being actively committed to the wellbeing of everyone, including the yet unborn, regardless of gender, economic status, race, religion, age, place of residence, species, etc. as well as the ecocentric positions."
Definition	Definition of a concept or term that determines exactly what the author(s) mean by this term.	The code encompasses all sentences which contain the description AND / OR definition of the terms used to refer to students' sustainability conceptions.	No. 163, p. 368: "Examining how this campus community defines the word sheds light on their understanding of sustainability (the authors do not claim this one measure is an assessment of sustainability literacy)."
National context	National context describes the country or nation where data has been collected.	Is coded where information on the national context of the data collection is mentioned in the article. It will not be coded and left out if no information is available. If other information in the text gives strong hints on the place of the experiment, this information is coded.	No. 27, p.1: "Altogether, 60 Slovenian and 60 Austrian pre-service biology teachers participated in the questionnaire-based study."
Scientific context	The scientific context means field of research or academic field in which the research has been conducted or the research question has been developed in.	The scientific context of the study is coded from the purpose of the study and statement from the theoretical background on which literature the study contributes on. This information is inductively categorized.	No. 27, p. 3: "ESD is increasingly achieving an interdisciplinary role in the curricula from kindergarten to the university level. SD goals are integrated into biology and other biology-related subjects at the lower and upper secondary school level in Slovenia and Austria."

Table B2. *Extraction criteria for data extraction.*

Information	Description	Coding and rules	Example
Research question / aim	The intention of researchers relies on what the researchers want to find out in their study – they can aim for one or several insights. Research Questions are explicitly stated questions which will be attempted to be answered within the paper. Hypothesis and propositions are assumptions of researchers that can be verified or falsified / supported or rather neglected by the results of a paper.	Is coded where information on the aim, research questions / hypotheses of the study are mentioned in the article. The coding unit is at least a whole sentence.	No. 163, p. 367: “The purpose of this paper is to analyze how faculty, staff and students at one American University define the term sustainability.”

Table B2. *Extraction criteria for data extraction.*

Information	Description	Coding and rules	Example
Sampling strategy	Sample describes a group of subjects selected from a larger population and representative of the population as a whole.	The main code encompasses all sentences which contain the description of the sampling strategy. The subcodes are used to specify the sampling strategy. Here, only the sentence containing the exact strategy is necessary. 1 = Convenience Sampling 2 = Purposive Sampling 3 = Quota Sampling 4 = Random Sampling 5 = Snowball Sampling 6 = Stratified Sampling 999 = Missing	No. 30, p. 6: "Seventy-seven New Zealand student teachers in the third year of a three-year Bachelor of Education (Primary Specialization) degree consented to complete the questionnaire. Of these 77, 56 identified as females, 7 as males and the remainder (14) did not complete this item. Over half of this group (51) were aged between 20 and 29 years, 12 were aged between 30 and 39 years and 11 were over aged 40 years and over. One student teacher was under 20 years of age." (1 = convenience sample (not further specified)
Mean age	Information on mean age.	If the mean is reported this is going to be coded. Extract exact number and standard deviation is recorded. 999 = Missing	No. 115, p. 783: "The average age of the participants was 22.4."
Age range	Information on the range of age	If the range is reported this is going to be coded. Extract exact number. Missing = 999.	No. 76, p. 84: "Respondents ranged in age from 17 to 55; most (92.8 percent) were younger than 25 and one-fourth of all respondents were 19 years old."
Students study program	Information on the study program, academic discipline, major or minor of the students.	If information on the study program, academic background or discipline is reported, the information is coded. Missing = 999.	No. 30, p. 6: "Seventy-seven New Zealand student teachers in the third year of a three-year Bachelor of Education (Primary Specialization) degree consented to complete the questionnaire."

Table B2. *Extraction criteria for data extraction.*

Information	Description	Coding and rules	Example
Educational level	This code encompasses Information on the time the students spent on campus.	If information on the year of the study program or the time spent at the university is reported, the information is coded here. Missing = 999.	No. 76, p. 83: „Surveys were randomly distributed to undergraduate students at two public universities in Alabama and at one community college in Hawaii during spring and fall semesters 2008. Data were collected from a total of 406 students – 258 (1.4 percent) undergraduate students at two major public universities in Alabama, and 148 undergraduate students (0.3 percent) at a public community college in Hawaii.“
Sample size	Number of the initial sample (N).	The overall and initial sample size will be coded. Reduction or deletions during the analysis are not coded here. If more than one sample is recorded than the sample sizes have to be merged for example in the case where samples from different universities are compared. If the study reports on pre- and post-samples, only the post sample is accounted for. 999 = Missing	No. 206, p. 235: “Thirty-two students enrolled in the course, and all thirty-two students consented to participate in the research study.”

Table B2. *Extraction criteria for data extraction.*

Information	Description	Coding and rules	Example
Research design	The design of a research topic is used to explain the type of research (experimental, survey, correlational, semi-experimental, review) and also its sub-type (experimental design, research problem, descriptive case-study). There are three main sections of research design: Data collection and Data analysis	The main code encompasses all sentences which contain the description of the study design. The subcodes are used to specify the research design. Here, only the sentence containing the exact strategy is necessary. The design that is primary aimed for of the study was coded, even when the study has characteristics of other designs. 1= Action Research Design 2= Case Study Design 3= Causal Design 4= Cohort Design 5= Cross-sectional Studies 6= Descriptive Design 7= Experimental Design 8= Exploratory Design 9= Historical Design 10= Longitudinal Design 11= Mixed-methods Design 12= Philosophical Design 13= Observational Design 14 = Sequential Design 999 = Missing	No. 206, p. 234: "The researcher used an action research framework and employed a mixed-methods research design. Action research presents an inclusive and solutions-oriented approach toward both research and solving real-life problems. Education has a tradition of conducting action research in which teachers act as researchers who consciously reflect on their own practice to improve their practice and solve problems in their educational settings (Herr and Anderson 2005)."

Table B2. *Extraction criteria for data extraction.*

Information	Description	Coding and rules	Example
Teaching approach	Describes the teaching and learning approach or another intervention designed to change the sustainability conceptions.	Is coded if the section contains the description of the approach, intervention, material. Information on the design procedure, creation process is not coded. The coding unit is at least a whole sentence.	No. 28, p. 89ff: "The development of ISU's course on sustainable engineering was driven by a need to expose students to the concepts of sustainability and prepare them for a workforce that will increasingly operate in a resource-constrained environment. The course titled Sustainable Engineering and International Development has been offered at ISU since 2005. Motivation for this course came from a need expressed by students associated with ISU's chapter of ESW (Steward et al. 2007). The course was, therefore, set in the context of global sustainability and poverty in the developing world. Faculty members from several engineering disciplines were involved in developing this interdisciplinary course, which was available as a technical elective that also met the university's requirements for international perspectives."

Table B2. *Extraction criteria for data extraction.*

Information	Description	Coding and rules	Example
Data collection method	Data collection method describes all procedures that are used to collect data for the research analysis.	Is coded where data collection methods in the text is mentioned. The coding unit is at least a whole sentence. In mixed-methods analysis all data collection methods are separately coded.	No. 27, p. 5: "The questionnaire developed by Burmeister and Eilks [7] was used. The questionnaire was originally developed in the German language and for chemistry teachers. It was slightly modified (one question was added: "Write 15 words you associate with the term sustainability") to serve for pre-service biology teachers; moreover, it was translated into Slovenian. The questionnaire included open questions and closed questions with Likert-scale response options (four levels of agreement)."
Data analysis method	Data analysis method describes all procedures that are used to analyze the collected data.	Is coded where data analysis methods in the text are mentioned. The coding unit is at least a whole sentence. In mixed-methods analysis all data analysis methods are separately coded.	No. 206, p. 236: "The researcher used a grounded theory approach to identify emergent themes in the qualitative data, and to code these themes (Maxwell 2005). Triangulation of the surveys, the students' work, and the researcher's observations served as a verification procedure to confirm the credibility of the study results."

Table B2. *Extraction criteria for data extraction.*

Information	Description	Coding and rules	Example
Results	Results encompasses all information on how the students in this study conceptualize sustainability.	Is coded where the study reports on the students' conceptions of sustainability/ sustainable development. The whole paragraph is extracted and then inductively synthesized and described for the complexity of structure of the sustainability conceptions, and the content (dimensionality, points of gravity etc.) as well as if and how conceptions changed.	No. 28, p. 93: "The series of pie charts illustrated in Fig. 2 summarizes student responses regarding their ability to consider techno-economic, environmental, and social aspects of sustainability. Although an equal number of students agreed or strongly agreed that the course improved their ability to consider the three aspects of sustainability, there were some students who felt that the course did not provide adequate background or training in considering social aspects of sustainability. None of the course instructors or invited speakers were professional social scientists. The instructors of the course included invited speakers whom had academic or professional backgrounds in architecture, environmental science; and agricultural, civil, electrical, environmental, or mechanical engineering. Thus, an authoritative consideration of social aspects of sustainability was missing from the course. This provides an opportunity to improve the course through consultation with social scientists or by inviting them to speak in future classes."

Table B2. *Extraction criteria for data extraction.*

Information	Description	Coding and rules	Example
Related constructs / internal and external conditions	This code encompasses all information on variables influencing and or related to students' sustainability conceptions.	Is coded where the study reports on constructs that seems to be related to sustainability conceptions and/or characteristics of the teaching or social context, the lecturers' contexts and/or characteristics or the students' characteristics.	No. 257, p. 282f: "Comparing the learning outcomes with the pedagogical approach used in each case study demonstrates that the more active the learning, the more focused on community and the more constructive, the higher the cognitive learning achieved by students. It is important to note that active learning education (ALE) is not only useful for teaching SD competencies, but also for teaching all kinds of competencies, for example, training engineering students to apply knowledge in practical situations, teaching communication skills or preparing them for a career of 'life-long learning' [27,28]. ALE usually increases student success rates and this is especially important in engineering education where the student dropout rate is very high. Moreover, there is a growing awareness that it is no longer possible to train engineers for a long career within a comparatively short period of time. "

Table B3. *Overview of the final sample (n = 32) in order of the year of publication.*

#	No	Authors	Year	National context	Scientific context	N	Terms
1	189	Reid A., Petocz P., Taylor P.	2009	Australia	Business education	44	Conceptions of sustainability; understanding of sustainability; views of sustainability
2	196	Sahin E., Ertepinar H., Teksoz G.	2009	Turkey	Educational science	958	Knowledge on sustainable development; Perceptions of sustainable development; understandings of sustainable development
3	257	Segalàs, J., Ferrer-Balas, D., & Mulder, K. F.	2010	Netherlands, Spain, Sweden, Ukraine	Engineering education	506	Knowledge of sustainable development; perception of sustainable development; understanding of sustainability;
4	28	Bhandari A., Ong S.K., Steward B.L.	2011	USA	Engineering education	22	Knowledge; sustainability concepts; understanding of aspects of sustainability,
5	76	Emanuel R., Adams J.N.	2011	USA	Higher education for sustainability	406	Knowledge; terms associated with sustainability; understanding of the concept of sustainability
6	258	Barth, M., & Timm, J. M.	2011	Germany	Higher education for sustainability	1462	Understanding of the meaning of the term “sustainability”
7	100	Hill J., Lee H.-H.	2012	USA	Engineering education	80	Perceptions of sustainability; knowledge of sustainability; understanding; view of sustainability
8	259_b	Kirby, S.	2012	USA	Business education	89	Concepts of sustainability; definitions of sustainability understanding of sustainability;

Table B3. *Overview of the final sample (n = 32) in order of the year of publication.*

#	No	Authors	Year	National context	Scientific context	N	Terms
9	260	Nicolaou, I., & Conlon, E.	2012	Ireland	Engineering education	143	Definition of sustainable development; knowledge about sustainable development; understanding about sustainable development,
10	93	Haase S.	2013	Denmark	Engineering education	1211	Sustainability concepts; sustainability conceptions; understandings of sustainability
11	108	Jollands M., Parthasarathy R.	2013	Australia	Engineering education	350	Understanding of sustainability; misunderstanding; View of sustainability (issues)
12	115	Kilinc A., Aydin A.	2013	Turkey	Teacher training education	113	Conceptions of sustainable development; understanding of the concept of sustainable development; view of sustainable development;
13	209	Sidiropoulos L., Wex I., Sibley J.	2013	Australia	Business education	267	Understanding of “sustainability”/ “sustainable development”; views about sustainability
14	261	Burmeister, M., & Eilks, I.	2013	Germany	Teacher training education	184	Knowledge concerning concepts of sustainability; understanding of the technical terms ‘sustainability’ and ‘sustainable development’; misunderstandings;

Table B3. *Overview of the final sample (n = 32) in order of the year of publication.*

#	No	Authors	Year	National context	Scientific context	N	Terms
15	30	Birdsall S.	2014	New Zealand	Teacher training education	77	Understandings of sustainability; ideas about sustainability; sustainability definitions,
16	252	Zeegers Y., Clark I.F.	2014	Australia	Business education	34	(Pre-)conceptions of sustainability; ideas about sustainability; perception about sustainability; perception of sustainability; view of sustainability;
17	39	Fisher B.P., McAdams E.	2015	USA	Higher education for sustainability	552	Conceptions of sustainability; perceptions of sustainability; understandings of sustainability; view of sustainability;
18	52	Clark I.F., Zeegers Y.	2015	Australia	Business education	31	(Pre-)conceptions of sustainability; knowledge of sustainability; perceptions of sustainability; understanding of sustainability; view of sustainability
19	73	Dyment J.E., Hill A.	2015	Australia	Teacher training education	329	Ideas of sustainability; understanding of sustainability
20	163	Owens K.A., Legere S.	2015	USA	Higher education for sustainability	119	Definitions of sustainability; understanding of sustainability;
21	206	Sherman J.D.B., Burns H.L.	2015	USA	Educational science	32	Definitions of sustainability; Understanding of sustainability

Table B3. *Overview of the final sample (n = 32) in order of the year of publication.*

#	No	Authors	Year	National context	Scientific context	N	Terms
22	175	Pestana M.H., Parreira A.	2016	Portugal	Business education	101	Definition of sustainability; idea of sustainability; sustainability concept; understanding of sustainability
23	95	Hales R., Jennings G.	2017	Australia	Business education	52	Conceptions of the term sustainability; understanding of sustainability
24	133	Lummis G.W., Morris J.E., Lock G., Odgaard J.	2017	Australia	Teacher training education	18	Conception of sustainability; definition of sustainability; perceptions of sustainability concepts;
25	241	Watson M.K., Barrella E.	2017	USA	Engineering education	161	Conceptual understanding of sustainability;
26	262	Camargo, B.A., & Gretzel, U.	2017	Argentina, Brazil, Colombia, Costa Rica, Ecuador, El Salvador, Mexico, Venezuela	Business education	175	Knowledge and understanding of sustainability; perceptions regarding sustainability; sustainability knowledge; view of sustainability
27	263	Elliott, H., & Wright, T.	2018	Canada	Higher education for sustainability	65	Conceptualizations of sustainability; understanding of sustainability; understanding of sustainable development
28	27	Bezeljak P., Scheuch M., Torkar G.	2020	Australia, Slovenia,	Teacher training education	120	Associations with the term sustainability; perceptions of sustainability; understanding of sustainable development
29	49	Chen M.J., Price A.M.	2020	China, UK	Nursing education	101	Perception of sustainability; understanding of sustainability;

Table B3. *Overview of the final sample (n = 32) in order of the year of publication.*

#	No	Authors	Year	National context	Scientific context	N	Terms
30	85	García-González E., Jiménez-Fontana R., Goded P.A.	2020	Spain	Teacher training education	116	Perceptions about/of sustainability; understanding of the concept of sustainability
31	113	Karaarslan Semiz G., Isler Baykal I.	2020	Turkey	Teacher training education	10	Definition of sustainability, perceptions related to sustainability; understanding of sustainability
32	179	Pruett J.L., Weigel E.G.	2020	USA	Science education	59	Sustainability knowledge; understanding; ideas of sustainability

Appendix C.

Conceptual Map Analysis

The students' conceptual maps have been analyzed by a content analysis approach and the coding scheme presented in Table C1. The analysis resulted in five categories: ecological, socio-cultural, economic-technical aspects and institutional and individual strategies as well as technical terms. The final categories and codes displayed in Table C1 have been adapted from Watson et al. (2013) and Segalàs et al. (2010). Additionally, memos have been used to take notes on structural complexity and content complexity modified from Pruett and Weigel (2020). The conceptual maps have been qualitatively evaluated based on a hierarchy modified from García-Gonzalez et al. (2020).

Results of the Conceptual Map Analysis

Table C2 displays the results of the conceptual map analysis. The resulting qualitative descriptions were then incorporated into case reports and included in the theme-based analysis in *article#4*.

Table C1. *Coding scheme for conceptual maps.*

Dimension	Definition	Example concepts included in the conceptual maps of the students
Ecological	Related to ecological principles and resource scarcity	Biodiversity, conservation, protect the world, habitat degradation, renewable energy, pollution, ecological footprint, non-renewable, meat, climate, resources, depletion of materials, ecofeminism, protection of species etc.
Socio-cultural	Related to values, unbalances, social impact, and temporal concepts	Material, wealth, gender, equality, culture, art, human-nature connectedness, awareness, solve social problems, start early, long-term, regionality, spirituality,
Economic-technical	Related to business and the economy, science, and technology	Globalization, greenwashing, internet, research and technological development, entrepreneurship, corporate social responsibility, long-term profit, costs and benefits, fair wages, cradle to cradle
Institutional and individual strategies	Related to education, players and stakeholders, strategies, and individual sustainability-related transformation strategies	Education, communication, lifestyle, developmental cooperation, urban gardening, NGOs, society, governance, recycling, bike-riding, efficiency, sufficiency governance, waste management, food consumption
Other	Related to definitions, dimensionality and meaning of the term sustainable development and criticism of the idea	Sustainability, integration of different cultural views into the concept, Brundtland definition, definition by Carlowitz

Table C2. *Qualitative description of the structural and content complexity of conceptual maps.*

Case	Qualitative description	Rating
1	The conceptual map consists of eight terms. In terms of structural complexity, the map has two hierarchical levels. The longest chain of terms consists of two terms. Four terms are shown without any connections to the main idea of sustainable development in the center of the conceptual map. In terms of content complexity, three dimensions are covered. The map focusses on socio-cultural concepts of sustainable development. The economic-technical dimension is not covered. The two concepts within the ecological dimension focus on resource consumption and conservation. The strategy mentioned in the conceptual map is education. The conceptual map does not show a high level of structural nor of content complexity. However, the student adds the criticism on development and progress to his conception. Moreover, this shows his understanding of mutual influence between education and a societal conception of sustainability as well as the mutual influence of resource consumption and resource conservation.	Level 2
2	The conceptual map consists of 34 terms. In terms of structural complexity, the map has three hierarchical levels. The longest chain of terms consists of five terms. Three concepts (advertisement, technology, and wealth) are shown without connections to the main idea of sustainable development. In terms of content complexity, the ecological, economic-technical, and socio-cultural as well as the institutional dimension are covered almost equally. There are three links between different dimensions. The student added bilateral links and labeled some of the links with terms. The student added a box where he describes the discussion and criticism around the term development. Thus, the map shows a highly complex sustainability conception with criticism and own ideas in terms of content and structure.	Level 4
3	The conceptual map consists of 23 terms. In terms of structural complexity, the map has two hierarchical levels. There are four links between different hierarchical levels. The longest chain of terms consists of two terms. In terms of content complexity, the ecological, economic-technical, and socio-cultural and the institutional dimensions are covered. There is a focus on institutional and individual strategies. There is one link between different dimensions. The student added bilateral links between two concepts. Thus, the map shows a moderately complex sustainability conception with criticism and own ideas in terms of content and structure.	Level 3

Table C2. *Qualitative description of the structural and content complexity of conceptual maps.*

Case	Qualitative description	Rating
4	The conceptual map is comprised of 16 terms. In terms of structural complexity, the map has three hierarchical levels, and the longest chain of terms connects three terms. There are five links between concepts of different levels. In terms of content complexity: The conceptual map covers five different dimensions. The focus is on socio-cultural concepts - mostly on awareness, values, and human-nature connection as a pre-requisite for all institutional and individual sustainability strategies. Two ecological and economic-technical concepts are mentioned. There are five links between concepts from different dimensions. The student shows in a non-traditional way that he has a unique sustainability conception based on the definition of Carlowitz. Although the map does not clearly show structural complexity or content complexity via links and number of dimensions and aspects, the way the student presents his own ideas shows that he has developed his own understanding via adding a focus. For him, individual awareness and a deep human-human, self-nature and human-nature connection is the core aspect of sustainable development. In his conception, all strategies should be based on awareness and connection. He also raises criticism on the anthropocentric character of the idea of sustainable development.	Level 3
5	The conceptual map consists of 20 terms from four dimensions of sustainable development. In terms of structural complexity, the map has two hierarchical levels, and the longest chain of terms connects three terms. There are 11 links between concepts from different levels. The dimensions are mentioned relatively equal. The concepts are almost exclusively assigned to the economic-technical dimension or the socio-cultural dimension of sustainable development. On the ecological dimension, there is merely one concept (protecting the environment). Some terms - such as actions or initiatives - are not particularly meaningful and unspecific. It seems that the concepts often focus on the responsibility of civil society or individuals. Thus, the conceptual map shows more a broad than a deep sustainability conception.	Level 2
6	The conceptual map consists of 27 terms. In terms of structural complexity, there are two hierarchical levels, and the longest chain of terms consists of four terms. There are 17 links between aspects on different levels. In terms of content complexity: All dimensions are covered, though there is a clear focus on ecological and economic-technical concepts of sustainable development. There is one link between concepts from different dimensions. In terms of content, there are many concepts that qualify sustainable development as valuable or thoughtful or long-term. In terms of strategies and solutions, the map covers business responsibility in terms of efficiency and personal awareness for the topic. Rethinking is the major strategy. The map shows more a broad conception than a complex one.	Level 2

Table C2. *Qualitative description of the structural and content complexity of conceptual maps.*

Case	Qualitative description	Rating
7	The conceptual map covers seven different terms. In terms of structural complexity, there are two hierarchical levels. Each main category is linked with one or two concepts on the second level. There are no links between the different categories on each level. In terms of content complexity, the map consists of concepts from two dimensions: the ecological and the economic-technical dimension. There are more concepts of the economic-technical dimension. There are no cross-dimensional links between concepts from different dimensions. It is the only map that mentions climate as an aspect of the ecological dimensions. However, concepts of the economic-technical dimension refer only to the financial aspects of long-term sustainability. Thus, there is no complexity in structure and content of the conceptual map.	Level 1
8	The conceptual map consists of 23 terms. In terms of structural complexity, there are three hierarchical levels, and the longest chain of terms consists of five terms. In terms of content complexity, there is a clear focus on concepts of criticism and own ideas regarding the idea of sustainable development. In addition, the map includes a strong focus on socio-cultural concepts and a few economic-technical, environmental, or institutional and individual strategies. There is one link between concepts of different dimensions. The map shows a lot of independent ideas on how to conceptualize sustainability. The presented sustainability conception has a clear focus on socio-cultural concepts and intragenerational justice, although it lacks complexity in terms of interconnectivity of the dimensions.	Level 1
9	The conceptual map consists of 33 terms. In terms of structural complexity, the map has four different hierarchical levels. The longest chain of terms consists of five terms. The map has overall a sequential structure. In terms of content complexity, all four dimensions are almost equally often covered. There are also terms about the political background of the idea of sustainable development, existing definitions, or the dimensionality. No criticism or independent focus is visible. The focus seems to be on different economic transformation strategies such as consistency, sufficiency, and efficiency.	Level 4
10	The conceptual map consists of 12 terms. In terms of structural complexity, the map has two hierarchical levels. The longest chain of terms consists of two terms. Overall, the map has a sequential structure. In terms of content complexity, three dimensions are covered. The map shows more ecological and institutional concepts. The socio-cultural dimension is not covered. The focus of the institutional dimension is on private and individual strategies and solutions for sustainable development. No criticism or independent focus is visible. The only concept in the economic-technical dimension is *project management: planning with a long-term perspective although it may be not cost-efficient*. There are no cross-dimensional links. The conceptual map thus does neither show a high level of structural nor of content complexity.	Level 1

Appendix D

Individual contribution to the dissertation

According to §16 of the guideline for cumulative dissertations, the following Table D1 details the individual contribution in preparing the three research articles and the book chapter. This entails specifying the individual scientific contribution of all co-authors, including the author of this dissertation (author's contributions), and the relative importance of the doctoral student's own contribution in relation to the contributions of the co-authors (declaration of authorship).

According to §12b of the guideline for cumulative dissertations, the doctoral student's contributions can be as follows (number in brackets is the respective weighting factor):

- Single authorship, if the doctoral student's own contribution is 100% (1.0).
- Predominant contribution, if the doctoral student's own contribution is greater than the individual share of all other co-authors and is at least 35% (1.0).
- Equal contribution, if (1) the doctoral student's own contribution is as high as the share of other co-authors, (2) no other co-author has a contribution higher than the PhD student's own contribution, and (3) the doctoral student's own contribution is at least 25% (1.0).
- Important contribution, if the doctoral student's own contribution is at least 25%, but is insufficient to qualify as single authorship, predominant or equal contribution (0.5).
- Small contribution, if the doctoral student's own contribution is less than 20% (0).

Table D1. *Individual scientific contributions of this dissertation.*

Characteristic	Article#1	Article#2	Chapter#3	Article#4
Title	On how business students' personal values and sustainability conceptions impact their sustainability management orientation: evidence from Germany, Indonesia and the USA	How does sustainability become professionally relevant? Exploring the role of sustainability conceptions in first year students	Die Nachhaltigkeitskonzepte Studierender im Studienverlauf: Einsichten aus einer Längsschnittstudie [Students' sustainability conceptions in the course of study: Insights from a longitudinal study].	Meaning-Making in higher education for sustainable development: Undergraduates´ long-term processes of experiencing and learning
Authors	Seidel, J., **Sundermann, A.**, Brieger, S. A., Strathoff, P., Jacob, G. H., Antonio, T., & Utami, C. W.	**Sundermann, A.,** & Fischer, D.	**Sundermann, A.**	**Sundermann, A.,** Weiser, A., & Barth, M.
Year of publication	2018	2019	2023	2022
Author contribution	Conceptualization, AS, JS, SAB and PS; Methodology: AS, AS, JS, SAB and PS; data collection, AS, JS, SAB, PS, JGH, AT, UCW Software, AS, JS, SAB and PS; formal analysis: AS, JS, SAB and PS; writing—original draft preparation, AS, JS, SAB and PS.; writing—review and editing: AS, JS, SAB and PS.; Visualization, AS, JS, SAB and PS; project administration: AS, JS, SAB and PS	Conceptualization, AS and DF; Methodology, AS; Software, A.S.; Formal analysis, AS; Writing—original draft preparation, AS and DF; writing—review and editing AS and DF; visualization, AS; supervision, DF; project administration, AS	Conceptualization, AS; Methodology: AS; Data collection, AS; Software, AS; formal analysis: AS; Writing—original draft and preparation, AS; Writing and editing: AS Visualization, AS; Project administration: AS	Conceptualization, AS; Methodology: AS, AW, MB; Data collection, AS; Software, AS; Formal analysis: AS, AW; writing—original draft and preparation, AS; writing and editing: AS, AW, MB; Visualization, AS; Supervision: MB; Project administration: AS
Declaration of authorship	Equal contribution 1.0	Predominant contribution 1.0	Single authorship 1.0	Predominant contribution 1.0

Table D1. *Individual scientific contributions of this dissertation.*

Characteristic	Article#1	Article#2	Chapter#3	Article#4
Publication status	Published in Journal of Global Responsibility	Published in Sustainability (Switzerland)	Published in Bildung für nachhaltige Entwicklung in der Hochschule – Wege und Wirkungen am Beispiel der Leuphana Universität Lüneburg	Published in Environmental Education Research
Impact factor without self-citations (JIF, 2022)	1.6	3.1	-	2.5
Conference presentations (selection)	**Sundermann, A.,** Brieger, B., Seidel, J., & Strathoff, P. (2016, August). Leadership for sustainability: The role of values, sustainability understanding, and education. Paper presented at the Academy of Management 2016 Annual Meeting, Anaheim, United States of America.	**Sundermann, A**., & Fischer, D. (2016, October). The role of preconceptions of sustainable development for perceived professional relevance and the development of inter- and transdisciplinary competencies among first year students. Paper presented at Competence 2016 Conference, Wageningen, Netherlands.	**Sundermann, A.,** Burandt, B., & Fischer, D. (2015, September). Using a longitudinal mixed-methods approach in HESD research: Reflections on pitfalls and added value. Paper presented at the European Conference on Educational Research 2015, Budapest, Hungary.	**Sundermann, A.** (2019, November). Analyzing students' sustainability conceptions: Insights from a longitudinal study on sustainability-related learning processes at Leuphana University Lüneburg. Paper presented at the 1st International UNESCO Chair Conference, Wuppertal, Germany.