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ORIGINAL ARTICLE

Key competencies in sustainability in higher education—toward an agreed-upon reference framework

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Abstract

Hundreds of sustainability programs have emerged at universities and colleges around the world over the past 2 decades. A prime question for employers, students, educators, and program administrators is what competencies these programs develop in students. This study explores convergence on competencies for sustainability programs. We conducted a Delphi study with 14 international experts in sustainability education on the framework of key competencies in sustainability by Wiek et al. (Sustain Sci 6: 203–218, 2011), the most frequently cited framework to date. While experts generally agreed with the framework, they propose two additional competencies, suggest a hierarchy of competencies, and specify learning objectives for students interested in a career as sustainability researcher. The refined framework can inform program development, implementation, and evaluation to enhance employability of graduates and facilitate comparison of sustainability programs worldwide.

Keywords Key competencies · Learning objectives · Curriculum development · Sustainability problem solving · Education for sustainable development

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Introduction

Over the past decade, the number of sustainability programs in higher education has grown significantly. In the USA, for example, between 2012 and 2016, this number increased by 15% to 2361, offered by 872 institutions (Vincent et al. 2017). These include sustainability-focused programs, reflecting the field of sustainability science (Kates 2011; Yarime et al. 2012; Lang et al. 2012; Wiek et al. 2015) and sustainability-oriented programs in business, education, law, and so forth. Graduates from these programs seek employment as sustainability professionals or sustainability researchers. Projections for the USA suggest up to 9% growth in the existing sustainability labor market through 2024 (Johnson et al. 2019).

However, it remains a challenge for employers, students, educators, and program administrators to clearly articulate what competencies these programs develop in students (Barth et al. 2007; Rieckmann 2012). Several frameworks of competencies in sustainability have been proposed, with the most commonly referenced one being the framework of key competencies in sustainability by Wiek et al. (2011). Despite this emerging convergence, a state of clarity has yet to be achieved. A first challenge is the variety of terms still in use for similar competencies, creating a "sea of labels" and resulting in "terminological confusion" (Sterling et al. 2017, p. 153, Shephard et al. 2018). A second challenge is that new proposals for sustainability competencies continue to be presented as lists of items (Wilhelm et al. 2019), although scholars acknowledge the importance of a framework as a set of distinct, yet interrelated competencies (Wals 2015; Glasser and Hirsh 2016; Engle et al. 2017). Lastly, there is no explicit consensus on a specific framework of key competencies in sustainability.

This lack of clarity has several negative effects. Sustainability programs often do not clearly articulate the learning objectives for their students (O'Byrne et al. 2015). Prospective students struggle to compare sustainability programs as they decide to which program to apply. Instructors lack guidance on what competencies to convey to students. Graduates of sustainability programs encounter difficulties in articulating their competencies while employers lack a trustworthy reference to compare candidates' profiles (Barber 2016). In the absence of commonly agreed upon key competencies in sustainability and related program-level learning objectives, accrediting bodies are unable to assess learning and benchmark degree programs (Vare et al. 2019), making systematic comparison and evaluation of degree programs difficult. This absence is at odds with the fact that sustainability is recognized as an established academic field (Kates 2011; Lang et al. 2012; Yarime et al. 2012; Miller et al. 2014; Wiek et al. 2015) and sustainability practice as a profession (ISSP 2020), respectively.

Considering these challenges, it is time to work toward "broadly acceptable, detailed descriptions" of key competencies in sustainability to provide "guidance for program and curriculum development or major re-organization of academic institutions" (Glasser and Hirsh 2016, p. 132). Creating a shared frame of reference and quality standards enables credibility and professional trust in sustainability programs. It would provide a shared language around program-level learning objectives, facilitating comparability of programs, and an increased understanding of what sustainability graduates can offer to society.

The National Council for Science and the Environment (NCSE) in the USA recognized this need and launched a Delphi study on expert consensus about key competencies for sustainability and sustainability-related programs. The results of this study are reported in this article. This Delphi study selected the framework of key competencies in sustainability by Wiek et al. (2011), synthesized from a comprehensive literature review, and the set of detailed learning objectives that operationalize the framework (Wiek et al. 2016). This framework was selected as the foundation because of its wide reception in sustainability education literature with 1308 *Google Scholar* citations (May 30, 2020), and its application in sustainability programs and courses around the world (Foucrier and Wiek 2019).

The goal of this Delphi study was to inform the NCSE's Council of Deans and Directors in preparing a consensus statement on key competencies in sustainability to foster sustainability and related programs at higher education institutions in the USA.

This article presents the findings of the Delphi study that involved 14 international experts from higher education institutions. The Delphi study addressed the following questions:

1. To what extent does the group of experts agree upon the framework of key competencies in sustainability (Wiek et al. 2011), which includes: a (1) basic definition of each competency, (2) an overall rationale (relationships among competencies), and (3) a set of learning objectives for each competency?
2. What additions, differentiations, and deletions to this framework (if any) do experts suggest?

This study complements the results of other studies. These include an EU-funded project, using a Delphi approach, to develop a competency model for ESD educators (Vare et al. 2019); the studies compiled in the special issue "Competencies in Education for Sustainable Development" (Cebrián et al. 2020), and a comprehensive literature review

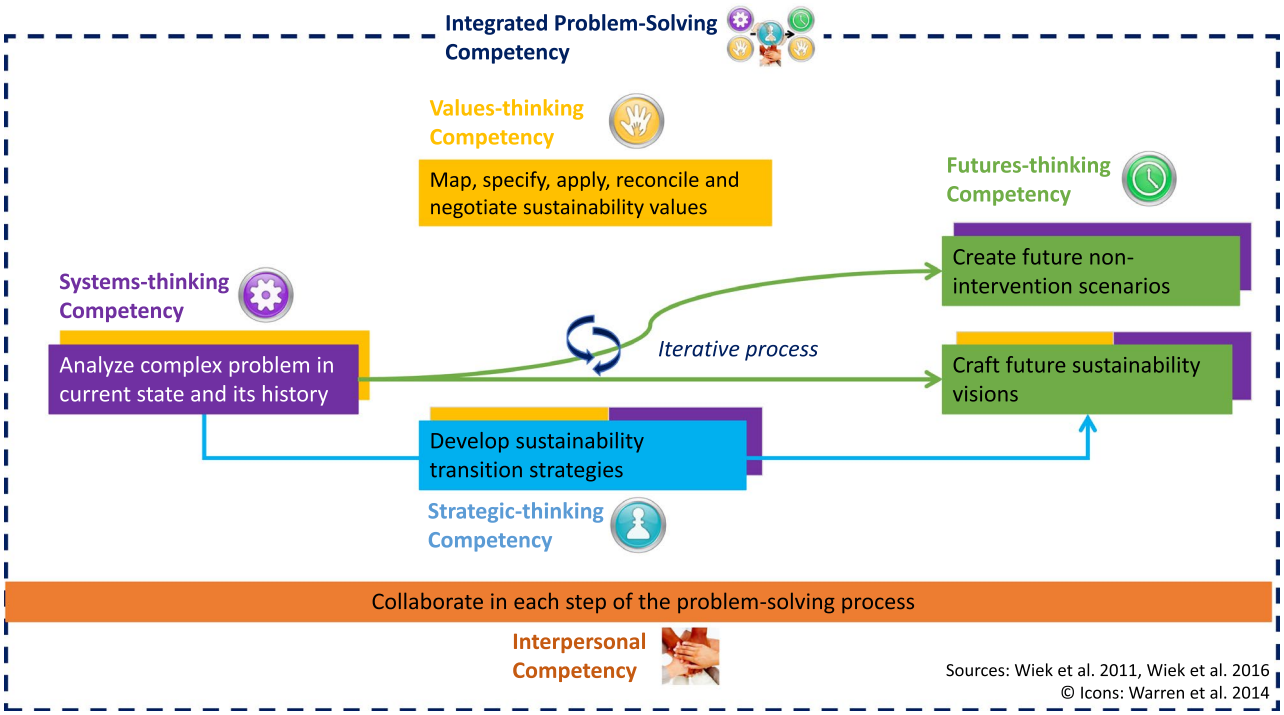

Fig. 1 Overview of the framework of key competencies in sustainability adapted from Wiek et al. (2011); icons credit: Warren et al. (2014)

on the framework of key competencies in sustainability (Redman and Wiek 2020).

The framework of key competencies in sustainability

This Delphi study selected the framework of key competencies in sustainability by Wiek et al. (2011), synthesized from a comprehensive literature review, and the set of detailed learning objectives that operationalize the framework (Wiek et al. 2016). We summarize the key components of the framework below (Fig. 1 and Table 1).

Three features of the key competencies framework need further explanation. First, key competencies serve as a cluster of related competencies. For instance, futures-thinking competency includes a cluster of competencies related to developing scenarios, visions, and/or extrapolations. Each of these competencies entails a combination of dispositions (knowledge, skills, motives, and attitudes) that enable successful task performance. For example, to successfully create a vision, one needs to know about related theories, identify suitable methods and apply these rigorously, which involves attitudes (e.g., attention to detail, open-mindedness, stubborn optimism[1]). Second, they are called key competencies in sustainability to distinguish them from other key competencies, including academic competency. Basic academic competency entails "[b]asic capacities in critical thinking, communication, pluralistic thinking, research, data management, and so forth" which are developed in every quality academic program, serving "as the foundation of academic sustainability education" (Wiek et al. 2011, p. 211–212). This is echoed by others adding self-regulated learning and generic problem-solving skills (Meijers et al. 2005; Waltner et al. 2019). Third, the key competencies in sustainability are referenced as a framework as they are interdependent; each contributes its part to sustainability problem-solving processes (Fig. 1).

Figure 1 depicts the integrated problem-solving process with its steps of problem analysis, developing future scenarios and shared sustainability visions, and determining strategies to transition from current state to desired sustainability vision. Each step involves the associated competency. For instance, systems thinking enables a holistic understanding of past, present, and future states and dynamics. Futures thinking allows exploring possible futures. Values thinking informs assessing past, present, and future states, determining what is a problem/what is desired for whom, why, and

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Table 1 Abbreviated definitions of the key competencies in sustainability (Wiek et al. 2011, 2016)

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

The full definition of each competency entails an explanation what the competency is, a justification why it is useful for sustainability problem-solving processes and examples of select concepts and methods entailed in the competency

how to design just processes. Strategic thinking provides guidance how to achieve identified goals in the short- and long-term. Interpersonal competency underpins all steps as sustainability problem-solving processes ought to be interdisciplinary and participatory processes. Basic academic competencies complement the framework.

Against this background, we follow the definitions provided in Table 2.

Research design

The study employed the Delphi method (Okoliand Pawlowski 2004), which supports consensus building by drawing on experts' insights through a structured process involving a series of questionnaires, which experts answer anonymously in written ways. The researchers serve as moderators compiling the responses and making a synthesis available to all experts. In each subsequent round, experts review and comment on the compilation and synthesis from the preceding round and answer the new questionnaire. This iterative and anonymous process allows experts to respond on their own time and from their location, expressing themselves freer than when engaged in real-time group and power dynamics.

This study used purposive sampling as a tool (Tongco 2007) to select 14 international sustainability education experts from universities and research institutes worldwide (US: 4 female, 4 male; Asia: 1 female; Asia Pacific: 1 female, 1 male; Europe (Spain, Germany): 1 female, 1 male; Canada: 1 female). All experts have a PhD, and 13 experts hold faculty positions while one expert works at UNESCO's Mahatma Gandhi Institute of Education for Peace and Sustainable Development (MGIEP). All experts have a track record (publications and research projects) in research on education for sustainability.

This Delphi study explored consensus around the framework of key competencies in sustainability over four rounds of questionnaires (Table 3). To address all features of the framework, each round entailed a modified questionnaire and the questionnaires built upon each other. Each round provided experts the option to review and comment on the compilation of the preceding responses from other experts. At the end, in round 4, the moderators invited all experts to review and revise the study's final synthesis. The synthesis was presented as a manuscript to facilitate understanding of how the results from the preceding rounds relate to each other. At this stage, the moderators invited all experts to consider co-authorship of the manuscript. All experts accepted, except one who declined due to workload considerations.[2]

Experts' responses to the questionnaires were sorted and allocated to the appropriate feature of the framework (e.g., definitions, relationships, learning objectives). The following rules were applied:

(1) If experts provided information that pertained to an earlier question, this information was allocated to this question. For instance, if in round 3 (review of learning objectives) experts added new concepts or methods to the learning objectives, these concepts or methods were added to the definition of competencies, which was the focus of Round 1.

(2) If experts suggested a revision to the framework by Wiek et al. (2011, 2016) that was already entailed in the framework, this suggestion was not added, but explained in reference to the original articles. For example, the basic academic competency was indi-

[2] Two experts participated with their teams. While they provided their contribution to the Delphi-study as one team, they are now listed individually as co-authors.

Table 2 Definitions of key terms in the literature on sustainability competencies

Terms and definition	Sources
Competency Cluster of specific and interrelated individual dispositions comprising knowledge, skills, motives, and attitudes, i.e., combining cognitive, affective, volitional and motivational elements. Competency facilitates self-organized action, a pre-condition to achieve successful performance and a positive outcome in various complex situations, responding to the specific situation and context. While competencies might be context-dependent; key competencies ought to be applicable across different contexts	Wiek et al. (2011); Rieckmann (2012, p. 129); UNESCO (2017)
Key competency A distinctive and multifunctional competency, which is composed of several competencies that intersect with each other. A key competency may be important for all individuals. It is essential for achieving successful performance and a positive outcome related to a particular endeavor in diverse contexts, for instance to achieve societal goals, which are normatively defined by their cultural context. In the most general sense, key competencies, requiring a high degree of individual reflexivity, facilitate positive outcomes in being able to think, to do, to be, and to live together in a range of contexts	Delors (1996); OECD (2005); Wiek et al. (2011); Rieckmann (2012); Barth (2015); UNESCO (2017)
Sustainability competencies Comprise the entirety of individual dispositions comprising knowledge, skills, motives, and attitudes necessary to solve sustainability-related problems and advancing sustainable development in a range of different contexts, including private, social and institutional	Engle et al. (2017); Waltner et al. (2019)
Key competency in sustainability A distinctive and multifunctional competency, which is composed of several sustainability competencies that functionally relate to each other. It facilitates achieving successful performance and a positive outcome that progresses sustainability (given what is known, valued, and aspired at a given moment in time), while working on specific sustainability challenges and opportunities in a range of contexts	Wals (2015); Wiek et al. (2011)
Framework of key competencies in sustainability A minimal set of distinct (non-overlapping), yet functionally interrelated key competencies, which are synthesized into an integrated perspective. This integrated set facilitates achieving successful performance and a positive outcome that progresses sustainability, while working on a specific sustainability challenge in its context and a range of contexts	Wiek et al. (2011); Glasser and Hirsh (2016); Sterling et al. (2017)

Table 3 Overview of questionnaires answered by the experts in the Delphi study

Round no	Topic	Instructions
Round 1	Competency definition	Evaluate and update the definition of each key competency in sustainability, including concepts and methods for each competency (Wiek et al. 2011) Review each definition Revise definitions, if necessary
Round 2	Framework (relationships among competencies)	Evaluate and update the framework of key competencies in sustainability that links competencies together into a sustainability problem-solving process (Wiek et al. 2011) Review relationships among the key competencies Refine relationships among the key competencies, if necessary; Add additional competency, if necessary Comment on results from round 1
Round 3	Learning objectives	Evaluate and update proposed learning objectives for each key competency in sustainability for three levels: novice (bachelor), intermediate (masters), and proficient (doctoral) (Wiek et al. 2016) Comment on results from rounds 1 and 2
Round 4	Final review	Review and revise proposed synthesis, presented in form of draft manuscript Comment on proposed synthesis of rounds 1–3
Final manuscript	Co-authorship	Accept/decline invitation to co-author the manuscript If accept: comment on final draft of manuscript

cated as missing by one expert, yet, this competency is defined in Wiek et al. (2011) as a separate competency underpinning the framework.

(3) If experts expressed the need for clarification or their responses indicated a misunderstanding, these issues were identified as reflections of diverse understandings

among experts in the field, warranting a broader discussion in the Discussion section of this paper.

In the context of this study, two more aspects of the term "competency" need to be clarified. First, this study focused on knowledge related to each of the key competencies in sustainability. For instance, future-thinking competency requires knowledge about pertinent concepts (e.g., risk, plausibility vs. probability, intergenerational equity, anticipatory governance) and methods (e.g., methodologies for scenarios, visioning, forecasting from statistical models). This competency-related knowledge complements topical knowledge on food, energy, water, ecosystems, transportation, social justice, and so forth. However, this study did not engage with topical sustainability knowledge.

Second, while competencies are operationalized through learning objectives and manifest in learning outcomes, this study focused on learning objectives for the key competencies in sustainability. Learning objectives present experts' agreement around what students ought to learn by the end of a course or program. While learning objectives need to be aligned with pedagogies suitable to attain these objectives and related assessments (Biggs 1996), a review of these pedagogies and assessments are beyond the scope of this study. They have been the subject of several recent studies (c.f., Vare et al. 2019; Lozano et al. 2019; Redman et al. 2020; Roy et al. 2019). Another step would explore agreement around learning outcomes, which describe an observed state of what students are able to do in measurable ways. (InTeGrate 2019)

Additional limitations of the research design include the lack of experts representing all world regions. The research team contacted a larger group of experts, including indigenous scholars and experts working in the Latin American and African regions. For time and other reasons, they declined to participate. Thus, this study will be contextualized using as proxy two Delphi studies, one involving experts engaged with sustainability work in Ethiopia (Demssie et al. 2019) and the other involving experts from Latin America (Chile, Ecuador, Mexico) and Europe (Germany, Great Britain) (Rieckmann 2012) (see "Conclusions").

Findings

In general, there was agreement on the framework of key competencies in sustainability developed by Wiek et al. (2011) and elaborated in Wiek et al. (2016). Yet, suggestions were made to refine the competencies' definitions, nuance the relationships among the competencies, add competencies, and specify the learning objectives. For each major result, the respective expert(s) and round(s) is/are indicated in anonymized form (experts were given numbers between 1–30; e.g., [9:R2]–stated by expert No. 9 in round 2). All detailed findings are compiled in Brundiers et al. (2019).[3]

Refined definitions of the key competencies

While experts generally agreed with the definitions of each competency (Table 1), they refined some definitions by adding and detailing concepts and methods. Some experts asked for explanations of those concepts that cut across different competencies [6:R1, 29:R1]. We summarize experts' suggested revisions focusing on strategic, values, interpersonal, and basic academic competencies and the relationship between competencies and topical knowledge.

For strategic-thinking competency, two experts suggested including the ability to engage in and lead radical change [30:R2, 9:R3], using concepts of transgression and disruption. This suggestion is in line with the recent literature that introduced these concepts. Transgressive learning refers to learning how to 'unlock' path-dependencies and dismantle oppressive power structures to transform toward sustainability in ways that are socially just, peaceful and ecologically sustainable (Wals 2015; Lotz-Sisitka et al. 2015; Transgressive Learning n.d.). Experiential learning on how to disrupt one's own habits facilitates insights into mechanisms sparking such radical social change (VanWynsberghe and Herman 2015). This addition reflected experts' conviction that disruptive and transgressive strategies and actions are needed to overcome inertia and ingrained structures of oppression, privilege, and exploitation. Discussing the definition of values-thinking, experts called for putting more emphasis on racial justice [4:R3], for differentiating between values thinking and the values displayed in acting [23:R1], and for not just listing broad concepts of sustainability values such as inter- or intra-generational equity, but to refine those through more specific values [9:R1].

Experts also suggested broadening the definition of interpersonal competency to include different types of collaboration from small to large interdisciplinary teams and stakeholder engagements as well as transdisciplinary and action research methods [5:R1, 9:R1, 26:R1, 29:R1, 30:R1].[4] This reinforces the emphasis that each competency requires collective efforts (see Table 1) and highlights the wider set of professional skills, such as communication and deliberation, project-management, lifelong-learning, and leadership,

[3] Respondent 10 is marked with an (*) as this respondent withdrew their participation due to a conflict of interest.

[4] In the remainder, we use the term transdisciplinary research methods as short shrift for methodologies facilitating collaborative research between academics and practitioners with action research being one of them. Interdisciplinarity refers to collaborative research among academics from different disciplines.

reflecting recent literature (NACE 2020; Seemiller 2013; Brundiers and Wiek 2017).

Finally, the definition of basic academic competency, which is not considered a key competency in sustainability but a competency underpinning key competencies in any degree program (Wiek et al. 2011: 204), was refined. Experts suggested expanding this definition to include: the abilities to recognize different approaches to theory building (e.g., social constructivism, critical theory) [5:R1]; to acquire basic research competencies to enable evidence-based decision making [9:R3], including conducting an interdisciplinary literature review [6:R1, 30:R2]. Critical thinking, being an important part of basic academic competency, was mentioned by two experts [27:R2, 30:R2] to align with the UNESCO's (2018) recent publication on Education for Sustainable Development. It defines "critical thinking competency" as "the ability to question norms, practices and opinions; to reflect on one's own values, perceptions and actions; and to take a position in the sustainability discourse" (UNESCO 2018, p. 12, Box 1.1).

When reviewing the definition of competencies (round 1) and associated learning objectives (round 3), experts discussed the relationship between the key competencies in sustainability and topical knowledge specifically related to sustainability topics (e.g., water, carbon cycle) from the natural and social sciences as well as the humanities in relation to the framework. Experts concurred that the framework articulates competencies and does not include explicit topical knowledge [9:R1; supported by 28:R1, 28:R2]. One expert stated that "the competencies are largely independent of specific topics, [which] is a strength of this framework" [4:R3]. This independence allows using the framework for sustainability-related courses in any academic program—with the understanding that specific sustainability topics ought to be incorporated into the respective sustainability course and/or curriculum [4:R3, 30:R3]. The expert explained that while the competencies do not entail topical knowledge, the framework entails an approach to addressing sustainability problems, such as climate change. This approach requires incorporating topical knowledge drawing on multiple disciplines.

One expert [29:R2] suggested changing the term from "competencies" to "capabilities" as advocated by Sadler (2013). However, we decided to retain "competency," based on its wide use within the context of sustainability and general education. Moreover, while competencies reflect current performance, the term capabilities might add complexity by shifting focus on potential development and ability to adapt for future needs. At the same time, we acknowledge that national educational institutions use different terms (e.g., "capabilities" is widely used in Australia, c.f., Sterling et al. 2017; Shephard et al. 2018).

Overall rationale for refined relationships among competencies and additional competencies

Refined relationships among the competencies

While the overall relationships among competencies were reinforced, revisions were recommended to better represent and visualize the relationships among the competencies and with the steps of the sustainability problem-solving process (referring to Wiek et al. 2011, p. 206 (Fig. 2)). See Fig. 1 for a simplified representation and Fig. 3 for a refined representation of the framework. For example, one expert suggested linking the competencies more explicitly: "all of them should be interacting synergistically and integratively" [7:R2], as articulated in Wiek et al. (2011, p. 212). A number of experts recommended that the visual representation of the sustainability problem-solving process ought to better represent an iterative process [1:R2, 4:R2, 6:R2, 7:R2, 29:R2]. Relatedly, others suggested that the visual ought to better communicate that the problem-solving process can be initiated at different points, starting with either problem analysis or visioning and the associated competencies [6:R1, 6:R2, 7:R2, 4:R3]. An overview of the existing sustainability problem-solving approaches is given in Wiek and Lang (2016). Figure 2 presents the five sustainability problem-solving approaches illustrating their different entry points and associated competencies. While the approaches differ related to entry points and sequences of steps, each involves all competencies.

A core notion underlying the framework is "for people to think about the connections" among the steps of the process and the competencies in relation to the select sustainability challenge [29:R2]. In light of this, one expert recommended tailoring how the framework is presented to the needs of different target audiences. For students, exploring how to connect the steps of the problem-solving process can support integrated learning; for faculty, thinking about the links between the problem-solving process and competencies can support teaching efforts; and for curriculum designers, understanding the connections between competencies can allow for mapping courses and curricula [7:R2, 28:R2, 29:R2]. One expert suggested an expanded visual that would allow zooming out to illustrate how the sustainability problem-solving process is embedded in the broader social-ecological system, and zooming in to show that accurate and useful data are required to support each step of the process [29:R2]. This comment explains how competency frameworks are scale-independent as competencies needed at one scale will be the same at any scale. Meanwhile topical knowledge is scale dependent.

There was also recognition of the potential need for hierarchy among the competencies, with values-thinking

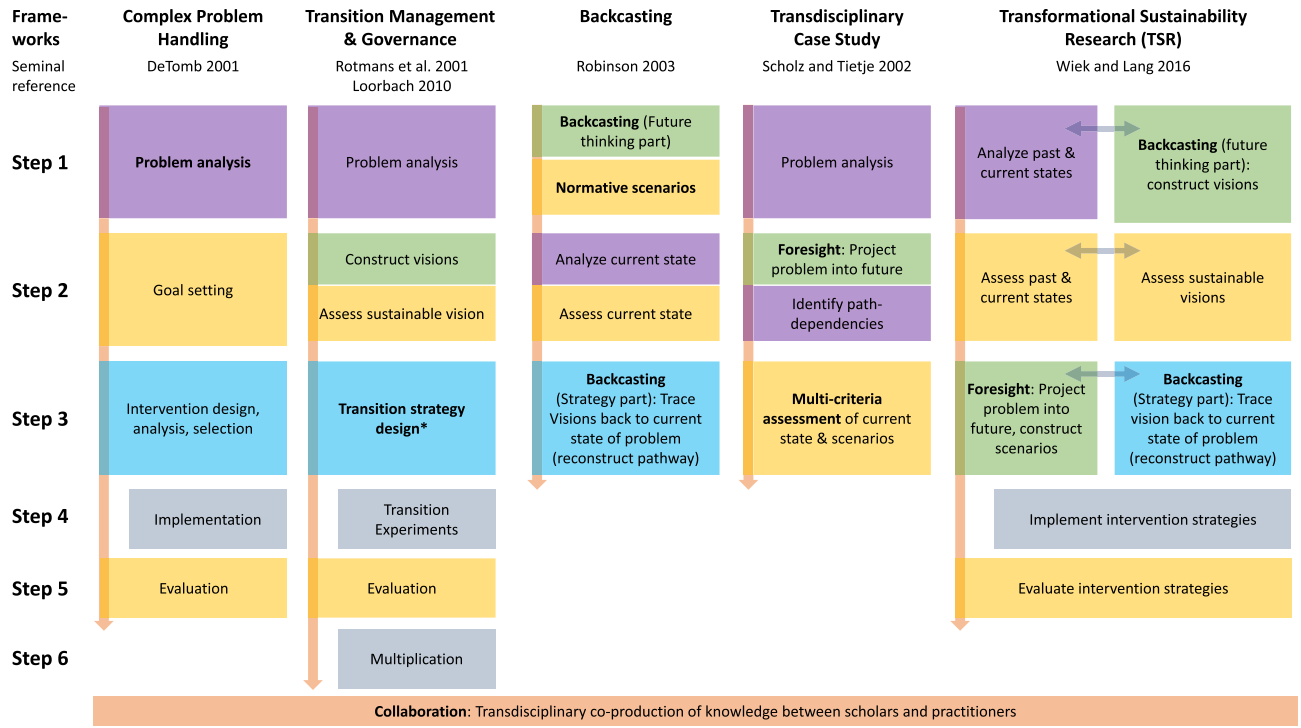

Fig. 2 Overview of integrated sustainability problem-solving approaches adapted from Wiek and Lang (2016, p.35), with permission of the authors. Each approach emphasizes a particular step (bolded) ordering the sequence of steps. The competencies per step are depicted through colors (purple: systems-, green: futures-, yellow: values-, turquoise: strategic-thinking, orange: collaborative competency). Grey boxes depict implementation, which, so far, is done by practitioners outside the collaborative research process. The TSR framework presents a synthesis of the four other frameworks combining two complementary processes (forecasting and backcasting) along the first three steps

competency providing the normative orientation for all the other competencies. One expert argued: "the key is to use the constellation of competencies to leverage and apply them toward [sustainability values expressed in] the Sustainable Development Goals (SDGs) and the Brundtland definition" [7:R2]. This expert stressed how values-thinking competency and sustainability values need to be the main reference point for the other competencies: "the competencies alone without [being] placed within a sustainability context can […] be utilized for distinctly unsustainable nefarious purposes […] and lead to very unsustainable outcomes" [7:R2].

Competencies added

While reviewing the framework, experts proposed new competencies, in line with the UNESCO's (2017) "Education for Sustainable Development Goals: Learning Objectives" and other pertinent literature.

Experts [7:R2, 27:R2,30:R2] echoed the calls for an integrated problem-solving competency, as indicated in Wiek et al. (2011: 212) and elaborated on in Wiek et al. (2016: 251f.).This competency refers to successfully integrating two or more of the key competencies in sustainability problem-solving endeavors and, ultimately, integrating all key competencies to create viable and equitable solutions for sustainability. This competency includes the ability to select and apply appropriate problem-solving frameworks (c.f., Wiek and Lang 2016). Experts [4:R3,9:R3, 10*:R1] suggested including the ability to differentiate among and connect with different disciplines and/or professional communities. This is often referred to as interdisciplinary and transdisciplinary capacities, respectively, which extend outwards from basic academic competency and competency in a primary discipline/epistemology.

Experts advocated for concepts and methods related to intra-personal or self-awareness competency [4:R1, 5:R1, 6:R1, 8:R1, 9:R1, 26:R1, 28:R1, 29:R1, 27:R2, 30:R2, 4:R3]. One expert [30:R2] articulated this as the ability to be aware of one's own emotions, desires, thoughts, behaviors, and personality, as well as to regulate, motivate, and continually improve oneself drawing on competencies related to emotional intelligence (Goleman and Boyatzis 2017) and social and emotional learning (CASEL n.d.).

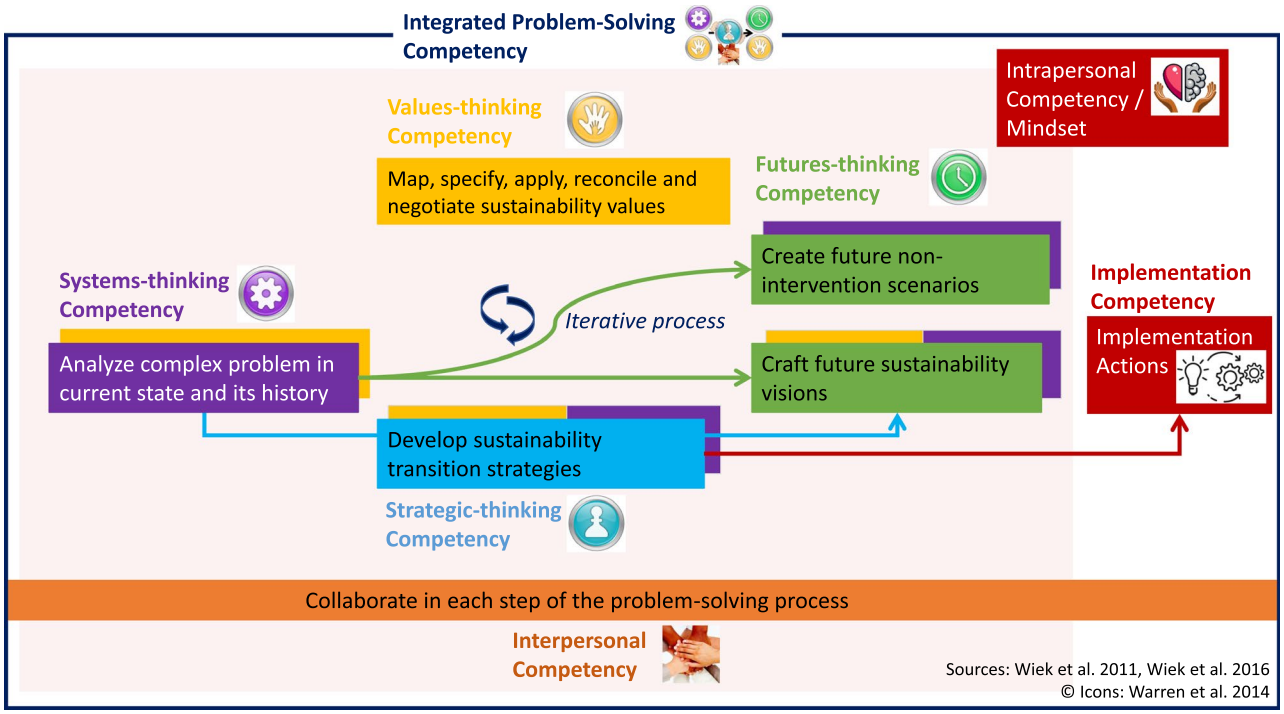

Fig. 3 Refined framework, building on the key competencies synthesized from the literature (Wiek et al. 2011; icons credit: Warren et al. 2014), visualizing in red boxes the additionally proposed competencies while emphasizing the integrated problem-solving competency (blue line around interrelated set of competencies). Note: the implementation competency results from the process developing the solution (red-shaded background); the classification of the intrapersonal competency as a competency is still debated

This recommendation is aligned with UNESCO's (2017, p. 10) key competencies for sustainability, which define "self-awareness competency" in relation to context and as "the ability to reflect on one's own role in the local community and (global) society; to continually evaluate and further motivate one's actions; and to deal with one's feelings and desires." Two experts emphasized the role of context in self-awareness competency as it entails the ability to reflect on one's "positionality" [5:R1] and "one's own role in the local community and (global) society" [30:R2, citing UNESCO (2017)]. Contemplative practices supporting self-awareness and self-regulation are increasingly incorporated into sustainability courses (Brundiers and Wiek 2017; Wamsler et al. 2018; Papenfuss et al. 2019). Similar to interpersonal competency, experts suggested that intrapersonal competency underpins all other competencies [30:R2].

Several experts [1:R2, 4:R2, 6:R2, 6:R3, 7:R3,9:R3, 30:R3] proposed an implementation competency, i.e., the collective ability to realize a planned solution toward a sustainability-informed vision, to monitor and evaluate the realization process, and to address emerging challenges (adjustments), recognizing that sustainability problem-solving is a long-term, iterative process between planning, realization, and evaluation. Implementation competency is essentially action competency, using actionable knowledge that has been created through strategic-thinking competency. While some experts considered implementation competency as an extension of strategic-thinking competency [29:R3, 30:R3], others argued for it as competency explicitly about taking action [4:R2, 9:R3]. This is in line with the recent literature: the ability to act, or to consciously implement interventions, was identified as a highly important competency for sustainability by student teachers (Cebrián and Junyent 2015) and sustainability professionals (Salgado et al. 2018). Two experts [30:R2, 9:R3] suggested to include the ability to disrupt and transgress in order to break habits and dominant and hegemonic structures and lead radical change as suggested in recent literature (Lotz-Sisitka et al. 2015; VanWynsberghe and Herman 2015; Wals 2015; UNESCO 2018). This ability to disrupt and transgress is a component of implementation competency. Implementation competency is about taking conscious action, i.e., doing the actions associated with the solution process that is the (intellectual) result of integrated problem-solving competency in the first place (Fig. 3).

Specified learning objectives

The proposed learning objectives for each key competency (Wiek et al. 2016) were generally agreed upon. Below we

list the commended refinements and/or explicit emphases that experts placed:

- *Futures-thinking competency* to be able to iterate and continuously refine one's own futures thinking (visions, scenarios, etc.), in productive and explicit tension to the status quo; recognizing the "implicitly held (and largely unrecognized) assumptions about how society works" and how they influence the status quo and critically reflecting how they might influence futures thinking [10*:R1].
- *Values-thinking competency* to be able to differentiate between intrinsic and extrinsic values in the social and natural world [28:R1]; to recognize normalized oppressive structures [5:R1; 4:R3]; to identify and clarify one's own values [5:R1,4:R3, 8:R3, 9:R1, 10*:R1]; to explain how values are contextually, culturally, and historically reinforced [5:R1]; to critically evaluate how particular stated values align with agreed-upon sustainability values [26:R1, 28:R1, 29:R1]; and to differentiate between espoused values and practiced values [26:R1].
- *Strategic-thinking competency* to be able to recognize the historical roots and embedded resilience of deliberate and unintended unsustainability and the barriers to change [10*:R3]; to creatively plan innovative experiments to test strategies [9:R3].
- *Interpersonal competency* to be able to apply the concepts and methods of each competency not merely as "technical skills," but in ways that truly engage and motivate diverse stakeholders [9:R3] and to empathically work with collaborators' and citizens' different ways of knowing and communication [10*:R3].
- *Integrated problem-solving competency* to be able to combine and integrate steps of the sustainability problem-solving process or competencies, while drawing on pertinent disciplinary, interdisciplinary, transdisciplinary, and other ways of knowing [7:R2, 4:R3, 9:R3].

Experts supported the scaffolding of competency development within each competency (e.g., through employing all levels of Bloom's revised taxonomy [7:R3][5]) and across levels (Novice/bachelor, Intermediate/masters, Proficient/doctoral) [6:R3, 7:R3]. Subsequently, this translates into scaffolding of learning objectives. Experts also suggested sequencing learning objectives, starting with objectives related to the personal and familiar, later expanding to more distant places and times as well as more abstract concepts and methods. They also suggested starting students on exploring their personal contributions before exploring their professional contributions to sustainability goals [4:R3,8:R3,28:R3]. These recommendations reflect how such scaffolding is used to design an undergraduate sustainability science program (c.f., Habron 2019).

When developing key competencies in sustainability, experts recommended formulating some learning objectives in direct response to widely held prejudices that sustainability science aims to overcome. These learning objectives would be for students to be able to:

1. Explain why sustainability is "not first and foremost about the environment" [4:R4] and not just about technical solutions and engineering [9:R3]; but is instead a layered concept with justice and equity as foundational elements [28:R1]. This would involve broadening the perspective on justice and equity beyond environmental justice to also include more general and explicit forms of social and racial justice [4:R3].
2. Integrate values into scientific inquiry [10*:R3], countering the positivistic perception that "values are outside of the realm of science" as science "is considered to be objective" [4:R3] and the positivistic instruction that "scientists should not deal in values" [10*:R3].
3. Articulate sustainability science as a solution-oriented field, which employs the same rigor, using systems-, values-, futures-, and strategic-thinking competencies, to researching solutions to sustainability challenges as to researching sustainability problems [4:R3].
4. Articulate the necessity of stakeholder engagement (a 'must' have) in sustainability science research (transdisciplinary approaches) [10*:R1, 26:R1, 27:R1, 30:R1, 4:R3, 6:R3, 7:R3, 9:R3].

These objectives are relevant for students aspiring to become a sustainability researchers or professionals; yet, for students pursuing an academic career, being able to succeed in objectives #2–4 also involves learning how to navigate the institutional challenges specifically pertaining to higher education.

[5] Bloom's Revised Taxonomy (RT) was developed by Anderson et al. (2001). It builds on Bloom's Original Taxonomy (OT) from 1956 while addressing its shortcomings: (1) The OT combined 'having knowledge' with the cognitive processes of 'acquiring knowledge' into one dimension. The RT breaks this into four dimensions of knowledge: factual: knowing the basic elements of a discipline, conceptual: knowing the relationships among the basic elements, procedural: knowing how to do something and metacognitive: knowledge about cognition, awareness of own cognition. (2) The OT presents learning objectives hierarchically within one knowledge dimension. The RT presents them in a matrix, connecting the four dimensions of knowledge with the six levels of learning objectives (Remember, Understand, Apply, Analyse, Evaluate, Create) (Amer 2006).

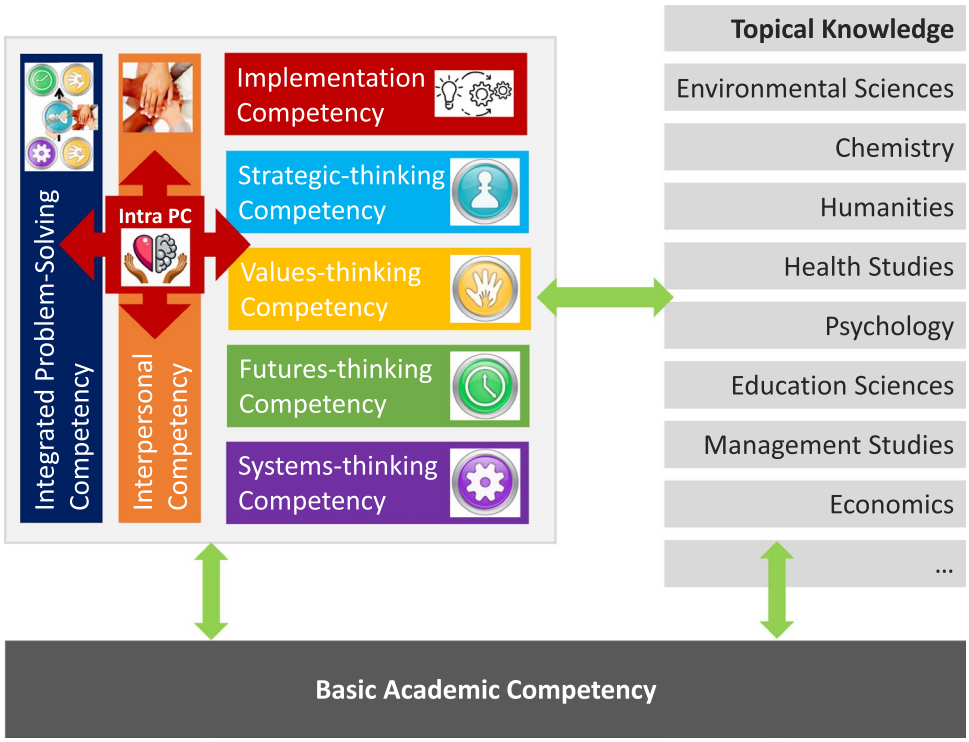

Fig. 4 Three-dimensional model linking the key competencies in sustainability framework, basic academic competencies and discipline-specific knowledge, (note: 'Intra PC' refers to Intrapersonal Competency/Mindset). The fictional example of a graduate working for a global reinsurer in its 'Department of Sustainability, Emerging and Political Risk Management' illustrates how students would develop a general understanding and specializations in each of the three dimensions. This graduate would have proficiency in basic academic competency (quantitative methods) and Environmental Sciences (atmospheric sciences), reached intermediate levels in Economics (theories, methods, subject matter) and novice-level in all six key competencies in sustainability, while specializing in futures- and values-thinking competencies (intermediate level)

Discussion

This study asked about the extent to which experts in sustainability in higher education agree upon the most commonly used framework of key competencies in sustainability (Wiek et al. 2011), and what additions, differentiations, and deletions they suggest.

There was general agreement on the main features of the framework, including: the purpose, namely, to enable and empower students to become effective in positively contributing to sustainability problem-solving in their lives, professions, and communities; the basic definition of the key competencies, focused on defining the competency-related knowledge, skills, motives, and attitudes independent of and complementary to sustainability topics; the integration of the key competencies into a sustainability problem-solving framework that reflects the integrated problem-solving competency; and the introductory set of learning objectives for each of the key competencies. Nevertheless, relevant additions and differentiations were proposed to this starting framework. Five points will be discussed.

First, in the context of the basic definitions, experts raised the question how to relate specific topical knowledge on water, energy, international development, etc., to the key competencies. This question resonates with a broader discussion as demonstrated in the European Project "University Educators for Sustainable Development" (Wilhelm et al. 2019). While experts appreciate that the framework is open to all relevant topics, academic disciplines, fields, and professions, they were asking for a meaningful conceptualization of the relationship between competencies and topics. A model that links the framework of key competencies in sustainability, basic academic competencies, and discipline-specific topical knowledge exists. Leuphana University of Lüneburg, Germany, uses such a three-dimensional model to define learning objectives for its sustainability science and other undergraduate programs. Also, students are asked to engage in recurring self-reflection followed up by a meeting with faculty to discuss ways to develop competencies and areas of specialization in each dimension (Barth 2019). Figure 4 draws attention to balancing general literacy about

each of the three dimensions (key competencies in sustainability framework, basic academic competencies, and topical field of study) with specialization in each of these three dimensions. While the three dimensions are applicable across contexts, the specifics of the context color the specifics in each dimension. For instance, conducting a collaborative tree-and-shade research project in a desert city in the Southwest of the USA requires understanding of this arid ecosystem and the history of this place (topical knowledge). This informs enacting the competencies associated with each step of the integrated problem-solving process. For instance, within collaborative competency specific consideration and care would be needed to facilitate an inclusive process that contributes to healing and avoids doing further harm; within values-thinking competency, understanding of indigenous values next to other values may require deep learning about indigenous ontologies in the first place; and within strategic-thinking competency transgressive skills may be emphasized to elevate indigenous voices while deconstructing white privilege.

Second, experts advocated for rethinking prior articulations of hierarchy among the competencies and propose values thinking as a lead-competency. Their argument is threefold. First, systems-thinking competency has sometimes been considered the key competency (c.f., Rieckmann 2012, Demssie et al. 2019), while inter-personal competency struggled to receive similar recognition (e.g., it is not included in prominent teacher education programs; c.f. Warren et al. 2014). This points to the challenge of articulating a hierarchy that emphasizes one competency, while not deemphasizing the importance of the other ones, as such select foci undermines the integrated nature of the framework of key competencies in sustainability. Second, the experts argue that values thinking competency provides the normative orientation for all others, clarifying values embedded in all other competencies. Recognizing values-thinking as a lead-competency will reinforce the integrated nature of the framework and the specific role of each of its competencies for sustainability problem-solving and not diminish their relevance. Thus, giving normative sustainability orientation to all competencies gives the framework a distinctive and applied purpose. Such an inherent normative orientation in all competencies distinguishes the competencies from their use in other disciplines (e.g., systems-thinking competency and strategic-thinking competencies are used in other disciplines as well, but often without clearly articulated and publicly deliberated values supporting sustainability including racial justice, ecosystem integrity, and regenerative economies). Working through the steps of the integrated sustainability problem-solving process results in an evidence-supported approach that can be applied. Once implemented, the contribution of sustainability researchers and professionals toward the 2030 Agenda for Sustainable Development and its accompanying set of SDGs (UN 2015) can be measured. Thus, in addition to accumulating knowledge and technical expertise, real-world sustainability impact is accounted for, reinforcing the applied characteristics of sustainability and sustainability science. Thirdly, values-thinking competency as lead competency jives with the earlier argument that entry into the integrated framework can be done at any point. Values-thinking as underpinning competency helps clarify values embedded in all other competencies whether the process starts with a systems-analysis to frame the problem or with backcasting from a desired future (see Fig. 2). Clearly, this perception might meet some opposition. Yet, the knowledge offered by science is applied by people in social contexts that are laden with values. Addressing values in decision-making is increasingly challenging in the "post-normal age", where "facts are uncertain, values in dispute, stakes high and decisions urgent" (Funtowicz and Ravetz 1993: 744).

Third, experts recommended adding two key competencies, i.e., intrapersonal competency and implementation competency (see Fig. 3). The additionally proposed competencies can be considered key competencies because they contribute significantly to sustainability problem-solving competency, do not overlap with any of the other competencies, and keep the framework to a minimal set of competencies (see Table 2). Yet, open questions remain.

Implementation competency requires further elaboration. The mostly cognitive orientation of the framework of key competencies in sustainability (most of the key competencies are 'thinking' competencies) aligns well with the mission and mandate of higher education institutions. In contrast, the more hands-on orientation of the implementation competency significantly alters and transcends this mandate, which might create frictions regarding the 'division of educational institutions' (regular universities vs. universities of applied sciences). It seems that not only differentiations but also demarcations would be necessary to capture implementation competency. For example, to assess students' implementation competency, it would be necessary for students to have the opportunity to not only learn from stakeholders how they have implemented change, but to practice it themselves by actually implementing a sustainability solution in a specific context, for example, on campus e.g., through campus living labs. Moreover, experts put emphasis on the ability to lead radical change by disrupting and transgressing normalized structures of injustice. This seems to reflect the movement toward immediate and transformational sustainability action. Examples include Fridays for Future demonstrations in Europe, civil disobedience by academics in the UK, or climate emergency declarations by local and national governments around the world. The question is whether and how educational institutions can support students in leading radical change, which could greatly enhance the chances of success for such endeavors. Lastly, the hands-on orientation

distinguishes implementation competency from integrated problem-solving competency. Implementation competency catalyzes the cognitively driven integrated problem-solving competency into manifest changes on the ground. It is thus a primary motivation for conducting sustainability research.

Intrapersonal competency raises questions as experts in this study hold two different views. The study identified a blind spot in the framework of key competencies and captured the missing capacities as a competency. This view is in line with scholarship proposing intrapersonal competency as an addition to the framework of key competencies in sustainability (Giangrande et al. 2019); offering starting points for learning objectives (Habron 2012; Burns 2016; Brundiers and Wiek 2017; UNESCO 2017) and pedagogies to acquire affective–motivational capacities through self-inquiry/self-experience-based learning (Frank and Stanszus 2019). In this view, intrapersonal competency links with the other competencies the same way as interpersonal competency does. For instance, collaborating with stakeholders (interpersonal competency) in a visioning project (futures-thinking and values-thinking competencies) presents an obvious link grounded in established professional practice. Intrapersonal competency links with futures-thinking as it is important to be aware of one's emotions (e.g., hope and fear) related to futures (Ojala 2012; Gardiner and Rieckmann 2015). It links with values-thinking through self-awareness of one's own values (e.g., equity, consumption, human-nature connections). It links with interpersonal competency through empathy, a skill involving both social awareness and management of others (interpersonal) as well as self-awareness and self-regulation (intrapersonal) (CASEL n.d.). Applying this argument, it is plausible that intrapersonal competency links to the other competencies through its motivational and attitudinal components. As attitudes can consist of intentions to act, they play a key role in translating acquired sustainability competencies into actions (UNESCO 2018: chapters 2, 4). For instance: entrepreneurial attitudes support strategic-thinking, open-mindedness facilitates systems thinking, creativity, and imagination stimulate visioning, wanting to make a difference pushes toward action. Engaging with others mindfully can facilitate collaboration in sustainability problem-solving processes (Wamsler 2018).

In contrast, some experts in this study question whether the intrapersonal factors form a competency or whether intrapersonal factors are more accurately captured through other concepts, such as mindsets.[6] They argue that intrapersonal factors act as moderators, indirectly influencing all other competencies. They agree with the first view on the relationships between intrapersonal factors and each of the other competencies. They might also agree with Dlouhá et al. (2019), asserting that these intrapersonal factors are a condition for integrative competency development, helping to integrate socio-emotional and behavioral aspects with cognitive processes. Yet, given the higher education context, they argue that intrapersonal factors (1) cannot be prescribed through learning objectives and (2) they do not manifest as performance. As performance (successfully acting out what was learned) is a defining element of the competency concept, serving to measure competency attainment, these experts argue that intrapersonal competency is not a competency. For instance, students developing research-based sustainability solutions might be able to describe, analyze and employ concepts from intra-personal competency (e.g., emotional intelligence) when analyzing racial justice issues (values-thinking competency) and transgressive actions (strategic-thinking competency). In this process, students might feel empathy for those suffering from pollution and economic disenfranchisement and reflect on their experience with these intrapersonal concepts in their assignments. Yet, this might or might not compel them to engage in implementing proposed actions themselves, enacting these intrapersonal concepts. Thus, this view argues that intrapersonal aspects can only be inferred. This view suggests to first assess students' performance of key competencies (e.g., to assess the in situ facilitation of a collaborative visioning exercise) and within this assessment to evaluate the role of mindsets as personal factors indirectly moderating one's performance and the process leading to it. The two views show that intrapersonal factors are important for sustainability. They are moderators of transformative learning when students engage with the framework of key competencies. Further research is needed to clarify the definition (mindset or competency). Based on research by Dweck (2006) on the importance of mindsets in students' achievement, future competencies research may want to consider re-framing attitudes in terms of mindsets (i.e., assumptions and views toward learning for sustainability). Moreover, more research is needed on how to activate this interpersonal potential.

Fourth, experts specified some new learning objectives primarily for those students, who want to become sustainability researchers. Wanting to continue their career within academia, they will need to learn how to cope with persisting prejudices in academia aroused by the characteristics that make sustainability science a specific kind of science. It is an interdisciplinary field of research and education aiming to impactfully contribute to real-world sustainability transformations by generating scientific evidence, co-produced with practitioners, and partnering with practitioners in implementation efforts (Kates 2011; Lang et al. 2012;

[6] Dweck (1999, 2006) defined mindset as a self-perception or self-theory that people hold about themselves and applied the concept of mindset to people's self-perceptions as learners (intelligent or unintelligent learner), or in their professional or personal lives (being a good teacher, being a bad parent). Glossary of Education Reform (2013).

Yarime et al. 2012; Miller et al. 2014; Wiek et al. 2015; Hart et al. 2016). To support students in such pursuits despite the reservations against these characteristics, higher education institutions can introduce students to available resources. First, specific theories of change for sustainability researchers have been identified, detailing activities, associated pathways toward impact, and roles for researchers in each pathway (Oberlack et al. 2019). Second, there is a growing international community of sustainability researchers pursuing similar goals; this community can provide mentorship (Bettencourt and Kaur 2011; Kajikawa et al. 2017). Third, considering the demanding academic culture in general and the evidence that students in interdisciplinary career tracks, such as sustainability science, have more difficulty in finding jobs within academia (Haider et al. 2018), higher education institutions should support aspiring sustainability researchers in creating a self-care plan focused on all dimensions of wellbeing as part of their professional development (Burns 2016). The work of sustainability researchers taking the use-inspired, participatory and outcomes-oriented approach of sustainability science to heart are only partially measured using standard evaluation criteria in Promotion and Tenure guidelines to measure sustainability outputs and outcomes in research, teaching and service.

Finally, the study revealed an interest among experts to learn more about sustainability competencies and through a collaborative effort. For example, experts asked questions specifically related to the methodology of sustainability science (e.g., what is meant by the 'functions' and 'steps' of methods, what does it mean to 'partly/fully operationalize sustainability,' and why were some methodical learning objectives associated with particular competencies). This points to a well-known challenge of emerging fields that students might receive trainings from individual sustainability researchers, who might not have received such training themselves (c.f., Heinrichs et al. 2016). Familiarizing oneself with the emerging ontology, epistemology, and methodology of sustainability science presents a challenge as sustainability science draws on a range of disciplines and innovative contributions published in a scattered landscape of academic journals. One promising approach is to adopt sustainability education professional development programs, which offer a multitude of benefits (Barth and Rieckmann 2012) and contribute to faculty and academic staff developing sustainability teaching competencies (Vare et al. 2019; Wilhelm et al. 2019).

Conclusions

This article presents the findings from a Delphi study focused on contributing to the consolidation of the key competencies in sustainability and related learning objectives, critically reviewing the most frequently referenced framework of key competencies in sustainability by Wiek et al. (2011). Study results provide a refined framework to support program and curriculum development worldwide. While there was general agreement on the framework and its main features, experts nuanced definitions, proposed a hierarchy (values-thinking competency as underpinning competency) and two additional key competencies (intrapersonal and implementation competencies), and specified learning objectives for aspiring sustainability professionals and for sustainability researchers in particular. Further research should clarify whether intrapersonal capacities impact key competencies in sustainability through the concept of competency or mindset and more research is needed to theorize the implementation competency.

The study also revealed that competencies are not naturally developed in teaching–learning settings, instead they require targeted and ongoing efforts to learn about competencies and through working with each competency's set of concepts, methods, and skills. Most notably, this seems applicable not only for students but for faculty as well. A key implication for practice is to offer faculty development programs and to build a shared literacy around key competencies in sustainability.

Finally, still more work remains with respect to the revised framework. Some experts pointed to the inclusion of other ways of knowing, notably indigenous perspectives, and of experts from Latin American, Middle Eastern, and African higher education institutions to address the cultural limitations of this study. Similar Delphi studies are emerging, involving experts from Latin America (Rieckmann 2012) and Ethiopia (Demssie et al. 2019) and showing overlap with the five key competencies in sustainability discussed here. This is relevant as these studies explicitly explored whether these competencies apply to non-European and developing country contexts. Both studies suggest that certain sustainability competencies may be relevant across contexts to guide learning outcomes in sustainability programs. A systematic comparison, including these studies and recent research conducted through the Education Future Change Agents research program[7] would help to further strengthen the framework as a reference framework for higher education's efforts related to sustainability education program and course development.

In sum, students, employers, educators, and program administrators are calling for higher education sustainability programs to articulate the competencies they are designed to help students achieve. To date, prescribed competencies,

[7] Educating Future Change Agents Research Project: https://www.leuphana.de/en/research-centers/cgsc/research-projects/educating-future-change-agents.html.

with some exceptions, have mostly been proposed as lists (vs related terms), and ideas that are difficult to assess. The refined framework presented in this article is a step forward in articulating key competencies in sustainability for post-secondary education, to drive curriculum development, implementation, and evaluation, as well as enhance the employability and effectiveness of graduates from sustainability programs worldwide.

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