

Assessment in Sustainability Education  
Learning Towards Innovations in Transdisciplinary Practice

by

Jordan King

A Dissertation Presented in Partial Fulfillment  
of the Requirements for the Degree  
Doctor of Philosophy

Approved March 2024 by the  
Graduate Supervisory Committee:

Daniel Fischer, Co-Chair  
Kelli Larson, Co-Chair  
Katja Brundiers

ARIZONA STATE UNIVERSITY

May 2024

## ABSTRACT

The learning journey toward sustainability requires the generation of action-oriented knowledge to understand the progress and potential adaptation of strategies to facilitate collective transformation. One integral area where advancing these strategies is essential is higher education. While efforts in the field have identified relevant learning objectives, pedagogies, and broader contributions for sustainability education to make, the sophistication of approaches to evaluating and enhancing collective learning has remained underdeveloped. This dissertation aimed to address this gap by exploring assessment in sustainability education, with the goal of supporting innovations in transdisciplinary practice by developing distinctive approaches for the field through deliberative processes that articulate design frameworks.

The first study, *Sustainability-Oriented Assessment*, applied a formative intervention within an undergraduate course focused on professional skill development to demonstrate how a student-led rubric co-design process that drew from participative, normative, and integrative approaches contributed to student agency, expansive learning, and self-formation. The study demonstrated how students leveraged challenges and changing perspectives towards development as students and sustainability professionals. The second study, *Boundary Crossings and Innovations*, applied an exploratory action research approach within a community of practice of program leaders and instructors to identify barriers and possibilities for assessment practices, suggesting conceptual, practical, and logistical innovations. The strategies to enable these innovations focused on defining the field and articulating practice characteristics related to interdisciplinary approaches and transdisciplinary strategies, while meeting demands and facilitating

innovations across course, program, and institutional levels. The third study, *Assessment-Oriented Sustainability*, applied a scoping literature review to develop a framework that integrates problem, solution, and learning orientations to sustainability by infusing educational purposes, processes, and principles to strengthen the efficacy of assessment approaches for transdisciplinary strategies.

Insights from the three studies suggest that the practice of assessment plays multifaceted roles as it facilitates the design, implementation, and evaluation of sustainability endeavors. These roles include evaluative and formative functions as it appraises and advances learning, normative and deliberative functions in encouraging discussion and critical reflection, and adaptive and generative functions by indicating, motivating, and enabling dynamic learning and action for sustainability.

## ACKNOWLEDGMENTS

Like sustainability, completing a dissertation is a learning journey. I am grateful for the wisdom, guidance, and support that I received throughout this journey from so many people.

My committee members were at the core of encouraging my efforts. Dr. Daniel Fischer provided the critical and ambitious lens to spur me forward and enabled me to approach my work with a sense of agency and discovery. I have become a better scholar because of him and am grateful for his dedication to see through our collaborations even with an ocean in between. Dr. Kelli Larson generously stepped in to help lead my committee in a unique situation. I appreciate her openness and the precision of her advice, which have made my efforts more successful. Dr. Katja Brundiers has offered an excellent example of what it looks like to be dedicated to one's work and those that it engages and impacts. I am grateful for all that I have learned from her and for our collaborations where I have witnessed her compassion, leadership, and intellectual curiosity.

I am also thankful for those in the School of Sustainability and the College of Global Futures. While there are many to note, I would specifically like to acknowledge Christopher Boone, Joshua Abbott, Lindsey Plait Jones, Ivy Gerbis, Melissa Dengler, Lee Vandendriessche, Susila Bhagavathula, and all of the others who I engaged with through courses, research, and other activities.

Beyond this community, I was able to connect with so many others at ASU and beyond who are looking to move forward sustainability education in higher education and our communities. These included the SustEd lab group and Education, Sustainability, and

Global Futures Learning Futures Collaborative, as well as my collaborators in Germany, the Netherlands, Finland, and elsewhere. I am also thankful for the friendship and collaboration of Carlos Casanova and Molly Cashion, who helped me to think critically about what this work is and does, while having some fun too.

My journey has also intersected with a variety of groups that have informed my achievements and future aspirations. At the University Design Institute, I am particularly grateful to have had the opportunity to work with Minu Ipe, Tamara Webb, Joel Dupuis, Dale Johnson, and April Edwards. My research, as well as the enjoyment of my time in the program, would not be the same without my connections to the Global Council for Science and the Environment, particularly its Sustainability Education Scholars Team and Community of Practice. My deepest gratitude for their outstanding commitment and accomplishments goes to Krista Hiser, Michelle Wyman, Rod Parnell, Alex Ramey, Ryan Johnson, and April Deckert.

I would not have reached this step without the experiences that came before this. For that, I am especially grateful to Tom Quinn, Scott Johnson, and Becca Franzen, as well as Marcus Nack and Sam DeRoche. I would not be who I am without Donn Behnke or Kevin Hopp, so I am thankful for the experiences that they fostered for me, with people like Jack Senefeld and Nate Hatton, to grow into myself.

Finally, I am forever grateful for the unwavering and enthusiastic support of my parents, Renee and Eugene King. They taught me to value learning, perseverance, and kindness, which I hope I have demonstrated more than anything else in this work. They inspire me every day. To Becca King, my wonderful wife, thank you for going on this crazy adventure with me. I am so excited for the next one with you. Our time together,

with Crosby and Indy too, brings me so much joy and has buoyed me throughout this experience. Because of this, the journey of completing a dissertation has been happy if not hard and I could not have asked for any other opportunity.

## TABLE OF CONTENTS

	Page
LIST OF TABLES .....	ix
LIST OF FIGURES .....	x
CHAPTER	
1 INTRODUCTION .....	1
Assessment for Teaching and Learning Sustainability in Higher Education .....	1
Research Aims .....	7
Research Design .....	11
Overview .....	16
2 SUSTAINABILITY-ORIENTED ASSESSMENT.....	18
Introduction.....	18
Student Agency in Rubric Co-Design.....	19
Sustainability-Oriented Assessment .....	22
Theoretical Framework .....	24
Methods.....	25
Results .....	32
Discussion .....	37
Conclusion .....	40
3 BOUNDARY CROSSINGS AND INNOVATIONS .....	42
Introduction.....	42
Background.....	43
Methods.....	46

CHAPTER	Page
Results .....	50
Discussion .....	60
Conclusion .....	63
4 ASSESSMENT-ORIENTED SUSTAINABILITY .....	66
Introduction.....	66
Transdisciplinary Sustainability Strategies, Assessment, and Learning.....	67
Transdisciplinary Sustainability Orientations.....	72
Assessment of Transdisciplinary Sustainability Strategies .....	76
Features and Functions of an Assessment Framework .....	80
An Assessment-Oriented Sustainability Framework.....	88
Conclusion .....	93
5 CONCLUSION .....	98
Summary of Findings .....	98
Situating Key Findings.....	99
Contributions and Implications .....	108
Future Research .....	115
Conclusion .....	117
REFERENCES .....	119
APPENDIX	
A ANNOTATED LIST OF ADDITIONAL WORKS .....	146
B PUBLICATION STATUS OF STUDIES .....	156
C IRB APPROVALS .....	158

APPENDIX

Page

D	STUDY 1 SUPPLEMENTARY MATERIALS.....	165
E	STUDY 2 SUPPLEMENTARY MATERIALS.....	175

## LIST OF TABLES

Table		Page
1.	Intervention Design Phases and Steps Informed by Expansive Learning Cycles (Engeström et al., 2014) .....	30-31
2.	Overview of Boundaries, Boundary Crossings, and Innovations in Assessment Practices .....	51
3.	Example Student Rubric .....	173-174

## LIST OF FIGURES

Figure		Page
1.	Elements of Research Design .....	13
2.	Activity System for Student-Led Rubric Co-Design Guided by a Sustainability-Oriented Assessment Approach .....	28
3.	Synthesis of Study 1 Results .....	33
4.	Orientations to Transdisciplinary Sustainability Aims and Approaches.....	76
5.	Assessment-Oriented Sustainability Framework .....	90
6.	Insights of Study 1: Sustainability-Oriented Assessment .....	106
7.	Insights of Study 2: Boundary Crossings and Innovations .....	107
8.	Insights of Study 3: Assessment-Oriented Sustainability .....	108
9.	Synthesis of Central Contributions of Dissertation Studies .....	110

## CHAPTER 1

### INTRODUCTION

#### **Assessment for Teaching and Learning Sustainability in Higher Education**

Sustainability is a learning journey. The process of creating a more sustainable future - or the endeavor of advancing personal, community, and planetary well-being by satisfying the social, economic, and environmental needs of the present and the future in just and equitable ways (Raworth, 2012) - involves setting goals, striving to attain them, generating actionable knowledge across multiple perspectives, adapting throughout the process, and emerging with new values, understandings, and behaviors. Pursuing the objectives entailed in sustainability transitions requires the development of context-sensitive solutions (Caniglia et al., 2017), the facilitation of their implementation through collaborative engagement (Lang et al., 2012), as well as formative and summative evaluation to enhance and measure progress along the way (Luederitz et al., 2017). Sustainability, therefore, is a purpose and a process. It is an endeavor of reflection, deliberation, and operationalization; of seeking to translate emergent insights into tangible practices that enable pathways towards more just, responsible, prosperous, and resilient futures.

In this way, the enactment of sustainability centers around learning. Learning can be conceptualized as a social activity of constructing knowledge (Wals, 2007), an expansion into the unknown (Engeström, 2001), a relational response to the people and world around us (Souza et al., 2019; Walsh et al., 2020), and a transformative experience that leads to new perspectives and skills that can be applied in action for change (Singer-Brodowski, 2023; Sterling, 2011). In this dissertation, learning can be understood as a

social activity in being interactive, reflexive, and critical to promote change, action, and impact through dynamic experiential pathways towards innovation and ultimately systemic transformation. As a driver and embodiment of the purposes and processes of sustainability, learning is operationalized through transversal (involving individuals, groups, and collectives), profound (engaging values and moral standards), and counter-hegemonic (exposing and questioning cultural habits and assumptions) features (Wals & Rodela, 2014). These features are intended as objectives in cultivating actions, or strategic endeavors to advance targeted solutions to sustainability problems, that contribute to impacts in fostering increased capacity and will to tangibly promote efforts toward more sustainable futures.

While the learning journey towards sustainability occurs in a myriad of ways and settings, one integral context is higher education. This space can be conceived of as the formal setting and set of experiences through which students participate towards qualification (development of knowledge and skills), socialization (engagement with cultural traditions and practices), and subjectification (enhancing autonomous capacities by encouraging existential engagement with one's self in the world) (Biesta, 2020). University engagement with sustainability has evolved in intensity and importance over the past thirty years, with a proliferation of opportunities and strategies in recent years (Hallinger & Chatpinyakoo, 2019; Menon & Suresh, 2020). Efforts have stretched across areas of higher education such as research (Hugé et al., 2016), campus operations (Fia et al., 2022), and community outreach (Findler et al., 2019) in strategies that encompass the whole institution (Kohl et al., 2022). Academic initiatives, which seek to enable students' critical engagement with sustainability topics to cultivate awareness and

skills to address them (Shephard, 2015), have been at the core of this movement. This has led to the articulation of relevant learning outcomes (Brundiens et al., 2021; Redman & Wiek, 2021; Wiek et al., 2011), pedagogies (Salonen et al., 2023; Sandri, 2022), and ambitions for transdisciplinary and transformative learning (Bernert et al., 2022). Though higher education remains one among many contexts for advancing sustainability more broadly, through comprehensive and learning-focused efforts universities can serve as catalysts for social change (Purcell et al., 2019) that contribute to meeting both local and global sustainability goals (Franco et al., 2018).

The increased attention on sustainability in higher education has spurred its spread as a focus of teaching and learning. Yet despite the growing prominence of sustainability education in higher education, sustainability issues around the world are continually amplified by inadequate collective action to address them (Engler et al., 2021). Many factors contribute to this knowledge-action gap (Kollmuss & Agyeman, 2002), among them the questionable efficacy of teaching and learning in higher education to translate to the willingness and ability of students to drive change toward sustainability (Shephard, 2022). The misalignment between increasing sustainability education opportunities in higher education, even as they mature in sophistication, and progress in meeting sustainability objectives reflects a possible gap in assessment practice. As this misalignment persists, the assumption becomes that teaching and learning in higher education lack the quality to contribute to sustainability action and impact, suggesting that new forms of assessment are needed to more adequately evaluate teaching and learning as a way to better understand and enhance its efficacy.

From this perspective, the achievements of the field of sustainability education in higher education also carry significant challenges that elevate the significance of developing more robust assessment approaches. These achievements and challenges can be synthesized in relation to three areas: (1) learning objectives, (2) teaching strategies, and (3) the growth of the field. First, while the conceptual articulation of learning objectives has provided a foundation for the design and evaluation of learning in the field (Brundiers et al., 2021; Wiek et al., 2015), a lack of practical consolidation and operationalization has hindered the advancement of effective assessment practices (Redman et al., 2021). Second, the experimentation with a variety of teaching strategies has led to identification of distinctive pedagogies in the field (Sandri, 2022), yet how these lead to actionable learning outcomes remains unclear (Walter et al., 2019; Wilhelm et al., 2019). Third, the diversification and spread of sustainability in higher education has led to different forms and approaches in a variety of settings, however the link to broader impact and how to assess this requires further attention (Cebrián Bernat et al., 2019).

### ***Problem and Opportunity Statement***

These broad challenges in the area of sustainability education in higher education culminate in the problem statement that provides the genesis and opportunity for this work. The practical dimensions of the problem to be addressed can be summarized in relation to descriptions of the purposes of assessment (Crisp, 2012). First, assessments of sustainability teaching and learning in higher education have proven inadequate in a *diagnostic* function as ways to interpret where learning stands and what needs to be done to sufficiently encourage it toward quality and impact. Second, assessments have

struggled from a *summative* function in appraising the quality and impact of teaching and learning in both immediate and more long-term contexts. Third, assessments require more robust capacity to fulfill a *formative* function where they structure and provide evidence in a way to enable adaptation that leads to the enhancement of quality and impact throughout the learning journey. These practical challenges have been exacerbated by shortcomings of research in this space. Specifically, this has entailed a lack of quantity in empirical work devoted to this topic as well as, more significantly, a lack of quality in this work. The robustness of research on assessment has been limited by several key inadequacies: lack of *theoretical engagement* (Barth, 2009); lack of *diverse perspectives* leading to an over-emphasis on certain perspectives, often those of researcher-instructors (Redman et al., 2021); and a lack of integrative approaches due to disconnect from the scholarly discourse on principles and practices of both educational assessment and sustainability science (Shephard, 2009).

Reviewing previous achievements and challenges in the field can be complemented by looking forward to three interconnected trends in the broader assessment research and practical discourse. First, assessments are shifting from a focus on *instructor-centered* approaches toward *student-centered* approaches that prioritize the perspectives and agency of students in shaping assessment practices (Pereira et al., 2016). Second, assessments are shifting from *summative* approaches toward *formative* approaches that seek to not only evaluate learning but leverage the assessment process in enhancing it (Andrade & Heritage, 2017). Third, assessments are shifting from *instructor-centered, linear, and cognitive-oriented* approaches toward *student-centered, interactive, iterative, and skill-oriented* approaches that emphasize multiple

understandings of learning with an emphasis on how learning can be applied, often in professional settings (Jorre de St Jorre & Oliver, 2018).

These trends have influenced several promising approaches in the context of assessment in sustainability education in higher education, such as an emphasis on authentic, reflective, and generative approaches. *Authentic* assessment approaches reflect the demands of professional settings to test the performance of learners on tasks and within contexts that demonstrate a high degree of fidelity to real-world practice (Sokhanvar et al., 2021). For example, in-vivo simulations in which students engage with real-world stakeholders to demonstrate learning through performance have been used to evaluate sustainability competencies (Foucrier, 2020). *Reflective* assessment approaches entail critical introspective and interactive contemplation of learning goals, progress, and potential strategy adaptations that go beyond the attainment of grades as the purpose of assessment (Liu, 2015; Winstone & Boud, 2020). For example, incorporating mindfulness into assessment processes can surface links between learning processes and outcomes with personal and social values (Frank et al., 2019). *Generative* assessment approaches indicate, motivate, and enable learning application during and after assessment tasks, which themselves create impact beyond the assessment activity (Crisp, 2012). For example, receiving feedback from project partners or stakeholders in applied learning experiences that address a campus or community sustainability challenge can contribute to learning motivations as well as increased efficacy of project strategies (Milican & Bourner, 2011). This dissertation seeks to build from these trends and promising approaches in order to address the challenges demonstrated in research and

practice by advancing conceptual and operationalizable insights to contribute to assessment innovations.

### **Research Aims**

This research aims to promote innovations in assessment practice across the areas of higher education, sustainability science, and learning. Innovation can be understood as an ethically-oriented future-creating activity that engages personal and social dimensions (Grinbaum & Groves, 2013) in cultivating breakthroughs that enable novel conceptual perspectives and emergent practical possibilities while reflecting and advancing learning (Beers et al., 2016). These breakthroughs and possibilities are fostered through inclusion, reflexivity, responsiveness (to contextualized practitioner needs), and anticipation (of evolving aspirations and considerations) (Stilgoe et al., 2013). Within the context of sustainability, innovations aim to disrupt existing (often unsustainable) systems by taking on particular directions of change, leveraging diversity in approaches and perspectives, and fostering distribution of new practices across contexts and audiences (Leach et al., 2012). Thus, throughout the dissertation innovation is explored as a normative and interactive process in relation to learning that spurs improved practice in areas such as higher education and transdisciplinary sustainability science.

In order to explore these innovations and the role of assessment in the learning journey of and towards sustainability, this work is situated at the intersection of several conceptual frameworks. These frameworks provide the basis for the broader aims of this research and are interwoven throughout the different studies. In the concluding chapter, the insights and implications of this dissertation's studies are analyzed against the backdrop of these frameworks. Specifically, this work engages with:

- *Practice theory*, as a way of interpreting individual and collective enactment of assessments within the structures of education and sustainability (Boud et al., 2018);
- *Action-oriented knowledge for sustainability*, as a way of interpreting how the outputs of the studies contribute to advancing the enactment of sustainability as a scholarly and applied activity (West et al., 2019); and
- *Dimensions of assessment*, as a way of interpreting the features and functions of how assessments are enacted in learning processes (Boud & Soler, 2016).

The three conceptual frameworks are described below, including a brief rationale explaining their relevance for this work.

### ***Practice Theory***

The foundational objective of this dissertation is to seek to understand ways to advance innovations in assessment practice, specifically within sustainability education and transdisciplinary sustainability science. To provide theoretical grounding to the notion of practice, this work is situated against practice theory, which emerged from the work of Pierre Bourdieu (1979; 1997) among others. Since then, practice theory has had a substantial influence on social science research, including on the field of sustainability science (Welch & Yates, 2018) in areas such as consumption (Sahakian & Wilhite, 2013), as well as educational research (Edwards-Groves & Kemmis, 2016) in areas such as assessment (Shay, 2008). Practice theory is a lens used to interpret how individuals, and ultimately groups, with goals, intentions, and subjectivities operate within particular social contexts (Bray, 2008). This focus on the interaction between individuals, groups,

contexts, tools, and activities makes practice theory a strong theoretical backdrop for this dissertation and its focus on education, sustainability, assessment, and learning.

While a deep engagement with the literature and conceptual tenets of practice theory is beyond the scope of this dissertation, several aspects of the theory are relevant in the context of this work. First, the theory provides a tool for thinking through the duality of practices at one level (e.g., insights on innovations in assessment within a specific study) and how they are translated at another level of social action (e.g., implications for innovations in assessment in the broader field of sustainability education) (Breiger, 2000). Second, the theory points attention toward agency and interaction in change processes, differentiating among various contexts and social configurations to highlight problems and possibilities (Holland & Lave, 2019). Third, the theory outlines distinct dimensions of practice that are helpful in interpreting how individuals and groups enact and seek to innovate their practices (Shove et al., 2012). These dimensions are: (1) *activities and skills*, or the application of a specific practice and the competencies applied in doing so; (2) *reflexivity and meaning*, or the ways practice is interpreted and made sense of; and (3) *materials and tools*, or the mediating artifacts through which practice is operationalized. Thus, from these key points of practice theory, this dissertation aims to think through practices at different levels, contexts, and among social configurations of different actors in order to derive insights on activities and skills, reflexivity and meaning, and materials and tools related to the assessment of learning in sustainability education.

### ***Action-Oriented Knowledge for Sustainability***

This work also aims to advance sustainability, both as a focus of teaching and learning in higher education but also as a societal endeavor. Caniglia and colleagues (2021) synthesized discourse in the field to advance a pluralistic and integrated framework of kinds of knowledge that support action across three dimensions. The first dimension, knowledge informing *intentional design*, focuses on generative, prescriptive, and strategic knowledges that support the development of transformative solutions. The second dimension, knowledge enhancing *shared agency*, focuses on critical, empowering, and co-produced knowledges that support the facilitation of collaborative change processes. The third dimension, knowledge enabling *contextual realization*, focuses on emergent, tactical, and situated knowledges that support the implementation of solutions to mobilize transformative change in specific settings. These kinds of knowledges operate at interfaces between science and society to promote collective learning and its application in improving practice (Apetrei et al., 2021). This dissertation aims to cultivate these kinds of knowledge to foster action in innovating assessments in sustainability education in higher education as well as transdisciplinary sustainability strategies.

### ***Dimensions of Assessment***

In addition to drawing from sustainability frameworks, this work also infuses educational and assessment concepts into its framing to inform its aims. Specifically, the notion of sustainable assessment, or “assessment that meets the needs of the present without compromising the ability of students to meet their own future learning needs” (Boud, 2000, p. 151), is applied to orient foundational understandings of assessment. Within this conceptual background, Boud and Soler (2016) articulate three key

dimensions of assessment: (1) *methods and practices*, or the general strategy and procedures, (2) *tools and criteria*, or the instruments and evaluative standards, and (3) *assumptions and normative judgments*, or the conceptual and ethical values. These dimensions are operationalized in the distinct functions of assessment, as it serves to: determine relevant benchmarks for learning, determine the quality of learning through systematic processes, and determine strategies for learning improvement (by students and instructors) through feedback and reflection (Boud, 2000). This dissertation aims to explore these different functions while advancing insights on the three dimensions of assessment in order to support comprehensive and integrated innovations in practice.

### **Research Design**

To leverage the conceptual frameworks in addressing the gaps in the area of assessment in sustainability education in higher education, this dissertation operationalizes the following research design. With the work situated at the intersection of education, learning, and sustainability science, the dissertation explores the practice of assessment across different contexts and in relation to different actors. The three practice contexts analyzed in this dissertation are: (1) a higher education sustainability course, (2) higher education sustainability programs, and (3) transdisciplinary sustainability strategies. The three sets of actors engaged in this dissertation are: (1) higher education students, (2) higher education program leaders and instructors, and (3) sustainability practitioners and scholars.

While there are overlaps in the engagement and implications of this work across practice contexts and actors, the three studies of this dissertation are aligned with specific

aspects in each of these areas. Together, the studies aim to engage with the central research question of this dissertation:

How can the multifaceted roles of assessment in sustainability education contribute to learning towards innovations in transdisciplinary practice?

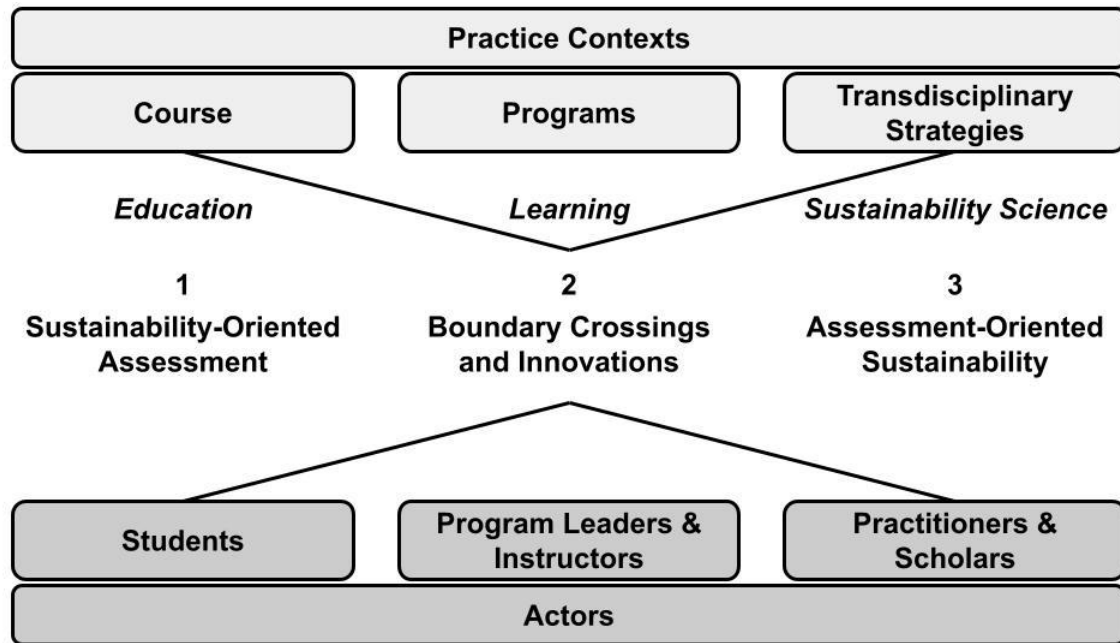
To respond to this question, the studies seek to address the following topics: (1) sustainability-oriented assessment, (2) boundary crossings and innovations, and (3) assessment-oriented sustainability. Through the research design articulated in Figure 1, these topics are explored from an educational perspective and through the lens of sustainability science, funneling towards insights for how collective and social learning is facilitated to foster advances in practice across contexts and actors.

The three studies examine the following primary research questions:

1. Sustainability-Oriented Assessment: How do students experience their role in guiding a rubric co-design process to assess their learning of professional skills related to sustainability?
2. Boundary Crossings and Innovations: How do program leaders and instructors of sustainability programs in higher education view and seek to negotiate barriers and possibilities for advancing assessment practices?
3. Assessment-Oriented Sustainability: How can concepts and practices from the educational discourse inform approaches to the learning-focused assessment of transdisciplinary sustainability strategies?

**Figure 1**

*Elements of Research Design*



*Methodological Approach*

The methodology and methods of this work are informed by my positionality as a scholar. As a white, straight, male, I recognize certain privileges, perspectives, and problematics that emerge from my positionality and its intersection with my work. Particularly while situated in the hegemony of higher education and academic culture, my positionality can influence my approach to research while obscuring certain relevant viewpoints or aspirations for my research. While I have aimed to be reflexive, responsive, and respectful throughout the inquiry process, particularly in engaging with actors from different backgrounds and contexts, this remains an ongoing endeavor that is incomplete as demonstrated in this dissertation.

One example of my critical engagement is that the studies aim to embed and facilitate inclusion and equity as reflections of fundamental principles in sustainability

science and educational practice. These principles focus on the participative, normative, and integrative qualities of practicing and learning toward sustainability (Barth, 2014). In this endeavor, this research centers the need for democratic collaboration, values negotiation, and engagement with diverse perspectives. Additionally, in engaging with my positionality as a scholar, I have considered the different roles that sustainability researchers inhabit, from self-reflexive scientist, change agent, and knowledge broker to process facilitator and reflective scientist (Wittmayer & Schöpke, 2014). Thus, as a researcher I aim to facilitate reflection, deliberation, and change through my work, prioritizing the discovery of practical applications and the conceptual structures that underpin them.

To respond to the three research questions, the studies apply different methods to generate insights on advancing assessment practices. These approaches are underpinned by the ontological and epistemological stance of critical realism, which informs the methodology of this dissertation (Bhaskar, 2016). This foundational frame serves to emphasize the interacting ways in which individuals shape their experiences and how social contexts in turn shape these experiences (Moller et al., 2021). Within this dissertation, critical realism is applied as a lens for understanding “the intertwining between context (the elements that make up the setting of an intervention), mechanisms (the unseen forces that trigger change) and the outcomes of an intervention” (Sturgiss & Clark, 2020, p. 144). Critical realism has been highlighted as an informative epistemological stance for education research (Scott, 2005), qualitative inquiry (Fletcher, 2017), and in the practice-oriented context of research on sustainability education in higher education (Huckle, 2004). The methods applied in each study draw from this

general methodological approach through a variety of compatible perspectives or strategies.

The methodological approach, and its entanglement with my positionality, have informed the methods applied in the three studies. The first study (Sustainability-Oriented Assessment) features participatory experimentation in which students engage in the process of changing practices by deliberating goals and strategies in assessing their learning. The second study (Boundary Crossings and Innovations) builds on this participatory approach with an action research strategy to explore the experiences, perspectives, values, and ambitions of program leaders and instructors related to assessment practices. The third study (Assessment-Oriented Sustainability) focuses on integrating conceptual approaches to assessment from education and sustainability through a comprehensive and generative analysis of the literature.

### ***Synthesis of Potential Contributions***

The different research and practical issues related to assessment in sustainability education, learning, and transdisciplinary practice can be synthesized into three gaps that this dissertation takes the opportunity to address. First, establishing *distinctive approaches* to assessment in sustainability education can support the intentional creation of methods and practices. Second, facilitating *deliberative processes* can enable the shared exploration of the assumptions and normative judgments that influence assessment practices. Third, determining *design frameworks* can strengthen the articulation of tools and criteria for evaluating sustainability learning across contexts. Addressing these gaps can inform the action-oriented knowledge for sustainability across assessment dimensions that is needed to stimulate innovations in practice.

Thus, this dissertation seeks to leverage opportunities in these areas toward empirical, theoretical, methodological, and practical contributions to the discourse on assessment of sustainability-related teaching and learning in higher education. From an empirical perspective, this research can provide evidence that maps different forms and considerations for practice in this space to inform future experimentation. From a theoretical perspective, this research can provide insights from engagement with different learning theories while helping to develop conceptual frameworks for work in this area. From a methodological perspective, this research can provide illustrations of the generative power of deliberative processes as a catalyst for inquiry that is situated at the intersection of research and social change. From a practical perspective, this research can provide technical and logistical knowledge for different actors operating within a variety of contexts. These contributions suggest the need for and significance of this work in strengthening the capacity of the field of sustainability education in higher education as well as sustainability science more broadly.

## **Overview**

The studies entailed in this dissertation address the areas described above in order to advance innovations in assessment practices. The context, goals, methods, and findings for each study are presented in the following chapters:

- Chapter 2 presents the study focused on *Sustainability-Oriented Assessment*. This study applied a formative intervention within an undergraduate course focused on professional skill development to explore how sustainability principles can inform student-led assessment processes.

- Chapter 3 presents the study focused on *Boundary Crossings and Innovations*. This study applied an exploratory action research approach within a community of practice of program leaders and instructors to determine barriers and possibilities for innovations in assessments.
- Chapter 4 presents the study focused on *Assessment-Oriented Sustainability*. This study applied a scoping literature review to advance a framework for developing assessments of transdisciplinary sustainability strategies.
- The Conclusion chapter will highlight the cumulative insights of the three studies and situate their implications within the practical and theoretical literature that provides the basis for this work.

In the learning journey of and towards sustainability, scholarship is needed to analyze and advance conceptual foundations for the design, facilitation, and evaluation of action-oriented knowledge. The work detailed in this dissertation aims to address this need by contributing insights on the practice of assessment within sustainability education, learning processes, and transdisciplinary strategies. If pathways are to be established that orient collaborative endeavors towards more sustainable futures, this type of work can offer steps forward in the present.

## CHAPTER 2

### SUSTAINABILITY-ORIENTED ASSESSMENT

#### **Introduction**

As students are increasingly confronted by complex social-ecological challenges, such as climate change or social injustice, higher education is compelled to prepare students to navigate these challenges by reimagining the function of teaching and learning as well as students' role within it (Smeers et al., 2020). The implications of this imperative create new types of learning activities and goals, in which students grapple with uncertain and urgent conditions that require diverse knowledges, interdisciplinary modes of instruction, and solution-oriented pedagogies (Salonen et al., 2023). The field of sustainability education offers an example of experimentation in these areas, as scholars seek to determine ways to adapt practices in higher education towards transdisciplinary and transformative learning (Bernert et al., 2022). However, within sustainability education and more broadly, assessment practices remain in the early stages of determining strategies that can respond to these evolving learning environments.

The role of students is a pivotal area for inquiry within these efforts (Nieminen & Yang, 2023), particularly related to critical, collaborative, and creative learning that can equip students with the skills to address the complex social-ecological challenges they will face as professionals (Smeers et al., 2020). One proposed strategy to facilitate and assess this type of learning is rubric co-design. These processes typically involve students taking an active role in the construction of assessment criteria by working with instructors to jointly discuss, negotiate, and evaluate student performance (Quesada et al., 2019). Despite its promising potential, research and practice on rubric co-design often

prioritize the perspective of instructors while limiting student engagement throughout the stages of the assessment process (Morton et al., 2021). Approaches are needed that elevate the role of students by operationalizing features that center their agency, interaction, and learning in developing and implementing rubrics (Rickett et al., 2019).

To address this gap, this study describes a student-led rubric co-design process that engages students throughout phases of an assessment procedure. A sustainability-oriented assessment approach is advanced to inform design principles for orienting the process toward learning that is responsive to complex social-ecological challenges.

### **Student Agency in Rubric Co-Design**

As higher education engages with the evolving needs of students, assessment scholarship has increasingly responded to the conditions that students will encounter in personal and professional settings. This includes a shift from instructor-centered, summative, linear, and cognitive-oriented assessment toward student-centered (Pereira et al., 2016), formative (Andrade & Heritage, 2017), and more interactive, iterative, and skill-oriented (Jorre de St Jorre & Oliver, 2018) approaches. Nieminen and Yang (2023) have conceptualized these ends of the spectrum as assessment that focuses on “other-formation” versus “self-formation”. Whereas other-formation centers around ordering student achievement, self-formation approaches become “an opportunity for agentic negotiation of one’s professional identity” (Nieminen & Yang, 2023, p. 8). This emphasis on student agency is central to self-formation through assessment as it is understood as the process of students’ active engagement in decision-making to promote ownership of learning and professional skill development (Adie et al., 2018).

Co-designing rubrics has been identified as a strategy for practicing self-formation through assessment, as it offers a more democratic form of participation and empowerment in which students can demonstrate and negotiate agency (Deeley & Bovill, 2017). As a distillation of shifts in assessment practice, student-led rubric co-design offers a promising approach. The literature on this topic reveals a need to examine student agency with these processes, specifically considering the following areas: (1) how students are positioned in the process; (2) the types of actions and outcomes that these processes contribute to; and (3) challenges faced along the way.

Despite calls for students' active involvement in assessment processes to support their development, there are still limited opportunities for students to assume this central role as higher education remains dominated by instructors' perspectives on what assessment should look like and aim to achieve (Morton et al., 2021). A key factor that has exacerbated these limitations is the persistent gap between declared advocacy for student engagement in assessment and demonstrated action in continued reliance on more traditional practices (Schellekens et al., 2021). Participating in peripheral roles, where rubrics serve the grading interests of instructors rather than the learning aspirations of students can lead to students misunderstanding assessment criteria and in turn feed low engagement (Joseph et al., 2020). In more student-centered approaches, the focus is on empowering students to engage in the assessment process as a way of developing their immediate and long-term learning capacities (Boud & Soler, 2016). For example, the work of Inoue (2004) outlined a community-based assessment pedagogy that supported students to determine assessment criteria for a writing assignment through critical reflection and collective deliberation, while they generated insights on quality

performance to guide their future work. As students are positioned in leading roles, they become able to problematize assumptions of learning and assessment methods while making judgments about the evolving quality of their own work (Particelli, 2020).

Rubric co-design processes have been demonstrated to contribute to a variety of actions and outcomes for students. This includes developing their voice as they engage with the cognitive challenges, iterative feedback cycles, values, and socio-emotional dynamics that they might face as professionals (Zhao et al., 2021). Students also explore new perspectives on the links between learning and assessment, such as how they might best utilize rubrics to support their professional development (Kilgour et al., 2020). These insights can occur when students gain perspective on instructors' roles by taking on similar responsibilities in designing their rubrics, leading to mutual learning focused on educational innovations and system transformation (Rickett et al., 2019). On a more immediate level, rubric co-design can create scaffolded processes that support increased engagement with assessment criteria, helping students to become more adept in navigating course expectations (Becker, 2016). To do so, students often leverage increased abilities in reflexivity (Litterio, 2018), self-regulation (Fraile et al., 2017), and evaluative judgment (Tai et al., 2018). On a group level, the deliberation and reflection facilitated through the co-design process enable students to develop communication and collaboration skills as they cultivate supportive group environments in reaching consensus on assessment criteria (Joseph et al., 2020).

Common challenges faced by instructors implementing rubric co-design are lack of time, increased workload, and the effort involved in fostering student engagement and negotiating conflicts or lack of competencies or confidence that both students and

instructors might display (Quesada et al., 2019). For students, common challenges include facing initial discomfort inhabiting new roles that challenge typical student-instructor power dynamics and dealing with uncertainty in expectations (Zhao et al., 2021). These challenges can be amplified by lack of clarity in understanding the organization of the often-novel process (Quesada et al., 2019), or how to complete the technical steps of refining and weighing assessment criteria by reaching consensus through group deliberation (Bacchus et al., 2020). Though students can respond negatively to these challenges, research has shown that they commonly overcome tensions by challenging themselves to adopt new perspectives and practices as they leverage contradictions as opportunities for learning (Rantavuori et al., 2016).

The literature regarding rubric co-design highlights the promise of student-led approaches in elevating student agency and learning. Yet, further work is needed, particularly in relation to the purpose dimension of assessment and how assessments might situate students within strategies responsive to complex social-ecological challenges. This suggests the need to investigate the design features of student-led rubric co-design in connection to the evolving demands on learning objectives and assessment practices in higher education.

### **Sustainability-Oriented Assessment**

We present sustainability-oriented assessment as an approach that draws from sustainability principles to guide the design of student-led rubric co-design and orient these processes toward the purposes of student agency and self-formation as a way of preparing students to engage with the complexities of social-ecological challenges. Sustainability-oriented assessment incorporates three key principles from sustainability

science, education, and practice (Barth, 2014): participative, by emphasizing inclusion, empowerment, and collaboration; normative, by highlighting how values shape goals and actions; and integrative, by bringing together insights from different perspectives to generate solutions.

The *participative* features are operationalized in student-led rubric co-design through the elevation of students' voices in inclusive and democratic ways to facilitate their agency in the development and implementation of their rubrics. This type of approach emphasizes the collaborative and reflective dimensions of learning (Boud & Bearman, 2022), while positioning assessment as a critical and generative dialogue in which students can advance authentic insights (Serrano et al., 2018).

*Normative* features are operationalized in students' agency to deliberate, both individually and collaboratively, the values and goals to be articulated in their rubrics. Student-led rubric co-design processes offer fertile ground for students to engage with the normative aspects of educational environments, such as how they define quality performance and represent (or obscure) diverse student identities and learning styles (Inoue, 2004). These processes can also provide opportunities to explore professional values and identity formation through critical examination of the skills demanded in specific fields (Zhao et al., 2021).

*Integrative* features are operationalized through students' agency in negotiating consensus across diverse perspectives regarding learning objectives and rubric design. As students engage in student-led rubric co-design, incorporating different perspectives in a group to reach compromises on assessment criteria can prove challenging (Bacchus et al., 2020). However, students find the process of synthesizing ideas and articulating them in

mutually agreed-upon ways to be a positive experience that fosters their agency in supportive group settings oriented toward the development of professional skills (Kilgour et al., 2020).

### **Theoretical Framework**

This study applies two interconnected theories to frame an intervention focused on students' experience in a rubric co-design process oriented by sustainability-oriented assessment. The first, cultural historical activity theory (CHAT), is applied to guide the inquiry process by outlining the components of a system that need to be considered in developing and analyzing the assessment practice. The second, expansive learning theory (ELT), is applied to guide the strategic actions of students throughout the steps of the rubric co-design process. These theories provide a frame for interpreting interacting elements within a dynamic setting (CHAT) and the learning that can happen as students explore new roles in assessment activities (ELT). In this study, the theories are operationalized in an activity system focused on student-led rubric co-design that leverages a sustainability-oriented assessment approach to facilitate expansive learning.

CHAT examines the interrelations between learners and mediating artifacts to frame how they transform within activity systems (Engeström, 2011). Though this theory is rare in assessment research (Nieminen et al., 2023), it has been used to examine factors that influence interactions in assessment processes (Macleod et al., 2020). Under this framework, activity systems are informed by four principles (Engeström, 2001). First, the system is influenced by its *historicity*, as its problems and potentials are grounded against their past iterations. Second, *contradictions* are pervasive in systems, yet can act as sources of change and development. Third, the system displays *multivoicedness* by

incorporating a range of perspectives, traditions, and interests. Fourth, participants in the system can undergo *expansive learning* through critical and collaborative reflection, visioning, deliberation, and enactment of change. These principles inform the areas of inquiry for this study and the student-led rubric co-design activity system as oriented by sustainability-oriented assessment.

ELT is a learning theory that describes how a group addresses a practical problem by engaging with emergent contradictions through joint cooperative action (Engeström, 2011). It draws on the metaphor of learning as expanding, or learning “new forms of activity which are not yet there” as “they are literally learned as they are being created” (Engeström, 2001, p. 138). Because of these features, the theory has been used to frame collective learning and change-oriented processes involving communities of practice (Rantavuori et al., 2016), though it has rarely been applied to guide the design of formative, student-led assessment processes. As an intervention frame for this study, the strategic learning actions described in ELT provide a reference for the steps that students take in the process of rubric co-design. Engeström (2001) explains how these strategic learning actions are operationalized in iterative cycles of the following steps: questioning, analysis, modeling the new solution, examining the new model, implementing the new model, reflecting on the process, and consolidating and generalizing the new practice. In shaping new practices, learners display different types of transformative agency through: resistance and critique, explicating and envisioning new activities, and commitment to consequential actions to transform the system (Engeström et al., 2014).

## **Methods**

This study seeks to respond to the following research question: how do students experience their role in guiding a rubric co-design process to assess their learning of professional skills related to sustainability? Several secondary research questions emerge from the principles of activity systems described above. These questions are:

1. RQ1: Historicity: In what ways do students perceive the student-led rubric co-design process compared to their previous experiences with assessment design and implementation?
2. RQ2: Contradictions: What contradictions did students experience within the student-led rubric co-design process and how were they leveraged as sources for change, growth, and transformative agency?
3. RQ3: Multivoicedness: How are the key features of sustainability-oriented assessment (participative, normative, integrative) experienced in the student-led rubric co-design process?
4. RQ4: Expansive Learning: Through what types of strategies did students display indicators of expansive learning in developing their sustainability professional skills and capacities as students?

### *Context*

The study was conducted in an undergraduate sustainability course at a large research-focused university in the United States. The course focused on “Professional Skills in Sustainability” with students typically majoring in sustainability and often in their second or third year within the undergraduate program. The course was delivered through two in-person, fifteen-week sessions (with 28 and 10 students), as well as one online, seven-week session (44 students). The primary learning objective for the course

was to support students in cultivating and reflecting on cross-cutting skills essential for sustainability professionals, namely: effective and compassionate communication, collaborative teamwork, responsive project management, preventative self-care, impactful stakeholder engagement, and advanced continuous learning (Brundiers & Wiek, 2017). Students were also supported to individually and collectively explore their self-formation as sustainability professionals and how they might apply their skills in the future.

### ***Intervention Design***

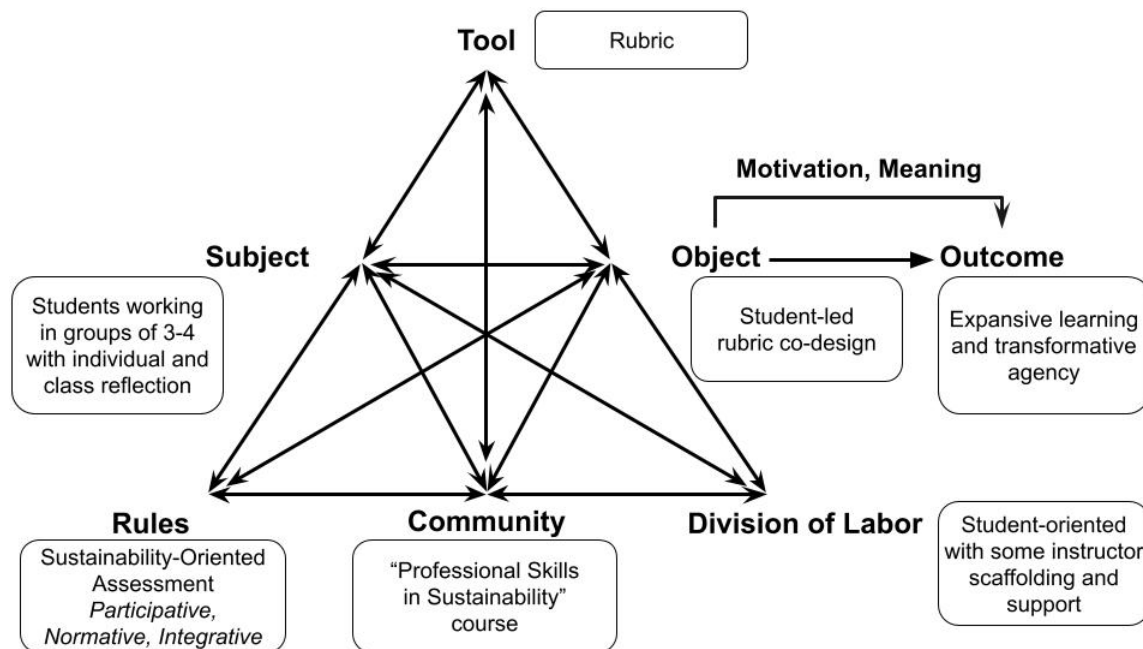
The student-led rubric co-design process was designed to act as a formative intervention (Engeström et al., 2014). This type of study involves research on an expansive learning process in which students demonstrate individual and collective agency by leading the design of new practices within an activity system through participatory analyses and implementation to develop generative solutions in a specific context (Sannino et al., 2016).

To guide the implementation of the student-led rubric co-design process, the researchers outlined elements of the activity system drawing from CHAT (Figure 2). Activity systems entail several elements, with the interactions between these shaping the evolving function of the system. These include: *subject*, the primary subgroup; *community*, the individuals and subgroups who share the same object; *division of labor*, the horizontal division of tasks and the vertical division of power and status; *rules*, the explicit and implicit regulations, norms, conventions and standards of the community; *object*, the problem space at which the activity is directed as an invitation for interpretation, meaning making, and potential transformation; *instruments*, the tools and

signs used to engage with the object; and *outcomes*, the results generated through the learning process (Engeström et al., 2014). Within the activity system, the rubric was positioned in a central role as a mediating artifact to both activate sustainability-oriented assessment design principles and support expansive learning processes among students.

**Figure 2**

*Activity System for Student-Led Rubric Co-Design Guided by a Sustainability-Oriented Assessment Approach*



The formative intervention situated students in groups of three to four in which they worked together to co-design a rubric to assess a presentation assignment. In this assignment, students reflected on the development of their sustainability professional skills and demonstrated their utility both within the course and for applications in future professional roles. After deliberating performance standards for the assignment, each group of students developed a customized rubric that articulated what they determined as relevant and meaningful assessment criteria. To grade each student, the instructor used

the group-specific student-led co-designed rubric to evaluate the assignment and produce distinct marks for each student in that group. Other students in the group applied the rubric in a peer assessment to provide additional feedback.

To complete their rubrics, students progressed through the formative intervention in two phases (Table 1) which aimed to reflect strategic learning actions articulated in ELT (Engeström et al., 2014). The first phase focused on students familiarizing themselves with the student-led rubric co-design process by adapting rubric templates for use in a midterm self- and peer-assessment. In the second phase, students were invited to create their own rubric by determining its format and criteria based on the values and objectives of their group. Throughout these phases, the lead author provided support for the students by offering a subtle scaffold in the form of initial guidance on the process, clarifying questions as they arose, and giving feedback at strategic points. However, an intentional pedagogical choice was made to encourage student freedom in the co-design process and refrain when possible from providing guidance beyond procedural matters. This approach aimed to overcome the common instructor dominance of rubric co-design processes (Morton et al., 2021). While this openness to student leadership of the process can contribute to potential issues in assessment quality, the two phases of the intervention were applied to support students in developing their assessment design skills. Though there may be trade-offs that occur in utilizing such an approach related to assessment reliability and validity, these were balanced by a prioritization on deep learning and possible gains in student self-efficacy as has been demonstrated in similar approaches to summative self-assessment (Nieminen et al., 2021).

**Table 1***Intervention Design Phases and Steps Informed by Expansive Learning Cycles**(Engeström et al., 2014)*

Intervention step	Phase 1 practice (in-person sessions only)	Phase 2 practice (all sessions)
Questioning, which is informed by a need state	Students performed their initial reflections on learning and assessment related to sustainability	Students reviewed their evolving perspectives and skills to consider ways to apply them in rubric development
Analysis, which through historical-genetic and actual-empirical inquiry often results in double bind scenarios	Students reviewed a process overview to brainstorm potential changes to predefined rubric template	Students review final assignment description to brainstorm potential standards and criteria for rubric
Modeling the new solution, which can facilitate breakthroughs	Students determined initial changes to their rubric	Students developed initial outline of rubric
Examining the new model, which requires adjustments to the changing system	Students conducted a discussion activity with other groups about their rubric and also receive feedback from the instructor	Students participated in a peer-review process to give and receive feedback, which is supplemented by feedback from the instructor Instructor applied the student-designed, customized rubrics to assess each member of a specific group, and students applied the rubric in peer-assessment as well
Implementing the new model, where there is a chance for resistance	Students applied their finalized rubric in a self- and peer-review	
Reflecting on the process, which often supports a stabilization of the new practice	Students responded to reflection prompts to provide insights and feedback on their experience	Students responded to reflection prompts to synthesize their insights on their experience

Consolidation and generalization of the new practice, which can lead to future evolutions	Building from the reflection, students considered potential adaptations to apply in Phase 2	Students were encouraged to consider how they might apply new perspectives and skills in the future, while the instructor considered further ways to iterate and integrate the assessment approach within the course
---	---	--

---

### ***Data Collection and Analysis***

Data were collected through several methods: interactive class reflection activities, individual reflections, and group reflections. These methods entailed written responses to prompts (Appendix D), with all participants (as an individual or group, where appropriate) responding to these through explanations of their design choices or reflections on their emergent insights from the experience. Data were collected to explore: (1) students’ evolving perspectives on sustainability, assessment, and learning, (2) the goals, strategies, challenges, and breakthroughs of their deliberation processes, (3) design features and rationale for each group’s rubric, and (4) insights on the types of knowledge, skills, and mindsets that students applied throughout the process.

Analysis was performed using reflexive thematic analysis to determine patterns within the data. Reflexive thematic analysis recognizes the central role of the researcher in qualitative inquiry and how this process leads to “creative and interpretive stories about the data, produced at the intersection of the researcher’s theoretical assumptions, their analytic resources and skill, and the data themselves” (Braun & Clarke, 2019, p. 594). To enact this approach, the authors collaborated to leverage and critically examine their positionalities within the research process (especially related to age, power, and role in the intervention) in crafting themes. The legitimacy of the coding output was ensured

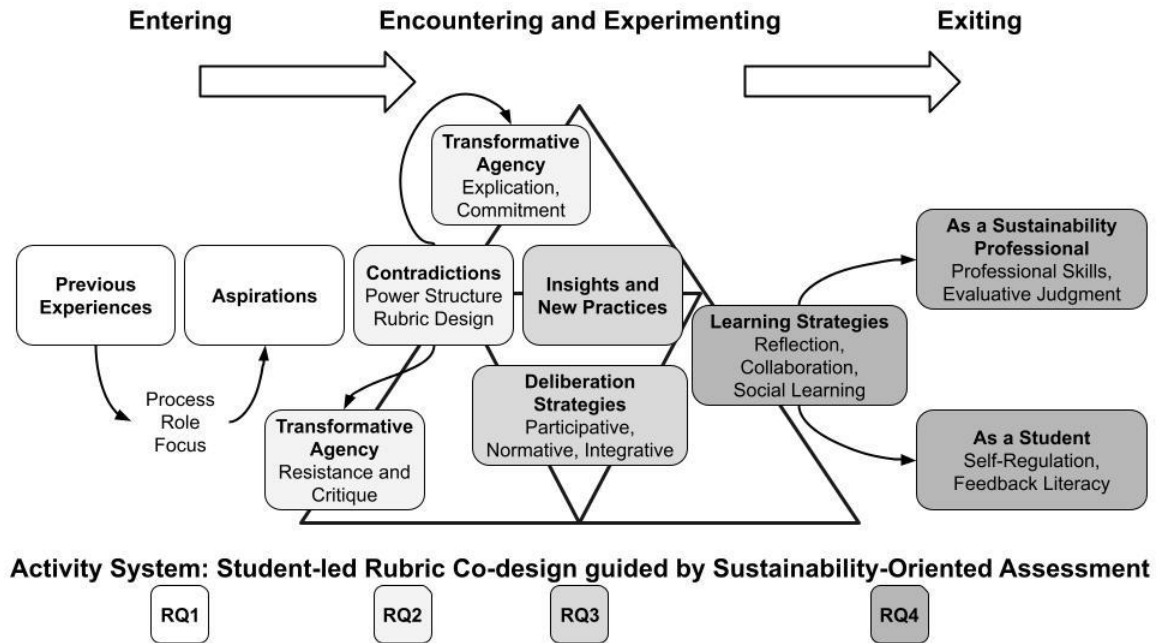
via this collaborative approach and continual engagement with the literature and data throughout the process. The analysis process journeyed through the six iterative steps of reflexive thematic analysis (Braun & Clarke, 2006). In *familiarization with the data*, data were prepared for analysis according to the constructs underlying the reflective prompts used for data collection. In *generating initial codes*, data received preliminary codes, blending inductive and deductive strategies. In *generating themes*, the coded entries were sorted into categories and reflexively worked through to establish a tentative set of themes and sub-themes related to the research questions. In *reviewing potential themes*, the researchers deliberated the themes and their connection to the data, the theoretical framework, and insights from practice and literature. In *defining and naming themes*, these themes were synthesized to reflect the students' progression through the activity system. The output of *producing the report* is presented in the next section.

## **Results**

The results are organized into three phases of students' experience that address the four research questions (Figure 3). These are: (a) engaging with historicity (RQ1) in entering the new activity system, (b) encountering contradictions (RQ2) in experimenting with the multivoicedness (RQ3) of the activity system; and, (c) reflecting on expansive learning (RQ4) in exiting the activity system.

**Figure 3**

*Synthesis of Study 1 Results*



*Engaging with Historicity in Entering the New Activity System*

As students compared their previous experiences to their aspirations for participating in student-led rubric co-design, they contrasted different features in the assessment process, its focus, and their new role.

In the *assessment process*, students lamented the limitations of their previous experiences, describing them as “mechanical”, “restrictive”, and “merely a process to get students in and out of the class”. Instead, they hoped that participating in the new activity system would enable a “sense of freedom” in an “interactive and creative” process to allow for the determination of assessment criteria.

For the *assessment focus*, students described previous experiences as taking a “cookie-cutter” approach in projecting the flawed assumption that “everyone has the same goals, same strengths, and same abilities”. One student highlighted that this caused

their energy to be devoted to compliance with expectations instead of discovery and growth, stating: “I feel like I have always just tried to follow the rubric and do work to pass, not taking the time to look at my work and see how doing it is benefiting me”. Instead, the student-led rubric co-design process was viewed as an opportunity to emphasize “different learning capabilities and styles” through an approach that supported “growing in our individual ways rather than a way forced by the instructor”.

Students also explored new *roles* within the assessment process. Previous experiences were described as being dictated by an “authority figure” who compelled students to “produce more and more work for them without having a say in how it was judged”. Students looked to student-led rubric co-design to provide “a platform to engage and talk to one another” so that they could act as an “advocate for my work” and “take responsibility for their learning, stay engaged, and feel empowered in their education”.

### ***Encountering Contradictions in Experimenting with the Multivoicedness of the New Activity System***

As students experimented with the novel experience, they encountered contradictions related to power structures and rubric design, responding to these with different forms of transformative agency.

In participating in the reorientation of the *power structures* of the activity system, many students found their enhanced authority as “odd”, “challenging”, or even “frustrating”. These feelings extended to the technical process of *rubric design*, where students initially craved “specific directions” as well as “examples and suggestions” to navigate the “very open and broad process”. As they faced these contradictions, students displayed different forms of transformative agency. Some students demonstrated

*resistance and critique* as they found the process to be a “daunting task” since they “have always been judged or evaluated by others and their rules, not my own, so it was a confusing assignment for me”. Others advanced their agency by *explicating and envisioning* new actions as they came to feel “much more in control as I felt like I had a birds-eye view of the course, rather than just jumping over every hurdle that came after the next”. This helped some students to progress towards *commitment to consequential actions* as they stepped “out of your comfort zone to expand your knowledge and confidence” to “decrease the risk of groupthink” and instead “voice our opinions and work off of each other’s ideas to work towards our goal of having a cohesive final rubric” that represented their unique perspectives.

To convert contradictions into sources of change and growth, students leveraged deliberative strategies that reflected the functions of sustainability-oriented assessment and the multivoicedness of the activity system. *Participative* features were operationalized as students worked in their groups to determine “what each member prioritizes for the group and what goals they have for the group, as well as how to progress as a team being able to talk about how to change together”. *Normative* features were displayed as students used the process to gain a “better understanding of where our values lie and how our work stays in line with that” and to identify how their learning and development as sustainability professionals could “be better grounded in those values we have”. *Integrative* features manifested as students became more “understanding and appreciative of others’ insights” as well as “more mindful of different working styles” so that they could “find a group consensus” in order to incorporate “different perspectives to ensure that the rubric was comprehensive and addressed all relevant criteria”.

Experimenting with the process helped students navigate the contradictions that they faced to achieve *insights and new practices*. For example, students came to “see the other side of how our professors grade and design our courses”, which, combined with their increased agency, contributed to a capacity “to think outside the box of a student and consider what characteristics make up sustainability professionals and which of those characteristics we wanted to embody”.

### ***Expansive Learning in Exiting the Activity System***

As students reflected on their experience, they described several strategies that contributed to indicators of expansive learning with regard to enhanced self-regulation and feedback literacy, as well as the development of professional skills and evaluative judgment.

At the individual level, expansive learning processes were encouraged through *reflection* as students considered how to engage in a process that did not present “a one-size-fits-all answer” and instead “shape new, more thoughtful paths forward”. At the group level, students stressed the importance of *collaboration* in crafting “a collective agreement on our own internal rules” and developing a shared “voice in the structure of our grades”. At the collective level, students embraced the *social learning* process as a way of participating in “multiple feedback loops from people both in our group and other groups” that allowed them “the opportunity to hear a variety of views and further develop our work”. Activities such as peer reviews and class discussions enabled students to explore “how different we all thought about what should be in it” and “opened my eyes to how we can sometimes make these complex ideas much simpler through synthesis”.

Indicators of expansive learning included descriptions of increased capacities in *self-regulation* as students explored how to “set goals for ourselves that were attainable and not overly complicated” through “self-directed” action. The experience also supported students’ *feedback literacy* as they came to better understand the course objectives and the functions of formative and performance-based assessments. Many students became more engaged in the learning process, coming to “look more closely at rubrics” since “constructing a rubric breaks down an objective’s expectations into more refined goals” and helps “determine what skills are comprised of different actions that lead to success”.

Students also described development as sustainability professionals with student-led rubric co-design serving as an effective way to “draw on all the skills we have been practicing” and “work in a group toward a shared goal that had a direct impact on my future work”. This particularly served to develop *professional skills* such as “effective and compassionate communication and collaborative teamwork in that we had to communicate our thoughts and desires and work together as a team to bring the rubric together”. Students also felt that their experience developed their *evaluative judgment* by encouraging them to “take a step back and see where we stand in relation to our goals, analyze what worked, and think how we want to progress from there”. This was highlighted as particularly relevant since “sustainability as a whole has very different goals than other areas, so it is pivotal to have guidelines that fit those goals”.

## **Discussion**

Results showed that students experienced the student-led rubric co-design process as a departure from previous experiences. Although challenging at times, the features of

the sustainability-oriented assessment approach enhanced their individual and collective agency in determining assessment criteria, contributing to their development as both students and sustainability professionals. The results confirm many of the challenges and outcomes identified in previous studies. For example, students at times struggled to navigate the novelty (Quesada et al., 2019) and uncertainties (Zhao et al., 2021) of the process, particularly in negotiating productive group deliberation processes and managing the nuances of rubric design (Bacchus et al., 2020). While a handful of students reacted against their leading role, many leveraged initial contradictions into sources of growth. In this, students achieved outcomes suggested by past research such as engagement with course expectations (Becker, 2016), reflexivity on the learning and assessment process (Litterio, 2018), self-regulation (Fraile et al., 2017), evaluative judgment (Tai et al., 2018), and development of professional skills such as communication and collaboration (Joseph et al., 2020).

The results build on previous insights by highlighting strategies to promote student agency, as well as delineating phases for students' experience of student-led rubric co-design. The identified individual, group, and collective learning strategies represent valuable actions to shape students' self-formation (Nieminen & Yang, 2023) and professional skill development (Jorre de St Jorre & Oliver, 2018) through assessment practices. The ways that these learning strategies worked across different elements of the activity system to encourage student agency also highlights the value of CHAT and ELT as theoretical frames for interpreting how students operate within a community to leverage interactions and mediating artifacts to advance and assess their learning. The phases outlined in the results (entering, encountering and experimenting, exiting) build

from these theoretical foundations to articulate the unfolding of students' experiences with student-led rubric co-design and how they engaged with sustainability-oriented assessment features to convert challenges into opportunities for growth as students and sustainability professionals.

The sustainability-oriented assessment approach articulated in this study provides not only a guiding mechanism for the design of student-led rubric co-design processes but serves to emphasize the purpose dimension of assessments. The participative, normative, and integrative features of this approach provide a frame for rethinking the what, how, and especially the why of assessment and for designing assessment practices geared toward student learning in the present and the cultivation of students' agency and self-formation to act in the future (Boud & Soler, 2016). In the case of this study, the exchange between educational scholarship and sustainability science has helped to address gaps in the student-led rubric co-design literature related to its purpose and the actions of students, suggesting that continued cross-pollination between fields could facilitate further conceptual and practical innovations (Barth & Michelsen, 2013).

The results of this study can be viewed against several limitations. From a methodological perspective, considerations are needed for the potential effect of other course activities to shape the actions and outcomes that students attributed to student-led rubric co-design, the lack of quantitative measurement to validate student learning, and the absence of cross-sample comparison to affirm the reliability of the results. From the perspective of the practical implications of this study, the focus of the study on the student experience should be contextualized against the influences of instructors and institutional infrastructure on the implementation of innovative assessments (Serrano et

al., 2018). Closer consideration of the drawbacks of emphasizing student agency and participation, though rarely observed in this study, is also needed to avoid the reinforcement of problematic power dynamics between instructors, institutions, and students. Critical reflection on these aspects of the study's findings can also point to the limitations of student-led rubric co-design and sustainability-oriented assessment approaches as serving distinctive purposes that may not be compatible with all assessment contexts.

## **Conclusion**

This study has demonstrated the promise of student-led rubric co-design, particularly when drawing from a sustainability-oriented assessment approach to guide the design of processes that contribute to student agency and professional self-formation. Future research in this area should continue to explore how the participative, normative, and integrative features of sustainability-oriented assessment can orient assessments in different contexts and across other subjects. This could include analysis of the perspective of instructors as they adapt to cultivating learning environments conducive to student-led rubric co-design, as well as investigation of strategies for scaling and institutionalizing these approaches as valid grading methods. In advancing student-centered learning, future work will also need to address persistent practical challenges, such as how to safeguard student engagement in assessment processes so that they are provided with learning opportunities while avoiding the risk of token participation to justify predetermined grading practices. Additionally, there is a need to identify and promote facilitation techniques and roles for instructors to effectively emphasize student agency while translating student-centered approaches into reliable grading strategies

through ongoing student-instructor deliberation. This may help both instructors and students to navigate the typical power dynamics that the student-led approach described in this study seeks to subvert. The features of sustainability-oriented assessment can begin to address these potential challenges by refocusing the purpose of assessment toward student deliberation and skill development, but instructors implementing student-led rubric co-design should also seek to establish safe and inclusive environments that foster respectful dialogue while promoting student agency and learning. Efforts such as these are needed to advance student participation in assessment practices as a way to reorient the functions of teaching and learning in higher education toward the purpose of preparing students to engage with complex social-ecological challenges.

## CHAPTER 3

### BOUNDARY CROSSINGS AND INNOVATIONS

#### **Introduction**

As the extent and forms of sustainability-related teaching and learning in higher education expand, understanding the quality and impact of these offerings becomes increasingly important. This suggests a priority for developing assessment practices with the efficacy to promote and evaluate the distinctive outcomes of sustainability programs. However, assessment has remained underdeveloped in the sustainability education discourse compared to the articulation of learning objectives (Brundiers et al., 2021) and pedagogies (Sandri, 2022). A crucial reason for the lack of maturation in assessment scholarship has been the complexities, confusion, and challenges faced in practice (Waltner et al., 2019). Yet, what these barriers look like in action, and the possible ways to examine and navigate them, has not been fully articulated in ways that support further progress. Thus, even with consolidation of existing methods and the suggestion of next steps for related scholarship (Redman et al., 2021), there is a dearth of innovations to advance assessment practice in the field.

A closer look is needed to understand the barriers that program leaders and instructors face in developing assessment practices. These practices entail not only the methods and tools used to evaluate learning, but the ways that these approaches align with the articulation of learning objectives and the enactment of pedagogies to achieve the outcomes that are the object of assessment processes (Biggs, 1996; Boud, 2000). Progress in this area can help to establish greater consistency and coherence in the design and evaluation of sustainability programs in higher education, which have been

characterized as disparate (O’Byrne et al., 2015). This study explores the status of assessment practices from the perspective of program leaders (including directors, curriculum developers, and other similar stakeholders) and instructors as well as their ambitions for novel approaches that overcome existing limitations. Synthesizing insights on this topic can contribute to forms of action-oriented knowledge for educational innovation that have been suggested as integral to sustainability: shared agency of diverse actors to foster change, intentional design of strategic practices, and capacity for contextual realization of innovations in evolving and emergent settings (Caniglia et al., 2021).

To achieve these insights, this study begins with an analysis of barriers and possibilities for assessment practices that have been identified in the literature. These are situated within a conceptual framework related to how innovations can be facilitated through deliberative processes. The context in which this framework was translated into the study’s research design is then described, resulting in an examination of the perspectives of program leaders and instructors. Findings are reviewed in relation to previous research and future practical opportunities to suggest advances in assessment within sustainability-related teaching and learning in higher education.

## **Background**

The barriers and possibilities that program leaders and instructors encounter in attempting to innovate assessment practices can be framed as *boundaries* that contribute to complexity, confusion, and challenge in design and implementation. In social learning theory, boundaries have been conceptualized as barriers that lead to a “discontinuity in action or interaction” (Akkerman & Bakker, 2011, p. 133) yet “carry learning potential”

(p. 132). The boundaries, or barriers and possibilities, described in the assessment literature focus on conceptual, practical, and logistical considerations. From a *conceptual* standpoint, the field has struggled to develop distinctive approaches for the types of learning outcomes that sustainability education fosters (Shephard, 2009), or elaborate on basic theoretical models to guide tool and criteria design (Barth, 2009). These difficulties have contributed to *practical* limitations, leading to a deficiency of robust, reliable, valid, and constructively-aligned methods (Annelin & Boström, 2023), which has led to calls for increased research on the design and implementation of assessments in the field (Redman et al., 2021). Lack of conceptual and practical progress has been exacerbated by the *logistical* challenges of innovating sustainability education in institutions and educational systems that are often incompatible with these ambitions (Wals, 2014). Though tensions can be navigated in the application of innovative assessment practices, advances of these practices in sustainability education reflect broader challenges in institutionalizing sustainability, which has remained overarchingly isolated and ineffectual (Kohl et al., 2022). The contested and ambiguous nature of sustainability-related teaching and learning in higher education has contributed to inadequate policies, resources, training, coordination, and vision to promote the conceptual and practical breakthroughs required for quality sustainability programs (Veiga Ávila et al., 2020).

The process of improving practice can be articulated as a negotiation of these boundaries to overcome barriers and achieve emergent possibilities (Vuojärvi et al., 2022). These *boundary crossings* entail strategies that mobilize transitions from one form of practice into new, unfamiliar yet progressive practices (Engeström et al., 1995; Suchman, 1993), which could be aligned with the ideals of sustainability education.

Potential boundary crossings from the status quo toward innovations have been advanced across course, program, and institutional levels. At the *course* level, promising approaches have focused on designing assessments for interdisciplinary and professional-oriented learning (Holdsworth et al., 2022), particularly through authentic experiences that engage stakeholders in transdisciplinary settings (Foucrier, 2020). At the *program* level, efforts to establish the links between assessment practices with the learning objectives and pedagogies in sustainability education have proven essential (Sterling et al., 2017), particularly as operationalized through formative approaches that provide opportunities for constructive and interactive reflection (King et al., 2023). Supporting program leaders and instructors to collaborate on program design and evaluation through contextualized communities of practice has been identified as a valuable approach to promoting these efforts (Warr Pedersen, 2017). At the *institutional* level, strategies are needed to provide the enabling conditions for innovations in assessment practices. These include participatory initiatives to reorient institutional cultures and requirements that can support champions to embed innovations in courses and programs (Weiss et al., 2021). Collectively, these potential boundary crossings suggest the need for multifaceted, collaborative, and reflexive strategies to promote innovative practices.

Boundaries and boundary crossings can be navigated through engagement with *boundary objects*, which are artifacts and deliberative processes that function to bridge and translate across forms and sites of practice (Star, 1989). Leveraging boundary objects has been demonstrated as an effective way of institutionalizing and improving practices related to sustainability-related teaching and learning in higher education (Benn et al., 2013; Benn & Edwards, 2010), though there are no examples of broader deliberation

concerning approaches to assessment in the field. A recent study did examine an informative participatory development process to embed sustainability in a business school curriculum, highlighting the efficacy of boundary objects in deliberative processes related to the complex and cross-cutting field of sustainability education in developing “malleable yet recognizable practical forms of knowing” among stakeholders (Edwards et al., 2020, p. 268). This study seeks to build from these promising applications in order to focus on the specific area of innovating assessment practices.

## **Methods**

The boundary-related concepts described above were used to provide a framework for this study to examine how program leaders view barriers and possibilities (boundaries) as they deliberate assessment practices (boundary object) in sustainability programs in higher education in order to envision innovations (boundary crossings). The research design for this study builds from these concepts to respond to the following primary research question:

How do program leaders and instructors of sustainability programs in higher education view and seek to negotiate barriers and possibilities for advancing assessment practices?

The study is situated at the intersection of pragmatic, interpretivist, and participative approaches in sustainability education research, in which social interactions are analyzed to generate practice-oriented insights as part of co-constructive change processes (Sterling et al., 2015). Research efforts advanced through these lenses contribute to technical and logistical knowledge that can be applied in navigating the challenges and opportunities for advancing sustainability education (Lotz-Sisitka et al., 2012). These

stances position this study as an enactment of the investigation of a specific process (deliberation of assessment practices) in order to seed the transformation of the outputs of this process (developing innovations in assessment practices).

Under the assumptions of these epistemological and ontological perspectives, the primary research question was operationalized into two secondary research questions:

1. According to program leaders and instructors, what are the boundaries of assessment practices that restrict quality or innovation?
2. How are potential boundary crossings described to suggest ways to move from the status quo toward innovations in practice?

### ***Data Collection and Analysis***

The sample for the study was composed of program leaders and instructors from the Sustainability Education Community of Practice within the Global Council for Science and the Environment (GCSE SE CoP). The GCSE SE CoP seeks to support and advance efforts in the design and evaluation of sustainability-related programs in higher education. The community includes individuals from nearly 100 higher education institutions from a range of geographical and institutional contexts around the world. Members of the community are engaged through a range of activities, such as monthly meetings for networking and sharing best practices. Due to the range of program leaders and instructors involved with the community, as well as the diverse types of institutions and programs that they represent, the GCSE SE CoP provides a strong audience to engage in this research and provide insights to inform quality assessment practices.

An exploratory action research approach was implemented to orient the process of examining practices to better understand and ultimately improve them (Smith &

Rebolledo, 2018). Data collection entailed two streams of deliberation processes that allowed participants to explore their perspectives on assessment practices and determine potential innovations. This approach is supported by an underlying socio-constructivist orientation, which describes knowledge as being individually and collectively crafted through deliberation in certain contexts where knowing is “a balance between what is familiar and what is novel” (Stauffacher et al., 2006, p. 257).

The first stream was oriented towards individual deliberation, in which data were collected through interviews ( $n=13$ ) and an extensive survey ( $n=14$ ). Participants described perspectives, examples, and ideas related to dimensions of assessment practice (methods, criteria, normative judgments) as outlined by Boud (2000). The second stream was oriented towards collective deliberation, in which data were gathered through a series of three workshops ( $n=48$ ). Participants provided ideas and examples of assessment practices via an interactive online platform. Then, a group discussion was facilitated in which participants elaborated on their perspectives and reflected on implications for potential innovations. In addition to focusing on assessment practices, the workshops also explored pedagogical approaches as well as curricula and content areas. Data from these workshops provided further context for how assessment practices are operationalized in connection to other areas of the constructive alignment of teaching and learning (Biggs, 1996).

The design of two streams of data collection, occurring at individual and collective deliberation levels, was implemented for two reasons. First, from a methodological perspective, the multiple data collection strategies were framed in a convergent design to allow for interplay between data sets, which were then merged in

the analysis process to enable a more targeted and rich review of the integrated data (Fetters et al., 2013). Second, from a practice-oriented perspective, the blend of different opportunities for deliberation positioned the research as an exercise in co-learning and changemaking to support improved practice (Dillon & Wals, 2006). The integration of individual reflection with social learning to advance innovations has a deep history in communities of practice (Lave, 1991), sustainability science (Reed et al., 2010), and sustainability education (Warr Pederson, 2017). Together, these rationales illustrate the value of the multifaceted approach to data collection in this study, which allowed for investigation - and potential facilitation - of practice changes at individual and collective levels.

Reflexive thematic analysis (Braun & Clarke, 2006) was applied to interpret the data and construct a narrative regarding boundaries and boundary crossings in assessment practices. An iterative process was followed to analyze the data, in which insights from the literature, practical experience, and collaborative engagement were drawn from in order to make meaning out of the data (Braun & Clarke, 2019). In the first step of the process, *familiarization with the data*, the data were organized and reviewed to ensure compatibility across sets. Next, in the *generating initial codes* step, memos were left to identify preliminary reflections and patterns. This led to the *generating themes* step, in which an assortment of clusters were developed to highlight recurring trends in the data that reflected the concerns and ideas of participants. Fourth, in the *reviewing potential themes* step, these clusters were sorted into distinct themes that aligned to areas of the conceptual framework guiding this study: boundaries and boundary crossings. Next, in the *defining and naming themes* step, the themes were refined and mapped to a

framework that represents areas for movement from the status quo towards potential innovations in assessment practices. This framework, and the themes entailed within it, are presented in the next section, which represents the final step of *producing the report*.

## **Results**

Analysis of the data led to the development of six key themes for how program leaders and instructors viewed barriers and possibilities for advancing innovations. The themes describe priority areas of consideration in the design and implementation of assessment practices. The six themes are:

1. Defining sustainability education: establishing clarity in the purposes and processes of sustainability-related teaching, learning, and assessment in higher education.
2. Practice characteristics: discerning the features and functions of the design and implementation of approaches to assessment.
3. Interdisciplinary approaches: managing the approaches, and implications, of assessing interdisciplinary teaching and learning for a wide range of topics and students.
4. Transdisciplinary strategies: grappling with the affordances of use-inspired and practice-oriented strategies that seek to understand learning within processes of analyzing and addressing sustainability challenges in collaboration with campus and community stakeholders.
5. Meeting demands: navigating the institutional factors and requirements that shape and constrain how practices are designed and implemented.

6. Facilitating innovations: developing adaptive strategies to negotiate the process of advancing new practices.

The six themes are used to organize the subsequent boundaries and boundary crossings, providing a framework of areas that move from conceptual through practical to logistical considerations (Table 2). For each theme, the identified boundary is described first. Then, practices representative of the status quo and potential innovations are described as the activities on either side of the boundary. The boundary crossings for each theme are then detailed to provide a comprehensive picture of how program leaders and instructors viewed possible advances for assessment practices.

**Table 2**

*Overview of Boundaries, Boundary Crossings, and Innovations in Assessment Practices*

Area	Theme	Boundary	Status Quo	Potential Innovation	Boundary Crossing
Conceptual	Defining sustainability education	Definition	Content-driven	Purpose-driven	Transformative plurality
	Practice characteristics	Design	Instructor-centered	Student-centered	Performative and reflective
Practical	Interdisciplinary approaches	Relevance	Multi-disciplinary	Inter-disciplinary	Adaptive progression
	Transdisciplinary strategies	Delivery	Problem-oriented	Solution-oriented	Project-based learning
Logistical	Meeting demands	Compliance	Navigating limitations	Navigating opportunities	Program improvement
	Facilitating innovations	Support	Negotiating resistance	Negotiating experimentation	Collaborative design

***Defining Sustainability Education***

The boundary for this theme is complexity in *definition*. As program leaders and instructors look to advance assessment practices, they encounter difficulties in outlining the objectives and parameters of the field. Participants described the field as “a huge beast” that lacks “coherence” because it can relate to “everything and nothing”. For example, one participant felt that the field has “too many learning outcomes” that are “too complex to assess”. This complexity posed challenges to participants seeking to develop the “ultimate assessment” as a way of generating evidence of learning and effective teaching.

The inside, status-quo of this boundary focuses on practices being *content-driven*. In this approach, the purposes and processes of sustainability education are defined by their engagement with a range of content areas that can be linked to sustainability, and subsequently how to assess students’ cognitive understanding of these areas. Examples described by participants included knowledge of different sustainability frameworks such as the Sustainable Development Goals or social and planetary boundaries (Raworth, 2012), or topical areas like the climate-energy-water-food nexus. The outside, potential innovation of the boundary is a *purpose-driven* orientation. In this approach, practices are defined by their stimulation of multiple learning domains to activate not only students’ cognitive knowledge but their abilities and willingness to contribute to sustainability transitions through continuous social learning. Participants suggested framings such as knowing-acting-being (Caniglia et al., 2018), multiple intelligences (Gardner, 2011), and the key competencies in sustainability (Brundiens et al., 2021) as ways to frame learning and assessment under this approach.

Participants described *transformative plurality* as a potential boundary crossing for this theme. This was explained as entailing reflexive and adaptive practices that are more distinctive to sustainability education as a way of allowing for diversity and transcending the constraints of traditional practices. It was suggested that for sustainability education to be “its own thing”, leveraging its multifaceted nature can serve to “help us move education in a new way”. For assessment practices this was described as applying multimodal strategies that “allow students diverse ways to express understanding”. Such approaches were advanced as ways for embodying the principle of “assess narrowly and you get a narrow view of what has been learned; assess broadly and you get a full view of what has been learned”.

### ***Practice Characteristics***

The boundary for this theme is complexity in *design*. As program leaders and instructors look to advance assessment practices, translating their approaches into methods and tools that align with learning objectives and pedagogies can prove challenging. This can lead to a disconnect between how assessment practices are conceptualized and how they are implemented, creating “a need for more intentionality and understanding of the pros and cons of assessment techniques”.

The inside, status quo of this boundary focuses on *instructor-centered* practices. Participants described themselves as often relying on “feasible” methods, such as multiple-choice tests or reading response essays, due to constraints on their ability to engage in more intensive practices. However, there was a strong desire to be able to implement more authentic and engaging assessments. The outside, potential innovation of the boundary is *student-centered* practices. For example, participants highlighted

“assessments that mimic authentic work activities, such as developing an action plan or writing to city council” as ways of “empowering students to make their own inquiries, express understanding on their own terms, and embrace learning as exploration”.

Participants described *performative and reflective* practices as a potential boundary crossing for this theme. These strategies emphasize formative, action-oriented experiences that can iteratively improve learning and its application. This included calls for assessments designed for “evaluating impact” by examining “individual actions” and using “participatory methods” such as portfolios, peer feedback, and engagement with external stakeholders. Other alternatives highlighted flexibility in assessment practices to “provide choice so students may connect with content” as a way of “increasing their interest and engagement”, possibilities for students to “build assessment criteria on their own and collaboratively”, and shifting towards “un-grading” through approaches such as contract-based grading.

### ***Interdisciplinary Approaches***

The boundary for this theme is complexity in *relevance*. As program leaders and instructors look to advance assessment practices, crafting experiences that cut across disciplines and are applicable for students from different backgrounds is often a demanding task. Participants described being overwhelmed in determining what content to engage with in such a “vast subject area” that is “so evolving” and what type of learning outcomes to assess as they enter into “new domains and new areas”. This leads to tensions between depth versus breadth in learning and assessment, as well as challenges for instructors in engaging with such a range of topics.

The inside, status quo of this boundary focuses on *multi-disciplinary* approaches. This entails drawing from or making connections to a variety of disciplines, yet rarely functionally integrating them. Assessment practices under this approach emphasize the evaluation of how well students can understand how “the competencies of their field of study can be applied to sustainability challenges and to recognize that sustainability can be an approach, lens, or worldview that is relevant to whatever their chosen field of study or future fields of work”. While this approach can prove valuable in spreading sustainability “across the curriculum”, participants lamented its limitations. Instead, the outside, potential innovation of this boundary focuses on true *inter-disciplinary* approaches. Participants valued the synthesis and cross-pollination of disciplines, advocating to “lead with a competency-based approach that illustrates its functions in various content areas”. This approach was suggested to help in emphasizing the “inclusion of diverse worldviews” in order to make learning and assessment practices “immediately relevant to students”.

Participants described *adaptive progression* as a potential boundary crossing for this theme. This was articulated as a strategy for programs to create intentional yet flexible pathways for students to engage with sustainability at the intersection of different disciplines. Under this approach, learning opportunities would be guided by “recurring themes throughout the curriculum” as well as “frameworks and scaffolding to allow for management of the huge range of topics and content in sustainability”. Assessment would target different types and levels of learning outcomes at different points as students navigated a “structured and progressive pathway towards the ability to design and facilitate collective sustainability problem solving processes”. However, participants

stressed that these types of interdisciplinary curricula need to be “done in a coordinated way by faculty from different courses” so that students don’t feel like it “is an unnecessary distraction from the disciplinary knowledge pursuit”.

### ***Transdisciplinary Strategies***

The boundary for this theme is complexity in *delivery*. As program leaders and instructors look to advance assessment practices, extending toward transdisciplinary activities that engage students in the community with stakeholders has raised challenges. The coordination of applied learning experiences was highlighted as a central obstacle, since “it is a big challenge if you have a big initiative to compartmentalize it into four or five different aspects” and adequately facilitate and assess student learning in these different areas. Participants also described how “collaborative projects with community partners can be stressful for students” because “there’s high anxiety, there’s high risk that they might feel like they’re going to fail and fail publicly”. These issues were exacerbated by incompatibility between transdisciplinary learning and time constraints, program requirements, and academic norms, suggesting that the “system has to update to accommodate the pedagogies” and assessment practices associated with these approaches.

The inside, status quo of this boundary focuses on *problem-oriented* strategies. This type of transdisciplinary learning centers on students’ abilities to analyze contextualized sustainability issues in collaboration with peers and stakeholders. For example, students would be assessed on how they are “able to systematically explore issues, objects or works through the collection and analysis of evidence that results in informed conclusions or judgments, and break down complex topics or issues into parts

to gain a better understanding of them”. The outside, potential innovation of this boundary focuses on *solution-oriented* strategies. While problem analysis was viewed as an essential learning objective, participants stressed the need to assess how “students make changes in their lives and the communities they live in” through “interaction with local communities addressing specific challenges”.

Participants described *project-based learning* as a potential boundary crossing for this theme. They highlighted how it offers opportunities for authentic “assessment by doing” as students work “to operationalize sustainability by developing and implementing a plan within an ongoing cycle of continuous learning and improvement”. This type of approach also opens up other possibilities for assessment such as “student-specific targets throughout the project” or “qualitative and quantitative assessment...combined with a formative and summative assessment and a student self-assessment”.

### ***Meeting Demands***

The boundary for this theme is complexity in *compliance*. As program leaders and instructors look to advance assessment practices, negotiating requirements that create restrictions or resistance in implementing innovative practices is a key challenge. This can lead to a prevailing attitude of doing what is “good enough” instead of working toward “deep, broad, or robust” approaches. Many participants described their history with institutional or external reviews as “a bad experience in checking the box” that was shaped more by political, financial, and logistical demands than aspirations to support student learning and innovative practice.

The inside, status quo of this boundary focuses on *navigating limitations*. This entails seeking to implement course- and program-level assessment approaches while addressing “very daunting” issues related to logistics and the lack of clear standards and metrics to guide practice. The outside, potential innovation of this boundary focuses on *navigating opportunities*. Participants described their ambitions to garner institutional recognition to support their efforts to develop “more rigorous and valid assessments”. Yet, they also highlighted the value in working around bureaucratic structures to creatively design their practices and grow possibilities through initiatives such as certificate programs and high-enrollment, technology-infused courses. While they recognized the barriers and commitment entailed in this work, participants found efforts to extend the reach and impact of their programs as ultimately worthwhile as “it comes down to where I’m putting my time and the value I get out of it”.

Participants described focusing on *program improvement* as a potential boundary crossing for this theme. As a way to balance innovations with demands, participants encouraged efforts “to get out in front of it” by taking “time to develop program level assessments rather than individual course objectives only”. These efforts were viewed as ways to advance “a nuanced kind of assessment that can be used for actionable curriculum changes”.

### ***Facilitating Innovations***

The boundary for this theme is complexity in *support*. As program leaders and instructors look to advance assessment practices, their focus often “drifts into systematic components and administrative bureaucracies” as the realities that shape their work. Participants described a lack of support and priorities related to teaching and assessment

in “faculty training and reward systems”. This can act as a barrier to experimenting with novel practices, particularly without strong incentives beyond the prospect of benefits for students, or as one participant lamented, “we have carrots, but we still don’t have sticks”.

The inside, status quo of this boundary focuses on *negotiating resistance*. Because innovations represent a departure from familiar practices, often involving more time and effort to initially implement, it can be difficult to encourage program leaders, instructors, and students to “let go of how it’s always been done and be willing and able to take a risk or try something new”. The outside, potential innovation of this boundary focuses on *negotiating experimentation*. Participants described that supportive institutional cultures and having “reasonably well-developed tools” were crucial to enabling engagement with innovative practices. Related to assessment, this entailed “reframing grading/ungrading, self-assessment, group and project-based learning with outcomes that are not just about passing or getting an A”.

Participants described *collaborative design* as a potential boundary crossing for this theme. These processes entailed program leaders and instructors working together to leverage collective strengths in promoting shared learning and enhancing assessment practices. Examples included communities of practice, team teaching, and guest lectures, as well as program evaluation processes that engaged faculty from across disciplines as well as external stakeholders. These approaches were identified as not only benefitting program leaders and instructors, but supporting students as well through approaches such as “faculty modeling interdisciplinary conversation through team teaching”. Yet considering such ways to facilitate innovations left participants focused on the “rabbit hole” of “what structural and administrative actions would support or encourage these

assessment practices”. While participants were hopeful that institutions and educational systems could become more supportive of innovations, particularly as emergent practices demonstrate promise, they recognized the persistent complexity and challenges ahead. As one participant stated, “it’s a paradigm shift, and things get messy in a paradigm shift”.

## **Discussion**

The results demonstrated a variety of boundaries aligned with the conceptual, practical, and logistical barriers found in the literature. The primary conceptual challenges centered around defining the parameters of the field of sustainability education and its characteristics in teaching, learning, and assessment. This difficulty in determining the details of what to assess stood out as a root issue preventing innovations, particularly as articulating learning objectives represents a foundational step in assessing sustainability-related teaching and learning (Redman et al., 2021). Competencies-based and student-centered approaches were proposed as potentially generative ways to more clearly define the distinctive learning outcomes to be assessed, while making them relevant for a range of subsections of students.

The practical challenges described emphasized difficulties related to inter- and trans-disciplinary learning, particularly how to assess learning in these approaches. A variety of approaches based on applied and formative principles were advanced, building on past calls for these types of assessment methods (Shephard, 2009). Yet understanding how to design and facilitate inter- and trans-disciplinary learning that goes beyond superficial engagement through strategies such as project-based learning (Stauffer et

al., 2006), remained an obstacle for program leaders and instructors to grapple with moving forward.

The results also confirmed the ongoing logistical challenges presented by the standard assumptions and practices within higher education that often restrict innovation (Wals, 2014). These challenges are exacerbated by the intersection of difficulties in better articulating the what and how of assessment practices, with program leaders and instructors juxtaposing their aspirations for innovations with the realities of limitations imposed by insufficient resources and resistance from administrators or lack of training to promote stronger understanding of the field of sustainability education and its applications within higher education (Veiga Ávila et al., 2020).

Despite the boundaries detailed by program leaders and instructors that disrupt moves from the status quo toward innovations, their learning potential was also leveraged as several boundary crossings were identified. These boundary crossings can be sorted into course, program, and institutional levels to provide tangible strategies for advancing assessment practices. At the course level, program leaders and instructors highlighted project-based learning as a feasible approach to facilitating authentic learning that opens up possibilities for assessment innovations. While previous research has demonstrated the value of project-based learning in sustainability programs (Birdman et al., 2022), this study expands on this by noting the importance of the performative and reflective aspects of how these experiences are assessed in formative and summative ways.

At the program level, program leaders and instructors stressed the importance of intentional planning and the embrace of multiple understandings of learning through concepts such as adaptive progression and transformative plurality. These approaches

were described as ways to ensure the constructive alignment of assessment practices with pedagogies and learning objectives (Sterling et al., 2017). They were also highlighted as ways to be responsive to students' by providing a scaffolded, interdisciplinary learning journey towards professional competence (Holdsworth et al., 2022) across stages in the program.

At the institutional level, program leaders and instructors focused on ways to address the frequent barriers that limit possibilities for innovation. One strategy was to leverage institutional reviews and requirements as opportunities for continuous program improvement by taking a proactive approach. Another strategy advocated for collaboration among program leaders and instructors as a way to extend innovation beyond isolated cases by embedding it in programs through systematic approaches and shared learning. These strategies reflect the bottom-up, participatory efforts that are often key drivers of innovation in and institutionalization of sustainability-related teaching and learning (Warr Pedersen, 2017; Weiss et al., 2021). Yet boundary crossings are not linear, as program leaders and instructors described the backslide that can occur in implementing innovations when resistance or requirements related to other priorities increases. While this was described as discouraging, transformative and transgressive strategies were emphasized as ways to situate sustainability programs as innovation spaces to respond to the urgency of sustainability challenges while stimulating change in higher education.

The implications of this study's results should be viewed against the influence of several limitations. First, the data were collected over a condensed time frame, which, particularly with the evolving nature of sustainability education and assessment practices, remains bound to the current status of higher education in a post-pandemic landscape.

Second, the results of the qualitative inquiry were not supplemented by a quantitative analysis or re-engagement of the participants to validate the findings from the workshops, interviews, and survey. Third, though the GCSE SE CoP represents a range of program leaders and instructors from different institutional contexts, this sample is not necessarily representative of the expanse of perspectives on assessment practices in sustainability-related teaching and learning in higher education. Taking a critical perspective, the self-selection of participants to engage in the GCSE SE CoP could lead to groupthink around barriers and possibilities in practice, with this potential convergence of perspectives even being a factor in limiting innovations. While these considerations bind the results of this study to a specific time, methodological approach, and audience, the insights generated suggest the ongoing value of participatory deliberation for exploring innovations in practice, thus providing a foundation for future research.

## **Conclusion**

Advancing assessment practices represents an underexplored yet integral dimension of further progress for the field of sustainability-related teaching and learning in higher education. Effective formative and summative approaches are needed to promote learning and validly evaluate its impact in enabling students to contribute to sustainability initiatives in professional and personal settings. This study has described how program leaders and instructors view the barriers and possibilities for existing approaches to assessment, as well as how shifts might be supported to move from the status quo toward innovations in practice. Building on the action-oriented knowledge required to promote sustainability (Caniglia et al., 2021), the boundaries and boundary crossings articulated in this study carry several implications. First, they serve as a basis

for the intentional design of assessment methods and criteria in sustainability programs in higher education. Second, they promote contextual realization of the aspirations demonstrated by program leaders and instructors. And third, they suggest the importance of cultivating shared agency among the stakeholders of sustainability programs in higher education across contexts to advance the field through conceptual, practical, and logistical breakthroughs at course, program, and institutional levels.

Future research should build on this study by examining the efficacy of the articulated boundary crossings and innovations in different institutional and programmatic contexts, as well as the conditions that enable their design and implementation. This could include comparative case studies or quantitative analysis of the perspectives of program leaders and instructors on these practices as they are being applied. Another strand of work should continue efforts to understand how boundary objects can be leveraged to promote advances in sustainability-related teaching and learning in higher education. This study demonstrated the potential of bringing together stakeholders to deliberate practical innovations for the dual purpose of translating these to different settings and advancing the broader field. Akkerman & Bakker (2011) have outlined the learning mechanisms that occur in this type of collaborative engagement with boundary objects as processes of identification (understanding the diverse practices of others), reflection (expanding perspectives on one's own practices), coordination (creating collaboration and exchange to improve practice), and ultimately transformation (co-development of innovations in practice). Future research should investigate how these learning mechanisms are operationalized in exchange among program leaders and instructors from diverse contexts. In order to better position sustainability programs in

higher education as drivers of societal change, this type of work is needed to enhance and assess the quality and impact of sustainability-related teaching and learning while advancing beyond existing barriers toward new possibilities for practice.

## CHAPTER 4

### ASSESSMENT-ORIENTED SUSTAINABILITY

#### **Introduction**

In the pursuit of generating solutions to sustainability problems, exploration and experimentation are crucial to increasing the efficacy of efforts to foster sustainability transformations (Caniglia et al., 2017). Success in this area requires learning among communities and individuals (Forrest & Wiek, 2014), as well as effective methods for measuring progress of how this learning is translated into strategies to foster transformations toward sustainability (Williams & Robinson, 2019). Transdisciplinary strategies, involving scholarly and societal partners collaborating to address community-based challenges, have been identified as an essential method for promoting sustainability (Moallemi et al., 2020). Despite this identification and the substantial conceptual attention and applied illustrations that it has led to (Jahn et al., 2022), the impact of transdisciplinary strategies on the sustainability of communities (and beyond) has remained ambiguous, including how they are improved, transferred, and scaled across contexts through broader learning processes (Scholz & Steiner, 2015a; 2015b).

One potential reason for the mixed effectiveness of transdisciplinary sustainability strategies, as well as the related neglect of learning strategies and opportunities, is an underdevelopment of the ways in which these initiatives are evaluated. Despite previous attempts to establish foundational evaluation frameworks of transdisciplinary sustainability strategies (Luederitz et al., 2017; Wiek et al., 2014), as well as more recent efforts to propose guides for evaluating the performance and impact of transdisciplinary partnerships (Plummer et al., 2022), gaps persist in the efficacy of evaluations of

transdisciplinary strategies and how they promote learning. These gaps have been informed by a lack of conceptual and practical sophistication and nuance in how evaluation is practiced and how it becomes learning-focused. Even though learning has been articulated as a central goal of sustainability processes (Wiek & Kay, 2015), its connection to and role in transdisciplinary strategies and their evaluation has remained vague (Barth et al., 2023). Evaluation approaches have rarely drawn from the robust literature and practice of educational (considered here as the discourse on formal and non-formal strategies for cultivating and appraising individual and collective learning) methods and theories, despite potential synergies between the fields (Barth & Michelsen, 2013). This paper seeks to address this gap by stimulating cross-pollination among the fields of transdisciplinary sustainability and education in order to generate advances in how the evaluation of transdisciplinary sustainability strategies is conceptualized, practiced, and linked to learning.

### **Transdisciplinary Sustainability Strategies, Assessment, and Learning**

This paper takes as a focus the efficacy of transdisciplinary strategies in promoting sustainability transformations. In this case, sustainability can be understood as the endeavor of advancing personal, community, and planetary well-being by satisfying the social, economic, and environmental needs of the present and the future in just and equitable ways (Raworth, 2012). While transdisciplinary strategies can take many forms across a variety of settings (Bergmann et al., 2021), this paper focuses on those initiatives that entail collaborations between academic and societal partners in aiming to generate action-oriented knowledge through scholarly research and practical innovation to inform community-driven solutions to complex sustainability problems (Brandt et al., 2013). In

targeting both scientific and societal insight and impact, these processes have been described as involving three interrelated and iterative phases: (1) problem framing and team building, (2) co-creation of solution-oriented transferable knowledge, and (3) (re-)integration and application of created knowledge (Lang et al., 2012). Because of the complex and collaborative features of transdisciplinary sustainability strategies, evaluations of them can target a variety of areas or criteria (Belcher et al., 2016; Wickson & Carew, 2014). While not aiming to be comprehensive of all of these areas, this paper focuses on how the inputs, processes, and outputs of transdisciplinary sustainability strategies are appraised (Luederitz et al., 2017; Wiek et al., 2014). To specify these areas and link them to the phases of transdisciplinary sustainability strategies, this paper seeks to understand ways to enhance the evaluation of problem analysis (inputs), solution generation (processes), and learning cultivation (outputs).

In order to enhance evaluation in these areas, particularly through engagement with the educational discourse, this paper proposes that a shift in terminology is necessary for opening new conceptual and practical possibilities. This shift involves a turn from *evaluation* toward *assessment*. Though evaluation has been the prominent term in relation to transdisciplinary sustainability strategies, its link to learning has often been tenuous, though certain exceptions, such as developmental evaluation (Patton, 1994), exist in the broader literature. This study posits that *assessment* proves a more generative concept in focusing on learning while taking into account the interactive and iterative nature of how transdisciplinary sustainability strategies involve problem analysis and solution generation (Norström, et al., 2020). Under the perspective of this study, whereas evaluation can be understood as conveying an objective final judgment from a singular

decision-maker or set of standards (Shaw et al., 2006), assessment (particularly in the educational context) alludes to an ongoing and dialogic process among actors that is tailored to a specific context and set of objectives (Broadfoot & Black, 2004). While there are overlaps and ambiguities among the two concepts, which both aim to systematically collect, document, and leverage evidence of progress towards goals (Hattie & Brown, 2010), an engagement with the distinguishing features of assessment can contribute to a stronger emphasis on learning as an integral aspect and outcome of transdisciplinary sustainability strategies. This focus also differentiates it from the discourse on sustainability assessment (Gibson, 2006a; 2006b), which primarily focuses on measurement of sustainability dimensions in a specific area.

In the educational context, assessment as a concept and practice has been demonstrated to enact several roles that suggest its relevance in relation to sustainability (Boud, 2000; Boud & Falchikov, 2007; Boud & Soler, 2016). Beyond a connection to fostering learning, the roles of assessment can be synthesized as evaluative, adaptive, normative, and deliberative. *Evaluative* roles involve identifying standards and implementing them in the process of making judgments about quality. *Adaptive* roles involve leveraging insights on current progress toward adaptations to achieve future progress. *Normative* roles involve communicating the objectives and criteria that are valued among a set of stakeholders. *Deliberative* roles involve promoting engagement, discussion, and informed decision-making among stakeholders and partners. Together, these roles illustrate the potential contributions of focusing on assessment and drawing from the educational discourse as a way of amplifying learning in, and the efficacy of, transdisciplinary sustainability strategies.

While learning can take a variety of forms and functions within the context of transdisciplinary sustainability (van Mierlo et al., 2020), in this study the purpose and process of learning refers to an interactive, reflexive, and critical activity among diverse configurations of individuals that promotes action-oriented knowledge toward sustainability transformations. Within this understanding, learning demonstrates transversal (involving individuals, groups, and collectives), profound (engaging values and moral standards), and counter-hegemonic (exposing and questioning cultural habits and assumptions) features (Wals & Rodela, 2014). Operationalizing these features can contribute to action-oriented knowledge that enables learning to move beyond the development of new insights or capacities at individual or collective levels toward more systemic transformation through its translation into impact for addressing sustainability challenges (Caniglia et al., 2021). This need to generate action-oriented knowledge, as well as appraise its contribution to tangible action and impact, highlights the priority link between assessment and learning as well as the need to further explore synergies between these activities.

The intersection of assessment, learning, and sustainability has most explicitly been articulated by educational scholar David Boud. The notion of “sustainable assessment”, or (drawing from the Brundtland definition of sustainable development) “assessment that meets the needs of the present without compromising the ability of students to meet their own future learning needs” (Boud, 2000, p. 151) suggests the importance of acknowledging inputs, processes, and outputs in assessments and how they can be translated into the context of transdisciplinary sustainability strategies. Boud’s concept was framed within the role of assessment and education in a learning society, but

can be applied beyond how students meet their learning needs to how configurations of individuals in transdisciplinary sustainability strategies leverage assessment to enhance their efficacy and amplify learning. To attain this objective, assessment can serve as a crucial mechanism in promoting learning for action-oriented knowledge and impact toward sustainable futures.

However, work is needed to operationalize the roles that assessment can play in transdisciplinary sustainability strategies and how they facilitate learning towards sustainability transformations. To address this gap, this study aims to articulate a framework to guide the development of approaches to assessing problem analysis (inputs), solution generation (processes), and learning cultivation (outputs) within transdisciplinary sustainability strategies. The framework is informed by an engagement with educational research, theory, and practice to advance key assessment concepts and link them with sustainability characteristics. This conceptual development process responds to the following research question:

How can concepts and practices from the educational discourse inform approaches to the learning-focused assessment of transdisciplinary sustainability strategies?

To explore this area, the next section considers different orientations to transdisciplinary sustainability and how assessment has been situated in relation to these different aims and approaches. With this background, an elaboration on the specific gaps related to the learning-focused assessment of transdisciplinary sustainability strategies is provided. These concepts are organized into a framework to guide the development of assessment approaches that can contribute to learning while determining the efficacy of

progress towards sustainability transformations. Insights and implications of this work, along with future directions for research and application related to the proposed framework, are offered in the final section.

### **Transdisciplinary Sustainability Orientations**

Since its emergence as an area of scholarly discourse around the early 2000s, the field of transdisciplinary sustainability has been defined by a variety of features and functions. In their seminal work, Kates et al. (2001) described the fundamental aims and approaches of transdisciplinary sustainability, which can be synthesized into three orientations:

- Problem-oriented: focused on understanding the fundamental interactions between nature and society;
- Solution-oriented: focused on guiding interactions along sustainable trajectories; and
- Learning-oriented: focused on promoting social change in order to navigate the transition to sustainability.

These three orientations have shaped the strands of subsequent research and practice in the field (Bergmann et al., 2021). The orientations represent distinctive aims and approaches in the field, even if they are overlapping and at times ambiguous in practice. Cumulatively, the three orientations offer a descriptive heuristic for how transdisciplinary sustainability strategies develop action-oriented knowledge about a specific problem to craft a contextualized solution while facilitating collective learning processes (Miller, 2013). While problem and solution orientations have been prominently explored in the literature, attention on inquiry and practice related to the learning orientation, particularly

beyond the scope of formal settings such as higher education, has been limited. Thus, examining the features and functions of each orientation can provide a foundation for elevating the role of learning in transdisciplinary sustainability strategies through its intersection with assessment practices.

*Problem-oriented* sustainability focuses on understanding the issues that contribute to unsustainability and posits that knowledge on these issues can lead to effective action (Kates, 2011). Problems range across multiple domains and sectors as well as different spatial and temporal scales (Robinson, 2003). A recent synthesis effort highlighted the core problems that sustainability research and practice seek to address as focused on: measuring sustainable development, promoting equity, adapting to shocks and surprises, transforming systems into more sustainable development pathways, linking knowledge to action, and devising government arrangements that allow for people to work together in addressing the other problem areas (Clark & Harley, 2020). These multidimensional problems “cut across disciplinary boundaries and defy both problem definition and easy solutions; they challenge not just the analytical tools and approaches of scientists but the usefulness of scientific knowledge” (Miller, 2013, p. 290). Due to these characteristics, problems in sustainability can be characterized as wicked (Lönngren & van Poeck, 2021) as they display features of volatility, uncertainty, complexity, and ambiguity (Zu, 2023) and are influenced by the normative aspects inherent in specific settings and stakeholder configurations (Kueffer et al., 2012).

*Solution-oriented* sustainability focuses on determining knowledge, actions, processes, and pathways that contribute to resolving complex problems (Sarewitz et al., 2012). This entails the advancement of visions, strategies, tactics, and interventions that

support progression toward greater sustainability for individuals, groups, institutions, and systems (Miller et al., 2014). The discourse on solutions-oriented sustainability has examined the efficacy of transdisciplinary strategies before, during, and after these implementation processes through embedded as well as more distant approaches (Lang & Wiek, 2022). Typical objectives include enhancing the resilience, adaptability, and transformability of a system (Folke et al., 2010) or developing capacity to implement more sustainable practices and policies (Eakin et al., 2014). In order to be relevant and operationalizable within specific contexts, solutions must be salient, credible, and legitimate to the concerned stakeholders (Cash et al., 2003). This often requires navigating the trade-offs entailed in transdisciplinary processes (de Magalhães et al., 2018; Ruppert-Winkel et al., 2015) in order to find ways to promote innovation and transformation (Leach et al., 2012).

*Learning-oriented* sustainability focuses on the iterative and interactive process of promoting sustainability transformations and how this process emerges and evolves over time in response to the problems and solutions being engaged with in a specific context (König, 2017). In learning-focused processes, sustainability is enhanced through participation, integration, and normative negotiation (Barth, 2014; van Kerkhoff & Lebel, 2006). Learning is leveraged as a way to overcome the challenges that come in mobilizing action for sustainability (Feeney et al., 2023) and a mechanism for translating knowledge into societal change through transdisciplinary strategies (Westberg & Polk, 2016). While learning on the individual or personal level plays a significant factor in the pursuit of sustainability (Frank et al., 2024), collective, or social, learning among groups or within institutions has consistently been an emphasis of sustainability research (Miller

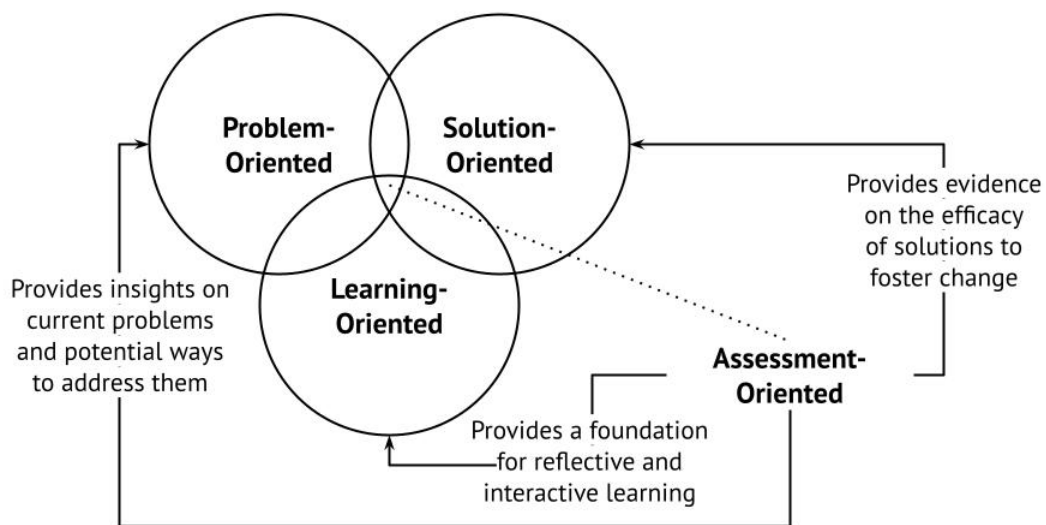
et al., 2014; Reed et al., 2010). Collective learning often takes the form of the co-production of action-oriented knowledge among different stakeholders, in which processes are interactive (engaging a variety of actors in iterative ways), context-based (situated in a particular setting and set of actors), pluralistic (recognizing multiple ways of knowing and doing), and goal-oriented (addressing defined, shared, and meaningful objectives) (Norström et al., 2020). Despite the early and persistent emphasis on the centrality of learning to transdisciplinary sustainability (Kates et al., 2005), the wide-ranging work on this orientation has remained under conceptualized (Sinclair et al., 2008), particularly in relation to broader theories of learning (van Mierlo & Beers, 2020). Stronger operationalization of learning-oriented sustainability will require the transformation of approaches to knowledge generation and its translation into action, particularly in transdisciplinary strategies (Fazey et al., 2020; Peters & Wals, 2013).

The three orientations provide a comprehensive overview of the foci of transdisciplinary sustainability, detailing the approaches through which the field has aimed to cultivate action-oriented knowledge and mobilize practices to engender transformation (West et al., 2019). However, an enduring gap in the transdisciplinary sustainability discourse has been the assessment of problems and solutions and how these are leveraged toward learning. Across the three orientations, the pivotal roles of assessment have been obscured or underdeveloped. To address this issue, this study proposes the notion of *assessment-oriented sustainability* (AOS). In the context of transdisciplinary sustainability strategies, AOS advances a focus on evaluating how solutions address specific problems to enhance learning toward sustainability in the present and future. AOS contributes to transdisciplinary sustainability by integrating and

supporting the ways that the three orientations build on each other (Figure 4). Specifically, AOS provides insights on current problems to inform potential ways to address them, evidence on the efficacy of solutions to foster change, and a foundation for reflective and interactive learning. By enhancing the efficacy and interconnectedness of each of the sustainability orientations, AOS amplifies the prospects of learning throughout the phases of transdisciplinary strategies.

**Figure 4**

*Orientations to Transdisciplinary Sustainability Aims and Approaches*



**Assessment of Transdisciplinary Strategies for Sustainability**

Scholarship on the assessment of transdisciplinary sustainability strategies has been characterized by disparate progress and an insular approach to potential engagement with broader concepts and practices that could inform work in the field. Achievements in the literature within this area include the proposal of a collection of conceptual models (Klein, 2008; Luederitz et al., 2017) and methodological schemes (Sala et al., 2015; Wiek

et al., 2014), as well as the establishment of potential criteria and analytical frameworks (Jahn & Keil, 2015; Tejada et al., 2019) that have led to a range of illustrative examples covering different topics and settings (e.g., Wiek & Larson, 2012; Wiek et al., 2012). Recent work by Plummer et al. (2022) developed a guide for the evaluation of transdisciplinary partnerships, highlighting the need to assess both performance and impact. However, they also lamented the ongoing limitations and gaps in the field related to what is assessed, who is involved, and how assessments are designed and implemented. These shortcomings reflect earlier observations on the conceptual and practical challenges that lead to ad hoc approaches (Gibson, 2006a). The lack of maturation in assessment approaches has contributed to difficulties in facilitating and analyzing collective learning through transdisciplinary sustainability strategies (Mascarenhas et al., 2021; Sala et al., 2013). In relation to the evaluative efficacy of assessment approaches, as well as their contribution to learning, three key gaps can be derived related to: (1) design purposes, (2) implementation processes, and (3) contextualization principles.

The first gap related to the assessment of transdisciplinary sustainability strategies concerns the *design* of assessments, or how the methods, tools, and criteria of assessment approaches are crafted. Limited progress has been made in crafting models to capture the “tailored, flexible and evolving” aspects of transdisciplinarity (Carew & Wickson, 2010, p. 66). This has been exacerbated by difficulties in clearly defining the *purposes* (intended objectives and distinguishing features) of assessments. With assessment foci targeting research quality (Belcher et al., 2016), project impact (Hansson & Polk, 2018), and knowledge development (Brennan & Rondón-Sulbarán, 2019), the intended purposes

have been multifaceted. While these foci aim to support decision-making (Gibson, 2006a; Singh et al., 2012) and ultimately aid progress towards meeting sustainability goals (Huan et al., 2020), they often obscure contributions of assessments to collective learning (Forrest & Wiek, 2014). This is especially reflected in the common privilege of academic insights, or their undermining in authentic collaboration with stakeholders, which further limits collective learning in connection to scientific and societal aspirations (Newig et al., 2019). More intentional and rigorous design is needed to fulfill the potential array of roles that assessments can serve, particularly in relation to collective learning and the mobilization of action-oriented knowledge.

The second gap concerns the *implementation* of assessments, or how they are applied to measure progress and facilitate increased effectiveness. Because achieving sustainability is a multifaceted and dynamic endeavor, advancing relevant tools, initiatives, and approaches to facilitate effective implementation has proven challenging (Bautista-Puig et al., 2022). Assessing sustainability outcomes of transdisciplinary strategies requires integrating social, economic, and environmental considerations (Gibson 2006b) while facilitating participatory and collaborative activities (Blackstock et al., 2007). This can create challenges in balancing the different aspects of assessment *processes* (strategic sequences of collecting, analyzing, and applying relevant information). Approaches to comprehensive yet flexible processes have been proposed that sequentially examine strategy inputs, processes, outcomes, and outputs (Luederitz et al., 2017), or map assessment checkpoints to the phases of transdisciplinary strategies (Plummer et al., 2022). However, these approaches, though noting the iterative nature of assessing transdisciplinary sustainability strategies, do not fully conceptualize the

implementation procedures of assessment processes or how they might contribute to learning.

The third gap concerns the *contextualization* of assessments, or how they respond to the needs and characteristics of specific actors and settings. In the design and implementation of assessments, this is a matter of demonstrating relevance, credibility, and legitimacy in the way that they are presented and performed (Hansson & Polk, 2018). Particularly as transdisciplinary sustainability strategies are place-based, participant-driven, and use-inspired (Bergmann et al., 2021; Brundiers et al., 2021), assessments must reflect the plurality of goals, outcomes, and methods entailed in these processes (Holzer et al., 2018; Klein, 2008). Challenges for contextualization have been spurred by a lack of *principles* (conceptual and normative guiding standards) to guide assessment approaches across different settings so that insights are comparable, transferable, and rigorous (Gibson, 2016). Luederitz et al. (2017) proposed that foundational approaches should aim at being generic (applicable to different types of strategies), comprehensive (examining inputs, processes, and outputs), operational (able to readily applied), and formative (supportive of strategies becoming more effective and efficient), but these principles do not adequately address the contextualization aspects of assessments or how they can be linked to learning for specific stakeholders.

Together, these gaps point to areas in which the practical and conceptual discourse on the assessment of transdisciplinary sustainability strategies can be advanced. Through deeper engagement with educational purposes, processes, and principles, the design, implementation, and contextualization of assessments may be enhanced to ensure

their efficacy in contributing to problem analysis, solution generation, and learning cultivation.

### **Features and Functions of an Assessment Framework**

To build toward a framework for the design, implementation, and contextualization of assessments of problem analysis, solution generation, and learning cultivation in transdisciplinary sustainability strategies, a scoping literature review was conducted. The review focused on identifying features and functions in educational concepts and practices to inform the purposes, processes, and principles of assessments in the context of transdisciplinary sustainability. Applying a scoping literature review offers a targeted way to survey the literature in complex and diverse areas in order to provide a rapid summary of evidence and key concepts (Arksey & O'Malley, 2005; Mays et al., 2001). This type of approach is particularly valuable in addressing knowledge gaps across a range of literature, clarifying characteristics and factors related to a topic, and investigating relevant practical and conceptual approaches (Munn et al., 2018). In fostering cross-pollination among fields, similar strategies have been used to make connections between education and sustainability (Barth & Michelsen, 2013), as well as sustainability and learning (Feeney et al., 2023), in addition to other areas related to education and assessment (O'Neill, 2012; O'Neill, 2016).

The review process entails establishing an objective and scope, iteratively selecting studies that relate to these, and crafting emergent insights through a dynamic analysis of pertinent work (Levac et al., 2010). Following this method, an initial sample of relevant work on assessment from the educational discourse was identified through a search that targeted journal publications focused on the key concepts examined in the

study (e.g., assessment, learning, etc.). This work was reflexively reviewed by drawing on principles of content analysis (Elo & Kyngäs, 2008) to both deductively and inductively determine relevant information. Key features and functions of assessment concepts and practices from the educational discourse were synthesized to develop a framework that provides guidance for the design, implementation, and contextualization of assessments of transdisciplinary sustainability strategies.

Building from the insights of the discourse on assessments of transdisciplinary sustainability strategies and gaps in practice, the output of the review focused on establishing key features and functions linked to purposes, processes, and principles. These areas serve as the dimensions of the framework, with specific components generated from the review described as options in developing assessment approaches. Aligned with the dimensions of the framework, two influential sources from the educational literature were applied to elaborate a structure that provides guidance on assessment design, implementation, and contextualization. The first source (Bearman et al., 2016), provides a heuristic for the decisions entailed in developing assessments, outlining six key areas: focus, purpose, outcomes, interactions and feedback processes, tasks, and context. This framing is integrated with the second source (Boud & Soler, 2016), which articulates three key elements entailed in assessment development: methods and practices (general strategy and procedures), tools and criteria (instruments and evaluative standards), and assumptions and normative judgments (conceptual and ethical values). Further elaboration of the elements entailed in these dimensions was drawn from the educational discourse and linked to key sustainability characteristics and considerations in order to ensure compatibility across fields.

### ***Purposes Dimension***

Purposes serve to orient the design of assessments. They are concerned with focus, or what the assessment aims to appraise; objectives, or what it aims to achieve; and outcomes, or what information it aims to produce. To link these to specific areas from the educational literature, as well as distinctive sustainability characteristics, these focal elements of the purposes of assessment can be described as concerned with: (1) orientations of sustainability, (2) objectives of assessment, and (3) outcomes of transdisciplinary strategies.

The *orientations of sustainability* have been described above, but their relationship to assessment can be further clarified here. Assessment in *problem-oriented* sustainability can help to understand the concepts involved in the issue, provide evidence of how they are linked, and suggest the conditions and procedures to be addressed (Gijbels et al., 2005). In the context of transdisciplinary sustainability strategies, this can be supported by analysis across scales that is informed by theories of change in order to appraise the status of problems and how they might evolve (for better or worse) in the future (Belcher & Hughes, 2021). Assessment in *solution-oriented* sustainability can help to evaluate performance within the process of solution generation and application, as well as the impacts that it contributes to (Plummer et al., 2022). This can lead to a focus on evaluating outcomes at different levels, such as individual skill-building, collective interactions, or systemic transformation (Wiek & Kay, 2015). Assessment in *learning-oriented* sustainability can facilitate iterative feedback and adaptation cycles that enable improved performance, decision-making, and impact (Taras, 2002; William, 2011). This can contribute to reflection on the application of action-oriented knowledge as well as

capacity building over time to navigate the challenges of complex systems (Brennan & Rondón-Sulbarán, 2019). This type of learning can also lead to the surfacing of different normative viewpoints through interactive deliberation and critical engagement (Radinger-Peer et al., 2022).

Closely aligned with the roles that assessment can play in relation to the sustainability orientations, are the *objectives of assessment*. The educational discourse has defined a set of nearly ubiquitous objectives (Schellekens et al., 2021) that are relevant for transdisciplinary sustainability. These objectives have been highlighted for their fundamental functions in practices such as assessing the development of sustainability competencies (Redman et al., 2021). However, they are rarely explicitly engaged with or operationalized in the assessment of transdisciplinary sustainability strategies. Crisp (2012) synthesizes them productively as taking diagnostic, formative, and summative functions. *Diagnostic* functions typically occur at the beginning of processes and aim to understand the existing status of capacity to achieve the intended goal, including how gaps can be addressed to enhance the efficiency and effectiveness of progress (Halverson et al., 2013; Sia & Lim, 2018). *Summative* functions typically occur at the end of a process or one of its subphases and aim to determine the cumulative quality of a strategy and its outcomes (Kibble, 2017; Schellekens et al., 2021), though it can also be linked to learning over the long-term (Fischer et al., 2024; Nieminen et al., 2021; Taras, 2009). *Formative* functions typically occur throughout the assessment process and aim to appraise progress and determine adaptations that can be made to improve inputs, processes, and outputs (Bennett, 2011; Black & Wiliam, 2009; Panadero et al., 2019). Though these different functions are applied in transdisciplinary sustainability as

assessments are iteratively performed in connection to problem-solving frameworks (Wiek & Lang, 2016), they are rarely explicitly labeled or drawn from the variety of techniques and theories that have been developed in the educational discourse.

In education, as in any form of evaluative practice, the form and goals of an assessment are closely dictated by the intended (learning) outcomes (Biggs, 1996). While education possesses its own forms of learning goals, efforts toward sustainability transformations pursue other types of *outcomes of transdisciplinary strategies*. These outcomes typically center on linking knowledge to action through innovative and transformative practices (Lang et al., 2012; West et al., 2019). Thus, in order to fit the emergent framework to the goals of transdisciplinary sustainability strategies, the pluralistic and integrated approach to action-oriented knowledge for sustainability advanced by Caniglia et al. (2021) is applied. The types of action-oriented knowledge that represent the outcomes of transdisciplinary sustainability strategies are: (1) knowledge informing *intentional design*, which leverages generative, prescriptive, and strategic knowledges to develop transformative solutions; (2) knowledge enhancing *shared agency*, which leverages critical, empowering, and co-produced knowledges to facilitate collaborative change processes; and (3) knowledge enabling *contextual realization*, which leverages emergent, tactical, and situated knowledges to mobilize transformative change in specific settings.

### ***Processes Dimension***

Processes serve to orient the implementation of assessments. They are concerned with the who, what, and how of assessing TSs, such as the interactions and feedback processes between stakeholders or the tasks that represent the assessment activity.

Specifically, the two elements of assessment processes that are most important to consider are: (1) methods and practices, and (2) tools and criteria.

The *methods and practices* of assessing transdisciplinary sustainability strategies can take many different forms. Rather than focusing on the variety of approaches for collecting data to inform assessments (such as interviews, observations, surveys, etc.) (Holzer et al., 2018), this element is more concerned with the structure of interactions between stakeholders and how this shapes the assessment process. A first type of assessment approach is *internal* assessment, where project leaders, who in this case are often academic researchers, lead the assessment process (Lang & Wiek, 2022). This can be compared to the educational practice of self-assessment in which individuals or groups perform the assessment of themselves (Andrade & Valtcheva, 2009; Panadero et al., 2016; Ross, 2019). While this approach can stimulate critical reflection as a genesis of potential transformation (Liu, 2015) and promote self-regulated learning (Nicol & Macfarlane-Dick, 2007), it can also be influenced by unintended biases of the individual or group that limit its validity or the generalizability of its insights (Gramzow et al., 2003; León et al., 2023; Taylor, 2014). On the other end of the spectrum, *external* assessment involves those outside or on the periphery of the project as the leaders of the assessment (Conley-Tyler, 2005). In the case of transdisciplinary sustainability strategies, this could be an overseeing agency, community stakeholders who are potentially impacted by the problem and its possible solutions, or the societal partners and practitioners who contribute to varying degrees to the strategy (van Drooge & Spaapen, 2022). In these processes, it is important to consider power dynamics (de Geus et al., 2023), participation preferences (Bieluch et al., 2017), and epistemological values (Fritz & Binder, 2020). A

third type of approach is *co-assessment*, in which academic and societal partners conduct the assessment together in iterative and collaborative ways (Blackstock et al., 2007).

There are two parallels in educational practice: peer assessment, in which students assess each other (Panadero et al., 2023; van Zundert et al., 2010), and strategies like rubric co-construction (Inoue, 2004; Quesada et al., 2019) in which students and instructors work together in determining and implementing assessment standards. While these approaches can face some challenges because of the need to integrate different perspectives (Bacchus et al., 2020), they can also offer strategies to support multidimensional perspectives on the quality of inputs, processes, and outputs while contributing to learning (Zhao et al., 2021).

The methods and practices of assessment become more targeted as they are linked to specific *tools and criteria*. While the theoretical, project, and methodological pluralism of sustainability leads to a variety of reliable tools for assessments of transdisciplinary sustainability strategies (Jerneck & Olsson, 2019; Likhacheva et al., 2023), connecting these to valid and rigorous criteria has proven challenging (Gasparatos et al., 2009). Educational assessment practices provide a structure for the types of criteria that tools can leverage as benchmarks in deriving meaningful assessment outputs (Atkinson, 2015). *Criterion*-referenced assessment compares performance and impact against established standards, often presented in a rubric (Lok et al., 2016). This type of approach is common in relation to sustainability, such as the assessment of progress on the Sustainable Development Goals through comparison against the established indicators (Allen et al., 2018). *Norm*-referenced assessment compares outcomes against those of peers to make judgments on quality (Freeman & Miller, 2001). This approach recognizes the need for

relative versus absolute assessments in trying to understand progress towards sustainability against strategies influenced by similar factors, for example comparing sustainability efforts in similar contexts, areas, or scales (Jahn et al., 2022). The third type is *ipsative* assessment, which compares outcomes of a specific endeavor by a set of actors against their own previous outcomes in order to motivate improved performance (Malecka & Boud, 2023). While ipsative approaches can demonstrate limitations related to validity or transferability, they often prove instrumental in promoting nuanced evaluation and learning over time (Hughes, 2011). This approach may be particularly effective in enabling the types of collective reflection, deliberation, and adaptation that is encouraged in transdisciplinary sustainability strategies (Lang et al., 2012).

### ***Principles Dimension***

Principles serve to orient the contextualization of assessments. The purposes and processes of assessments do not exist in a vacuum and, particularly in relation to transdisciplinary sustainability strategies, are connected to the principles and values demonstrated by stakeholders operating within specific contexts. In educational discourse, *assumptions and normative judgments*, regarding how assessment is practiced and what it contributes to, strongly shape approaches in particular settings. These different normative aspects can include the sociological, philosophical, and ethical-political perspectives that stakeholders bring to influence the content and procedures of assessments (Delandshere, 2011). Similarly, the implementation and evaluation of sustainability are inherently normative practices (Raymond et al., 2023). This is particularly apparent in relation to transdisciplinary sustainability, which promotes deliberation of the perspectives of different stakeholders to promote convergence on

shared sustainability values while still fostering respect for divergent and emergent values concerning different goals, strategies, and metrics (Horcea-Milcu et al., 2022). In defining the purpose and operationalizing the process of assessments, engaging with the principles embodied in the assumptions and normative judgments demonstrated as contextualizing factors for different engaged stakeholders is an essential task to encourage learning (Casanova et al., 2023). While doing so can contribute to challenges and conflict (Kenter et al., 2019), endeavors to surface implicit values, negotiate values, elicit values, and transform through values are needed (Horcea-Milcu et al., 2019). Specifically, these normative engagements can support transdisciplinary sustainability strategies to contribute to collective learning (Stahl et al., 2011). Since assessment functions as “an act of communication about what we value” (Boud, 2000, p. 160), the way that normative aspects are articulated, prescribed, and measured represents an integral element in how assessments are enacted in relation to specific contexts and stakeholders in transdisciplinary strategies.

### **An Assessment-Oriented Sustainability Framework**

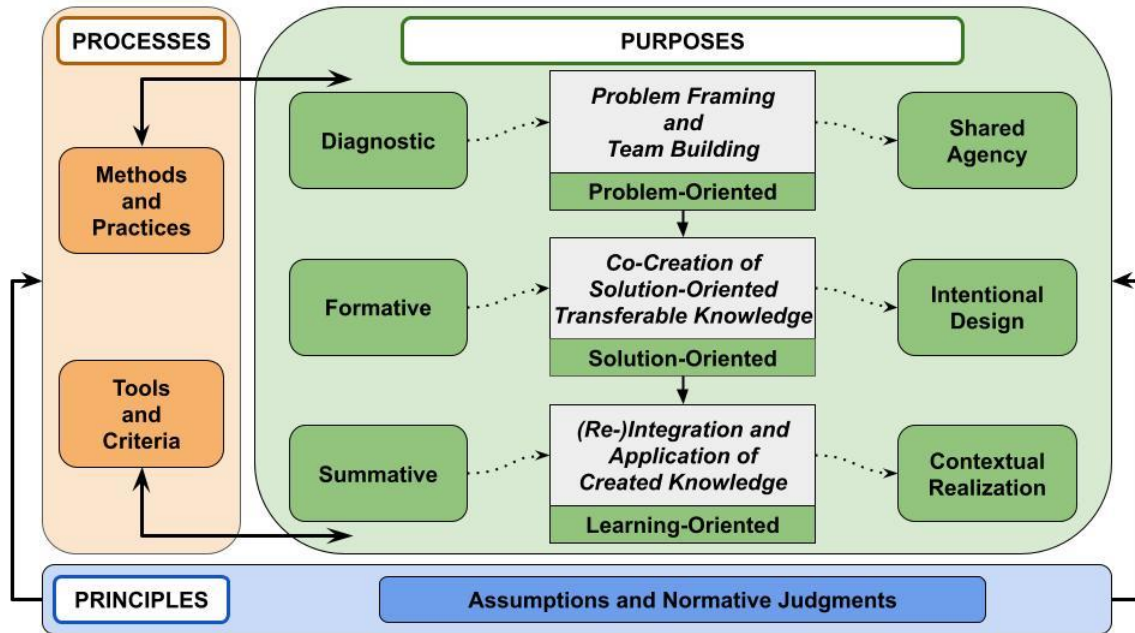
The dimensions and components described above can be organized in an analytical framework for the assessment of problem analysis, solution generation, and learning cultivation in transdisciplinary sustainability strategies. This framework serves as a way to operationalize AOS by providing a heuristic for practitioners and scholars to develop assessment approaches for their own transdisciplinary strategies while enhancing opportunities and capacities for learning geared toward sustainability transformations. Articulating this framework generates several contributions of AOS. First, the framework integrates the problem, solution, and learning orientations of transdisciplinary

sustainability, which each inform the effectiveness of transdisciplinary strategies. Second, the framework connects the purposes, processes, and principles of assessment approaches to support their design, implementation, and contextualization. Third, the framework clarifies and emphasizes the pivotal role of assessment throughout the iterative progression of transdisciplinary sustainability strategies. Fourth, the framework elevates the focus on learning within transdisciplinary strategies by articulating the myriad roles that assessment can play and how it can be leveraged in generating action-oriented knowledge to support learning that can be translated into impact for advancing sustainability transformations.

Similar to the recent work of Plummer et al. (2022), this framework is mapped onto the phases of transdisciplinary sustainability strategies outlined by Lang et al. (2012) to support its application. These phases entail: (1) problem framing and team building, (2) co-creation of solution-oriented transferable knowledge, and (3) (re-)integration and application of created knowledge. In demonstrating different features and functions across these phases, assessment approaches can support the cultivation and tracking of action-oriented knowledge in connection to the inputs, processes, and outputs of transdisciplinary sustainability strategies (Figure 5). To further elaborate on this potential, the details of the AOS framework are described below.

**Figure 5**

*Assessment-Oriented Sustainability Framework*



In the *problem framing and team building* phase, the AOS framework emphasizes problem-oriented sustainability by focusing on the diagnostic assessment of the analysis of the targeted problem. In addition to generating evidence regarding the features of the problem and the ways that potential solutions might address them, going through this process in a collaborative and deliberative way can promote shared agency among transdisciplinary teams. Taking an AOS approach can be leveraged as a way to inform problem framing and stimulate team building by providing action-oriented knowledge through and for interactive engagement. For example, a transdisciplinary team might apply the framework in this phase to help them consider the metrics (processes) that they are using to analyze a problem, such as sustainable mobility in an urban area. This discussion could help the team to clarify how the evidence generated in this process supports their shared agency in understanding and being prepared to address the problem

(purposes) as well as the values and aspirations that are shaping the evaluation criteria (principles).

In the *co-creation of solution-oriented transferable knowledge* phase, the AOS framework emphasizes solution-oriented sustainability by focusing on the formative assessment of generated solutions. This approach serves to prioritize the iterative development and adaptation of solutions so that they effectively address the targeted problem. Fostering increases in the intentional design of solutions through continuous learning is a key function of the AOS approach as it supports knowledge co-creation and evidence-informed decision-making. For example, a transdisciplinary team might apply the framework in considering how to create alignment among their assessment methods, their information outputs, and how these are used to enhance the efficacy of their project, such as fostering regenerative local agricultural systems. The team could consider their different options in creating the features and functions of their assessment practice, being guided by the priority of increasing the intentional design of their project as suggested by the framework.

In the *(re-)integration and application of created knowledge* phase, the AOS framework emphasizes learning-oriented sustainability by focusing on the summative assessment of the cultivation of learning related to the solutions that address the targeted problems. This link between summative assessment and a learning-orientation reflects the notion of “sustainable assessment” (Boud, 2000), as well as the generative capacity for summative approaches to contribute to broader, long-term capacity for learning and change that are increasingly recognized in the educational (Fischer et al., 2024; Nieminen et al., 2021) and sustainability discourses (Luederitz et al., 2017; Plummer et al., 2022).

This type of learning is needed to promote the contextual realization of solutions in relation to the original setting and stakeholders. However, these insights can also be translated into other settings, as the AOS framework serves as both a landing point for singular transdisciplinary sustainability strategies and a launching pad for future endeavors. For example, a transdisciplinary team seeking to promote initiatives related to SDG 13 on climate action in their community might apply the framework in guiding their choice of widely recognized evaluation standards as the criteria to assess their initiative. By adapting the set of standards to their local context, the team could promote the contextual realization of their initiative's ambitions while retaining the capacity to link their insights to broader efforts related to SDG 13 in an endeavor to promote wide-scale learning through intentional assessment approaches.

Cutting across these phases and the ways that they intersect with the *Purposes* dimension of the AOS framework are the *Processes* and *Principles* dimensions. In applying the framework, the elements related to methods and practices as well as tools and criteria can be engaged with iteratively at each stage. The development of these elements can both be shaped by and shape assessment purposes, particularly as they are defined by the logistical features (e.g., reporting imperatives, team expertise, etc.) of the situation (Norström et al., 2020). For example, the project team might have a specific set of evaluative standards mandated by an external agency to apply in assessing their project. This would inform the tools and criteria used throughout different phases of the process. Conversely, establishing the priority of a formative assessment function in relation to solution-oriented sustainability might guide the development of methods and practices that emphasize certain types of data (e.g., qualitative insights from project

partners and community stakeholders) as the most effective way to support the iterative adaptation of the planned transdisciplinary sustainability strategy.

Underlying the choice of approaches are the principles that inform the assumptions and normative judgments which act as contextualizing factors for engaged stakeholders. These principles influence both the purposes and processes of the assessment approach, determining how specific sociological, philosophical, and ethical-political perspectives are operationalized (Delandshere, 2011). They also shape the normative and epistemological priorities of the assessment, particularly as scientific and societal actors negotiate power dynamics to integrate diverse viewpoints and intentions in fair and inclusive ways (Fritz & Binder, 2020). Together, these dimensions and components outline considerations for the development of assessments of problem analysis, solution generation, and learning cultivation in transdisciplinary sustainability strategies, providing a framework for how approaches can be designed, implemented, and contextualized throughout phases of these efforts.

## **Conclusion**

This article has aimed to advance the roles of assessment in transdisciplinary sustainability by identifying relevant concepts and practices from the educational discourse to propose a framework for developing assessments of the inputs, processes, and outputs of transdisciplinary sustainability strategies. Applying an AOS approach serves to integrate the other orientations to transdisciplinary sustainability (problem, solution, and learning), while enhancing their efficacy in analyzing, generating, and learning from action-oriented knowledge. Returning to the evaluative, adaptive, normative, and deliberative roles that assessment plays offers a way of synthesizing the

contributions of this work to the discourse on transdisciplinary sustainability. These roles particularly enable collective learning processes, which are essential for translating research and practice into meaningful impacts in advancing sustainability transformations (Barth et al., 2023). These multifaceted roles of assessment also suggest the potential utility of the AOS framework in different settings and fields. For example, though the framework has been developed in relation to community-based transdisciplinary sustainability strategies it may be valuable in contexts such as other transdisciplinary efforts, interdisciplinary approaches to sustainability research, or even applied forms of educational research and practice that are increasingly engaging with sustainability and transdisciplinarity. Specifically, the deliberative and generative mechanisms of the framework could support discussion of assessment purposes, processes, and principles and how they appraise or advance the efficacy of problem analysis, solution generation, and learning cultivation in applied strategies that seek to foster action-oriented knowledge for transformative impact.

While the ideas articulated in this article provide a foundation for further work, several limitations should be considered in appraising its contributions and the ways that they inform future directions. First, this article has prioritized a research synthesis approach in order to support cross-pollination between educational and sustainability fields. This has yielded a conceptual framework that has yet to be validated through empirical or practical applications, suggesting that experimentation is needed to enhance its operationalizability. Second, the scoping literature review method prioritizes breadth over depth to explore the parameters of a particular intellectual landscape. While this method is suited to the development of a tentative heuristic approach to crafting

assessments, it also runs the risk of missing relevant work that hinders the presentation of a full critical appraisal of the relevant discourse, as well as examples of key concepts and practices. Third, the framework itself is not necessarily prescriptive of certain assessment approaches but seeks to provide a basis for developing them in robust ways that meet the needs of specific contexts and stakeholders. While this openness provides certain advantages as well as opportunities for future work, it also contributes to some of the ongoing ambiguities regarding the assessment of transdisciplinary sustainability strategies. In response, the framework aims to leverage its versatility in the encouragement of inclusive participatory deliberation among stakeholders to develop context-sensitive assessments while pointing to the extensive educational discourse for clarity on what potential approaches could look like in practice and how collective learning can be effectively stimulated.

This article provides one example of the mutual synergies existing between education and sustainability (Barth & Michelsen, 2013). Further engagement between these fields can support research and practice in transdisciplinary sustainability, particularly as efforts focus on collective learning and transformative change across different levels (Lotz-Sisitka et al., 2016). Continued exchange can provide new insights on the purposes, processes, and principles that guide efforts to achieve sustainability transformations. For example, educational concepts like sustainable assessment (Boud, 2000) or practices like self-regulated learning (Zimmerman, 2002) can inform the purposes of sustainability by framing objectives that balance immediate impacts and long-term capacity for change. Similarly, the broad array of theories, methods, and tools articulated in the educational discourse can offer insights for how sustainability

processes, particularly as they seek to cultivate collective learning (van Mierlo & Beers, 2020). There are also alignments between principles in education and sustainability, such as emphases on transformative interactions, dialogic relationships, epistemological pluralism, and critical praxis (Souza et al., 2019). These connections provide ample opportunities for cross-pollination among these fields with the potential outcome that learning and learning-focused assessment receive more critical attention to promote conceptual and practical sophistication in these areas.

Future research on this topic should seek to elaborate on the roles of AOS in transdisciplinary sustainability strategies and how assessments can promote learning. From a conceptual perspective, further efforts to customize the AOS framework so that it fully operationalizes the distinctive characteristics of transdisciplinary sustainability will better situate this work in relation to ongoing assessment (and evaluation) efforts in the field. This could include the development of guiding questions, tiered standards, or other such details that increase the framework's prescriptive capacities while retaining its generic versatility. As with sustainability strategies more broadly (Walker et al., 2023), articulating a diverse range of assessment approaches and corresponding examples may be valuable in capturing and promoting the outcomes of learning-focused assessment in transdisciplinary sustainability. From an empirical perspective, the application of the framework could be tested in different contexts with a variety of stakeholder configurations. Experimentation across different areas of sustainability (e.g., climate change, water-energy-food nexus, consumption and production, etc.) would also help to confirm the framework's efficacy in supporting the design, implementation, and contextualization of assessments, particularly in relation to problem analysis, solution

generation, and learning cultivation. This work is especially needed to ensure that the evidence developed through engagement with the framework is valid and reliable in the assessment of transdisciplinary sustainability strategies. Such testings could be done ex-ante, in-situ, and ex-post (Lang & Wiek, 2022) in order to better understand the descriptive, reflective, and analytical potential of the framework.

Advancing toward sustainability transformations will require action-oriented knowledge to be articulated through robust assessments. Sophisticated approaches are needed to understand the problems that are faced and the efficacy of proposed solutions, while amplifying the collective learning that is necessary to foster tangible impacts. A shift toward assessment, and the emphasis on learning that it conveys, can promote advances in how scholars and practitioners evaluate, adapt, and deliberate evidence of and normative interpretations on progress toward sustainability. Educational discourse provides a generative lens for enhancing the conceptual and practical rigor of work in this space. The assessment-oriented framework proposed in this article serves as a basis for the maturation of future endeavors in evaluating transdisciplinary sustainability strategies and advancing their focus on learning. Adding this assessment emphasis to problem, solution, and learning orientations can facilitate the evolution of the field of transdisciplinary sustainability in how it learns towards the transformations that it aims to achieve.

## CHAPTER 5

### CONCLUSION

#### **Summary of Findings**

In the learning journey of and towards sustainability, assessing progress is necessary to ensure quality and impact in the implementation of actionable strategies. Whether in higher education or transdisciplinary endeavors, assessment plays a crucial role in setting benchmarks for success, evaluating efforts to achieve them, and encouraging adaptations to enhance efficiency and effectiveness. This dissertation has examined the ways that assessment might function across different practice contexts and in engaging a variety of actors in their work to learn towards sustainability. Specifically, the three studies of this dissertation aimed to respond to the following central research question:

How can the multifaceted roles of assessment in sustainability education contribute to learning towards innovations in transdisciplinary practice?

Insights from the three studies suggest that the practice of assessment is integral in facilitating the design, implementation, and evaluation of sustainability endeavors. In addition to serving diagnostic, formative, and summative functions, assessment plays multifaceted roles by indicating, motivating, and enabling learning and action for sustainability. Different actors engage with these functions in unique ways, but across the three studies the roles of assessment are operationalized through individual and collective reflection, deliberation, and innovation among communities of practice.

To expand on these overall insights, each study provides particular findings on operationalizing the various roles of assessment practices. The first study, *Sustainability-*

*Oriented Assessment*, demonstrates how a student-led rubric co-design process that draws from participative, normative, and integrative approaches can contribute to student agency, expansive learning, and self-formation. The second study, *Boundary Crossings and Innovations*, identifies barriers and possibilities for assessment practices according to higher education program leaders and instructors, suggesting conceptual, practical, and logistical innovations to enable more distinctive approaches for sustainability education. The third study, *Assessment-Oriented Sustainability*, develops a framework to integrate problem, solution, and learning orientations to sustainability by infusing educational purposes, processes, and principles to strengthen the efficacy of assessment approaches for transdisciplinary strategies. Together, these studies suggest that innovations in assessment practices are needed, desired, and possible from the perspective of different actors who pursued these emergent practices through interactive and integrative strategies.

### **Situating Key Findings**

In the Introduction, several areas of key aims and innovations for this work were described. Specifically, these entailed connections to: (1) practice theory, (2) action-oriented knowledge for sustainability, and (3) dimensions of assessment. This section presents insights from the three studies in relation to these aims before synthesizing findings in relation to the research gaps and practical functions of assessment.

### ***Practice Theory***

Findings related to practice theory can be sorted into insights related to: activities and skills, reflexivity and meaning, and materials and tools (Shove et al., 2012). Across the three studies, insights related to *activities and skills* indicated the types of

competences needed for different actors to operationalize effective assessment practices. Specifically, these findings noted the importance of interactive approaches to evaluation and adaptation through participatory collaboration that supported the navigation of conceptual, practical, and logistical challenges. Insights related to *reflexivity and meaning* considered the intentions and purposes embodied in the examined assessment practices. Findings pointed to the need to link assessment purposes (the what and why) with processes (the how) to engage with the normative aspects of sustainability, as exemplified by the aspirations of problem, solution, and learning orientations. Insights related to *materials and tools* described the mediating artifacts that supported actors in their practices. Findings from the studies proposed the importance of these artifacts in reflecting normative choices and contextual factors, with objects like rubrics and evaluation reports integrating diverse perspectives and facilitating shared learning. As practices reflect specific configurations of competence, meaning, and materiality, these findings suggest the influence of specific settings, conditions, and actors in shaping assessment practices. In inquiry related to these practices, the findings highlight how alignments in the areas described above (e.g., participatory approaches that engage with assessment purposes and values) are often constructive, though tensions across the areas may also prove generative. Overall, these findings suggest how assessment practices, when considered in this theoretically-contextualized way, can link and cut across areas of education, learning, and sustainability science, particularly as they emphasize the power of agency and collaboration to shape innovations in practice.

### ***Action-Oriented Knowledge for Sustainability***

Findings related to action-oriented knowledge for sustainability can be sorted into insights related to: intentional design, shared agency, and contextual realization (Caniglia et al., 2021). Across the three studies, insights related to *intentional design* explained how robust conceptual approaches can be leveraged in crafting effective assessments, as can illustrations of innovations from different contexts for strategies such as creating formative rubrics. These findings suggest the significance of dynamically linking theory and practice in the design of assessments. Insights related to *shared agency* highlighted how social interactions in settings such as communities of practice can support generative discussions that surface perspectives on assessments and how they embody normative perspectives and goals. The findings also suggest that these interactions can contribute to individual and collective learning toward the development of shared approaches to practice. Insights related to *contextual realization* built on these findings to highlight the importance of practices to reflect principles of engaged stakeholders in order to support effective implementation strategies of participatory assessments. Findings also elaborated on the conceptual, practical, and logistical barriers that can hinder effective implementation in specific contexts but suggested how these might be negotiated to promote innovations. Overall, these findings demonstrate how these types of action-oriented knowledge have been cultivated and the ways that they enable innovations in assessment practices, which in turn can contribute to further generation of action-oriented knowledge for sustainability.

### ***Dimensions of Assessment***

Findings related to dimensions of assessment can be sorted into insights related to: methods and practices, tools and criteria, and assumptions and normative judgments

(Boud & Soler, 2016). Across the three studies, insights related to *methods and practices* noted the potential of cultivating synergies among educational and sustainability approaches. For example, findings described the relevance of participatory approaches that take student-centered forms, or encourage reflection and collaboration through strategies like co-assessment. Insights related to *tools and criteria* stressed the value of performative and authentic practices, characterized by the development and implementation of student-led rubric co-design processes. Findings also outlined different forms that practices can take, but emphasized the need for them to be crafted in ways that facilitate learning in the present and improve capacity for improvement moving toward the future. Insights related to *assumptions and normative judgments* echoed the need to reflect the conditions presented by specific contexts and actors, but also highlighted the unique purposes of assessment in sustainability education. Specifically, the findings indicated the significance of the purpose dimension of assessments (e.g., to ensure that students are prepared with the competencies needed to address complex sustainability problems), as well as the ambitions of actors to transform educational systems and learning processes to be more conducive to innovative practices that engage with sustainability. Overall, these findings suggest the need for dimensions of assessment to be connected to learning opportunities, particularly by centering the voices, values, and visions of actors in specific contexts.

### ***Synthesis***

In addition to addressing the aims of this research, the three studies also provided insights related to the research gaps and practical functions of assessment as described in the Introduction. Figure 6 (Sustainability-Oriented Assessment), Figure 7 (Boundary

Crossings and Innovations), and Figure 8 (Assessment-Oriented Sustainability) highlight the outputs of the studies in relation to these areas, the aims of the dissertation described above, and the subsequent contributions described in the next section.

The Introduction of this dissertation provided an overview of three core gaps in the research on assessment in sustainability education. Specifically, these gaps concerned: (1) a lack of theoretical engagement, (2) inadequacy in engaging diverse perspectives, and (3) minimal progress in the examination of integrative approaches that blend educational and sustainability perspectives.

In relation to *theoretical engagement*, this dissertation applied a variety of theoretical frameworks to conceptualize the practices that were the focus of its inquiry. These include expansive learning theory and cultural-historical activity theory (Study 1), boundary objects and boundary crossings (Study 2), and an array of educational concepts and principles (Study 3). The theories engaged with throughout the dissertation particularly frame assessment as a learning process, reflecting the notion of sustainable assessment that meets the learning needs of both the present and the future (Boud, 2000). In addition to informing the purpose of assessments, these theories can also inform the assessment process and the principles that it reflects, which have been called out by Barth (2009) and Shephard (2009) as additional areas for deeper theoretical engagement.

In relation to *diverse perspectives*, this dissertation focused on a range of actors in different contexts. This engagement aimed to go beyond the typical standard approach of reporting on case studies by researcher-instructors (Corcoran et al., 2004) that has influenced the directions and limitations of discourse on this topic (Redman et al., 2021). Instead, the three studies prioritized the perspectives of students, program leaders, and

instructors as active observers of practices and change agents in the field, as well as transdisciplinary practitioners and scholars in sustainability science. Drawing from these perspectives helped to illustrate ambitions for innovations in practice (Study 1) that reflect broader trends in the assessment discourse (Pereira et al., 2016), barriers and possibilities for those innovations (Study 2), and ways to infuse assessment within the problem, solution, and learning orientations of sustainability (Study 3).

In relation to *integrative approaches*, this dissertation sought to draw from educational and sustainability discourse in order to inform advances in assessment practices. Study 1 focused on infusing sustainability principles into educational assessment practice by translating participative, normative, and integrative features (Barth, 2014) into a student-led rubric co-design process. Study 3 focused on infusing educational concepts into the assessment practices of transdisciplinary sustainability strategies by articulating relevant elements in dimensions related to purposes, processes, and principles. Fusing the convergent insights from these two studies is Study 2, which addresses potential innovations for assessment practices within sustainability programs in higher education. While constructively aligned (Biggs, 1996) approaches that reflect the specific learning conditions and outcomes of sustainability education have remained elusive in these programs (Sterling et al., 2017), this research suggests that integrative approaches can contribute to conceptual, practical, and logistical innovations.

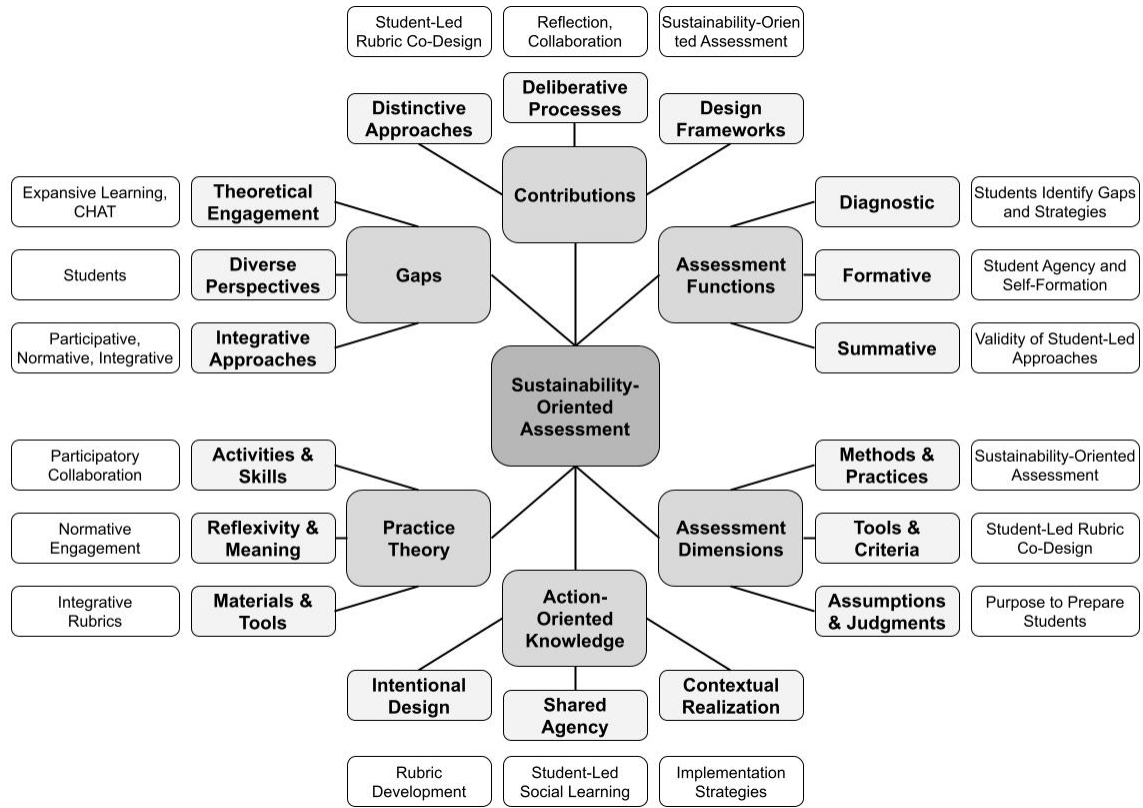
The Introduction also covered the need for work on assessments in sustainability education that addressed the three primary practical assessment functions: diagnostic, formative, and summative. The studies addressed *diagnostic* assessment functions by advancing their connection to problem-oriented sustainability, as well as how the process

of identifying current barriers and possibilities can contribute to strategies and learning opportunities among students as well as program leaders and instructors. The studies addressed *formative* assessment functions through a fundamental emphasis on the link between assessment and learning in both sustainability education and sustainability science. Particularly in higher education, formative functions were demonstrated in how assessment can contribute to student agency and self-formation at the course level, and how strategies such as adaptive progression can guide curriculum design and evaluation at the program level. The studies addressed *summative* assessment functions in highlighting how solution-oriented sustainability approaches can leverage assessment to track and ensure the quality and impact of transdisciplinary strategies. Insights connected to summative approaches also highlighted its emergent link to broader, long-term learning as it is proactively leveraged to develop learning capacity in students, program leaders and instructors, as well as practitioners and scholars.

Though further work is needed, this dissertation has advanced findings and innovations that address several aims of the research while addressing key gaps and practical needs across assessment functions. These insights suggest several contributions and implications that are outlined in the next section.

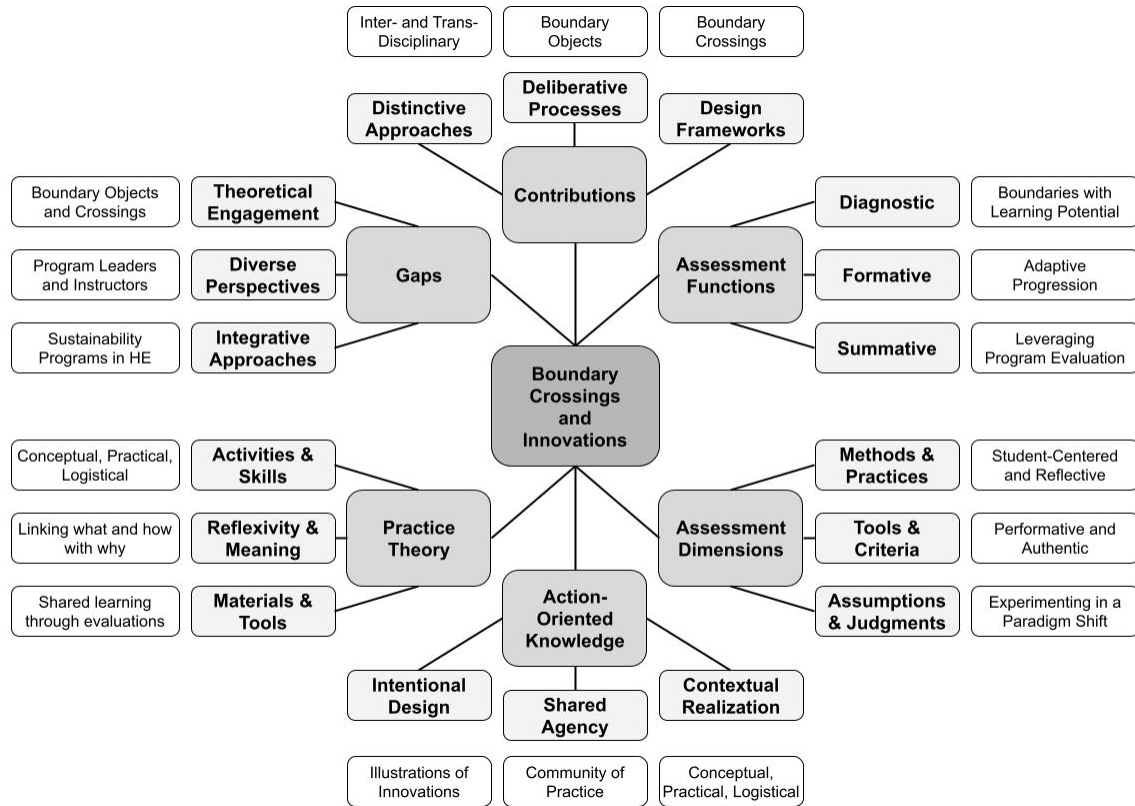
**Figure 6**

*Insights of Study 1: Sustainability-Oriented Assessment*



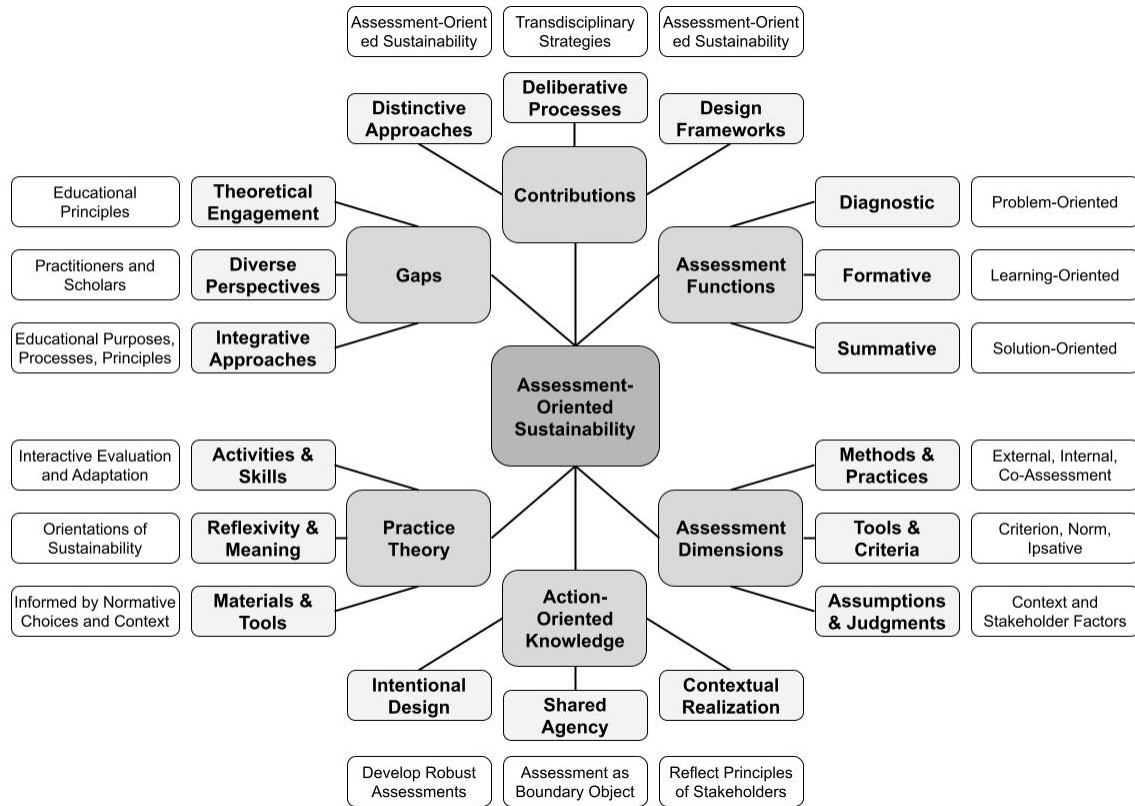
**Figure 7**

*Insights of Study 2: Boundary Crossings and Innovations*



**Figure 8**

*Insights of Study 3: Assessment-Oriented Sustainability*



**Contributions and Implications**

Before distinguishing the empirical, theoretical, methodological, and practical contributions and implications of this dissertation, three central contributions are highlighted. These relate to how the work has developed insights related to gaps in three areas of research on assessment in sustainability education: (1) distinctive approaches, (2) deliberative processes, and (3) design frameworks. A synthesis of the contributions in these areas is presented in Figure 9.

The first central contribution of this dissertation explores *distinctive approaches* to assessment in sustainability education. The three studies highlighted how these can

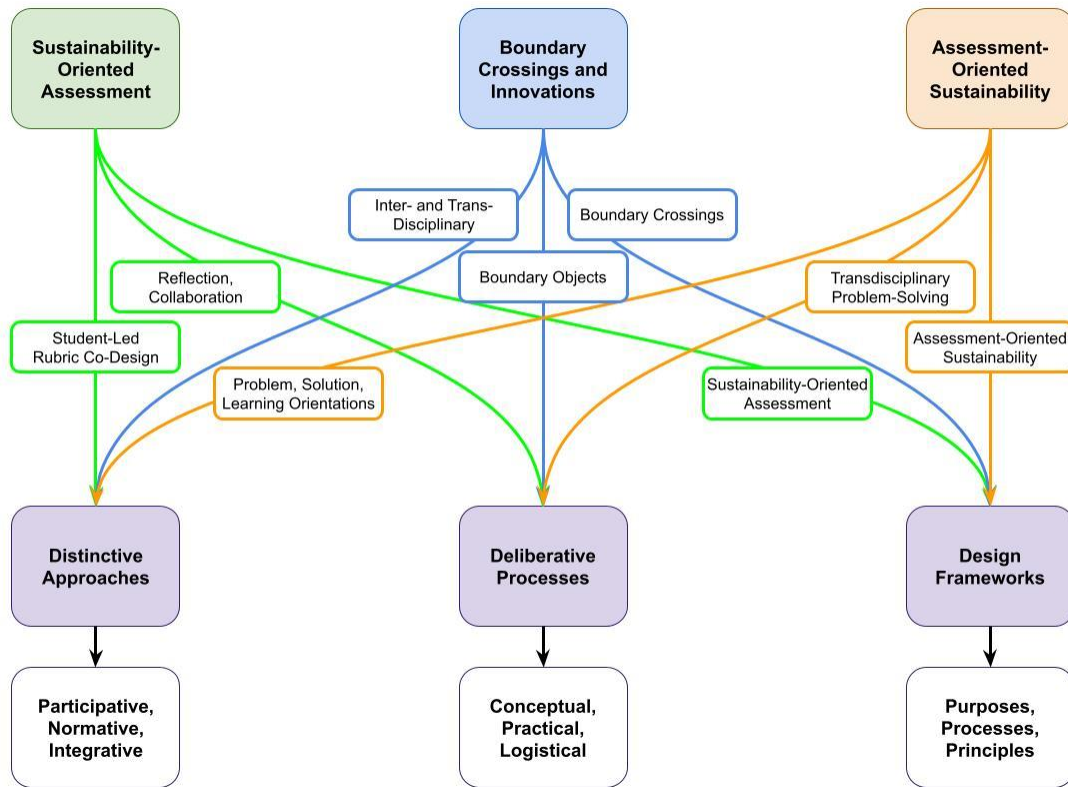
entail student-led rubric co-design, inter- and trans-disciplinary strategies, and intersections with problem, solution, and learning orientations to sustainability. The primary insight related to distinctive approaches is that their features should engage with participative, normative, and integrative functions as reflections of sustainability and educational principles within assessment practices.

The second central contribution of this dissertation emphasizes *deliberative processes* as ways to develop assessments in sustainability education. The three studies highlighted how these can entail reflection and collaboration, for example in engaging with boundary objects in curriculum development or transdisciplinary problem-solving processes. The primary insight related to deliberative processes is that they should analyze and articulate conceptual, practical, and logistical considerations in order to support innovations in assessment practices.

The third central contribution of this dissertation proposes *design frameworks* for assessments in sustainability education. The three studies highlighted how these can entail sustainability-oriented approaches, identify boundary crossings, and elevate assessment-orientated perspectives on sustainability. The primary insight related to design frameworks is that they should address purposes, processes, and principles of assessment to advance comprehensive yet versatile heuristics for developing assessment practices.

**Figure 9**

*Synthesis of Central Contributions of Dissertation Studies*



**Empirical**

From an empirical perspective, the studies of this dissertation advanced several relevant outputs. The first study, *Sustainability-Oriented Assessment*, demonstrated that guiding the design of student-led rubric co-design through a sustainability-oriented approach can contribute to student agency and their self-formation as both students and emerging sustainability professionals. The second study, *Boundary Crossings and Innovations*, revealed barriers, possibilities, and transgressive strategies that exist to improve practices across conceptual, practical, and logistical areas of sustainability programs in higher education. The third study, *Assessment-Oriented Sustainability*,

addresses the often-overlooked role that assessment plays in the sustainability discourse, proposing that a stronger emphasis on assessment practices can lead to more rigorous design, implementation, and contextualization of assessments for transdisciplinary sustainability strategies. These empirical insights highlight the variety of areas to address related to assessment in sustainability education that cut across practice contexts, actors, and thematic concentrations.

### ***Theoretical***

From a theoretical perspective, the studies engaged with or advanced several different frames for this work. The first study, *Sustainability-Oriented Assessment*, applied expansive learning theory to frame the types of learning that students might encounter as they prepare for the complex uncertainties that they will face in personal and professional settings. Cultural-historical activity theory was also applied as a way to interpret the different elements and interactions that shape learning and assessment practices in sustainability education in higher education. The second study, *Boundary Crossings and Innovations*, leveraged the conceptual lens of boundaries, boundary objects, and boundary crossings as a productive way of considering how to overcome challenges in moving from the status quo toward innovative practices. The third study, *Assessment-Oriented Sustainability*, articulates a tentative theoretical framework that draws on the educational discourse to conceptualize the development of purposes, processes, and principles for assessments of problem analysis, solution generation, and learning cultivation in transdisciplinary sustainability strategies. In this dissertation, this array of theories has been leveraged to map the way that different artifacts/objects, interactions, and reflections can be engaged with in order to generate innovations and

new perspectives on assessment practices. Articulating theoretical frameworks specific to this space is important for supporting assessment practice and research, however this dissertation sheds light on the robust array of existing theoretical frameworks that can illuminate the relationship between assessment, practice, and learning.

### ***Methodological***

From a methodological perspective, the studies utilized several approaches that offer tangible insights for research at the intersection of education, learning, and sustainability science. The first study, *Sustainability-Oriented Assessment*, conducted a formative intervention, which draws on expansive learning theory and cultural-historical activity theory. This type of action-oriented research provided additional theoretical and practical rigor to the examination of a specific teaching, learning, and assessment example. The second study, *Boundary Crossings and Innovations*, facilitated action research workshops that leveraged interactive technologies and group deliberation to surface divergent, convergent, and emergent perspectives on assessment practices while contributing to connections among participants. The third study, *Assessment-Oriented Sustainability*, leveraged a scoping literature review as a way to stimulate cross-pollination among different fields for the cultivation of conceptual and practical insights. Additionally, the lens of critical realism provided a foundational framing for considering the intertwining of research context, method, epistemological and ontological stance, and interpretation of outcomes. In investigating the ways that different actors (students, program leaders and instructors, practitioners) engage with and innovate assessment practices in different settings (higher education, transdisciplinary sustainability science), the methodological perspective of critical realism served to highlight both surface-level

and implicit factors that shaped the empirical and practical outcomes of each study (e.g., analysis of potential boundary crossings in the second study). Overall, the exploratory and primarily qualitative inquiry applied in this dissertation, supported through the lens of critical realism, has helped to better map the area of assessment in sustainability education while providing considerations for additional aspects to be addressed through future research that applies different methodological lenses and strategies toward experimentation in this area.

### ***Practical***

From a practical perspective, the studies generated insights across different contexts and actors. The first study, *Sustainability-Oriented Assessment*, addressed assessment at the course level with a primary focus on students. The study suggested that students should take on agential roles in designing and implementing assessments, particularly as a way to promote the learning experiences and skills that are needed to prepare them to respond to complex social-ecological challenges. The second study, *Boundary Crossings and Innovations*, addressed assessment at the program level with a primary focus on program leaders and instructors. The study suggested that these actors should seek more collaborative approaches that encourage shared learning and experimentation with the design and evaluation of sustainability programs in higher education. The third study, *Assessment-Oriented Sustainability*, addressed assessment at the level of transdisciplinary strategies with a primary focus on practitioners and scholars. The study suggested that these actors should consider the array of design frameworks and tools that educational research, theory, and practice can offer, particularly in efforts to leverage assessment in enhancing the efficacy of and learning within transdisciplinary

strategies for sustainability. The implications of these contributions point to the promise of leveraging deliberation in designing more distinctive practices to assessment in sustainability education and sustainability science.

### ***Limitations***

The contributions and implications of this dissertation can be viewed against several limitations. The research design was underpinned by a critical realist methodological approach, which engaged primarily in qualitative inquiry. These perspectives rely on context, subjective experiences, and interpretivist analysis, leading to limitations in the representative generalizability of results (Lawani, 2021; Ochieng, 2009) when considered against the expectations of positivist research paradigms (Aliyu et al., 2014). Yet, pluralistic views on analytical generalization in qualitative research suggest alternative conceptions on how findings produced under these paradigms can be interpreted and applied beyond the immediate context (Halkier, 2011; Larsson, 2009). In relation to these alternative conceptions, research in the paradigms applied in this dissertation can also provide nuances that illustrate potential understandings of the ways that practices become imbued with meaning, especially as they change over time (Hibbert et al., 2014). In fields such as sustainability and education, particularly in relation to their foci on transdisciplinarity and learning, these types of approaches can be applied in rethinking research inputs, processes, and outputs against the backdrop of uncertainty and urgency as factors shaping the need for practical innovations (Funtowicz & Ravetz, 1993).

Another limitation concerns the scope, scale, and time-parameters that imposed a boundedness on certain aspects of the research. For example, given the context-sensitive

and continually evolving nature, particularly of assessments of both sustainability (Blackstock et al., 2007) and education (Broadfoot & Black, 2004), as well as the targeted nature of who was engaged and at what scale in the research during a specific point in time, the findings must be considered in light of a potential lack of representativeness or transferability. However, rather than viewing research as the pursuit of abstracted results that exist as absolute knowledge, this work has been focused on delivering insights that rethinking scope and scale by targeting contributions to the potential spread and sustainability of its findings, as well as the depth and shift in agency of change that they might enable (Coburn, 2003). In light of both sustainability science and educational practice being place-based and participant-driven (Barth & Michelsen, 2013), aiming to pursue insights related to certain practice contexts and actors provided a more relevant research pathway than a positivist approach.

A final reflection on possible limitations regarding this work is its orientation toward exploratory and generative research. Rather than aiming at empirical results to confirm or disprove proposed hypotheses, this dissertation has endeavored to develop conceptual foundations and practical innovations as a stimulus for further work (Hanington, 2007). While this may restrict the validity of certain aspects of the findings, this approach also cultivates use-inspired applications that can support students, program leaders, instructors, practitioners, and scholars to further develop their assessment practices. These ambitions are influenced by my positionality and priorities as a researcher, particularly to serve as a process facilitator, knowledge broker, and change agent (Wittmayer & Schöpke, 2014).

## **Future Research**

Specific areas of future research have been articulated in relation to each of the three studies. However, broader directions are also possible for work on assessment in relation to education, learning, and sustainability science.

One direction for work on this topic is to further examine the dimensions of assessment (methods and practices, tools and criteria, assumptions and normative judgments) and how these are translated into approaches with strong fidelity and feasibility. Developing tools and criteria, for example, and testing their validity, reliability, and responsiveness to change is needed to capture learning in higher education and transdisciplinary contexts. This is especially important given shifts in practice toward student-centered, formative, subjective and skill-oriented assessment approaches. These trends, along with the characteristics of distinctive sustainability education approaches, compel new perspectives on validity and reliability measurements.

Another direction is to focus inquiry on in-depth illustrations of how action-oriented knowledge for sustainability is applied in the development and implementation of assessments. For example, investigating the features of deliberative processes in order to map how different actors effectively establish assessment approaches would support shared agency and intentional design. Analysis of the implementation of innovative assessment approaches across different settings would also provide insights on contextual realization and the ways that implementation processes can be navigated to achieve the generative functions of quality assessments.

A final direction for future research is to continue probing the intersection of assessment with learning and innovation in higher education and transdisciplinary settings. Leveraging the design frameworks advanced in this dissertation can provide a

basis for this work, but additional efforts are needed to determine pathways between assessment practices and collective learning toward sustainability. A series of comparative action research case studies could examine how the functions and capacities of assessment are operationalized across different scopes and scales. If in striving toward the prospect of more sustainable futures, goals continue to be set and progress tracked, understanding how assessment can facilitate and evaluate learning will continue to be a critical endeavor in the present and future.

## **Conclusion**

Returning to the research question that serves as both the starting point and destination of this research, this dissertation explored the potential roles that assessment can play in sustainability education and transdisciplinary sustainability science. Through the learning journey of this research, I have identified six roles for assessment at the intersection of higher education, sustainability science, and learning. These roles are a crystallization of the insights of this work and point to innovations in the present and future for assessment practices. Assessment plays an *evaluative* role in appraising the quality and impact of teaching, learning, and action related to advancing sustainable futures. Assessment plays a *formative* role in cultivating transversal learning towards sustainability. Assessment plays a *normative* role in surfacing key values and the ways that they are operationalized in goals, metrics, and strategies. Assessment plays a *deliberative* role in enabling critical reflection and discussion on the efficacy of those goals, metrics, and strategies. Assessment plays an *adaptive* role in supporting adjustments in iterative processes to increase efficacy in sustainability learning and practice. Finally, assessment plays a *generative* role in contributing to innovations and

learning in practice by crafting emergent opportunities for how sustainability is conceptualized and pursued.

In identifying these different roles, this dissertation has aimed to examine assessment in sustainability education as a way of promoting learning toward innovations in transdisciplinary practice. The insights and the implications of the three studies, as synthesized in this chapter, demonstrate the value of this work and the need for further endeavors that advance the conceptual and practical discourse related to assessment, teaching, and learning sustainability in higher education and beyond. Expanding the inclusivity and impact of the learning journey of and towards sustainability will require an emphasis on participatory engagement to establish and evaluate societal goals. It will require normative reflection on the values and habits that have contributed to unsustainability as well as how these might be transformed to enhance the capacity for collective action. It will require the integration of diverse perspectives and ambitions to achieve outcomes that are greater than the sum of their inputs yet that reflect the unique aspects of those inputs. This will entail learning and change to support the emergence of new prospects for local and global communities and their relationships to the ecological, economic, social, and technological aspects of society. As the uncertainty and complexity of this change process is navigated and negotiated, the practice of assessment offers a way to generate actionable knowledge for learning what sustainability is, how it is pursued, and why it is important.

## REFERENCES

- Akkerman, S.F., & Bakker, A. (2011). Boundary crossing and boundary objects. *Review of Educational Research, 81*(2), 132-169.  
<https://doi.org/10.3102/0034654311404435>
- Aliyu, A.A., Bello, M.U., Kasim, R., & Martin, D. (2014). Positivist and non-positivist paradigm in social science research: Conflicting paradigms or perfect partners? *Journal of Management and Sustainability, 4*(3), 79-95.  
<https://doi.org/10.5539/jms.v4n3p79>
- Allen, C., Metternicht, G., & Wiedmann, T. (2018). Initial progress in implementing the Sustainable Development Goals (SDGs): A review of evidence from countries. *Sustainability Science, 13*, 1453-1467. <https://doi.org/10.1007/s11625-018-0572-3>
- Andrade, H.L., & Heritage, M. (2018). *Using formative assessment to enhance learning, achievement, and academic self-regulation*. Routledge.
- Andrade, H., & Valtcheva, A. (2009). Promoting learning and achievement through self-assessment. *Theory Into Practice, 48*(1), 12-19.  
<https://doi.org/10.1080/00405840802577544>
- Annelin, A., & Boström, G.-O. (2023). An assessment of key sustainability competencies: A review of scales and propositions for validation. *International Journal of Sustainability in Higher Education, 24*(9), 53-69.  
<https://doi.org/10.1108/IJSHE-05-2022-0166>
- Apetrei, C.I., Caniglia, G., von Wehrden, & Lang, D.J. (2021). Just another buzzword? A systematic literature review of knowledge-related concepts in sustainability science. *Global Environmental Change, 68*, 102222.  
<https://doi.org/10.1016/j.gloenvcha.2021.102222>
- Arksey, H., & O'Malley, L. (2005). Scoping studies: Towards a methodological framework. *International Journal of Social Research Methodology, 8*(1), 19-32.  
<https://doi.org/10.1080/1364557032000119616>
- Atkinson, S.P. (2015). Adaptive learning and learning analytics: A new learning design paradigm. *BPP Working Papers*.
- Bacchus, R., Colvin, E., Knight, E.B., & Ritter, L. (2020). When rubrics aren't enough: Exploring exemplars and student rubric co-construction. *Journal of Curriculum and Pedagogy, 17*(1), 48-61. <https://doi.org/10.1080/15505170.2019.1627617>

- Barr, N., Hartley, K., Lopata, J.A., McFarlane, B., & Mcnamara (2022). Learning in an uncertain world: Transforming higher education for the Anthropocene. In R.A. Beghetto & G.J. Jaeger (Eds.), *Uncertainty: A catalyst for creativity, learning and development* (pp. 337-357). Springer. [https://doi.org/10.1007/978-3-030-98729-9\\_18](https://doi.org/10.1007/978-3-030-98729-9_18)
- Barth, M. (2009). Assessment of sustainability competencies: A conceptual framework. In M. Adomßent, M. Barth, & A. Beringer (Eds.), *World in transition: Sustainability perspectives for higher education* (pp. 93-100). VAS Verlag.
- Barth, M. (2014). *Implementing sustainability in higher education: Learning in an age of transformation*. Routledge.
- Barth, M., & Michelsen, G. (2013). Learning for change: An educational contribution to sustainability science. *Sustainability Science*, 8, 103-119. <https://doi.org/10.1007/s11625-012-0181-5>
- Bautista-Puig, N., Lozano, R., Barreiro-Gen, M. (2023). Developing a sustainability implementation framework: Insights from academic research on tools, initiatives and approaches. *Environment, Development and Sustainability*, 25, 11011-11031. <https://doi.org/10.1007/s10668-022-02516-y>
- Bearman, M., & Ajjawi, R. (2021). Can a rubric do more than be transparent? Invitation as a new metaphor for assessment criteria. *Studies in Higher Education*, 46(2), 359-368. <https://doi.org/10.1080/03075079.2019.1637842>
- Bearman, M., Boud, D., & Ajjawi, R. (2020). New directions for assessment in a digital world. In M. Bearman, P. Dawson, R. Ajjawi, J. Tai, & D. Boud (Eds.), *Re-imagining university assessment in a digital world* (pp. 7-18). Springer. [https://doi.org/10.1007/978-3-030-41956-1\\_2](https://doi.org/10.1007/978-3-030-41956-1_2)
- Bearman, M., Dawson, P., Boud, D., Bennett, S., Hall, M., & Molloy, E. (2016). Support for assessment practice: Developing the Assessment Design Decisions Framework. *Teaching in Higher Education*, 21(5), 545-556. <https://doi.org/10.1080/13562517.2016.1160217>
- Becker, A. (2016). Student-generated scoring rubrics: Examining their formative value for improving ESL students' writing performance. *Assessing Writing*, 29, 15-24. <https://doi.org/10.1016/j.asw.2016.05.002>
- Beers, P.J., van Mierlo, B., & Hoes, A. (2016). Toward an integrative perspective on social learning in system innovation initiatives. *Ecology and Society*, 21(1).

- Belcher, B.M., & Hughes, K. (2021). Understanding and evaluating the impact of integrated problem-oriented research programmes: Concepts and considerations. *Research Evaluation*, 30(2), 154-168. <https://doi.org/10.1093/reseval/rvaa024>
- Belcher, B.M., Rasmusen, K.E., Kemhsaw, M.R., & Zornes, D.A. (2016). Defining and assessing research quality in a transdisciplinary context. *Research Evaluation*, 25(1), 1-17. <https://doi.org/10.1093/reseval/rvv025>
- Benn, S., Edwards, M., & Angus-Leppan, T. (2013). Organizational learning and the sustainability community of practice: The role of boundary objects. *Organization & Environment*, 26(2), 184-202. <https://doi.org/10.1177/1086026613489559>
- Benn, S., & Martin, A. (2010). Learning and change for sustainability reconsidered: A role for boundary objects. *Academy of Management Learning & Education*, 9(3), 397-412.
- Bennett, R.E. (2011). Formative assessment: A critical review. *Assessment in Education: Principles, Policy & Practice*, 18(1), 5-25. <https://doi.org/10.1080/0969594X.2010.513678>
- Bergmann, M., Schöpke, N., Marg, O., Stelzer, F., Lang, D.J., Bossert, M., Gantert, M., Häußler, E., Marquardt, E., Piontek, F.M., Potthast, T., Rhodius, R., Rudolph, M., Ruddat, M., Seebacher, A., & Sußmann, N. (2021). Transdisciplinary sustainability research in real-world labs: Success factors and methods for change. *Sustainability Science*, 16, 541-564. <https://doi.org/10.1007/s11625-020-00886-8>
- Bernert, P., Wanner, M., Fischer, N., & Barth, M. (2022). Design principles for advancing higher education sustainability learning through transformative research. *Environment, Development and Sustainability*. <https://doi.org/10.1007/s10668-022-02801-w>
- Bhaskar, R. (2016). *Enlightened common sense: The philosophy of critical realism*. Routledge.
- Bieluch, K.H., Bell, K.P., Teisl, M.F., Lindenfeld, L.A., Leahy, J., & Silka, L. (2017). Transdisciplinary research partnerships in sustainability science: An examination of stakeholder participation preferences. *Sustainability Science*, 12, 87-104. <https://doi.org/10.1007/s11625-016-0360-x>
- Biesta, G. (2020). Risking ourselves in education: Qualification, socialization, and subjectification revisited. *Educational Theory*, 70(1), 89-104. <https://doi.org/10.1111/edth.12411>
- Biggs, J. (1996). Enhancing teaching through constructive alignment. *Higher Education*, 32, 347-364. <https://doi.org/10.1007/BF00138871>

- Birdman, J., Wiek, A., & Lang, D.J. (2022). Developing key competencies in sustainability through project-based learning in graduate sustainability programs. *International Journal of Sustainability in Higher Education*, 23(5), 1139-1157. <https://doi.org/10.1108/IJSHE-12-2020-0506>
- Black, P., & Wiliam, D. (2009). Developing the theory of formative assessment. *Educational Assessment, Evaluation and Accountability*, 21, 5-31. <https://doi.org/10.1007/s11092-008-9068-5>
- Blackstock, K.L., Kelly, G.J., & Horsey, B.L. (2007). Developing and applying a framework to evaluate participatory research for sustainability. *Ecological Economics*, 60(4), 726-742. <https://doi.org/10.1016/j.ecolecon.2006.05.014>
- Boud, D. (2000). Sustainable assessment: Rethinking assessment for the learning society. *Studies in Continuing Education*, 22(2), 151-167. <https://doi.org/10.1080/713695728>
- Boud, D., & Bearman, M. (2022). The assessment challenge of social and collaborative learning in higher education. *Educational Philosophy and Theory*. <https://doi.org/10.1080/00131857.2022.2114346>
- Boud, D., Dawson, P., Bearman, M., Bennett, S., Joughin, G., & Molloy, E. (2018). Reframing assessment research: Through a practice perspective. *Studies in Higher Education*, 43(7), 1107-1118. <https://doi.org/10.1080/03075079.2016.1202913>
- Boud, D., & Falchikov, N. (2007). Developing assessment for informing judgment. In D. Boud, & N. Falchikov (Eds.), *Rethinking assessment for higher education: Learning for the longer term* (pp. 181-197).
- Boud, D., & Soler, R. (2016). Sustainable assessment revisited. *Assessment & Evaluation in Higher Education*, 41(3), 400-413. <https://doi.org/10.1080/02602938.2015.1018133>
- Bourdieu, P. (1979). *La distinction critique sociale du jugement [Distinction: A Social Critique of the Judgement of Taste]*. Les Editions de Minuit.
- Bourdieu, P. (1997). *Méditations pascaliennes [Pascalian Meditations]*. Seuil.
- Brandt, P., Ernst, A., Gralla, F., Luederitz, C., Lang, D.J., Newig, J., Reinert, F., Abson, D.J., & von Wehrden, H. (2013). A review of transdisciplinary research in sustainability science. *Ecological Economics*, 92, 1-15. <https://doi.org/10.1016/j.ecolecon.2013.04.008>

- Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2), 77-101. <https://doi.org/10.1191/1478088706qp063oa>
- Braun, V., & Clarke, V. (2019). Reflecting on reflexive thematic analysis. *Qualitative Research in Sport, Exercise and Health*, 11(4), 589-597. <https://doi.org/10.1080/2159676X.2019.1628806>
- Bray, T.L. (2008). Agency. *Encyclopedia of Archaeology*, 106-110. <https://doi.org/10.1016/B978-012373962-9.00411-8>
- Breiger, R.L. (2000). A tool kit for practice theory. *Poetics*, 27(2-3), 91-115. [https://doi.org/10.1016/S0304-422X\(99\)00026-1](https://doi.org/10.1016/S0304-422X(99)00026-1)
- Brennan, M., & Rondón-Sulbarán, J. (2019). Transdisciplinary research: Exploring impact, knowledge and quality in the early stages of a sustainable development project. *World Development*, 122, 481-391. <https://doi.org/10.1016/j.worlddev.2019.06.001>
- Broadfoot, P., & Black, P. (2004). Redefining assessment? The first ten years of *assessment in education*. *Assessment in Education: Principles, Policy & Practice*, 11(1), 7-26. <https://doi.org/10.1080/0969594042000208976>
- Brundiers, K., Barth, M., Cebrián, G., Cohen, M., Diaz, L., Doucette-Remington, S., Dripps, W., Habron, G., Harré, N., Jarchow, M., Losch, K., Michel, J., Mochizuki, Y., Rieckmann, M., Parnell, R., Walker, P., & Zint, M. (2021). Key competencies in sustainability in higher education: Toward an agreed-upon reference framework. *Sustainability Science*, 16, 13-29. <https://doi.org/10.1007/s11625-020-00838-2>
- Brundiers, K., & Wiek, A. (2017). Beyond interpersonal competence: Teaching and learning professional skills in sustainability. *Education Sciences*, 7(1): 39. <https://doi.org/10.3390/educsci7010039>
- Caniglia, G., John, B., Bellina, L., Lang, D.J., Wiek, A., Cohmer, S., & Laubichler, M.D. (2018). The *glocal* curriculum: A model for transnational collaboration in higher education for sustainable development. *Journal of Cleaner Production*, 171, 368-376. <https://doi.org/10.1016/j.jclepro.2017.09.207>
- Caniglia, G., Luederitz, C., von Wirth, T., Fazey, I., Martín-López, B., Hondrila, K., König, A., von Wehrden, H., Schöpke, N.A., Laubichler, M.D., & Lang, D.J. (2021). A pluralistic and integrated approach to action-oriented knowledge for sustainability. *Nature Sustainability*, 4, 93-100. <https://doi.org/10.1038/s41893-020-00616-z>

- Caniglia, G., Schöpke, N., Lang, D.J., Abson, D.J., Luederitz, C., Wiek, A., Laubichler, M.D., Gralla, F., & von Wehrden, H. (2017). Experiments and evidence in sustainability science: A typology. *Journal of Cleaner Production*, 169, 39-47. <https://doi.org/10.1016/j.jclepro.2017.05.164>
- Carew, A.L., & Wickson, F. (2010). The TD Wheel: A heuristic to shape, support and evaluate transdisciplinary research. *Futures*, 42(10), 1146-1155. <https://doi.org/10.1016/j.futures.2010.04.025>
- Casanova, C., King, J.A., & Fischer, D. (2023). Exploring the role of intentions and expectations in continuing professional development in sustainability education. *Teaching and Teacher Education*, 128, 104115. <https://doi.org/10.1016/j.tate.2023.104115>
- Cash, D., Clark, W.C., Alcock, F., Dickson, M.D., Eckley, N., & Jäger, J. (2003). Saliency, credibility, legitimacy and boundaries: Linking research, assessment and decision making. *KGS Working Paper Series*. <https://doi.org/10.2139/ssrn.372280>
- Cebrián Bernat, G., Segalàs, J., & Hernández, À. (2019). Assessment of sustainability competencies: A literature review and future pathways for ESD research and practice. *Central European Review of Economics and Management*, 3(3), 19-44. <https://doi.org/10.29015/cerem.664>
- Clark, W.C., & Harley, A.G. (2020). Sustainability science: Toward a synthesis. *Annual Review of Environment and Resources*, 45, 331-386. <https://doi.org/10.1146/annurev-environ-012420-043621>
- Coburn, C.E. (2003). Rethinking scale: Moving beyond numbers to deep and lasting change. *Educational Researcher*, 32(6), 3-12. <https://doi.org/10.3102/0013189X032006003>
- Conley-Tyler, M. (2005). A fundamental choice: Internal or external evaluation? *Evaluation Journal of Australasia*, 4(1-2), 3-11. <https://doi.org/10.1177/1035719X05004001-202>
- Corcoran, P.B. Walker, K.E., & Wals, A.E.J. (2004). Case studies, make-your-case studies, and case stories: A critique of case-study methodology in sustainability in higher education. *Environmental Education Research*, 10(1), 7-21. <https://doi.org/10.1080/1350462032000173670>
- Crisp, G.T. (2012). Integrative assessment: Reframing assessment practice for current and future learning. *Assessment & Evaluation in Higher Education*, 37(1), 33-43. <https://doi.org/10.1080/02602938.2010.494234>

- de Gues, T., Avelino, F., Strumińska-Kutra, M., Pitzer, M., Wittmayer, J.M., Hendrikx, L., Joshi, V., Schrandt, N., Widdel, L., Fraaije, M., Iskandarova, M., Hielscher, S., & Rogge, K. (2023). Making sense of power through transdisciplinary sustainability research: Insights from a Transformative Power Lab. *Sustainability Science*, 18, 1311-1327. <https://doi.org/10.1007/s11625-023-01294-4>
- de Magalhães, R.F., Danilevicz, Â.d.M.F., & Palazzo, J. (2019). Managing trade-offs in complex scenarios: A decision-making tool for sustainability projects. *Journal of Cleaner Production*, 212, 447-460. <https://doi.org/10.1016/j.jclepro.2018.12.023>
- Deeley, S.J., & Bovill, C. (2017). Staff student partnership in assessment: Enhancing assessment literacy through democratic practices. *Assessment & Evaluation in Higher Education*, 42(3), 463-477. <https://doi.org/10.1080/02602938.2015.1126551>
- Delandshere, G. (2001). Implicit theories, unexamined assumptions and the status quo of educational assessment. *Assessment in Education: Principles, Policy & Practice*, 8(2), 113-133. <https://doi.org/10.1080/09695940123828>
- Dillon, J., & Wals, A.E.J. (2006). On the danger of blurring methods, methodologies and ideologies in environmental education research. *Environmental Education Research*, 12(3-4), 549-558. <https://doi.org/10.1080/13504620600799315>
- Eakin, H.C., Lemos, M.C., & Nelson, D.R. (2014). Differentiating capacities as a means to sustainable climate change adaptation. *Global Environmental Change*, 27, 1-8. <http://dx.doi.org/10.1016/j.gloenvcha.2014.04.013>
- Edwards, M., Brown, P., Benn, S., Bajada, C., Perey, R., Cotton, D., Jarvis, W., Menzies, G., McGregor, I., & Waite, K. (2020). Developing sustainability learning in business school curricula – productive boundary objects and participatory processes. *Environmental Education Research*, 26(2), 253-274. <https://doi.org/10.1080/13504622.2019.1696948>
- Edwards-Groves, C., & Kemmis, S. (2016). Pedagogy, education and praxis: Understanding new forms of intersubjectivity through action research and practice theory. *Educational Action Research*, 24(1), 77-96. <https://doi.org/10.1080/09650792.2015.1076730>
- Elo, S., & Kyngäs, H. (2008). The qualitative content analysis process. *Journal of Advanced Nursing*, 62(1), 107-115. <https://doi.org/10.1111/j.1365-2648.2007.04569.x>
- Engeström, Y. (2001). Expansive learning at work: Toward an activity theoretical reconceptualization. *Journal of Education and Work*, 14(1), 133-156. <https://doi.org/10.1080/13639080020028747>

- Engeström, Y. (2011). From design interventions to formative interventions. *Theory & Psychology*, 21(5), 598-628. <https://doi.org/10.1177/0959354311419252>
- Engeström, Y., Engeström, R., & Kärkkäinen, M. (1995). Polycontextuality and boundary crossing in expert cognition: Learning and problem solving in complex work activities. *Learning and Instruction*, 5(4), 319-336. [https://doi.org/10.1016/0959-4752\(95\)00021-6](https://doi.org/10.1016/0959-4752(95)00021-6)
- Engeström, Y., Sannino, A., & Virkkunen, J. (2014). On the methodological demands of formative interventions. *Mind, Culture, and Activity*, 21(2), 118-128. <https://doi.org/10.1080/10749039.2014.891868>
- Engler, J., Abson, D.J., & von Wehrden, H. (2021). The coronavirus pandemic as an analogy for future sustainability challenges. *Sustainability Science*, 16, 317-319. <https://doi.org/10.1007/s11625-020-00852-4>
- Fazey, I., Schöpke, N., Caniglia, G., Hodgson, A., Kendrick, I., Lyon, C., Page, G., Patterson, J., Riedy, C., Strasser, T., Verveen, S., Adams, D., Goldstein, B., Klaes, M., Leicester, G., Lanyard, A., McCurdy, A., Ryan, P., Sharpe, B., ... Young, H.R. (2020). Transforming knowledge systems for life on Earth: Visions of future systems and how to get there. *Energy Research & Social Science*, 70, 101724. <https://doi.org/10.1016/j.erss.2020.101724>
- Feeney, M., Grohnert, T., Gijsselaers, W., & Martens, P. (2023). Organizations, learning, and sustainability: A cross-disciplinary review and research agenda. *Journal of Business Ethics*, 184, 217-235. <https://doi.org/10.1007/s10551-022-05072-7>
- Fetters, M.D., Curry, L.A., & Creswell, J.W. (2013). Achieving integration in mixed methods designs - Principles and practices. *Health Services Research*, 48(6 Pt 2), 2134-2156. <https://doi.org/10.1111/1475-6773.12117>
- Fia, M., Ghasemzadeh, K., & Paletta, A. (2022). How higher education institutions walk their talk on the 2030 agenda: A systematic literature review. *Higher Education Policy*. <https://doi.org/10.1057/s41307-022-00277-x>
- Findler, F., Schönherr, N., Lozano, R., Reider, D., & Martinuzzi, A. (2019). The impacts of higher education institutions on sustainable development: A review and conceptualization. *International Journal of Sustainability in Higher Education*, 20(1), 23-38. <https://doi.org/10.1108/IJSHE-07-2017-0114>
- Fischer, J., Bearman, M., Boud, D., & Tai, J. (2024). How does assessment drive learning? A focus on students' development of evaluative judgement. *Assessment & Evaluation in Higher Education*, 49(2), 233-245. <https://doi.org/10.1080/02602938.2023.2206986>

- Fletcher, A.J. (2017). Applying critical realism in qualitative research: Methodology meets method. *International Journal of Social Research Methodology*, 20(2), 181-194. <https://doi.org/10.1080/13645579.2016.1144401>
- Folke, C., Carpenter, S.R., Walker, B., Scheffer, M., Chapin, T., & Rockström, J. (2010). Resilience thinking: Integrating resilience, adaptability and transformability. *Ecology and Society*, 15(4), 20.
- Forrest, N., & Wiek, A. (2014). Learning from success - Toward evidence-informed sustainability transitions in communities. *Environmental Innovation and Societal Transitions*, 12, 66-88. <https://doi.org/10.1016/j.eist.2014.01.003>
- Foucrier, T. (2020). *Training future entrepreneurs: Developing and assessing sustainability competencies in entrepreneurship education* [Doctoral dissertation, Arizona State University].
- Fraile, J., Panadero, E., & Pardo, R. (2017). Co-creating rubrics: The effects on self-regulated learning, self-efficacy and performance of establishing assessment criteria with students. *Studies in Educational Evaluation*, 53, 69-76. <https://doi.org/10.1016/j.stueduc.2017.03.003>
- Franco, I., Saito, O., Vaughter, P., Whereat, J., Kanie, N., & Takemoto, K. (2019). Higher education for sustainable development: Actioning the global goals in policy, curriculum and practice. *Sustainability Science*, 14, 1621-1642. <https://doi.org/10.1007/s11625-018-0628-4>
- Frank, P., Sunderman, 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>
- Frank, P., Wagemann, J., Grund, J., & Parodi, O. (2024). Directing personal sustainability science toward subjective experience: Conceptual, methodological, and normative cornerstones for a first-person inquiry into inner worlds. *Sustainability Science*, 19, 555-574. <https://doi.org/10.1007/s11625-023-01442-w>
- Freeman, L., & Miller, A. (2001). Norm-referenced, criterion-reference, and dynamic assessment: What exactly is the point? *Educational Psychology in Practice*, 17(1), 3-16. <https://doi.org/10.1080/02667360120039942>
- Fritz, L., & Binder, C.R. (2020). Whose knowledge, whose values? An empirical analysis of power in transdisciplinary sustainability research. *European Journal of Futures Research*, 8, 3. <https://doi.org/10.1186/s40309-020-0161-4>

- Funtowicz, S.O., & Ravetz, J.R. (1993). Science for the post-normal age. *Futures*, 25(7), 739-755. [https://doi.org/10.1016/0016-3287\(93\)90022-L](https://doi.org/10.1016/0016-3287(93)90022-L)
- Gardner, H. (2011). *Frames of mind: The theory of multiple intelligences*. Hachette Book Group.
- Gasparatos, A., El-Haram, M., & Horner, M. (2009). The argument against a reductionist approach for measuring sustainable development performance and the need for methodological pluralism. *Accounting Forum*, 33(3), 245-256. <https://doi.org/10.1016/j.accfor.2008.07.006>
- Gibson, R.B. (2006a). Sustainability assessment: Basic components of a practical approach. *Impact Assessment and Project Appraisal*, 24(3), 170-182. <https://doi.org/10.3152/147154606781765147>
- Gibson, R.B. (2006b). Beyond the pillars: Sustainability assessment as a framework for effective integration of social, economic and ecological considerations in significant decision-making. *Journal of Environmental Assessment Policy and Management*, 8(3), 259-280. <https://doi.org/10.1142/S1464333206002517>
- Gibson, R.B. (2016). Applications: From generic criteria to assessments in particular places. In R.B. Gibson (Ed.), *Sustainability assessment: Applications and opportunities* (pp. 16-41). Routledge.
- Gijbels, D., Dochy, F., Van den Bossche, P., & Segers, M. (2005). Effects of problem-based learning: A meta-analysis from the angle of assessment. *Review of Educational Research*, 75(1), 27-61. <https://doi.org/10.3102/00346543075001027>
- Gramzow, R.H., Elliot, A.J., Asher, E., McGregor, H.A. (2003). Self-evaluation bias and academic performance: Some ways and some reasons why. *Journal of Research in Personality*, 37(2), 41-61. [https://doi.org/10.1016/S0092-6566\(02\)00535-4](https://doi.org/10.1016/S0092-6566(02)00535-4)
- Grinbaum, A., & Groves, C. (2013). What is “responsible” about responsible innovation? Understanding the ethical issues. In R. Owen, J. Bessant, & M. Heintz (Eds.), *Responsible innovation: Managing the responsible emergence of science and innovation in society* (pp. 119-142). John Wiley & Sons, Ltd.
- Hallinger, P., & Chatpinyakoo, C. (2019). A bibliometric review of research on higher education for sustainable development, 1998-2018. *Sustainability*, 11(8), 2401. <https://doi.org/10.3390/su11082401>
- Halkier, B. (2011). Methodological practicalities in analytical generalization. *Qualitative Inquiry*, 17(9), 787-797. <https://doi.org/10.1177/1077800411423194>

- Halverson, K.L., Boyce, C.J., & Maroo, J.D. (2013). Order matters: Pre-assessments and student generated representations. *Evolution: Education and Outreach*, 6, 24. <https://doi.org/10.1186/1936-6434-6-24>
- Hanington, B.M. (2007). Generative research in design education. In *International Association of Societies for Design Research 2007*. International Association of Societies for Design Research.
- Hansson, S., & Polk, M. (2018). Assessing the impact of transdisciplinary research: The usefulness of relevance, credibility, and legitimacy for understanding the link between process and impact. *Research Evaluation*, 27(2), 132-144. <https://doi.org/10.1093/reseval/rvy004>
- Harris, L.R., Brown, G.T.L., & Dargush, J. (2018). Not playing the game: Student assessment resistance as a form of agency. *The Australian Educational Researcher*, 45, 125-140. <https://doi.org/10.1007/s13384-018-0264-0>
- Hattie, J.A., & Brown, G.T.L. (2010). Assessment and evaluation. In C.M. Rubie-Davies (2010), *Educational psychology: Concepts, research and challenges* (pp. 102-117). Routledge.
- Hibbert, P., Sillince, J., Diefenbach, T., Cunliffe, A.L. (2014). Relationally reflexive practice: A generative approach to theory development in qualitative research. *Organizational Research Methods*, 17(3), 278-298. <https://doi.org/10.1177/1094428114524829>
- Holdsworth, S. Hegarty, K., & Sandri, O. (2022). Assessment design for interdisciplinary, professional and sustainability education. In W. Leal Filho, & C.R. Portela de Vasconcelos (Eds.), *Handbook of best practices in sustainable development at university level* (pp. 131-150). Springer.
- Holland, D., & Lave, J. (2019). Social practice theory and the historical production of persons. In A. Edwards, M. Flear, & L. Bøttcher (Eds.), *Cultural-historical approaches to studying learning and development: Societal, institutional and personal perspectives* (pp. 235-248). Springer. [https://doi.org/10.1007/978-981-13-6826-4\\_15](https://doi.org/10.1007/978-981-13-6826-4_15)
- Holzer, J. M., Carmon, N., Orenstein, D.E. (2018). A methodology for evaluating transdisciplinary research on coupled socio-ecological systems. *Ecological Indicators*, 85, 808-819. <https://doi.org/10.1016/j.ecolind.2017.10.074>
- Horcea-Milcu, A., Abson, D.J., Apetrei, C.I., Duse, I.A., Freeth, R., Riechers, M., Lam, D.P.M., Dornigher, C., & Lang, D.J. (2019). Values in transformational sustainability science: Four perspectives for change. *Sustainability Science*, 14, 1425-1437. <https://doi.org/10.1007/s11625-019-00656-1>

- Horcea-Milcu, A., Leventon, J., & Lang, D.J. (2022). Making transdisciplinarity happen: Phase 0, or before the beginning. *Environmental Science & Policy*, 136, 187-197. <https://doi.org/10.1016/j.envsci.2022.05.019>
- Huan, Y., Liang, T., Li, H., & Zhang, C. (2021). A systematic method for assessing progress of achieving sustainable development goals: A case study of 15 countries. *Science of The Total Environment*, 752, 141875. <https://doi.org/10.1016/j.scitotenv.2020.141875>
- Huckle, J. (2004). Critical realism: A philosophical framework for higher education for sustainability. In P.B. Corcoran, & A.E.J. Wals (Eds.), *Higher education and the challenge of sustainability* (pp. 33-47). [https://doi.org/10.1007/0-306-48515-X\\_4](https://doi.org/10.1007/0-306-48515-X_4)
- Hugé, J., Block, T., Waas, T., Wright, T., & Dahdouh-Guebas, F. (2016). How to walk the talk? Developing actions for sustainability in academic research. *Journal of Cleaner Production*, 137, 83-92. <https://doi.org/10.1016/j.jclepro.2016.07.010>
- Hughes, G. (2011). Towards a personal best A case for introducing ipsative assessment in higher education. *Studies in Higher Education*, 36(3), 353-367. <https://doi.org/10.1080/03075079.2010.486859>
- Inoue, A.B. (2004). Community-based assessment pedagogy. *Assessing Writing*, 9(3), 208-238. <https://doi.org/10.1016/j.asw.2004.12.001>
- Inoue, A.B. (2015). *Antiracist writing assessment ecologies: Teaching and assessing writing for a socially just future*. The WAC Clearinghouse.
- Jahn, T., & Keil, F. (2015). An actor-specific guideline for quality assurance in transdisciplinary research. *Futures*, 65, 195-208. <https://doi.org/10.1016/j.futures.2014.10.015>
- Jahn, S., Newig, J., Lang, D.J., Kahle, J., & Bergmann, M. (2022). Demarcating transdisciplinary research in sustainability science—Five clusters of research modes based on evidence from 59 research projects. *Sustainable Development*, 30(2), 343-357. <https://doi.org/10.1002/sd.2278>
- Jerneck, A., & Olsson, L. (2020). Theoretical and methodological pluralism in sustainability science. In T. Mino, & S. Kudo (Eds.), *Framing in sustainability science* (pp. 17-33). Springer. [https://doi.org/10.1007/978-981-13-9061-6\\_2](https://doi.org/10.1007/978-981-13-9061-6_2)
- Jorre de St Jorre, T., & Oliver, B. (2018). Want students to engage? Contextualise graduate learning outcomes and assess for employability. *Higher Education Research & Development*, 37(1), 44-57. <https://doi.org/10.1080/07294360.2017.1339183>

- Kates, R.W. (2011). What kind of a science is sustainability science? *PNAS*, *108*(49), 19449-19450. <https://doi.org/10.1073/pnas.1116097108>
- Kates, R.W., Clark, W.C., Corell, R., Hall, J.M., Jaeger, C.C., Low, I., McCarthy, J.J., Schellnhuber, H.J., Bolin, B., Dickson, N.M., Faucheux, S., Gallopin, G.C., Grübler, A., Huntley, B., Jäger, J., Jodha, N.S., Kasperson, R.E., Mabogunje, A., Matson, P.,...Svedin, U. (2001). Sustainability science. *Science*, *292*(5517), 641-642. <https://doi.org/10.1126/science.1059386>
- Kates, R.W., Parris, T.M., & Leiserowitz, A.A. (2005). What is sustainable development? Goals, indicators, values, and practice. *Environment: Science and Policy for Sustainable Development*, *47*(3), 8-21. <https://doi.org/10.1080/00139157.2005.10524444>
- Kenter, J.O., Raymond, C.M., van Riper, C.J., Azzopardi, E., Brear, M.R., Calcagni, F., Christie, I., Christie, M., Fordham, A., Gould, R.K., Ives, C.D., Hejnowicz, A.P., Gunton, R., Horcea-Milcu, A., Kendal, D., Kronenberg, J., Massenberg, J.R., O'Connor, S., Ravenscroft, N.,...Thankappan, S. (2019). Loving the mess: Navigating diversity and conflict in social values for sustainability. *Sustainability Science*, *14*, 1439-1461. <https://doi.org/10.1007/s11625-019-00726-4>
- Kibble, J.D. (2017). Best practices in summative assessment. *Advances in Physiology Education*, *41*(1), 110-119. <https://doi.org/10.1152/advan.00116.2016>
- Kilgour, P. Northcote, M., Williams, A., & Kilgour, A. (2020). A plan for the co-construction and collaborative use of rubrics for student learning. *Assessment & Evaluation in Higher Education*, *45*(1), 140-153. <https://doi.org/10.1080/02602938.2019.1614523>
- King, J., Fischer, D., Sahakian, M., Dyer, J., & Seyfang, G. (2023). Assessing learning in teaching sustainable consumption. In D. Fischer, M. Sahakian, J. King, J. Dyer, & G. Seyfang (Eds.), *Teaching and learning sustainable consumption: A guidebook* (pp. 49-65). Routledge.
- Klein, J.T. (2008). Evaluation of interdisciplinary and transdisciplinary research: A literature review. *American Journal of Preventive Medicine*, *35*(2, Supplement), S116-S123. <https://doi.org/10.1016/j.amepre.2008.05.010>
- Kohl, K., Hopkins, C., Barth, M., Michelsen, G., Dlouhá, J., Razak, D.A., Abidin Bin Sanusi, Z., & Toman, I. (2022). A whole-institution approach towards sustainability: A crucial aspect of higher education's individual and collective engagement with the SDGs and beyond. *International Journal of Sustainability in Higher Education*, *23*(2), 218-236. <https://doi.org/10.1108/IJSHE-10-2020-0398>

- Kollmuss, A., & Agyeman, J. (2002). Mind the gap: Why do people act environmentally and what are the barriers to pro-environmental behavior? *Environmental Education Research*, 8(3), 239-260. <https://doi.org/10.1080/13504620220145401>
- König, A. (2017). Sustainability science as a transformative social learning process. In A. König (Ed.), *Sustainability science: Key issues* (pp. 3-28). Routledge.
- Kueffer, C., Underwood, E., Hirsch Hadorn, G., Holderegger, R., Lehning, M., Pohl, C., Schirmer, M., Schwarzenbach, R., Stauffacher, M., Wuelser, G., & Edwards, P. (2012). Enabling effective problem-oriented research for sustainable development. *Ecology and Society*, 17(4), 8. <http://dx.doi.org/10.5751/ES-05045-170408>
- Lang, D.J., Wiek, A., Bergmann, M., Stauffacher, M., Martens, P., Moll, P., Swilling, M., & Thomas, C.J. (2012). Transdisciplinary research in sustainability science: Practice, principles, and challenges. *Sustainability Science*, 7 (Supplement 1), 25-43. <https://doi.org/10.1007/s11625-011-0149-x>
- Lang, D.J., & Wiek, A. (2022). Structuring and advancing solution-oriented research for sustainability. *Ambio*, 51, 31-35. <https://doi.org/10.1007/s13280-021-01537-7>
- Larsson, S. (2009). A pluralist view of generalization in qualitative research. *International Journal of Research & Method in Education*, 32(1), 25-38. <https://doi.org/10.1080/17437270902759931>
- Lave, J. (1991). Situating learning in communities of practice. In L.B. Resnick, J.M. Levine, & S.D. Teasley (Eds.), *Perspectives on socially shared cognition* (pp. 63-82). American Psychological Association.
- Lawani, A. (2021). Critical realism: What you should know and how to apply it. *Qualitative Research Journal*, 21(3), 320-333. <https://doi.org/10.1108/QRJ-08-2020-0101>
- Leach, M., Rockström, J., Raskin, P., Scoones, I., Stirling, A.C., Smith, A., Thompson, J., Millstone, E., Ely, A., Arond, E., Folke, C., & Olsson, P. (2012). Transforming innovation for sustainability. *Ecology and Society*, 17(2), 11. <http://dx.doi.org/10.5751/ES-04933-170211>
- León, S.P., Panadero, E., & García-Martínez, I. (2023). How accurate are our students? A meta-analytic systematic review on self-assessment scoring accuracy. *Educational Psychology Review*, 35, 106. <https://doi.org/10.1007/s10648-023-09819-0>
- Levac, D., Colquhoun, H., & O'Brien, K.K. (2010). Scoping studies: Advancing the methodology. *Implementation Science*, 5, 69. <https://doi.org/10.1186/1748-5908-5-69>

- Likhacheva, K., Bretagnolle, V., & Arpin, I. (2023). An exploration of the influence of problem wickedness on project pluralism in sustainability science. *Sustainability Science*, 18, 2423-2440. <https://doi.org/10.1007/s11625-023-01373-6>
- Litterio, L.M. (2018). Contract-grading in the technical writing classroom: Blending community-based assessment and self-assessment. *Assessing Writing*, 38, 1-9. <https://doi.org/10.1016/j.asw.2018.06.002>
- Liu, K. (2015). Critical reflection as a framework for transformative learning in teacher education. *Educational Review*, 67(2), 135-157. <https://doi.org/10.1080/00131911.2013.839546>
- Lok, B., McNaught, C., & Young, K. (2016). Criterion-referenced and norm-referenced assessments: Compatibility and complementarity. *Assessment & Evaluation in Higher Education*, 41(3), 450-465. <https://doi.org/10.1080/02602938.2015.1022136>
- Lönngren, J., & van Poeck, K. (2021). Wicked problems: A mapping review of the literature. *International Journal of Sustainable Development & World Ecology*, 28(6), 481-502. <https://doi.org/10.1080/13504509.2020.1859415>
- Lotz-Sisitka, H., Ali, M.B., Mphepo, G., Chaves, M., Macintyre, T., Pesanayi, T., Wals, A., Mukute, M., Kronlid, D., Tran, D.T., Joon, D., & McGarry, D. (2016). Co-designing research on transgressive learning in times of climate change. *Current Opinion in Environmental Sustainability*, 20, 50-55. <https://doi.org/10.1016/j.cosust.2016.04.004>
- Lotz-Sisitka, H., Fien, J., & Ketlhoilwe, M. (2012). Traditions and new niches: An overview of environmental education curriculum and learning research. In R.B. Stevenson, M. Brody, J. Dillon, & A.E.J. Wals (Eds.), *International handbook of research on environmental education* (pp. 194-205). Routledge.
- Luederitz, C., Schöpke, N., Wiek, A., Lang, D.J., Bergmann, M., Bos, J.J., Burch, S., Davies, A., Evans, J., König, A., Farrelly, M.A., Forrest, N., Frantzeskaki, N., Gibson, R.B., Kay, B., Loorbach, D., McCormick, K., Parodi, O., Rauschmayer, F.,... Westley, F.R. (2017). Learning through evaluation: A tentative evaluative scheme for sustainability transition experiments. *Journal of Cleaner Production*, 169, 61-76. <https://doi.org/10.1016/j.jclepro.2016.09.005>
- Macleod, G., Lent, N., Tian, X., Lian, Y., Moore, M., & Sen, S. (2020). Balancing supportive relationships and developing independence: An activity theory approach to understanding feedback in context for master's students. *Assessment & Evaluation in Higher Education*, 45(7), 958-972. <https://doi.org/10.1080/02602938.2020.1719976>

- Malecka, B., & Boud, D. (2023). Fostering student motivation and engagement with feedback through ipsative processes. *Teaching in Higher Education*, 28(7), 1761-1776. <https://doi.org/10.1080/13562517.2021.1928061>
- Mascarenhas, A., Langemeyer, J., Haase, D., & Borgström, S. (2021). Assessing the learning process in transdisciplinary research through a novel analytical approach. *Ecology and Society*, 26(4), 19.
- Matshedisho, K.R. (2020). Straddling rows and columns: Students' (mis)conceptions of an assessment rubric. *Assessment & Evaluation in Higher Education*, 45(2), 169-179. <https://doi.org/10.1080/02602938.2019.1616671>
- Mays, N., Roberts, E., & Popay, J. (2001). Synthesising research evidence. In N. Fulop, P. Allen, A. Clarke, & N. Black (Eds.), *Studying the organisation and delivery of health services: Research methods* (pp. 188-219). Routledge.
- Menon, S., & Suresh, M. (2020). Synergizing education, research, campus operations, and community engagements towards sustainability in higher education: A literature review. *International Journal of Sustainability in Higher Education*, 21(5), 1015-1051. <https://doi.org/10.1108/IJSHE-03-2020-0089>
- Miller, T.R. (2013). Constructing sustainability science: Emerging perspectives and research trajectories. *Sustainability Science*, 8, 279-293. <https://doi.org/10.1007/s11625-012-0180-6>
- Miller, T.R., Wiek, A., Sarewitz, D., Robinson, J., Olsson, L., Kriebel, D., & Loorbach, D. (2014). The future of sustainability science: A solutions-oriented research agenda. *Sustainability Science*, 9, 239-246. <https://doi.org/10.1007/s11625-013-0224-6>
- Millican, J., & Bourner, T. (2011). Student-community engagement and the changing role and context of higher education. *Education + Training*, 53(2-3), 89-99. <https://doi.org/10.1108/00400911111115645>
- Moallemi, E.A., Malekpour, S., Hadjidakou, M., Raven, R., Szetey, K., Ningrum, D., Dhiaulhaq, A., & Bryan, B.A. (2020). Achieving the Sustainable Development Goals requires transdisciplinary innovation at the local scale. *One Earth*, 3(3), 300-313. <https://doi.org/10.1016/j.oneear.2020.08.006>
- Moller, N.P., Clarke, V., Braun, V., Tischner, I., & Vossler, A. (2021). Qualitative story completion for counseling psychology research: A creative method to interrogate dominant discourses. *Journal of Counseling Psychology*, 68(3), 286-298. <https://psycnet.apa.org/doi/10.1037/cou0000538>

- Morton, J.K., Northcote, M., Kilgour, P., & Jackson, W.A. (2021). Sharing the construction of assessment rubrics with students: A model for collaborative rubric construction. *Journal of University Teaching & Learning Practice*, 18(4). <https://doi.org/10.53761/1.18.4.9>
- Munn, Z., Peters, M.D.J., Stern, C., Tufanaru, C., McArthur, A., Aromataris, E. (2018). Systematic review or scoping review? Guidance for authors when choosing between a systematic or scoping review approach. *BMC Medical Research Methodology*, 18, 143. <https://doi.org/10.1186/s12874-018-0611-x>
- Newig, J., Jahn, S., Lang, D.J., Kahle, J., & Bergmann, M. (2019). Linking modes of research to their scientific and societal outcomes: Evidence from 81 sustainability-oriented research projects. *Environmental Science & Policy*, 101, 147-155. <https://doi.org/10.1016/j.envsci.2019.08.008>
- Nicol, D.J., & Macfarlane-Dick, D. (2006). Formative assessment and self-regulated learning: A model and seven principles of good feedback practice. *Studies in Higher Education*, 31(2), 199-218. <https://doi.org/10.1080/03075070600572090>
- Nieminen, J.H., Asikainen, H., & Rämö, J. (2021). Promoting deep approach to learning and self-efficacy by changing the purpose of self-assessment: A comparison of summative and formative models. *Studies in Higher Education*, 46(7), 1296-1311. <https://doi.org/10.1080/03075079.2019.1688282>
- Nieminen, J.H., Bearman, M., & Tai, J. (2023). How is theory used in assessment and feedback research? A critical review. *Assessment & Evaluation in Higher Education*, 48(1), 77-94. <https://doi.org/10.1080/02602938.2022.2047154>
- Nieminen, J.H., & Yang, L. (2023). Assessment as a matter of being and becoming: Theorising student formation in assessment. *Studies in Higher Education*. <https://doi.org/10.1080/03075079.2023.2257740>
- Norström, A.V., Cvitanovic, C., Löf, M.F., West, S., Wyborn, C., Balvanera, P., Bednarek, A.T., Bennett, E.M., Biggs, R., de Bremond, A., Campbell, B.M., Canadell, J.G., Carpenter, S.R., Folke, C., Fulton, E.A., Gaffney, O., Gelcich, S., Jouffray, J., Leach, M.,...Österblom, H. (2020). Principles for knowledge co-production in sustainability research. *Nature Sustainability*, 3, 182-190. <https://doi.org/10.1038/s41893-019-0448-2>
- O'Byrne, D., Dripps, W., & Nicholas, K.A. (2015). Teaching and learning sustainability: An assessment of the curriculum content and structure of sustainability degree programs in higher education. *Sustainability Science*, 10, 43-59. <https://doi.org/10.1007/s11625-014-0251-y>

- O'Neill, D.K. (2012). Designs that fly: What the history of aeronautics tells us about the future of design-based research in education. *International Journal of Research & Method in Education*, 35(2), 119-140.  
<https://doi.org/10.1080/1743727X.2012.683573>
- O'Neill, D.K. (2016). When form follows fantasy: Lessons for learning scientists from modernist architecture and urban planning. *Journal of the Learning Sciences*, 25(1), 133-152. <https://doi.org/10.1080/10508406.2015.1094736>
- Ochieng, P.A. (2009). An analysis of the strengths and limitation of qualitative and quantitative research paradigms. *Problems of Education in the 21st Century*, 13, 13-18.
- Panadero, E., Alqassab, M., Ruiz, J.F., & Ocampo, J.C. (2023). A systematic review on peer assessment: Intrapersonal and interpersonal factors. *Assessment & Evaluation in Higher Education*, 48(8), 1053-1075.  
<https://doi.org/10.1080/02602938.2023.2164884>
- Panadero, E., Broadbent, J., Boud, D., & Lodge, J.M. (2019). Using formative assessment to influence self- and co-regulated learning: The role of evaluative judgement. *European Journal of Psychology of Education*, 34, 535-557.  
<https://doi.org/10.1007/s10212-018-0407-8>
- Panadero, E., Brown, G.T.L., & Strijbos-J. (2016). The future of student self-assessment: A review of known unknowns and potential directions. *Educational Psychology Review*, 28, 803-830. <https://doi.org/10.1007/s10648-015-9350-2>
- Particelli, B. (2020). Student-led assessment: A small study on classroom rubric development and peer grading practices. *Journal of Response to Writing*, 6(1), 3.
- Patton, M.Q. (1994). Developmental evaluation. *American Journal of Evaluation*, 15(3), 311-319. <https://doi.org/10.1177/109821409401500312>
- Pereira, D., Flores, M.A., Niklasson, L. (2016). Assessment revisited: A review of research in *Assessment and Evaluation in Higher Education*. *Assessment & Evaluation in Higher Education*, 41(7), 1008-1032.  
<https://doi.org/10.1080/02602938.2015.1055233>
- Peters, S., & Wals, A.E.J. (2013). Learning and knowing in pursuit of sustainability: Concepts and tools for transdisciplinary environmental research. In M. Krasny & J. Dillon (Eds.), *Trading zones in environmental education: Creating trans-disciplinary dialogue* (pp. 79-104). Peter Lang.

- Plummer, R., Blythe, J., Gurney, G.G., Witkowski, S., & Armitage, D. (2022). Transdisciplinary partnerships for sustainability: An evaluation guide. *Sustainability Science*, 17, 955-967. <https://doi.org/10.1007/s11625-021-01074-y>
- Purcell, W.M., Henriksen, H., & Spengler, J.D. (2019). Universities as the engine of transformational sustainability toward delivering the sustainable development goals: “Living labs” for sustainability. *International Journal of Sustainability in Higher Education*, 20(8), 1343-1357. <https://doi.org/10.1108/IJSHE-02-2019-0103>
- Quesada, V., Gómez Ruiz, M. Á., Gallego Noche, M.B., & Cubero-Ibáñez, J. (2019). Should I use co-assessment in higher education? Pros and cons from teachers and students’ perspectives. *Assessment & Evaluation in Higher Education*, 44(7), 987-1002. <https://doi.org/10.1080/02602938.2018.1531970>
- Radinger-Peer, V., Schuppenlehner-Kloyber, E., Penker, M., & Gugerell, K. (2022). Different perspectives on a common goal? The Q-method as a formative assessment to elucidate varying expectations towards transdisciplinary research collaborations. *Sustainability Science*, 17, 2459-2472. <https://doi.org/10.1007/s11625-022-01192-1>
- Rantavouri, J., Engeström, Y., & Lipponen, L. (2016). Learning actions, objects and types of interaction: A methodological analysis of expansive learning among pre-service teachers. *Frontline Learning Research*, 4(3), 1-27. <https://doi.org/10.14786/flr.v4i3.174>
- Raworth, K. (2012). *A safe and just space for humanity: Can we live within the doughnut?* Oxfam.
- Raymond, C.M., Anderson, C.B., Athayde, S., Vatn, A., Amin, A.M., Arias-Arévalo, P., Christie, M., Cantú-Fernández, M., Gould, R.K., Himes, A., Kenter, J.O., Lenzi, D., Muraca, B., Murali, R., O’Connor, S., Pascual, U., Sachdeva, S., Samakov, A., & Zent, E. (2023). An inclusive typology of values for navigating transformations towards a just and sustainable future. *Current Opinion in Environmental Sustainability*, 64, 101301. <https://doi.org/10.1016/j.cosust.2023.101301>
- Redman, A., & Wiek, A. (2021). Competencies for advancing transformations towards sustainability. *Frontiers in Education*, 6, 785163. <https://doi.org/10.3389/educ.2021.785163>
- Redman, A., Wiek, A., & Barth, M. (2021). Current practices of assessing students’ sustainability competencies: A review of tools. *Sustainability Science*, 16, 117-135. <https://doi.org/10.1007/s11625-020-00855-1>

- Reed, M.S., Evely, A.C., Cundill, G., Fazey, I., Glass, J., Laing, A., Newig, J., Parrish, B., Prell, C., Raymond, C., & Stringer, L.C. (2010). What is social learning? *Ecology and Society*, 15(4), r1.
- Reynolds, M., & Trehan, K. (2000). Assessment: A critical perspective. *Studies in Higher Education*, 25(3), 267-278. <https://doi.org/10.1080/03075070050193406>
- Rickett, C., Joseph, S., Northcote, M., Christian, B.J., & Seddon, J. (2019). Peripheries and praxis: The effect of rubric co-construction on student perceptions of their learning. *TEXT*, 23(57). <https://doi.org/10.52086/001c.23589>
- Robinson, J. (2003). Future subjunctive: Backcasting as social learning. *Futures*, 35(8), 839-856. [https://doi.org/10.1016/S0016-3287\(03\)00039-9](https://doi.org/10.1016/S0016-3287(03)00039-9)
- Rocca, K.A. (2010). Student participation in the college classroom: An extended multidisciplinary literature review. *Communication Education*, 59(2), 185-213. <https://doi.org/10.1080/03634520903505936>
- Ruppert-Winkel, C., Arlinghaus, A., Deppisch, S., Eisenack, K., Gotsschlich, D., Hirschl, B., Matzdorf, B., Mölders, T., Padmanabhan, M., Selbmann, K., Ziegler, R., & Plieninger, T. (2015). Characteristics, emerging needs, and challenges of transdisciplinary sustainability science: Experiences from the German Social-Ecological Research Program. *Ecology and Society*, 20(3), 13.
- Sahakian, M., Wilhite, H. (2014). Making practice theory practicable: Towards more sustainable forms of consumption. *Journal of Consumer Culture*, 14(1), 25-44. <https://doi.org/10.1177/1469540513505607>
- Sala, S., Ciuffo, B., & Nijkamp, P. (2015). A systematic framework for sustainability assessment. *Ecological Economics*, 119, 314-325. <https://doi.org/10.1016/j.ecolecon.2015.09.015>
- Sala, S., Farioli, F., & Zamagni, A. (2013). Progress in sustainability science: Lessons learnt from current methodologies for sustainability assessment: Part 1. *The International Journal of Life Cycle Assessment*, 18, 1653-1672. <https://doi.org/10.1007/s11367-012-0508-6>
- Salonen, A.O., Laininen, E., Hämäläinen, J., & Sterling, S. (2023). A theory of planetary social pedagogy. *Educational Theory*, 73(4), 615-637. <https://doi.org/10.1111/edth.12588>
- Sandri, O. (2022). What do we mean by ‘pedagogy’ in sustainability education? *Teaching in Higher Education*, 27(1), 114-129. <https://doi.org/10.1080/13562517.2019.1699528>

- Sannino, A., Engeström, Y., & Lemos, M. (2016). Formative interventions for expansive learning and transformative agency. *Journal of the Learning Sciences, 25*(4), 599-633. <https://doi.org/10.1080/10508406.2016.1204547>
- Sarewitz, D., Clapp, D., Crumbley, C., Hoppin, P., Jacobs, M., Kriebel, & Tickner, J. (2012). The sustainability solutions agenda. In R. Clapp (Ed.), *From critical science to solutions: The best of scientific solutions* (pp. 195-206). Taylor & Francis Group.
- Schellekens, L.H., Bok, H.G.J., de Jong, L.H., van der Schaaf, M.F., Kremer, W.D.J., & van der Vleuten, C.P.M. (2021). A scoping review on the notions of assessment as learning (AaL), assessment for learning (AfL), and assessment of learning (AoL). *Studies in Educational Evaluation, 71*, 101094. <https://doi.org/10.1016/j.stueduc.2021.101094>
- Scholz, R.W., & Steinder, G. (2015a). The real type and ideal type of transdisciplinary processes: Part I—Theoretical foundations. *Sustainability Science, 10*, 527-544. <https://doi.org/10.1007/s11625-015-0326-4>
- Scholz, R.W., & Steinder, G. (2015b). The real type and ideal type of transdisciplinary processes: Part II—What constraints and obstacles do we meet in practice? *Sustainability Science, 10*, 653-671. <https://doi.org/10.1007/s11625-015-0327-3>
- Scott, D. (2005). Critical realism and empirical research methods in education. *Journal of Philosophy of Education, 39*(4), 633-646. <https://doi.org/10.1111/j.1467-9752.2005.00460.x>
- Serrano, M.M., O'Brien, M., Roberts, K., & Whyte, D. (2018). Critical pedagogy and assessment in higher education: The ideal of 'authenticity' in learning. *Active Learning in Higher Education, 19*(1), 9-21. <https://doi.org/10.1177/1469787417723244>
- Shaw, I., Greene, J.C., & Mark, M.M. (2006). *The SAGE handbook of evaluation*. Sage Publications Ltd.
- Shay, S. (2008). Researching assessment as social practice: Implications for research methodology. *International Journal of Educational Research, 47*(3), 159-164. <https://doi.org/10.1016/j.ijer.2008.01.003>
- Shephard, K. (2009). e is for exploration. Assessing hard-to-measure learning outcomes. *British Journal of Educational Technology, 40*(2), 386-398. <https://doi.org/10.1111/j.1467-8535.2008.00927.x>
- Shephard, K. (2015). *Higher education for sustainable development*. Palgrave Macmillan.

- Shephard, K. (2022). On the educational difference between being able and being willing. In P. Vare, N. Lausset, & M. Rieckmann, *Competences in education for sustainable development* (pp. 45-52). Springer.
- Shove, E., Pantzar, M., & Watson, M. (2012). *The dynamics of social practice: Everyday life and how it changes*. Sage.
- Sia, C.J.L., & Lim, C.S. (2018). Cognitive diagnostic assessment: An alternative mode of assessment for learning. In D. Thompson, M. Burton, A. Cusi, & D. Wright (Eds.), *Classroom assessment in mathematics* (pp. 123-137). [https://doi.org/10.1007/978-3-319-73748-5\\_9](https://doi.org/10.1007/978-3-319-73748-5_9)
- Sinclair, A.J., Diduck, A., & Fitzpatrick, P. (2008). Conceptualizing learning for sustainability through environmental assessment: Critical reflections on 15 years of research. *Environmental Impact Assessment Review*, 28(7), 415-428. <https://doi.org/10.1016/j.eiar.2007.11.001>
- Singer-Brodowski, M. (2023). The potential of transformative learning for sustainability transitions: Moving beyond formal learning environments. *Environment, Development and Sustainability*. <https://doi.org/10.1007/s10668-022-02444-x>
- Singh, R.K., Murty, H.R., Gupta, S.K., & Dikshit, A.K. (2012). An overview of sustainability assessment methodologies. *Ecological Indicators*, 15(1), 281-299. <https://doi.org/10.1016/j.ecolind.2011.01.007>
- Smeers, I., Himpens, J., Granticelli, L., & Snick, A. (2020). Co-creating a young persons' guide to a sustainable future: Analysis of learning steps in a transdisciplinary honours course. *Transdisciplinary Insights*, 4(1), 25-47. <https://doi.org/10.11116/TDI2020.4.2>
- Smith, R., & Rebolledo, P. (2018). *A handbook for exploratory action research*. British Council.
- Sokhanvar, Z., Salehi, K., & Sokhanvar, F. (2021). Advantages of authentic assessment for improving the learning experience and employability skills of higher education students: A systematic literature review. *Studies in Educational Evaluation*, 70, 101030. <https://doi.org/10.1016/j.stueduc.2021.101030>
- Souza, D.T., Wals, A.E.J., & Jacobi, P.R. (2019). Learning-based transformation towards sustainability: A relational approach based on Humberto Maturana and Paulo Freire. *Environmental Education Research*, 25(11), 1605-1619. <https://doi.org/10.1080/13504622.2019.1641183>

- Stahl, C., Cimorelli, A., Mazzarella, C., & Jenkins, B. (2011). Toward sustainability: A case study demonstrating transdisciplinary learning through the selection and use of indicators in a decision-making process. *Integrated Environmental Assessment and Management*, 7(3), 483-498. <https://doi.org/10.1002/ieam.181>
- Star, S. (1989). The structure of ill-structured solutions: Boundary objects and heterogeneous distributed problem solving. In L. Gasser, & M. Huhns (Eds.), *Distributed artificial intelligence* (pp. 37-54). Morgan Kaufman.
- Stauffacher, M., Walter, A.I., Lang, D.J., Wiek, A., & Scholz, R.W. (2006). Learning to research environmental problems from a functional socio-cultural constructivism perspective: The transdisciplinary case study approach. *International Journal of Sustainability in Higher Education*, 7(4), 252-275. <https://doi.org/10.1108/14676370610677838>
- Sterling, S. (2011). Transformative learning and sustainability: Sketching the conceptual ground. *Learning and Teaching in Higher Education*, (5)11, 17-33.
- Sterling, S., Glasser, H., Rieckmann, M., & Warwick, P. (2017). "More than scaling up": A critical and practical inquiry into operationalizing sustainability competencies. In P.B. Corcoran, J.P. Weakland, and A.E.J. Wals (Eds.), *Envisioning futures for environmental and sustainability education* (pp. 153-168). Wageningen Academic.
- Sterling, S., Warwick, P., & Wyness, L. (2015). Understanding approaches to ESD research on teaching and learning in higher education. In M. Barth, G. Michelsen, M. Rieckmann, & I. Thomas (Eds.), *Routledge handbook of higher education for sustainable development* (pp. 89-99). Routledge.
- Stilgoe, J., Owen, R., & Macnaghten, P. (2013). Developing a framework for responsible innovation. *Research Policy*, 42(9), 1568-1580. <https://doi.org/10.1016/j.respol.2013.05.008>
- Sturgiss, E.A., & Clark, A.M. (2020). Using critical realism in primary care research: An overview of methods. *Family Practice*, 37(1), 143-145. <https://doi.org/10.1093/fampra/cmz084>
- Suchman, L. (1993). Working relations of technology production and use. *Computer Supported Cooperative Work*, 2, 21-39. <https://doi.org/10.1007/BF00749282>
- Tai, J., Ajjawi, R., Boud, D., Dawson, P., & Panadero, E. (2018). Developing evaluative judgement: Enabling students to make decisions about the quality of work. *Higher Education*, 76, 467-481. <https://doi.org/10.1007/s10734-017-0220-3>

- Taras, M. (2002). Using assessment for learning and learning from assessment. *Assessment & Evaluation in Higher Education*, 27(6), 501-510. <https://doi.org/10.1080/0260293022000020273>
- Taras, M. (2009). Summative assessment: The missing link for formative assessment. *Journal of Further and Higher Education*, 33(1), 57-69. <https://doi.org/10.1080/03098770802638671>
- Taylor, S.N. (2013). Student self-assessment and multisource feedback assessment: Exploring benefits, limitations, and remedies. *Journal of Management Education*, 38(3), 359-383. <https://doi.org/10.1177/1052562913488111>
- Tejada, G., Cracco, M., Boluleau, C.R., Bolay, J., & Hostettler, S. (2019). Testing analytical frameworks in transdisciplinary research for sustainable development. *Sustainability*, 11(16), 4343. <https://doi.org/10.3390/su11164343>
- van Drooge, L., & Spaapen, J. (2022). Evaluation and monitoring of transdisciplinary collaborations. *The Journal of Technology Transfer*, 47, 747-761. <https://doi.org/10.1007/s10961-017-9607-7>
- van Kerkhoff, L., & Lebel, L. (2006). Linking knowledge and action for sustainable development. *Annual Review of Environment and Resources*, 31, 445-477. <https://doi.org/10.1146/annurev.energy.31.102405.170850>
- van Mierlo, B., & Beers, P.J. (2020). Understanding and governing learning in sustainability transitions: A review. *Environmental Innovation and Societal Transitions*, 34, 255-269. <https://doi.org/10.1016/j.eist.2018.08.002>
- van Mierlo, B., Halbe, J., Beers, P.J., Scholz, G., & Vinke-de Kruijf, J. (2020). Learning about learning in sustainability transitions. *Environmental Innovation and Societal Transitions*, 34, 251-254. <https://doi.org/10.1016/j.eist.2019.11.001>
- van Zundert, M., Sluijsmans, D., & van Merriënboer, J. (2010). Effective peer assessment processes: Research findings and future directions. *Learning and Instruction*, 20(4), 270-279. <https://doi.org/10.1016/j.learninstruc.2009.08.004>
- Vattøy, K., Gamlen, S.M., & Rogne, W.M. (2021). Examining students' feedback engagement and assessment experiences: A mixed study. *Studies in Higher Education*, 21(11), 2325-2337. <https://doi.org/10.1080/03075079.2020.1723523>
- Veiga Ávila, L., Neuron, T.A., Brandli, L.L., Damke, L.I., Pereira, R.S., & Klein, L.L. (2019). Barriers to innovation and sustainability in universities: An international comparison. *International Journal of Sustainability in Higher Education*, 20(5), 805-821. <https://doi.org/10.1108/IJSHE-02-2019-0067>

- Vuojärvi, H., Vartiainen, H., Eriksson, M., Ratinen, I., Saramäki, K., Torssonen, P., Vanninen, P., & Pöllänen, S. (2022). Boundaries and boundary crossing in a multidisciplinary online higher education course on forest bioeconomy. *Teaching in Higher Education*. <https://doi.org/10.1080/13562517.2022.2122791>
- Walker, B., Crépin, A., Nyström, M., Anderies, J.M., Andersson, E., Elmqvist, T., Queiroz, C., Barrett, S., Bennett, E., Cardenas, J.C., Carpenter, S.R., Chapin III, F.S., de Zeeuw, A., Fischer, J., Folke, C., Levin, S., Nyborg, K., Polasky, S., Segerson, K.,... Vincent, J.R. (2023). Response diversity as a sustainability strategy. *Nature Sustainability*, 6, 621-629. <https://doi.org/10.1038/s41893-022-01048-7>
- Wals, A.E.J. (Ed.) (2007). *Social learning: Towards a sustainable world*. Wageningen Academic Publishers.
- Wals, A.E.J. (2010). Mirroring, gestaltswitching and transformative social learning: Stepping stones for developing sustainability competence. *International Journal of Sustainability in Higher Education*, 11(4), 380-390. <https://doi.org/10.1108/14676371011077595>
- Wals, A.E.J. (2014). Sustainability in higher education in the context of the UN DESD: A review of learning and institutionalization processes. *Journal of Cleaner Production*, 62, 8-15. <https://doi.org/10.1016/j.jclepro.2013.06.007>
- Wals, A.E.J., & Rodela, R. (2014). Social learning towards sustainability: Problematic, perspectives and promise. *NJAS - Wageningen Journal of Life Sciences*, 69(6), 1-3. <https://doi.org/10.1016/j.njas.2014.04.001>
- Walsh, Z., Böhme, J., Lavelle, B.D., & Wamsler, C. (2020). Transformative education: towards a relational, justice-oriented approach to sustainability. *International Journal of Sustainability in Higher Education*, 21(7), 1587-1606. <https://doi.org/10.1108/IJSHE-05-2020-0176>
- Waltner, E., Rieß, W., Mischo, C. (2019). Development and validation of an instrument for measuring student sustainability competencies. *Sustainability*, 11(6), 1717. <https://doi.org/10.3390/su11061717>
- Warr Pedersen, K. (2017). Supporting collaborative and continuing professional development in education for sustainability through a communities of practice approach. *International Journal of Sustainability in Higher Education*, 18(5), 681-696. <https://doi.org/10.1108/IJSHE-02-2016-0033>
- Weiss, M., Barth, M., & von Wehrden, H. (2021). The patterns of curriculum change processes that embed sustainability in higher education institutions. *Sustainability Science*, 16, 1579-1593. <https://doi.org/10.1007/s11625-021-00984-1>

- Welch, D., & Yates, L. (2018). The practices of collective action: Practice theory, sustainability transitions and social change. *Journal for the Theory of Social Behaviour*, 48(3), 288-305. <https://doi.org/10.1111/jtsb.12168>
- West, S., van Kerkhoff, L., Wagenaar, H. (2019). Beyond “linking knowledge and action”: Towards a practice-based approach to transdisciplinary sustainability interventions. *Policy Studies*, 40(5), 534-555. <https://doi.org/10.1080/01442872.2019.1618810>
- Westberg, L., & Polk, M. (2016). The role of learning in transdisciplinary research: Moving from a normative concept to an analytical tool through a practice-based approach. *Sustainability Science*, 11, 385-397. <https://doi.org/10.1007/s11625-016-0358-4>
- Wickson, F., & Carew, A.L. (2014). Quality criteria and indicators for responsible research and innovation: Learning from transdisciplinarity. *Journal of Responsible Innovation*, 1(3), 254-273. <https://doi.org/10.1080/23299460.2014.963004>
- Wiek, A., Bernstein, M.J., Foley, R.W., Cohen, M., Forrest, N., Kuzdas, C., Kay, B., & Withycombe Keeler, L. (2015). Operationalising competencies in higher education for sustainable development. In M. Barth, G. Michelsen, M. Rieckmann, & I. Thomas (Eds.), *Routledge handbook of higher education for sustainable development* (pp. 241-260). Routledge.
- Wiek, A., & Kay, B. (2015). Learning while transforming: Solution-oriented learning for urban sustainability in Phoenix, Arizona. *Current Opinion in Environmental Sustainability*, 16, 29-36. <https://doi.org/10.1016/j.cosust.2015.07.001>
- Wiek, A., & Lang, D.J. (2016). Transformational sustainability research methodology. In H. Heinrichs, P. Martens, G. Michelsen, & A. Wiek (Eds.), *Sustainability science: An introduction* (pp. 31-41). Springer. [https://doi.org/10.1007/978-94-017-7242-6\\_3](https://doi.org/10.1007/978-94-017-7242-6_3)
- Wiek, A., & Larson, K.L. (2012). Water, people, and sustainability - A systems framework for analyzing and assessing water governance regimes. *Water Resources Management*, 26, 3153-3171. <https://doi.org/10.1007/s11269-012-0065-6>
- Wiek, A., Ness, B., Schweizer-Ries, P., Brand, F.S., & Farioli, F. (2012). From complex systems analysis to transformational change: A comparative appraisal of sustainability science projects. *Sustainability Science*, 7, 5-24. <https://doi.org/10.1007/s11625-011-0148-y>

- Wiek, A., Talwar, S., O'Shea, M., & Robinson, J. (2014). Toward a methodological scheme for capturing societal effects of participatory sustainability research. *Research Evaluation*, 23(2), 117-132. <https://doi.org/10.1093/reseval/rvt031>
- Wiek, A., Withycombe, L., & Redman, C.L. (2011). Key competencies in sustainability: A reference framework for academic program development. *Sustainability Science*, 6, 203-218. <https://doi.org/10.1007/s11625-011-0132-6>
- Wilhelm, S., Förster, R., Zimmerman, A.B. (2019). Implementing competence orientation: Towards constructively aligned education for sustainable development in university-level teaching-and-learning. *Sustainability*, 11(7), 1891. <https://doi.org/10.3390/su11071891>
- William, D. (2011). What is assessment for learning? *Studies in Educational Evaluation*, 37(1), 3-14. <https://doi.org/10.1016/j.stueduc.2011.03.001>
- Williams, S., & Robinson, J. (2020). Measuring sustainability: An evaluation framework for sustainability transition experiments. *Environmental Science & Policy*, 103, 58-66. <https://doi.org/10.1016/j.envsci.2019.10.012>
- Winstone, N.E., & Boud, D. (2022). The need to disentangle assessment and feedback in higher education. *Studies in Higher Education*, 47(3), 656-667. <https://doi.org/10.1080/03075079.2020.1779687>
- Wittmayer, J.M., & Schöpke, N. (2014). Action, research and participation: Roles of researchers in sustainability transitions. *Sustainability Science*, 9, 483-496. <https://doi.org/10.1007/s11625-014-0258-4>
- Zhao, K., Zhou, J., & Dawson, P. (2021). Using student-instructor co-constructed rubrics in signature assessment for business students: Benefits and challenges. *Assessment in Education: Principles, Policy & Practice*, 28(2), 170-190. <https://doi.org/10.1080/0969594X.2021.1908225>
- Zimmerman, B.J. (2002). Becoming a self-regulated learner: An overview. *Theory Into Practice*, 41(2), 64-70. [https://doi.org/10.1207/s15430421tip4102\\_2](https://doi.org/10.1207/s15430421tip4102_2)
- Zou, T.X.P., Kochhar-Lindgren, G., Hoang, A.P., Lam, K., Barry, T.J., & Leung, L.Y.Y. (2023). Facilitating students as partners: Co-researching with undergraduates in Asian university contexts. *Educational Review*. <https://doi.org/10.1080/00131911.2023.2246674>
- Zu, L. (2023). Wicked problems and sustainability challenges in the era of VUCA. In S.O. Idowu, & L. Zu (Eds.), *The Elgar companion to corporate social responsibility and the Sustainable Development Goals* (pp. 9-26). <https://doi.org/10.4337/9781803927367.00010>

APPENDIX A  
ANNOTATED LIST OF ADDITIONAL WORKS

Over the course of completing this dissertation, I have also developed an array of intersecting work that supplements the research presented in this document. This Appendix provides a list of works with brief summaries in order to elaborate on the achievements of this dissertation.

### **Journal Articles**

Casanova, C.R., King, J.A., Fischer, D. (2023). Exploring the role of intentions and expectations in continuing professional development in sustainability education. *Teaching and Teacher Education, 128*, 104115.  
<https://doi.org/10.1016/j.tate.2023.104115>

This article examined how the intentions and expectations of instructors and participants in a professional development program on sustainability education can be leveraged in evaluating program inputs, activities, and outcomes. The paper adapts a typical logic model to develop a Socio-Relational Evaluation Framework. This framework links to the inclusive assessment strategies and participatory research approach demonstrated in this dissertation.

Fischer, D., King, J.A., Rieckmann, M., Barth, M., Büssing, A., Hemmer, I., Lindau-Bank, D. (2022). Teacher education for sustainable development: A review of an emerging research field. *Journal of Teacher Education, 73*(5), 509-524.  
<https://doi.org/10.1177/00224871221105784>

This article provides an overview of the literature at the intersection of sustainability education and teacher education. Participating as a co-lead author on this project during the early phases of my program supported the development of my abilities

to lead research and synthesize insights to map complex and dynamic scholarly areas that cut across fields.

King, J.A. (2021). Shades of becoming towards regenerative futures: Revelatory purposes and processes in sustainability education and public pedagogy. *Journal of Public Pedagogies*, 6, 39-56. <https://doi.org/10.15209/jpp.1244>

This article takes a conceptual approach to explore the areas of convergence between the field of public pedagogy (generally focused on critical, reflexive informal learning) and sustainability education. A framework highlighting how insights from sustainability education can facilitate un-learning, re-learning, and learning (presented as “shades of becoming”) is described as a way to orient the purpose dimension of public pedagogy in response to complex social-ecological challenges.

Hakkarainen, V., King, J., Brundiers, K., Redman, A., Anderson, C.B., Goodall, C., Pate, A., & Raymond, C.M. (in review). Online sustainability education: Purpose, process and implementation for transformative universities. *International Journal of Sustainability in Higher Education*.

This article examines three case studies from different international contexts in order to investigate how sustainability education is practiced in online settings. Findings map challenges and opportunities in this space, while bringing to the forefront the programmatic and logistical aspects that informed innovative approaches, as explored throughout this dissertation.

## **Books**

Fischer, D., Sahakian, M., King, J., Dyer, J., Seyfang, G. (Eds.) (2023). *Teaching and learning sustainable consumption: A guidebook*. Routledge.

This book provided an overview of the emerging field of teaching and learning sustainable consumption in higher education. The collaborative project brings together a first part with the conceptual background of the field with a second part that highlights practical examples from settings around the world. Participating in this project was helpful in building my expertise on the broader field of sustainability education in higher education by engaging with a diverse range of instructors and analyzing myriad examples of how teaching, learning, and assessment are practiced in the field.

### **Book Chapters**

King, J., Fischer, D., Sahakian, M., Dyer, J., & Seyfang, G. (2023). Learning objectives for teaching sustainable consumption. In D. Fischer, M. Sahakian, J. King, J. Dyer, & G. Seyfang (Eds.), *Teaching and learning sustainable consumption: A guidebook* (pp. 32-48). Routledge.

This book chapter synthesized key approaches to learning objectives in the field, mapping different perspectives to suggest how they might be operationalized in practice.

King, J., Fischer, D., Sahakian, M., Dyer, J., & Seyfang, G. (2023). Assessing learning in teaching sustainable consumption. In D. Fischer, M. Sahakian, J. King, J. Dyer, & G. Seyfang (Eds.), *Teaching and learning sustainable consumption: A guidebook* (pp. 49-65). Routledge.

This book chapter offered the opportunity to delve into the assessment literature in order to become more familiar with achievements and gaps by presenting an overview of work in this space. The framing presented on this topic, as well as many of the initial insights and implications derived from this work, have informed subsequent efforts in my dissertation.

King, J., Fischer, D., & Brundiers, K. (2023). A change is gonna come: Designing campus interventions to promote behavior change for sustainable consumption. In D. Fischer, M. Sahakian, J. King, J. Dyer, & G. Seyfang (Eds.), *Teaching and learning sustainable consumption: A guidebook* (pp. 296-301). Routledge.

This book chapter describes a practical example of an applied learning project focused on promoting behavior change for sustainable consumption on the ASU campus. In the project, students collaborated with campus partners to develop behavior change interventions. Describing this project and its connections to important concepts in the field was informative for me in thinking about how to link theory and practice in my research.

Fischer, D., King, J., Sahakian, M., Dyer, J., & Seyfang, G. (2023). Learning theories and pedagogies in teaching sustainable consumption. In D. Fischer, M. Sahakian, J. King, J. Dyer, & G. Seyfang (Eds.), *Teaching and learning sustainable consumption: A guidebook* (pp. 17-31). Routledge.

This book chapter outlines several key learning theories and pedagogical approaches that are commonly used in the field. Supporting the development of this chapter was helpful for me in thinking about the distinctive features of sustainability education and how they converge or diverge with broader innovative practices.

Fischer, D., King, J., & Casanova, C.R. (2023). I can't get no satisfaction: Deliberating needs and satisfiers in sustainable consumption. In D. Fischer, M. Sahakian, J. King, J. Dyer, & G. Seyfang (Eds.), *Teaching and learning sustainable consumption: A guidebook* (pp. 302-307). Routledge.

This book chapter explains a pedagogical approach that engaged students in experiential, personalized learning to alter relationships to sustainable consumption in their everyday lives. Articulating the example was helpful in attempting to think from the students' perspective, which has informed other aspects of this dissertation.

Sahakian, M., King, J., Dyer, J., Fischer, D., & Seyfang, G. (2023). Sustainable consumption, a tricky topic to teach. In D. Fischer, M. Sahakian, J. King, J. Dyer, & G. Seyfang (Eds.), *Teaching and learning sustainable consumption: A guidebook* (pp. 3-16). Routledge.

This book chapter provides a summary of the field of teaching and learning sustainable consumption in higher education. Completing this was helpful in synthesizing key features and functions of the field, as well as how they are translated into practice in different contexts.

Sahakian, M., King, J., Dyer, J., Fischer, D., & Seyfang, G. (2023). Examples of teaching and learning in sustainable consumption. In D. Fischer, M. Sahakian, J. King, J. Dyer, & G. Seyfang (Eds.), *Teaching and learning sustainable consumption: A guidebook* (pp. 67-75). Routledge.

This book chapter provides an overview of examples from around the world that demonstrate different strategies for teaching and learning sustainable consumption. Engaging in this space was helpful to think about the variety of contexts in which sustainability education is practiced in higher education.

King, J. (2023). A design-based approach to activating key competencies in sustainability through multifaceted formative assessment. In R. Potter, K. Hiser, T. Evans, I. Feldman (Eds.), *Key competencies: Practical approaches to teaching*

*sustainability* (pp. 97-107). Sustainability Curriculum Consortium and The Association for the Advancement of Sustainability in Higher Education.

This book chapter describes an action research method and pedagogical approach that I implemented as a type of pilot study for exploring assessment in its applications within sustainability education in higher education. The conceptual, methodological, and practical ideas that I engaged provided a foundation for several elements of my work in this dissertation.

King, J., Rieckmann, M., Fischer, D., Barth, M., Büssing, A., Hemmer, I., Lindau-Bank, D. (2022). International trends in environmental and sustainability education-teacher education. In M.A. Peters (Ed.), *Encyclopedia of teacher education*. Springer.

This book chapter synthesizes forms of research on sustainability education in teacher education. The process of leading this chapter was helpful for thinking about how to develop typologies of broad areas of work, as well as in gaining experience in facilitating collaborative writing processes.

King, J., & Casanova, C.R. (2021). Pedagogies for cultivating critical consciousness: Principles for teaching and learning to engage with racial equity, social justice, and sustainability. In M. Urbanski, & J. Dautremont (Eds.), *No sustainability without justice: An anthology on racial equity & social justice* (pp. 58-65). The Association for the Advancement of Sustainability in Higher Education.

This book chapter examined connections between sustainability education and social justice education. This was a helpful project for thinking about how practice in the field can engage with justice, equity, diversity, and inclusion while promoting critical

consciousness among students. Several of these tenets surfaced in other areas of this dissertation.

King, J., Brundiars, K., & Hiser, K. (expected publication March 2024). Needs and opportunities in the design and evaluation of sustainability programs in higher education: Insights from the Global Council for Science and the Environment's Pathways toward Accreditation initiative. In M. Starik & P. Shrivastava (Eds.), *Sustainable universities and colleges: Leading or following society toward resilience?* Edward Elgar Publishing.

This book chapter reviews a range of literature to identify key needs and opportunities for how sustainability programs in higher education are designed and evaluated. Engaging with this literature supported me to think critically about gaps in the field and how my research might address them.

## **Reports**

Brundiars, K., King, J., Hiser, K., Wyman, M., & Parnell, R. (2023). *Key competencies in sustainability: A GCSE proposal statement*. Global Council for Science and the Environment.

This report presented the shared reference framework on key competencies in sustainability as foundation for developing program-level learning objectives related to sustainability in higher education. The report was followed by an input process to gather feedback from stakeholders and practitioners in the field, which helped to directly inform my research in thinking about best practices and innovations in teaching, learning, and assessment across different contexts.

Brundiars, K., King, J., & Hiser, K. (forthcoming April 2024). *Convergence statement on key competencies in sustainability: A guide for program design and evaluation in higher education*. Global Council for Science and the Environment.

This report builds from the above and the related input process to describe convergence on the key competencies in sustainability as a framework for program-level learning objectives. The report also provides insights on operationalizing this into practice to support program leaders and instructors, offering a practical output related to much of my dissertation work.

### **Conference Papers**

King, J., Ramey, A., Brundiars, K., & Hiser, K. (2023). Closing the sustainability skills gap: Workforce perspectives on the key competencies in sustainability from the Global Council for Science and the Environment's Sustainability Education Initiative. In *Proceedings from the International Conference on Sustainable Development 2023*. Sustainable Development Solutions Network.

This conference paper investigates the link between sustainability education in higher education with the development of sustainability professionals who can operate across a range of fields and contexts. Completing this project, which synthesizes key practical insights and presents recommendations for cross-cutting initiatives in the field, was helpful in considering the broader context of higher education and its link to sustainability as developed through professional organizations.

King, J. (2021). Generating transformative learning futures: Leveraging innovations in assessment to activate sustainability competencies. In *Proceedings from the 1st International Yidan Prize Doctoral Conference*. University of Oxford.

This conference paper was an initial attempt to outline some of the assessment literature and its potential contributions to the discourse on sustainability education. In this way, it provided a helpful foundation for the further cross-pollination among fields that I would explore.

King, J. (2020). Pursuing the Sustainable Development Goals through teaching and learning: A review of interdisciplinary research in higher education. In J.D. Sachs (Ed.), *Proceedings from the International Conference on Sustainable Development 2020*. Sustainable Development Solutions Network.

This conference paper offered the opportunity to map engagement with sustainability across higher education. I reviewed research connected to the SDGs in teaching and learning in order to understand trends and gaps in the discourse. This helped to provide a basis from which to delve into more targeted directions, such as the link to assessment. The paper was also awarded best paper in its theme for the conference.

APPENDIX B  
PUBLICATION STATUS OF STUDIES

Study 1 has been published in *Assessment & Evaluation in Higher Education* as “Student agency in a sustainability-oriented assessment process: Exploring expansive learning in student-led rubric co-design”, with co-authors Katja Brundiers and Daniel Fischer, who have granted their permission for use of this work.

Study 2 has been submitted for publication to the *International Journal of Sustainability in Higher Education* as “Boundary crossings: Innovating assessment practices in higher education”.

Study 3 has been submitted for publication to *Sustainability Science* as “Assessment-oriented sustainability: Infusing educational principles into transdisciplinary strategies to promote learning”.

APPENDIX C  
IRB APPROVALS



EXEMPTION GRANTED

Katja Brundiers  
 CGF-SOS: Faculty & Researchers  
 480/965-1304  
 Katja.Brundiers@asu.edu Dear

Katja Brundiers:

On 8/19/2022 the ASU IRB reviewed the following protocol:

Type of Review:	Initial Study
Title:	Student-Centered Assessment of Sustainability- Related Professional Skills
Investigator:	Katja Brundiers
IRB ID:	STUDY00016401
Funding:	None
Grant Title:	None
Grant ID:	None
Documents Reviewed:	<ul style="list-style-type: none"> <li>• Consent_08-15-2022.pdf, Category: Consent Form;</li> <li>• Focus Group Activity 1_08-15-2022.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions);</li> <li>• Focus Group Activity 2_08-15-2022.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions);</li> <li>• Focus Group Activity 3_08-15-2022.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions);</li> <li>• Focus Group Activity 4_08-15-2022.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions);</li> <li>• Protocol_08-15-2022.docx, Category: IRB</li> </ul>

	Protocol; • Recruitment Script_08-15-2022.pdf, Category: Recruitment Materials; • Reflective Questionnaires_08-15-2022.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions); • Supporting Documents 08-15-2022.pdf, Category: Resource list;
--	---

The IRB determined that the protocol is considered exempt pursuant to Federal Regulations 45CFR46 (1) Educational settings, (2) Tests, surveys, interviews, or observation on 8/19/2022.

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

If any changes are made to the study, the IRB must be notified at [research.integrity@asu.edu](mailto:research.integrity@asu.edu) to determine if additional reviews/approvals are required. Changes may include but not limited to revisions to data collection, survey and/or interview questions, and vulnerable populations, etc.

REMINDER - - Effective January 12, 2022, in-person interactions with human subjects require adherence to all current policies for ASU faculty, staff, students and visitors. Up-to-date information regarding ASU's COVID-19 Management Strategy can be found [here](#). IRB approval is related to the research activity involving human subjects, all other protocols related to COVID-19 management including face coverings, health checks, facility access, etc. are governed by current ASU policy.

Sincerely,

IRB Administrator

cc: Jordan King

EXEMPTION GRANTED

Katja Brundiers  
 CGF-SOS: Faculty & Researchers  
 480/965-1304  
 Katja.Brundiers@asu.edu

Dear Katja Brundiers:

On 2/9/2023 the ASU IRB reviewed the following protocol:

Type of Review:	Initial Study
Title:	Input Process on Key Competencies in Sustainability Framework
Investigator:	Katja Brundiers
IRB ID:	STUDY00017465
Funding:	None
Grant Title:	None
Grant ID:	None
Documents Reviewed:	<ul style="list-style-type: none"> <li>• Consent_Focus Group_08-02-2023.pdf, Category: Consent Form;</li> <li>• Consent_Online Survey_08-02-2023.pdf, Category: Consent Form;</li> <li>• Protocol_08-02-2023.docx, Category: IRB Protocol;</li> <li>• Recruitment_Methods_Focus Group Interest Form_08-02-2023.pdf, Category: Recruitment Materials;</li> <li>• Recruitment_Methods_Online Survey Email_08-02-2023.pdf, Category: Recruitment Materials;</li> <li>• Supporting Documents_08-02-2023.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions);</li> </ul>

The IRB determined that the protocol is considered exempt pursuant to Federal Regulations 45CFR46 (2)(i) Tests, surveys, interviews, or observation (non-identifiable), (2)(ii) Tests, surveys, interviews, or observation (low risk) on 2/9/2023.

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

If any changes are made to the study, the IRB must be notified at [research.integrity@asu.edu](mailto:research.integrity@asu.edu) to determine if additional reviews/approvals are required. Changes may include but not limited to revisions to data collection, survey and/or interview questions, and vulnerable populations, etc.

Sincerely,

IRB Administrator

cc: Jordan King



EXEMPTION GRANTED

Katja Brundiers

CGF-SOS: Faculty & Researchers  
480/965-1304

Katja.Brundiers@asu.edu

Dear Katja Brundiers:

On 5/19/2023 the ASU IRB reviewed the following protocol:

Type of Review:	Modification / Update
Title:	Input Process on Key Competencies in Sustainability Framework
Investigator:	Katja Brundiers
IRB ID:	STUDY00017465
Funding:	None
Grant Title:	None
Grant ID:	None
Documents Reviewed:	<ul style="list-style-type: none"> <li>• Consent_Phase 2 Interview_05-17-2023.pdf, Category: Consent Form;</li> <li>• Consent_Phase 2 Survey_05-17-2023.pdf, Category: Consent Form;</li> <li>• Protocol Modification_05-17-2023.docx, Category: IRB Protocol;</li> <li>• Recruitment Methods_Phase 2 Interview_05-17-2023.pdf, Category: Recruitment Materials;</li> <li>• Recruitment Methods_Phase 2 Survey_05-17-2023.pdf, Category: Recruitment Materials;</li> <li>• Supporting Documents_08-02-2023.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions);</li> <li>• Supporting Documents_Modification_05-17-2023.pdf, Category: Measures (Survey questions/Interview questions /interview guides/focus group questions);</li> </ul>

The IRB determined that the protocol is considered exempt pursuant to Federal Regulations 45CFR46 (2)(i) Tests, surveys, interviews, or observation (non-identifiable), (2)(ii) Tests, surveys, interviews, or observation (low risk) on 5/19/2023.

In conducting this protocol you are required to follow the requirements listed in the INVESTIGATOR MANUAL (HRP-103).

If any changes are made to the study, the IRB must be notified at [research.integrity@asu.edu](mailto:research.integrity@asu.edu) to determine if additional reviews/approvals are required. Changes may include but not limited to revisions to data collection, survey and/or interview questions, and vulnerable populations, etc.

Sincerely,

IRB

Administrator

cc: Jordan King

APPENDIX D

STUDY 1 SUPPLEMENTARY MATERIALS

## **Data Collection Prompts**

### ***Data Collection Methods***

- Interactive class reflection activities: Students provided written responses to prompts via an interactive online platform, which was supported by collective discussion before and after their responses.
- Individual reflections: Students responded in writing to prompts to provide insights on their experience or perspective on assessment practices.
- Group reflections: Students provided explanations of their deliberative process to co-design rubrics, including rationale on design features and description of emergent insights from their experience.

### ***Previous Experiences and Assessment Aspirations (Individual Reflection)***

- How do you think that education and reflection can help you to prepare to be a sustainability professional?
  - E.g., “Constant learning and reflection is important in sustainability because this life is constantly new and changing. If we allow ourselves to reflect and learn, we can become better communicators and push for better progress surrounding sustainability issues.”
- Why do you think reflection and assessment abilities might be important for sustainability professionals?
- How would you describe how our work has been assessed in the past? What was your role in the process?
- What did you like or dislike about the methods that have been used to assess your work in the past?

- In your experience, what makes a sustainability learning experience or assessment activity good?
- What ideas do you have to improve your sustainability learning experiences and how your work is assessed? How might your role change?
- Please add any other thoughts that might have emerged while you completed this activity.

***Phase I Analysis of Rubric Template (Group Reflection)***

- What features of the rubric do you like or possibly want to keep?
  - E.g., “We like how it looks for consistency within the application of our group work and skill assessments. We like how it assesses team members on an individual level as well as a group level. The rubric is in depth and detailed.”
- What features of the rubric do you dislike or possibly want to change?
- What ideas do you have to improve the rubric (changes, additions, subtractions, etc.)?
- Provide a short summary of what actions or decisions you made during today’s session.
- Provide a short summary of the insights that might have emerged in today’s process.
- Identify any potential next steps, questions, or unresolved issues that you need to focus on next time.
- Provide any other notes or thoughts about today’s session or to help your group moving forward.

*Phase 1 Rubric Development (Group Reflection)*

- What changes to the rubric are you going to make? Please list a short explanation.
  - E.g., “One big change to the rubric we want to implement is the grading range of performance for each area. We believe that a group activity should be graded on a larger scale, rather than lower, intermediate, and higher performance. Because some activities are more challenging than others, this would be a large hit to the team if we were only able to achieve 50% on each activity. Therefore, it would be nice to have more performance grading like lower, sufficient, intermediate, satisfactory, and higher performance.”
- What changes to the rubric did you decide on to make it more relevant (this means that your rubric reflects real-world practice and is specific to your group)? In what ways are these important or helpful?
  - Why did you make these changes? What evidence or rationale supports the changes?
- What changes to the rubric did you decide on to make it more constructive (this means that your rubric provides criticism and reinforcement that helps you to improve)? In what ways are these important or helpful?
  - Why did you make these changes? What evidence or rationale supports the changes?
- What changes to the rubric did you decide on to make it more motivational (this means that your rubric inspires you to further learning and to apply it in impactful ways)? In what ways are these important or helpful?

- Why did you make these changes? What evidence or rationale supports the changes?

***Phase 1 Reflection (Interactive Class Reflection)***

- What have you liked about the group rubric development process?
  - E.g., “I liked being able to examine as a group what is expected of us and deciding how we thought we could be fairly evaluated.”
- What has been challenging about the process? What have you not liked?
- What might you change about the group rubric development process and how?
- What types of things did you consider in the process of changing your rubric? What factors influenced your decisions?
- What skills have you had to use in the group rubric development process?
- What insights or areas of growth has the process helped to support?
- Do you think participating in the group rubric development process has changed how you might use rubrics or feedback? How so?
- Please add any other thoughts that might have emerged while you completed this activity.

***Phase 2 Rubric Development Brainstorming (Group Reflection)***

- What are the potential dimensions of the assignment to be assessed?
  - E.g., “Critical self-reflection on progress in the class as well as gained professional skills and group collaboration skills.”
- How do these dimensions relate to the key parts of the assignment? Why are these dimensions important?
- What are the potential characteristics of these dimensions?

- How did you decide on these characteristics? Please provide at least 2 references to support your rationale (they can be listed at the bottom of the box with your response).
- How do the characteristics represent the qualities of an effective sustainability professional?
- What are potential criteria or levels to judge these characteristics and dimensions?
- In what ways do the criteria suggest the key aspects of learning and performance?
- How will the different levels that you have identified help to evaluate learning and performance?
- How does your rubric incorporate principles of justice, equity, diversity, and/or inclusion?
- Why is this important for assessing the assignment?
- What parts of your rubric do you want specific feedback on or have questions about?
- Please add any other thoughts or questions that you have.

***Phase 2 Rubric Design Rationale (Group Reflection)***

- What are the key features of your rubric? Why have you included these key features?
  - E.g., “The rubric includes these features to evaluate the student's understanding of the topic, personal growth, ability to communicate ideas, engagement, creativity, language proficiency, thoughtfulness, and efficiency in conveying information. These are important criteria for assessing student performance in any field, including sustainability. The

rubric collects feedback by evaluating the student's performance in each of the criteria described in the rubric. By providing a clear set of expectations for each characteristic, the rubric provides specific and actionable feedback that helps the student identify areas for improvement. Moreover, the rubric includes different levels of performance, allowing the student to see the progression of their performance and determine areas for future growth."

- Describe why you have included these key features. Include references from at least two sources and from other experiences to support your reasoning.
- In what ways does your rubric emphasize justice, equity, diversity, and inclusion? Why was this important to your group?
- In what ways do the characteristics and criteria described in your rubric represent the real-world practices of sustainability professionals?
- How does your rubric collect feedback to help you improve your learning and performance in the future? What did you consider when designing your rubric to ensure that it provides constructive feedback?
- How has the team rubric development process supported your development as a student and as a sustainability professional?
- What were the key things that your group did to work together in designing the rubric? What insights or benefits did your group gain from the collaborative and active approach to designing your assessment for the final assignment?
- What types of information or perspectives did your group consider in the rubric development process? Why was it important to integrate different perspectives?

- In what ways did your group engage with key sustainability concepts, values, mindsets, or methods in the rubric development process?

***Final Reflection (Individual Reflection)***

- What insights or experiences stand out as the most valuable from the group rubric development process?
  - E.g., “I believe the most valuable insights from the group rubric development was seeing what other people thought was important to include in the rubric. This gave us a better idea of what other professionals and instructors would be looking for.”
- Which parts of the process were the most challenging?
- How did you overcome these challenges?"
- What changes would you make to process?
- Which parts would you keep?
- In what ways did the group rubric development process contribute to the development of your professional skills? Which skills?
- How do you think the group rubric development process will support you in your work in the future as a student?
- What other skills or insights related to being a sustainability professional or a student did the group rubric development process contribute to for you?
- What makes an assessment or activity in a sustainability course good?
- Why are skills related to assessment, reflection, and feedback important for sustainability professionals?

- Why is it important for students to take an active role in assessment and feedback processes?

**Example Student Rubric**

**Table 3**

*Example Student Rubric*

Dimension	Characteristics	High 2.5 Points	Intermediate 1.5-2 Points	Low 0.5-1 Points
Key insights on 6 professional skill domains	Demonstrates clear understanding of the topics, how they relate to sustainability, and how they promote JEDI principles	Demonstrates clear understanding of the topics, how they relate to sustainability, and how they promote the JEDI principles (JEDI is addressed throughout the presentation)	Provides only a broad understanding of the topics, their relationship to sustainability, and mentions JEDI only briefly (once or twice as opposed to throughout)	Lacks a general understanding of the topics, their relationship to sustainability, and fails to address JEDI principles throughout the presentation
Learning experiences from the course	Specific learning experiences and examples of how they have encouraged growth are provided (minimum of 1 example per professional skill domain)	Provides at least 1 exemplar per professional skill domain	Provides examples for some of the professional skill domains	Does not provide examples for each professional skill domain

Future use of skills	Specific examples of potential future uses of these skills (minimum of 1 example for future use per professional skill domain)	Provides at least 1 exemplar per professional skill domain	Provides examples for some of the professional skill domains	Does not provide examples for each professional skill domain
Quality of the presentation, slides, visuals, and organization	Do they follow/show an understanding of Pecha Kucha presentations? Is the video they make presentable? Can you hear them? Are you able to easily understand their visuals? Is the presentation approximately 6 minutes long?	Slides are visually appealing, contain the information needed to keep the audience engaged without being too lengthy and overwhelming. Slides are engaging for a diverse audience and easy to read and contain content suitable for all different audiences.	Slides follow some Pecha Kucha rules but not all. Slides are somewhat organized but lack engaging material or content of high quality. Slides are somewhat unreadable or contain some alienating content.	Slides do not follow Pecha Kucha rules. Slides are disorganized and uninteresting. Slides are filled with too much information and lack flow. Slides are difficult to read, the presentation uses divisive language, contains difficult to understand jargon, or is hard to hear.

APPENDIX E

STUDY 2 SUPPLEMENTARY MATERIALS

## **Workshop Data Collection Prompts**

### ***Defining and Describing Best Practices***

- In your perspective, what are best practices for assessment activities/pedagogical practices/curricula and content areas/pedagogical practices/curricula and content areas in sustainability and sustainability-related programs in higher education?
- What are examples of potential best practices from your own program and experiences?
- How can these best practices address justice, equity, diversity, and inclusion as content areas or aspects of the teaching and learning process?

### ***Deliberating Best Practice Possibilities***

- Review the best practices and examples shared. What stands out to you?
- What insights did the activity raise about your own assessment activities/pedagogical practices/curricula and content areas or practices in the field?
- Why do you think the assessment activities/pedagogical practices/curricula and content areas described can be considered “best” practices? Why are they important to sustainability and sustainability-related programs in higher education?

### ***Synthesis***

- If you had to deliver one best practice based on your experience and today’s workshop, what would it be?
- What questions are you left with at the end of the activity?
- What directions or ideas should we explore further or next?

### *Discussion*

- What are your visions for the features and functions of the design and evaluation sustainability and sustainability-related programs in higher education?
- What innovations or change strategies (program, institutional, or field levels) could make these visions possible?
- What limitations or challenges do you face in your role and context related to program design and evaluation?

### **Interview Data Collection Prompts**

- Please describe your role and its connection to the field of sustainability programs in higher education.
- Please give an example of how you have engaged with teaching, learning, and assessment in sustainability programs in higher education.
- What do you envision as the essential learning objectives for graduates of sustainability programs in higher education? How are these objectives potentially linked to broader societal transformations, possibly through capacities like sustainability problem-solving or sustainability change agency?
- What do you see as potentially effective ways to assess students' learning or their development of key competencies?
- What considerations influence potential assessment practices? What challenges or limitations do you see? What are potential innovations?
- How might these assessment practices contribute to program design and evaluation?

- What are the key conditions and factors to consider in aiming to facilitate the outcomes of your vision for strengthening sustainability programs in higher education?
- Particularly as we aim to work with a variety of programs and stakeholders, context (institutional, disciplinary, geographical, socioeconomic, etc.) is an important influence. What do you see as the role of context in influencing how your assessment practices are interpreted and applied? How can the diversity of contexts of sustainability programs in higher education be productively engaged with?
- Do you have any additional thoughts?

#### **Survey Data Collection Prompts**

- In your program, what criteria or indicators do you use to assess the following key competencies in sustainability (general, systems-thinking, futures-thinking, values-thinking, strategic-thinking, interpersonal, intrapersonal, intrapersonal, integrated problem-solving)?
- In your program, what tools or methods do you use to assess the following key competencies in sustainability (general, systems-thinking, futures-thinking, values-thinking, strategic-thinking, interpersonal, intrapersonal, intrapersonal, integrated problem-solving)?
- In your program or perspective, what assumptions, values, frameworks, or requirements guide and inform your approaches to assessment and program evaluation?

- What challenges do you experience that limit the ability to validly assess students' learning outcomes in your program?
- What opportunities or potential strategies do you see that could improve the assessment of student learning in your program or in general?