



The spectrum of knowledge: integrating knowledge dimensions in the context of forests and climate change

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Abstract

Integrated approaches to knowledge that recognize meaning, behavior, culture, and systems as domains of knowledge are increasingly employed in holistic views on sustainability transformation but often remain conceptually driven. In this study, we analyze empirical data from a collaborative process with local forest stakeholders in Sweden through the lens of individual, collective, interior, and exterior knowledge dimensions. We show that the participants' understanding of knowledge about forests and climate change presents a nuanced picture of how knowledge and acting are connected. Meaning-making, cultural frames, and techno-scientific knowledge conceptions converge, interact, and, at times, replace or diminish each other. The connection and interplay of these dimensions, we suggest, can be understood as a knowledge spectrum. These insights into integrated knowledge, based on an empirical case, must be addressed in the production of knowledge, both to grasp the climate and sustainability issues that face us and to support action in response to them.

Keywords Knowledge · Sustainability · Transformation · Climate change · Forests · Sweden

Introduction

The contentious role of forests in Swedish climate action is a prime example of the confusion arising when the “‘what’ and the ‘how’ [of sustainability transformation] are conflated” (Bentz et al. 2022). Reducing carbon dioxide emissions is considered central to sustainability transformation, and the importance of forests for climate change mitigation is widely acknowledged (Jordan et al. 2018; Lundmark et al. 2014). Yet, this knowledge does not imply one clear path of action. Instead, management options and policies following

from the overarching goal of effectively connecting forests with climate action are conflicting (Andersson et al. 2022). Moreover, different social interests and perspectives intersect in the forest, making conflicts more tangible and visible. The trade-offs between different action paths polarize society and have moved the connections of forests and climate change into a highly politicized and emotionally charged realm beyond technical and scientific knowledge (Jakobsson et al. 2021; Sarewitz 2004).

To unpack the ‘what’ and ‘how’ of transformation in this context of contested knowledge claims, this study investigates how interior and exterior, individual and collective ways of knowing interact in the context of climate action in a Swedish context. Knowledge is here understood in an inclusive way to describe human ways of understanding reality with different ontological and epistemological implications, that is, leading to different understandings of *what* can be and *how* it can be known (Caniglia et al. 2021; Wilber 2005). The knowledge that underlies actions for sustainability transformations is seen to include different dimensions of individual meaning-making, shared cultures, natural and social systems, and observations and experiences (Shrivastava et al. 2020; Wamsler 2019). Integrated approaches to these knowledge dimensions are recognized to have the potential to generate deep leverage for change (Horlings 2015; Leventon et al. 2021; Shrivastava et al. 2020;

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Woiwode et al. 2021) and to enable fast-paced societal change (O'Brien 2021; Wamsler et al. 2021). Only a limited number of studies, however, explore knowledge dimensions in empirical material to advance this field of study (Gosnell 2022; Nguyen and Bosch 2013; Tourangeau and Sherren 2020).

Sweden, the context of our empirical case, has historically had a pronounced timber-production framework within which society's development, and national and cultural identities in the twentieth century is placed (Beland Lindahl et al. 2015; Berg et al. 2008; Kunnas et al. 2019; Mårald and Westholm 2016). Since the last decades, however, the forests' multiple uses and social values, including recreational functions, emotional attachment, use of non-wood forest resources and cultural and historical heritage, including Indigenous forest uses, are increasingly recognized as policy issues (e.g., Beland Lindahl et al. 2017; Lidestav et al. 2020; Zhang et al. 2022). As a result, multiple perspectives on the material and immaterial aspects of forest–climate change connections are relevant to managing the forest toward more diverse societal goals, and multiple uses and values, while also accounting for its role in climate action and society's transformation toward sustainability.

With Sweden's development toward a post-production paradigm and multiplication of interests and knowledge claims (Beland Lindahl et al. 2017; Lidestav et al. 2020), this context is a compelling setting for an empirical study of the role of knowledge dimensions and their role in sustainability transformation. We therefore apply an integrated approach to knowledge to the empirical case of the forest and climate change context in Sweden. How do the different knowledge dimensions become visible in local forest stakeholders' reasoning about climate action? What is the interplay between these knowledge dimensions in our empirical setting?

In the following, we describe our conceptualization of knowledge dimensions based on literature on integrated approaches in the field of sustainability science and relate our study to the forest and climate change literature ("Conceptualization of knowledge dimensions"). After an account of our empirical material and methods ("Materials and methods"), we present and discuss our results of the empirical analysis ("Results and discussion").

Conceptualization of knowledge dimensions

Relevant knowledge for bringing about change is increasingly understood as including the creation of meaning through experience and emotions, culture and worldviews, behavior and practices, and knowledge of the functions of social and ecological systems (Caniglia et al. 2021; Floyd and Zubovich 2010; Shrivastava et al. 2020; Wamsler 2019; Wamsler et al. 2021). In these integrated approaches to sustainability transformation, the production and understanding of knowledge is

described in a holistic way. Four overarching ways of knowing the world and constituting reality commonly are recognized. Although their exact definition may vary, the conceptualization of knowledge dimensions commonly relate to Wilber's (2000, 2005) integral theory as a meta-perspective to explore multiple perspectives on the intersection of societies and ecologies in a sustainability context (Brown 2005; e.g., Cumming 2014; Manuel-Navarrete et al. 2004; Nicol 2015). In the following, we refer to these aspects as knowledge dimensions (the four quadrants, see Fig. 1). Each knowledge dimension has ontological, epistemological and ethical consequences for action based on the knowledge created through that particular lens (Walsh et al. 2021). There is a growing body of literature that seeks to apply integrated approaches, based on integral theory, to environmental issues and sustainability challenges over the past decades. Bringing together interior and exterior knowledge dimensions in models derived from integral theory can serve as map, a theory, a framework and a catalyst for empirical investigations to create "a space for multiple perspectives to contribute to the discovery of viable solutions" (Esbjörn-Hargens 2010, p. 58). In the following, we use the notion of knowledge dimensions as an analytical framework to approach our empirical material.

Investigating collective-exterior knowledge dimensions is seen to produce insights toward how individuals function together in a system (see Fig. 1, quadrant "system"), such as in climate or ecological systems, or how humans function collectively in society and the economic system (Shrivastava et al. 2020). In the context of this study, this includes scholarship on socio-ecological systems at the intersection of forest–climate issues and collective ways of formulating a response, for example, at the community level (Brnkalakova et al. 2022; Hallberg-Sramek et al. 2022a).

The role of collective meaning-making is captured in the notion of culture as a shared set of understandings within a social system (see Fig. 1, quadrant "culture"). Studies have

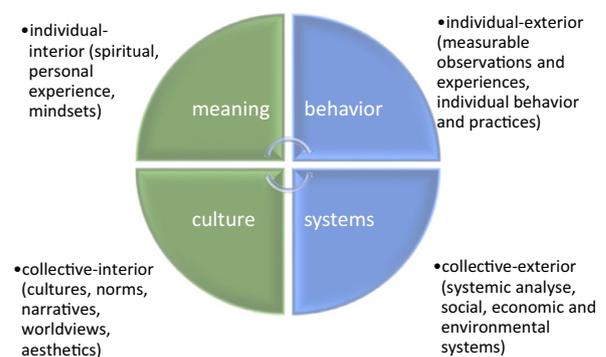


Fig. 1 The four quadrants representing four knowledge dimensions, according to Shrivastava et al. (2020). The arrows in the middle of the figure illustrate the interplay and synergies between these ways of knowing

shown how culture shapes societal responses to climate change (Adger et al. 2013). In the context of forests and climate change, this dimension is reflected in studies engaging with society- or community-wide norms and preferences, for example, studies on social forest values (Lidestav et al. 2020), or in studies mobilizing a given definition of culture applied to forested landscapes (Eriksson 2018).

Individual exterior knowledge refers to knowledge that can be acquired externally about the behavior of an individual organism or singular unit of a system, through measurable experiences and observations (see Fig. 1, quadrant “behavior”). In the context of forest–climate change connections, relevant scholarship relates to, for example, behavioral changes and practices of individual forest owners (Vulturius et al. 2019).

In the context of forests and climate change, studies mobilizing individual and interior aspects of knowledge (see Fig. 1, quadrant “meaning”) highlight the individual’s sense of urgency and concern (Wong-Parodi and Berlin Rubin 2022), and the individual’s beliefs and attitudes toward and understanding of scientific knowledge on climate change in a forest context (e.g., Eriksson and Klapwijk 2019; Vulturius et al. 2018).

Investigating interior knowledge dimensions (see Fig. 1, upper half) leads to insights through personal experiences (individual) and shared cultural experiences and worldviews (collective) of places and practices. The interior knowledge dimensions encompassing worldviews, values, mental paradigms, critical self-reflection, and place attachment have received increasing attention for adapting and further developing integrated approaches that connect to exterior knowledge dimensions (see Fig. 1, lower half) (Grenni et al. 2020; Sacks 2018; Wamsler 2020). These ways of understanding and navigating in the world may challenge, or uphold material structures and path dependencies of unsustainability tied to exterior systems, such as transport infrastructures (Horlings 2015; Ives et al. 2020). There is, thus, no normative valuation attached to either dimension. Instead, these knowledge dimensions are seen to be nested within each other and have to be approached in an integrated way in order to enable deep transformative change (Floyd and Zubevich 2010; O’Brien 2018).

Materials and methods

Empirical data

The empirical data for this study were gathered in the context of two forest stakeholder workshops, one held with stakeholders from Vindeln and Umeå in Västerbotten County in northern Sweden, and one held with stakeholders from Lessebo and Växjö in Kronoberg County in southern Sweden. The workshops were part of a workshop

series with four consecutive workshops that took place over six months in 2019, in a parallel set-up at both locations, as part of an interdisciplinary research project on forests and local climate action pathways. The workshop series corresponded to the following steps: (1) past and future transformative changes in relation to forest and climate in the local community, (2) policy instruments for local climate action, (3) risks and opportunities for local forest uses, and (4) collaboration with local decision-makers. The analysis of other aspects of the empirical material produced by the workshop series is presented in Hallberg-Sramek et al. (2022b), Hallberg-Sramek et al. (2023) and Priebe et al. (2022).

The collaborative process was facilitated by a research team comprising historians of science and ideas, political scientists, and forest scientists, and emphasized bottom-up and participatory knowledge production. The dialog during the workshops was guided by principles of transdisciplinarity, with an emphasis on relational viewpoints on sustainability issues. This means that we aimed for a shift away from research agendas defined solely by academic disciplinary communities, toward focusing on the knowledge brought to the collaborative process through the local stakeholders participating in the workshop series (Knapp et al. 2019; Lang et al. 2012; Walsh et al. 2021).

The two participant groups consisted of 14 and 16 participants, respectively, with similarly balanced age, gender, and interest distributions. The participants included local forest owners, forest industry representatives, people engaged in environmental non-governmental organizations, hunters, educators, local development representatives, tourism entrepreneurs, and Indigenous Sámi reindeer herders. About half of the participants in each group came from the regional urban center of the respective municipality (the cities of Umeå in Umeå municipality, and Växjö in Växjö municipality), and half from rural municipalities (Vindeln and Lessebo, respectively). The workshops were led by a professional facilitator.

The empirical material analyzed in this study consists of interviews with the participants conducted individually prior to the workshop series; personal reflections that the participants wrote individually and anonymously after the workshop sessions of step (1) in both the northern and southern location, and an individual post-workshop series survey completed by the participants online. The individual, anonymous reflections were collected to mitigate any power asymmetries in the workshop situation (Onwuegbuzie et al. 2009). The interviews prior to the workshop series were conducted by the members of the research group in a semi-structured way and took between 45 min and 1.5 h individually with each participant. The interviews were transcribed by a professional service. The post-workshop survey was conducted via an online

form after the end of the workshop series. The empirical material was analyzed in the original Swedish language. Quotations in this study were taken from the anonymized pre-workshop interviews, individual reflections, and post-workshop survey, and were translated into English by the authors of this study.

Method of analysis

The coding of the empirical material was conducted in three steps. First, the data were qualitatively coded according to the key aspects commonly associated with integral approaches adapted for the context of sustainability issues, as summarized in Table 1. These key aspects were identified to operationalize the conceptualization of knowledge in a coherent way as a basis for the qualitative coding. We have chosen those key aspects as defined in empirical or conceptual studies on integrated approaches to environmental and sustainability issues (see Table 1). Instead of being employed as absolute, exclusive traits, these important aspects are used in the literature to show the key properties of these dimensions. To make our analysis as transparent as possible, we explicitly state these aspects that led the empirical material analysis. Second, to validate this categorization (Shenton 2004), the data were coded independently and the initial coding was, if necessary, adapted. To triangulate the coding (Flick 2004; Shenton 2004) and to contextualize the participants' statements if necessary for comprehension, additional material collected from the workshops was also used, for example, the researchers' notes from plenary discussions; recordings of group discussions; and visual and text-based material produced by the participants during group exercises. This material was,

however, not part of the main empirical data analyzed in this study and was only used for clarification.

Categorizations in the cited literature occasionally differed, albeit marginally, across the individual–collective dimensions. For instance, 'worldview' was categorized as an 'individual' indicator by Wamsler et al. (2021) while we chose to list these aspects as a collectively held cultural expression, as originally proposed by Wilber (2000). In such cases of ambiguous interpretation, we aimed to be as transparent as possible in our analysis while recognizing the multiple meanings the quadrants have acquired in studies using integrated approaches to sustainability issues (Ballard et al. 2008; Gosnell 2022; Tourangeau and Sherren 2020). This very ambiguity, however, highlights the need to further develop the conceptualization and empirical applicability of integrated approaches to knowledge in the context of sustainability issues to provide consistent analytical guidance. In our empirical context, it was also important to note that these knowledge domains may or may not be congruent with a particular person's views, values, or political stances toward forests and climate change (Poortinga et al. 2019).

Results and discussion

The order of this section and knowledge dimensions as presented below does not imply any evaluation. Rather, it is a logical order reflecting the fact that the dimensions are interconnected, share certain aspects, and can be explained by building upon each other. The analysis should therefore be read as an attempt to structure the results, rather than as a strict and clear division.

Table 1 Key aspects associated with the knowledge domains of integrated approaches (see also Fig. 1)

Meaning	Behavior
Adapted from Wamsler et al. (2021, appendix A): Mindset Values Cognition Emotion Beliefs Personal motivation and intent	Adapted from Fleming (2015) and Shrivastava et al. (2020): Behavior Practices Habits Measurable experiences External observations Empirical data
Culture	Systems
Partly adapted from Wamsler et al. (2021, appendix A): Society/societal Social structures Culture(s)/cultural Social relations Shared worldviews Ideologies (assumptions underlying) governance	Partly adapted from O'Brien (2018): Social systems System behaviors Systems science perspectives on ecological, climate systems, etc. Formalized and institutionalized relations in a (social or natural) system

SYSTEMS: the collective-exterior knowledge dimension

A systems-based perspective on knowledge about forests and climate was a recurring and prevailing dimension in the participants' reflections and discussions. This perspective was strongly influenced by a focus on the 'hard science' to explain the behavior of these systems, which are also strongly influenced by the cultures within which they are defined and created (Shrivastava et al. 2020). Participants highlighted the cyclical processes that connect forest and climate, such as carbon dioxide cycles, forest growth and carbon dioxide uptake and storage, and precipitation, commonly referred to in literature about forests' ecosystem services (Brockerhoff et al. 2017). In connection with these natural cycles, many statements also referred to cycles of financial or economic production, often with a focus on the valuation of ecosystem services and their integration into the economic system. In this way, the knowledge dimension focused on systems, including both physical and social processes of valuating forest and climate in economic terms.

The participants repeatedly emphasized that the level of this kind of knowledge, about the forest's ecosystem services and the climate system, should be higher in society. One participant expressed this view as: "We need a higher level of knowledge about how everything works in our boreal forest region, and this can be applied globally". This example also indicated that the insights into the processes of systems (such as the boreal forest) were seen to be transferrable to other contexts, and possible to 'apply' elsewhere. The lack of common knowledge about forest ecosystems and species, for example, was seen as standing in stark contrast to the dominance of forests in the Swedish landscape. One participant stated that it was "frightening that so many do not know anything, they know what a forest is, but they do not know the difference between a spruce and pine tree. And we have so much forest in Sweden".

With a focus on climate issues, climate science was often described as 'common facts' about the climate system. With this expression, the notion of a shared understanding of the climate was emphasized by contrasting it indirectly with a notion of knowledge and understanding that was contested and not shared. The media representation of climate science, with Al Gore as a prominent and recurring example in the participants' statements, was described as the epitome of shared, uncontested knowledge based on models and simulations of future climate developments. Statements in this direction reflect the overwhelming focus on calculations and models in formulating societal responses to climate change (Bray and von Storch 2009; Hulme 2011). External, scientific methods

for predicting the future availability of resources, for example, through projections and simulations, manifest more broadly as the central position of techno-scientific knowledge in environmental policy discussions that is also reflected in the participants' statements (Andersson 2018; Sörlin 2013).

Some participants reflected on the notion of system-based knowledge as providing a map for the future, often grounded in ideas of the neutrality of (natural) science producing this type of knowledge. In the participants' reflections and discussions, the value of this knowledge was often measured against the economic and political neutrality of its producers (scientists) and mediators (e.g., politicians), which reflects a traditional scientific ideal (Turnhout et al. 2013). As one participant stated, "... what politicians say should not be unchallenged. Politicians and organizations must present balanced knowledge". In this example, and throughout several instances of the collaborative process, knowledge about natural systems, such as forests, was seen to ideally be disconnected from worldly political and economic interests. A perceived lack of independence of knowledge producers was seen particularly in statements connected to the theme of property rights, and statements lamenting an apparent entanglement of economic interests and power over decision-making. Research activities on forests and climate change in Sweden were seen to be too closely connected to industrial interests, thereby hampering the neutrality of the science: "Research has to be independent from the Swedish pulp- and paper industries". When seen through the lens of systems, the participants highlighted the frictions between economic and natural systems.

The role of science to produce knowledge about the complex systems of climate and forests as neutral guidance was also highlighted by statements pointing out the lack of objectivity of the general public and of individual actors, such as industries and forest owners. Statements in this direction revealed assumptions of a stark division between a public that is too easily carried away by 'interests' and a science community that provides 'neutral' and objective answers. Understanding the functioning of systems was associated with an external, removed observer who produced more complete, balanced, neutral, and therefore more just, knowledge. As one participant stated, "When it comes to forestry, to adapt to climate change, we need external examiners ['granskare' in Swedish, A.N.] who have better, more comprehensive knowledge to see everything from a higher level, to see who else is affected". In this context, science-based knowledge, independent from material interests, was silently taken as a basis for providing this type of neutral and just advice.

The notion of lack of knowledge seen to dominate the climate discourse is, in the context of forests, exchanged with the notion of a lack of 'neutral' knowledge (Hulme

2018). The politization of science in the Swedish forest–climate context was seen as a problem further aggravated by the complexity and scale of the climate crisis, understood to go beyond common people’s comprehension (Druckman 2017). One participant expressed this viewpoint in the survey conducted after the collaborative process, in response to a question about how society, forests, and climate change can interact in the future to support local development: “This question is maybe too big for the general public where there are many ideas, vested interests, and beliefs that are more a mess of opinions than facts and knowledge.”

An interesting nuance of the dimension of system-related knowledge emerged in an early phase of the collaborative process. After a workshop day reflecting on past and future transformative changes (see Priebe et al. 2022), several participants emphasized the importance of facts but connected this with an awareness that went beyond knowledge as the comprehension of natural processes. For example, when reflecting on the future, some participants called for “better knowledge about the dependence on nature and functioning ecosystems and ecosystem services”, and “more/increased global knowledge and understanding necessary for all decisions and actions”. What exactly ‘global knowledge’ meant remained elusive, as it could refer to knowledge of global processes as well as the global dissemination of knowledge. In any case, the notion of system-related knowledge suggested an ability to develop understanding (*‘förståelse’* in Swedish), which, just as in English, has a double meaning, of both intellectual comprehension and sympathetic awareness. From this perspective, knowledge is extended from knowing *what* happens to *why* it happens. One participant wrote in a reflection during the collaborative process: “We need to know why things happen so that we can use the right countermeasures”. In several reflections on future change, the role of knowledge through the lens of systems was also connected to a preparedness for future crises and a deeper understanding of not only describing or predicting what would happen in the future, but why it would happen.

The participants noted, however, that there was not one clear path of action that could be derived from scientific knowledge about forest and climate systems. This became especially clear as authorities acting on knowledge about complex systems provided conflicting advice. In the plenary discussions and in the interviews, participants repeatedly pointed out that there were “too many authorities and knowledge holders” when it came to forest and climate issues in Sweden. Examples included the County Administrative Board and the Swedish Forest Agency, which were all understood to be providers of science-based advice. The major problem was seen to be that there were too many ways to short-circuit knowing and doing because the recommendations for action were, at times, conflicting.

This understanding of linking knowing to doing, however, also revealed other frictions. After the collaborative process, the survey revealed, to some extent, disappointment with the research project’s basic assumptions. In the search for advice, the notion that science and research provided answers and solutions to current conflicts was understood by the participants to be an inherent goal of a research project on forests and climate change. One participant lamented the lack of concrete suggestions provided in the collaborative process in the post-process survey: “It is a shame that you [the researchers] did not take the chance to show the forest owners how they can use the forest in a climate-friendly way”. In such statements, and during the discussions of the collaborative process, there was no explanation given on how and why science was seen to be able to resolve conflicting views on the forest’s role in climate action. This connection being made so directly showed that the collective knowledge dimension that focuses on systems is understood to conflate knowing and doing, and that knowledge about the forest and climate systems was seen to imply only one proper way of doing—even if it turned out there were different ways of doing that could be contradictory.

CULTURE: the collective-interior knowledge dimension

The knowledge dimension of culture, in the context of sustainability transformation, can be understood as concerning individual lifestyles, but it is also seen to encompass the shared worldviews and structures of social relations guided by a “general process of intellectual, spiritual or esthetic development” (Soini and Dessein 2016, p. 5). This general process, or culture, became visible in the local stakeholders’ reasoning about normative aspects, that is, how things *should* be done when it comes to forests and climate change. The normatively positive role of technological advancements was recurring in the participants’ statements, including, for example, the development of machines used in the forestry sector and forest-based materials seen as part of society’s climate action strategies. This kind of forward-moving, teleological development of society was also linked to expanding current solutions and extrapolating current developments (Priebe et al. 2021). A shared societal vision of technological advancement was reflected in statements about ‘improved’ or ‘more efficient’ use of the forest for climate action in the future.

These normative aspects of knowledge about climate change and forest related primarily to the forest’s role to offset and mitigate carbon dioxide emissions. In this understanding, the superiority of natural science knowledge claims made ‘doing’ possible, in a normative and teleological way, as illustrated in this quote from an interview conducted prior to the collaborative process:

“More scientific knowledge is needed. So that we learn what happens biologically. 50 years ago, it would have been difficult to believe that we can make clothes from trees, but this is what we do today. This knowledge brings development forward ... It is hard to see how philosophy helps to extract oil from trees. We need scientific grounds for that”.

The dimension of culture was most prominent in statements relating to implementation, for example, regarding challenges that are solved by technology and through ‘implementing knowledge’. Less attention was usually given to the political decisions and the cultural context involved in putting this knowledge into practice. Participants’ references to the role of knowledge as providing advice in the past were mostly concerned with the development of Swedish forestry in the 1990s and the results of the Swedish Forestry Act of 1993, which sought to mitigate tensions by enshrining the double-goal of production and conservation. Since then, however, multiple-use conflicts over land have increased (Beland Lindahl et al. 2017; Holmgren and Arora-Jonsson 2015). “The knowledge that was implemented in the mid-1990s and at the end of the 90s gave good results concerning environmental consideration ... We have strengthened environmental consideration in a quantitative way”. In our analysis we found several instances, as illustrated above, where ‘knowing’ and ‘doing’ were conflated (that is, where knowledge was seen to be directly implemented) and the outcome of knowledge, interpreted as advice, was seen to be verifiable through quantifiable results.

A reflective stance and the participants’ awareness of how different knowledge dimensions relate to each other became clearly visible. In several instances during the collaborative process, the participants noted that knowledge of systems based on scientific data and technological advancements tends to marginalize other collective ways of knowing and shared understandings of forests and climate. For example, one participant suggested that globalization of trade with wood products had led to domestic knowledge and practices about, for example, woodworking and about the quality of wood being lost. The technological shortcuts to knowledge about places and environment, which linked knowledge directly to how things should be done, were also described in relation to the hunting community. Some participants noted that the use of global positioning systems (GPS) and hunting devices with advanced digital technologies had changed how the environment was known and how the practice of hunting was carried out. In the example of hunting, data-driven technologies acted as a shortcut between forest-related knowledge and action. The culture of hunting, meaning the social relations and attachment to the place, was seen to be weakened.

BEHAVIOR: individual-exterior knowledge

In our empirical context, the knowledge dimension of behavior relates primarily to the participants’ observations of behavior and sensory experiences, that is, measurable experiences. This dimension is closely tied to the interior processes of meaning-making and the collective culture that act as interpretative frameworks for making sense of external stimuli (Nguyen et al. 2016). We found that this knowledge dimension also included both the participants’ own observations and narratives handed down from older generations. We understand experiences, therefore, as depending on individual people and particular places, although it could be transferred across generations and communities.

Our empirical material illustrates that our participants’ experiences were anchored in certain social groups and could only be interpreted and used within these groups. This could include, for example, people who lived in the same geographical area, or who shared demographic characteristics. One participant described the male family members’ exclusive access to practices related to forest management and use:

“I do not feel I am well-informed because I was the girl in the family. Concerning the forest, there was nothing to talk about with me. I did not understand it then, but it was dominated by men ... My uncle and my father ... I heard their stories about what they did [with the forest]”.

Even though the description related to the past, the lack of experience and knowledge handed down within the family left a feeling of a lack of information, that is, a perceived lack of collective-exterior knowledge about the forest system. This example illustrates how the dimensions of knowledge interact and how the gain, loss, or lack of access to one knowledge dimension can affect the perceived level of knowledge situated in another dimension.

Moreover, observations and experiences were understood, accepted, and assimilated or could be ignored, neglected, and deemed insignificant through social groups. One participant remarked in an interview that certain age groups managed and distributed the knowledge that was handed down from older generations differently. The participant suggested that older generations were more likely to trust in and act on experiences that they had acquired indirectly from previous generations. Young generations, in contrast, would sometimes act differently and consciously oppose this kind of knowledge.

One participant remarked jokingly that experience-based knowledge could be very ‘sensible’—but it could also often restrict the acceptance of scientific knowledge. “In the worst case”, the participant stated, “this knowledge resides with those men over 50”. In this example, and throughout the

plenary discussions, we observed a juxtaposition of different knowledge dimensions. Comparing collective and individual knowledge dimensions led to an evaluation in favor of systems knowledge, that is, the ‘facts’ that could be reproduced and corroborated externally. An individual’s observations, and measurable and observable experience was then seen to validate or support the facts (and to propel action based on it), or it could be disruptive and hinder or block what could be achieved through knowledge as fact and advice.

With this understanding, the individual’s experience had to be validated, or it could clash with other ways of knowing. One participant recalled how his experience-based knowledge about how to tend a particular forest patch was brushed aside by state authorities, who recommended another way of management based on scientific knowledge. The universality of exterior knowledge was, in this case, deemed to be crucial and valid regardless of the context, but it conflicted with one’s own experiences. The role of observations and trial and error in experience-based knowledge also hints at the blurred lines between individual and collective knowledge dimensions.

There were other examples of juxtaposing knowledge dimensions. References to Sámi experience, for instance, usually tied knowledge to the environment and ecological and physical processes, especially regarding the characteristics of ice and frozen rivers and landscapes important to reindeer herding. The role of Indigenous knowledge, however, seemed to remain unconnected from the larger context of knowledge about societal challenges resulting from climate change and divergent interests regarding the forest. In the participants’ reflections, the focus was mainly on the epistemic justification of including Sámi perspectives in discussions on climate change, meaning that this perspective was needed to add to systems-based knowledge: “I always highlight that reindeer herders possess knowledge about the forest and nature. Ask them”. The experience of individuals and groups in the Indigenous Sámi community was seen as important but nevertheless framed as a supplement and described in terms of what this experience could contribute to existing natural scientific knowledge about the environment.

Observable and measurable experiences about climate change and forests could not only be distributed temporally and shared between different generations, but it could also be shared and disseminated horizontally, according to the participants’ understandings. In the first workshop session of the collaborative process, several participants described how the collaboration between local groups and networks was crucial to achieving change in their community. Many perceived the sharing of experiences and observations as positive for local development. In reflections on challenges in the past, most participants highlighted cooperation beyond personal interests and the informal dissemination of

knowledge within newly emerging groups. In their understanding of how future changes could be handled at a local level, this way of sharing knowledge informally was identified as a crucial component: “Create groups who collaborate, disseminate knowledge and prepare”. Sharing knowledge informally and in horizontal networks seemed to be particularly relevant within the knowledge dimension of behavior, whereas the dissemination of systems-based knowledge was seen to be reserved for formalized and professional forums, such as schools, public education, and media.

MEANING: individual-interior knowledge

In the field of sustainability science, the interior processes of creating meaning and awareness are commonly seen to be crucial to initiating climate action collectively. This view is complicated, however, by the dangers of inaction and skepticism created by the ‘ontological pluralism’ of ‘climate changes’ (Hochachka 2022). Yet, meaning and subjective interior processes do not need to contradict other knowledge dimensions, but can translate them into action, as Hochachka (2022) also points out. In our empirical case, the creation of meaning seemed to act as a moral compass for the individual. Regardless of the decision or action taken, participants pointed out that it was important to be “affected as a human, then you can make smart decisions. This is what happens when you hear about these examples [of others’ experiences]”. This aspect of being personally moved and affected resurfaced in the workshops during the collaborative process, when emotional engagement was highlighted as a vital ingredient for the success of local collaboration and action in the face of acute crises.

Emotional engagement, in our context, in several instances exceeded the notion of urgency commonly reflected in literature on individual’s commitment to climate action (van der Leeuw et al. 2012) and related more to interior dimensions of knowing rather than being alarmed to act. One participant described their impression of past climate change as a feeling: “There is both a gut feeling from my childhood [in the village]. I have a feeling of what has changed, and then there is the part about the facts”. Just as with the measurable experiences, the feeling was also quickly juxtaposed against the ‘facts’ and validated. In our collaborative process, the participants often used words like ‘kännedom’, which is commonly translated as ‘knowledge’, although it includes another nuance, too. ‘Kännedom’ reflects the original meaning of being deeply aware, recognizing (historically, mainly in a spiritual context) the existence or identity of something, and a learning. This points to acquiring knowledge primarily through experience, and through teaching (Swedish Academy’s Dictionary, ‘kännedom’/‘känna’).

One participant stated in an interview: “When we are in the forest, or in nature, we can obtain knowledge [‘kännedom’ in original Swedish] about the planet’s boundaries”. Planetary boundaries can be understood as an exteriorly identified benchmark of human impact, but by connecting this knowledge to an individual’s viewpoint and concrete place it becomes a way of creating meaning. The example also hints at the notion that this knowledge can be transferred and taught to others once they are in the same place as the knowing subject, for example, in the forest. Meaning is created through experiences tied to a particular place, and the same forest place can take on a plurality of meanings (Stedman 2003).

In our empirical context, this way of creating meaning produced a dichotomy between notions of ‘place-based’ and ‘remote’ knowledge of climate change and forests, often framed in terms of urban versus rural knowledge. Several participants referred to conflicts between urban and rural environmental perspectives that were seen to result from how people acquired their knowledge and how they were able to relate this to their immediate and every-day surroundings. During the collaborative process, the participants highlighted the importance of being in a particular place, such as the forest, and the negative effects of urban life and forest ownership not being tied to living in or near the owned forest.

In several interviews prior to the collaborative process, as well as in the workshops and the survey conducted afterwards, there were comments and statements emphasizing that there was enough knowledge already available and that inaction did not result from a lack of ‘knowledge’. When seen within the individual-interior knowledge dimension, the obstacle to taking action appeared to be a lack of deep awareness and a failure to relate climate change to human identity. The problem was, in other words, seen as a failure to convey the seriousness of the crisis—both at a political and a personal level. As one participant stated when asked about how they thought decision-making and action on climate change could be influenced: “When it comes to scientific knowledge, I think I have enough of that. It is rather rhetoric and communication where I lack knowledge”.

Another aspect of the same principle was visible in statements that highlighted the importance of feeling and understanding, almost in a spiritual sense, that “we are part of something bigger”. This creation of meaning was often also seen as a condition for truly grasping the implications of systems-based knowledge, and vice versa. As one participant put it, there needs to be a systems perspective, “system thinking, that we understand the climate system, forest ecology, and interconnected natural processes in order to understand and fully grasp the human role in these mechanisms”. A sense of urgency revealed its potential to initiate action if

it was connected with exterior knowledge about the interconnected functioning of the systems’ parts.

The importance of places and spaces of experience was present in the individual-interior knowledge dimension. One participant elaborated on how they found that neither the term knowledge, nor feeling, conveyed the meaning of a deeper understanding. Instead, this participant created a new word to capture this dimension:

“In general, people need to have better knowledge, or a feeling. It is a nature-feeling [‘naturkänsla’ in Swedish, A.N.] and basic knowledge about nature ... Nowadays, we live in cities, and we are further and further away from nature, and you do not need to care about nature, and you do not need to know [‘kunna’ in Swedish, A.N.]. We need to create a word for it, like ‘feel-edge’, which is both feeling and knowledge about the forest that has to be there for many”.

For understanding, awareness and grasping the situation, from this perspective, it seemed to be essential *where* forests, climate change and environmental issues were experienced.

In several instances during the collaborative process, we saw the importance of knowledge distribution and dissemination, indicating the importance attached to the question of how many people had acquired a particular dimension of knowledge. The notion of a threshold of knowledge holders appeared across knowledge dimensions, as exemplified in the statement cited above, but was particularly prominent in the collective-exterior dimension of knowledge. Regardless of the knowledge dimension that the statements referred to, the need for a critical mass of knowledge holders was highlighted, and also a certain level of knowledge in the general public for action to take place and be effective.

Another nuance of meaning-making was visible in the example mentioned above, and it, too, related to the blurred lines between knowing and doing. To be able, capable and knowledgeable enough ‘to do things’ is captured by the Swedish term ‘kunna’. It refers to action and practice based on knowledge (‘kunskap’ in Swedish), but it is also connected to a deeper awareness and normativity of ‘caring for nature’ (cf. ‘känsla’ in Swedish, commonly translated to ‘intuitive knowledge’, or ‘feeling’, SAOB 1893). In other words, it is, in this case, the dimension of feeling that translates knowledge into action.

This dimension of meaning seemed to open up a process of interior reflection. The ability to view one’s own position as being a part of a larger system went beyond intellectual comprehension and created imaginative space for change. In the survey after the collaborative process, one participant stated: “With a growing understanding, one also starts to question and to think about the changes that are possible”. The creation of meaning, ascribed to the individual-interior

knowledge dimension, seemed to allow a self-reflective perspective on actions, practices, and positions that no other dimension of knowledge provided.

Conclusions

In this study, we analyzed the different dimensions of knowledge about forests and climate change that became visible in the participants' reflections and discussions during a collaborative process on local climate action pathways. Our results highlight that there is a considerable interplay, convergence, and mutual influence between interior and exterior knowledge dimensions. Thus, we can understand the knowledge dimensions as a knowledge spectrum. A spectrum is a continuum or continuous sequence or range that resembles a "color spectrum in consisting of an ordered arrangement by a particular characteristic" ('spectrum', Merriam-Webster Dictionary). The notion of a knowledge spectrum allows a dynamic approach to knowledge and opens new ways of recognizing the transitional and in-between-states of knowledge.

In our empirical material, overall, we saw a tendency to seek validation or support for the interior dimensions from the exterior dimensions of knowledge. Only if validated from an exterior viewpoint, it seemed, were interior knowledge dimensions recognized as a valid basis for action. Yet both interior knowledge dimensions were tied to the past and, very closely, to the present. They therefore represented an immediate link to collective action that is invaluable for propelling actions directed toward the future. Meaning, at the individual and subjective level, was often seen to expand and contribute to a deeper knowledge and awareness of 'how things are'. It was in the context of this understanding that feeling compelled someone to act based on the facts, represented in the external-collective knowledge dimension.

Across the interior and exterior knowledge dimensions, we could identify the notion of the environment, and the global and the local forest as a 'socio-ecological system', a whole within which humans live that, although complex, could be understood and managed from an exterior and neutral viewpoint. With this understanding, uncertainty stemming from climatic variability or from unpredictable developments of human societies also appeared to be a hindrance to fully grasping the whole system and its functions (Klapwijk et al. 2018).

The lack of linguistic clarity when it comes to knowledge of climate and forests, illustrated by the statements that sought to find a new term for simultaneously knowing and feeling, was a recurring issue in our data. It reflects the wider problem of grasping the complexity and nuances of knowledge about sustainability and sustainability transformation (Caniglia et al. 2021). We suggest that attempts

to attain knowledge about sustainability must include not only a pluralistic but also an integrated understanding. People often describe their openness toward different attitudes and opinions on forests and climate change—as long as everyone agrees upon 'the facts'. There is little point attempting to raise the importance of diverse perspectives, knowledge types, values, and attitudes if the core of the conflict lies in differences in how factual, externally verifiable knowledge is contrasted with 'the rest', or other types of knowledge.

Research on societal change as a response to climate and sustainability crises increasingly draws attention to the human experience and meaning-making of sustainability transformation (e.g., Blythe et al. 2018; Duncan et al. 2018; Wibeck and Linnér 2021), as well as to the ways in which different actors engage in co-production of knowledge for climate action (Howarth et al. 2022; Wamsler et al. 2021). After decades of inaction on climate and sustainability crises, and various attempts at explaining the challenge of translating knowledge into action (Naustdalslid 2011; Poortinga et al. 2019), it is, therefore, time to scrutinize and widen our understanding of knowledge itself in order to explore new connections between knowing and acting.

This study has sought to contribute to the growing research field on transformation within sustainability science that builds on the ambition to produce holistic understandings of how deep change in society and socio-ecological relations comes about. It hopefully serves as an example for the rich insights that can be produced when theoretical frameworks of integrated approaches to knowledge are brought into a dialog with the 'messiness' of situated knowledge (Arnott and Lemos 2021). The contested ways of relating forests to climate action highlight the importance of striving "toward inhabiting multiple perspectives—especially those that stand in contrast to our own habits of thinking and feeling" (Esbjörn-Hargens 2010, pp. 58–59). An understanding of the knowledge dimensions of integrated approaches as a spectrum of knowledge, as discussed and illustrated in this study, highlights that knowledge is neither purely interior nor exterior, neither purely individual nor collective. To comprehend the climate and sustainability crises that face us as well as to facilitate action in response to them, the interaction and interplay of these dimensions must be addressed in the production of knowledge.

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Data availability The data presented in this study are available on request from the corresponding author. The data are not publicly available to safeguard the anonymity and privacy of the local stakeholders.

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