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ORIGINAL ARTICLE

Knowledge sources, narratives, and living in social-ecological systems

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Abstract
Humans exist as part of social-ecological systems (SES) in which biological, physical, chemical, economic, political and other social processes are tightly interwoven. Global change within these systems presents an increasingly untenable situation for long-term human security. Further, knowledge that humans possess about ourselves and SES represents a complex amalgamation of individual and collective factors. Because of various evolutionary pressures, people often reject this complex reality in favor of more simplistic perceptions and explanations. This thought paper offers an overview of how and where people acquire knowledge and how that knowledge acquisition process reflects and influences narratives, which subsequently affect efforts to address challenges in SES. We highlight three narratives as examples of constraints on finding ways forward toward a more resilient future. Our focal narratives include tendencies to conflate tame and wicked problems; to posit a false human-nature duality; and to resist the explanatory evidence from biocultural evolution. We then discuss the human cognitive propensity to create narratives to think about how we might intentionally develop narratives that are more appropriate for living in coevolving SES.

Keywords Knowledge · Social-ecological systems · Biocultural evolution · Wicked problems · Narratives

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1 Introduction

Modern humans possess a strong sense of certainty that each individual knows what happens within their own mind. As humans, we[1] tend to ignore or discount suggestions that we may not fully control what we think or how we behave. Indeed, knowledge is often defined as being *aware* of something, explicitly invoking consciousness (cf Wikipedia, Cambridge Dictionary). Humans are inclined to trust people who express confidence (Anderson and Kilduff 2009) partially because there is an assumption that superior knowledge undergirds expressed confidence (Pulford et al. 2018). Knowledge is linked to having a sense of certainty and people are also prone to believe and support efforts that profess to control uncertainty (Arceneaux and Stein 2006; Wachinger et al 2013; Boyd 2018). This strong belief in individual cognitive abilities and related perceptions of certainty are attributes of the dynamic evolutionary relationship between human biology and human culture (Simpson 1949; Goodman and Leatherman 1998; Dunbar 1996; Carroll et al. 2017; Mesoudi 2017; Little et al. 2023). These attributes prevent individuals from being overwhelmed by the flood of information and stimuli received via the social-ecological systems (SES) in which all humans exist (Sloman and Fernbach 2017).

All phenomena, actions, events occur within social-ecological systems. As the phrase suggests, in SES biological, physical, chemical, economic, political and other social processes are intertwined. There is no standard definition for SES. In this paper, we use SES to refer to habitats, inhabitants (human and non-human) of those habitats, and issues routinely labeled environmental, including resource use, climate change, and biophysical events (e.g. heatwaves, floods, earthquakes). We apply a biocultural evolutionary frame to consider how and why humans perceive and navigate SES in the ways we do. Biocultural evolution (also called gene-culture coevolution and dual-inheritance theory) crosses disciplines and recognizes the complex, interactive relationships between human biology and culture. In short, there is abundant evidence dating back to Darwin himself, that culture influences natural selection and that biologic necessities (e.g. survival, mating, sociality) influence culture (Richerson and Boyd 2005; Aarssen 2015; Carroll et al 2017). Via biocultural evolution, *Homo sapiens* and our cultures have developed and adapted over millennia; and the circumstances adapted to are not always relevant in modern SES conditions. The scale and speed with which modern humans can alter SES represents both opportunities for and threats to human (and some non-human) sustainability. Exploring how to better understand SES and when, where and how to act upon that understanding is a necessary and complex endeavor. This task entails grappling with the reality of biocultural evolution, its role in how humans 'know' anything as individuals or as groups (e.g. communities, cultures) and how knowledge acquisition processes are implicated in creating and perpetuating narratives that influence actions within SES.

There is a long and diverse list of thinkers from antiquity through modern day who have expressed views on knowledge, its nature, and assessing what can be considered true. It is beyond our purview to review or debate existing work on *what knowledge is*. We do recognize the complex and fluid interactions among awareness, evidence, belief, and what

[1] As humans writing about humans, it can be awkward to clearly employ first and/or third person constructions. Writing solely in third person segregates the authors from the group humans, while writing in the first person about research that is not our own is problematic. We have endeavored to employ "we" or "our" when referring to this paper and when referring to human attributes generally. We employ "they" or "their" when referring to work by others about human attributes.

is construed as knowledge and that any construal may change over time (Lassig 2016). For the purposes of this paper, we consider knowledge the conscious or unconscious intersection of information and beliefs internalized and available for taking action (Glynn et al.2022a). From this base, we examine knowledge sources (meaning the processes and mechanisms by which people acquire knowledge), how these sources shape and are shaped by evolved human cognition, and how they are influenced by and reflect individual and cultural narratives. This work builds on recent attention to biocultural evolution and how to use that information to catalyze change (cf. Aarssen 2022; Galef 2021; Sloman and Fernbach 2017). If humans are to ensure that the 'social' remains pertinent to SES, there is a need for "a richer understanding of human behavior, taking into account the role of broader contexts in shaping behavior and how it continuously co-evolves with changing local to global contexts" (Schill et al. 2019). While a possible use of our work is to improve SES-focused decision-making, this paper does not revisit the many studies on decision-making itself and all of the variables relevant to that activity. We are interested instead in the conditions preceding a decision. We explore how and where people acquire knowledge and what lies behind applying that knowledge via narratives that then may be used in making decisions. Further, rather than being explicitly hypothesis driven, this is an exploratory venture. We offer abundant evidence from across disciplines dating back centuries, to consider broadly the relationships among the biocultural roots of knowledge acquisition, the importance of narratives, and attempts to address pressing SES challenges.

In the next section we provide an overview of an often ignored aspect of human cognition, which is how and where humans acquire knowledge. We highlight the interconnectedness of individual (from self and from observation) and social—cultural (socially transmitted and shared) knowledge in shaping 'knowledge from.' This background in cognition establishes a basis for understanding how and why narratives are instrumental in considering ways forward in thinking about mitigating impacts from or adapting to rapidly changing SES. We then discuss three examples of prominent narratives that hinder efforts to mitigate or adapt. These narratives include tendencies to (1) conflate tame and wicked problems; (2) posit a false human-nature duality; and (3) resist the explanatory evidence from biocultural evolution. Finally, we discuss the potential for making conscious decisions to apply understanding of biocultural evolution and knowledge acquisition processes to intentionally generate new or counter narratives to promote a more resilient future.

2 Epistemology: Knowledge that to knowledge from

Most work exploring knowledge has focused on understanding facts or truths about the world (Bruner 1991). Within an SES framework, declarative knowledge embraces 'knowledge *that'* something is true about the physical world and/or about social institutions and relationships (Table 1). Another kind of knowledge is 'knowledge *how'* to do something, or procedural knowledge, which undergirds many SES-relevant public engagement efforts where the task is to identify issues and subsequently identify *how* to act to achieve some goal. Related to this is "effectiveness knowledge" (Kaiser and Fuhrer 2003) which determines if and/or at what cost a particular action will achieve a specific goal. Literature on participatory processes and science communication offers insight into how people gain and apply 'knowledge that' and 'knowledge how' within SES contexts (cf Raymond et al. 2010; Elsawah et al. 2020; Leßmöllmann et al. 2020; Cross et al. 2022).

Table 1 Kinds of knowledge and their relevance to living in social-ecological systems

Knowledge Kind	SES Relevance
Knowledge that Declarative knowledge	Facts, truths about the physical world and/or about social institutions, cultural relationships
Knowledge how Procedural knowledge Effectiveness knowledge	Knowledge of how to do something, how to address goals, whether particular actions will be effective and at what cost
Social knowledge	Common knowledge, knowledge about social norms
Knowledge from ***Knowledge sources***	***How and where people acquire knowledge, including knowledge that, knowledge how, social knowledge***

Recent scholarship has focused on how, when, and where knowledge circulates—that is how it moves across disciplines and through society and is subsequently affected by those processes (Ostling et al. 2018). This idea of circulation informs our work, which focuses on 'knowledge *from'* or sources of knowledge. In considering behavior that contributes to environmental preservation or conservation, Kaiser and Fuhrer (2003) discuss "social knowledge" as including common knowledge and social norms. Our 'knowledge from' is a more expansive category for thinking about how and where individuals or groups gain knowledge, including how declarative, procedural, effectiveness and social knowledge are acquired. To be clear, our use of 'source' is not concerned with television, books or social media, but with cognitive processes by which knowledge is accumulated. Compared to 'knowledge that' or 'knowledge how,' 'knowledge from' is not well documented within SES contexts. We argue that 'knowledge from' is an important influence on all perceptions, attitudes, and behaviors. It is therefore, core to understanding the 'social' in SES and core to eliciting and interpreting narratives related to managing or adapting to changing SES.

2.1 Knowledge acquisition

At its root, information seeking is often about reducing uncertainty and it can increase "evolutionary fitness in rapidly changing environmental conditions" (Gottlieb et al. 2013). Reducing uncertainty has clear ties to survival. Knowing when rains come or if fruit is ripe, as well as noticing when these conditions change, has enabled human evolutionary success. An intrinsic motivation to understand the physical world helps explain why declarative knowledge has been the focus of much attention throughout human history (cf van Doren 1991; Burke 2000).

In this paper, we invoke biocultural evolution as the basis for thinking about knowledge. More specifically, research from diverse disciplines has found that schema theory offers valuable insight into understanding how humans acquire, store, and access information. Marshall (1995) provides a thorough review of how schema theory has been conceived from Plato to artificial intelligence and notes that "it has played a central role in many influential philosophical and psychological investigations of how we know what we know." Research on schema has evolved from social science methods (e.g. experiments, surveys) to neuroscience-based efforts that reveal what is happening in the brain as schema develop, when knowledge or memories are retrieved, and if or how decision-making heuristics are influenced (Graber 1988; Schacter et al. 2007; Edelson et al. 2011; Ghosh and Gilboa 2014; Kappes et al. 2020).

Various disciplines have differentially used the term schema or applied alternate terms (e.g. frames, scripts) to the same concept (Marshall 1995; Whitney 2001; Wood et al. 2018). Despite this variation, in their literature review Ghosh and Gilboa (2014) note that there is strong consensus on schema functions, which include facilitating how new information is encoded, expediting information retrieval, and guiding behavior. Individual schema develop via repetition and pattern recognition. A simple example occurs as children learn to differentiate animals. If the first animal they learn is a cat and then they encounter a dog, they may call it a cat because their schema for cat (e.g. four legs, fur, tail) is activated. When given information about differences between cats and dogs, their brains can apply that information to develop a more detailed schema.

Schemata[2] are how humans organize and store knowledge to navigate the daily bombardment of information. They are "knowledge structures that represent objects or events and provide default assumptions about their characteristics, relationships, and entailments under conditions of incomplete information" (Di Maggio 1997). Schemas are not concrete or detailed, but more like conceptual stereotypes and hence they allow rapid categorization to reduce uncertainty. Schemata and memory are linked as an individual's schemata influence how *well* they remember things as well as *what* they remember (Bartlett 1932; Di Maggio 1997; Kleider et al. 2008; Frost et al. 2015; Greve et al 2019; Cockcroft et al. 2022; Patel et al. 2022). There is now general consensus that memory is not a replicative process, but a reconstructive process whereby "only the gist or overall impression of the material is preserved and rebuilt around pre-existing knowledge structures or schemas" (Mesoudi and Whiten 2008). Memory is adaptive and is always culturally embedded. Counter to prevailing narratives, memory is not an archive of the past, but is a process for dealing with the present and planning for the future (Schacter et al. 2007).

Although adaptability is essential for schema function, there are distinct differences in how the brain processes new information that is congruent with existing schemas compared to incongruent information. Established schemas resist fundamental change (Anderson et al. 1980; Anderson 1983; Campbell 1989; Richter et al. 2019) and significantly influence what an individual pays attention to (Webb and Graziano 2015; Frodin 2017). They create a basis for confirmation bias, whereby individuals seek information that aligns with some existing schema. This phenomenon has long been recognized and in 1620 Francis Bacon observed, "The human understanding, when any proposition has been once laid down (either from general admission and belief, or from the pleasure it affords), forces everything else to add fresh support and confirmation." When new information does align, it is readily assimilated into that person's knowledge corpus. When new information does not readily align with or contradicts existing schema, it is either ignored or must be modified so that it can be accommodated within an existing schema (Bartlett 1932, 1958; Axelrod 1973; Tversky and Kahneman 1982; Wicks and Drew 1991; Ghosh and Gilboa 2014; Richter et al. 2019). This language of assimilation and accommodation is intentionally rooted in evolutionary biology. Because he was trained as a biologist, when he began formulating his ideas about schema, Piaget (1976) drew an analogy between assimilating food into the body and assimilating information. Likewise, the idea of accommodation drew upon non-hereditary phenotypic changes seen in embryonic development.

Of course, individuals are embedded in social groups and individual schema are tightly woven with cultural experience (Vygotsky 1978; McVee et al. 2005; Frodin 2017;

[2] Schema is the singular form while schemata and schemas are both accepted plural forms.

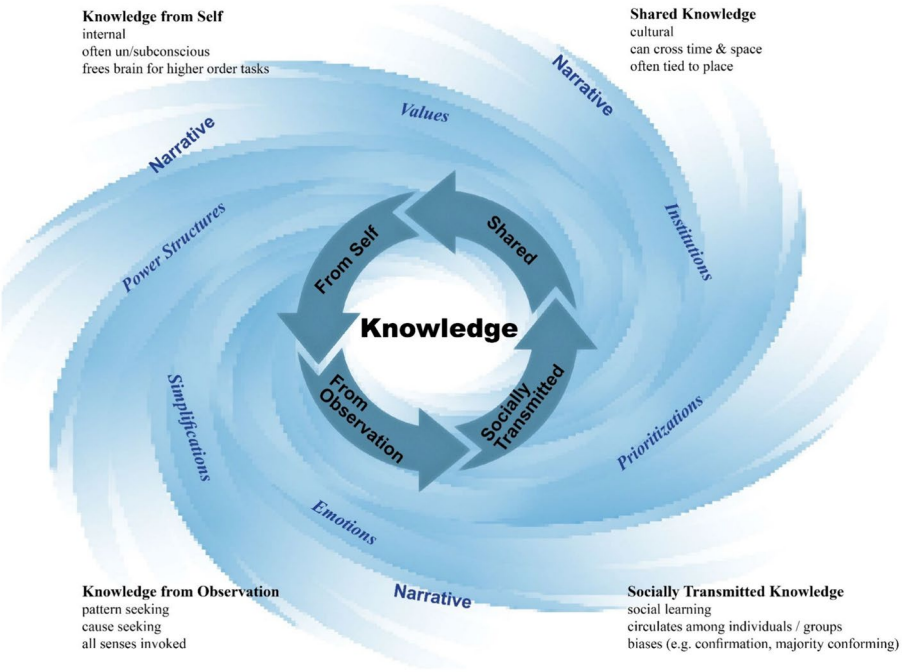

Fig. 1 Knowledge acquisition and related narrative development operate in a maelstrom of social and psychological processes. Knowledge sources (from self, shared, socially-transmitted, from observation) are highly dynamic. They overlap and interact with each other, and influence perceptions, attitudes, and schema. Knowledge sources and their interactions affect narrative creation (conscious or unconscious), affecting decisions and actions. Knowledge acquisition combines with other biocultural evolutionary processes to shape SES coevolution

Anderson 2018). A key tenet in assessing linkages between biological evolution and cultural evolution is how knowledge is transmitted across time (Mesoudi 2017; Dennett 2017; Mesoudi and Whiten 2008). Although there is debate about the specific mechanisms and contexts, there is significant evidence that the uptake of knowledge is rooted in biocultural dynamics of individual cognition (schema) *and* the complexity of being a social species.

From this starting point in understanding schemas as key cognitive mechanisms, we identify four knowledge sources: knowledge from self, knowledge from observation, socially transmitted knowledge, and shared knowledge. The boundaries of these four knowledge sources are not discrete or static. Rather, they overlap and interact with each other. Taken together, they influence whether someone accepts or rejects 'knowledge that' or 'knowledge how' and subsequently influence perceptions, attitudes, behaviors relevant to SES. Whether specific knowledge is acknowledged, accepted, or rejected is in constant flux. Figure 1 shows our four knowledge sources as interrelated and that the knowledge acquisition process is embedded in a maelstrom of influences that include emotions, institutions, and power structures (Ostling et al. 2018; Lassig 2016). It is in this milieu that narratives arise and it is under these conditions that we crafted this paper. Our ideas and the choices we made in thinking about this topic, in drafting a manuscript, and in responding to reviewer comments were all subject to knowledge acquisition processes and reflect various cultural narratives. It is beyond the scope of this paper to dig deeply into the broader

context shown in Fig. 1, but this context suggests opportunities for future work, for example, to consider how knowledge acquisition within institutions affects narratives about SES management.

2.1.1 Knowledge from self

The most basic source of 'knowledge from' is internal and is accessed via largely unconscious processes. This type of knowledge is responsible for the 'fight or flight' response and in daily activity people rely on it to complete a multitude of actions such as tying shoelaces or responding to traffic signs. There is a "subjective innateness" to this kind of knowledge, as it is culturally influenced, but becomes embedded in individual schema such that it is reactive (personal communication with Dr. Mark Nunes 2023). It is subsequently the knowledge source for System 1 heuristics, whereby decisions and actions are subconscious and automatic (Wason and Evans 1975; Tversky and Kahneman 1982; Evans and Stanovich 2013). This type of 'knowledge from' has important evolutionary advantages as it frees the brain for other, more challenging tasks.

While unconscious knowledge has clear benefits, it also means that, as humans, we are often not fully aware of our own minds. Summarizing decades of philosophical and psychological research on knowledge and the idea of self, Campbell (1989) writes:

> What we take to be the self is really a network of knowledge, probably the richest there is, that is saturated in language and organized in such a way as to be useful rather than true. Whereas the world is known by means of mental structures, the self is a system of structures. It is not a thing to be known, but a process of knowing, which is why it escapes description, and baffles scrutiny, as if we were to look through a telescope in the hope of seeing the telescope itself instead of the sky.

Humans resist evidence that might disrupt how their knowledge is organized because such disruption would make that knowledge less useful and would reduce cognitive efficiency. The drive to be efficient contributes to cognitive dissonance where what we say we believe or think is sometimes at odds with how we behave. Research has also consistently shown discordance between un/subconscious perceptions and attitudes and consciously expressed perceptions and attitudes (cf Glynn et al. 2022b). This particular disconnect is prominent in the narratives we create about ourselves, our personalities, and our levels of self-esteem (Wilson and Dunn 2004). Further, knowledge about our physical selves (i.e. body schema) provides the mechanism for navigating our bodies spatially (Head and Holmes 1911) and helps explain how we became such adept tool users (Carlson et al. 2010), which has clear connections to engaging with SES. Additionally, knowledge about our place in the world and our awareness that our lives will end, have engendered strong biocultural influences on our relationships with each other and with the physical world (Aarssen 2022). Our individual identities are enmeshed in this mix of consciously and unconsciously acquired knowledge from and about ourselves.

2.1.2 Knowledge from observation

Patterns are core to human consciousness and cognition. Humans are innately drawn to rhythm, which represent patterns found not only in music, but in heartbeats, language, physical movement and planetary cycles. Indeed, "rhythms in the brain have been called out as a basis for consciousness itself" (Kraus 2023). Even in-utero, humans are

well-attuned to patterns and begin to assimilate information based on those 'observations' (Partanen et al. 2013; Reid et al. 2017). As already noted, schemata are created via repetition and pattern recognition. Humans will seek and identify patterns, even where they don't exist (Kahneman 2011). Humans seek patterns because they align well with causal reasoning and a default for human thinking is based on cause and effect relationships (Tversky and Kahneman 1982; Rips 2011; Sloman and Fernbach 2017). While the human ability to successfully identify cause and effect is strong, it is not infallible and the strong drive to think causally means humans often generate causal models that are fundamentally wrong (Campbell 1989; Evans 2017; Sloman and Fernbach 2017; Boyd 2018; Johnson et al. 2023).

In seeking patterns and causes, humans rely on all our senses to navigate our surroundings and all senses contribute to what we experience and hence what we know. While all senses are important, humans are a visual species and we place tremendous faith on the idea that if we see something it is true, hence the adage that 'seeing is believing.' Oft-repeated observations become the basis for specific schema and this contributes to confirmation bias as we preferentially and subconsciously 'see' what aligns with what we already know or think. Additionally, research demonstrates that "experience is not so much a matter of what the eye observes, as of what the mind does, or how its weblike connections trap little motes of data and enlarge them into full-blown scenarios, lifelike personalities, sweeping narratives" (Campbell 1989). This contributes to a false sense of certainty about what is known. Research shows that "people feel they understand complex phenomena with far greater precision, coherence, and depth than they really do" (Rozenblit & Keil 2002). Moreover, in what has become known as the Kruger-Dunning Effect, those who are least knowledgeable are more likely to overestimate what they know (Kruger and Dunning 1999). Human brains are also quick to adopt other people's knowledge as if it were our own. Experiments show that when individuals receive outside help to explain something (e.g. an Internet search) it increases their confidence in what they know not only about the focal topic, but also about unrelated topics (Fisher et al. 2015; Fisher and Oppenheimer 2021). Other studies show that when individuals are given new information and told that scientists understand it well, it increases their self-reported level of understanding of that information. Conversely if they are told that no one understands the information or that what is known is a secret, it reduces self-reported levels of understanding (Sloman and Fernbach 2017).

Relevant to knowledge about SES, individuals in many contemporary cultures are spending less time outdoors and hence have reduced direct experience with the physical environment (Soga and Gaston 2016). This lack of interaction means less opportunity to observe and to gain experiential knowledge about biophysical processes or phenomena. Further, people in nations with well-developed infrastructure generally face minimal daily risk from biophysical processes. This has created new or enforced longstanding narratives that assume that the physical environment can be or should be risk-free (Cockerill et al. 2017). The ready availability of information about biophysical processes and events likely means individuals experience the knowledge by association phenomena described above and subsequently have a false sense of what they actually know. This then generates perceived knowledge that is not founded in experience or expertise, contributing to misplaced expectations about how the physical world functions, with significant implications for managing and/or adapting to variability in SES.

2.1.3 Socially transmitted knowledge

As a social species, humans gain knowledge from each other in multi-faceted ways, including observing others, listening to others, and making inquiries of others. In their literature review, Olsson and colleagues (2020) find that cross-species research shows strong neural linkages between experiential (individual) learning and social learning as well as unique attributes of social learning. Key to social learning strategies are knowing when to rely on social learning, who to rely on for information, and when to conform to the majority. Even young children "are sophisticated social learners and exhibit biases predicted by models to be adaptive, such as preferentially learning from accurate over inaccurate individuals and prestigious over non prestigious individuals" (Mesoudi 2017). Social learning has obvious adaptive benefits, as each individual does not need to 'start from scratch' by engaging in lengthy trial and error to learn which foods are edible, how to drive a car, or what behaviors are culturally appropriate. Ensuring that all members of a group 'know' various things provides group cohesion, which is advantageous for ensuring the group not only survives, but thrives (Boyd et al. 2011; Olsson et al. 2020; Falandays et al. 2022; Little et al. 2023). Of course, relying on others can also be maladaptive if the information transmitted is flawed (Laland and Rendell 2013; Olsson et al. 2020).

Schema sway how humans interpret and internalize information from or about others (Campbell 1989), which then influences how, when, and from whom knowledge is socially transmitted. Humans, even as children, experience strong social pressure to accept or adopt a majority group's knowledge, attitudes, and behaviors (Asch 1955; Cialdini and Goldstein 2004; Haun et al. 2013; Olsson et al 2020). The dynamics for social transmission however, are complex and there is significant individual variation in conforming behavior in various contexts (Mesoudi and Whiten 2008; Hodges et al. 2014). For example, confirmation bias is stronger when the information source is a friend but if the information received contradicts an individual's existing schema, they are more likely to misattribute the source as having been a stranger rather than a friend (Frost et al. 2015). As noted in the introduction, people tend to react positively when information or opinions are delivered with confidence. Neuroscience based research also reveals, however, that the brain treats disconfirming information differently from confirming information and people are less likely to be receptive to confidently expressed opinion if the information is contradictory to their existing opinions (Kappes et al. 2020). For controversial issues, which includes many SES-relevant concerns, there is evidence that even highly numerate individuals will interpret information and provide answers that align with their social group's attitudes rather than providing an objectively correct answer (Kahan et al. 2017; Nurse and Grant 2020). This fits well with ingroup—outgroup dynamics inherent in biocultural evolution. Knowing what the ingroup thinks and agreeing with that position is key to ensuring an individual's place within the group. As Kaiser and Fuhrer (2003) note, social knowledge "depends heavily on socialisation and consists mainly of normative beliefs about what people think they have to do." Our individual identities are inextricably linked to our role within groups and being able to quickly recognize who shares aspects of our identity and who does not is a key aspect of socially transmitted knowledge.

Scholars have long studied how knowledge moves from individual to individual and recognize that there is a fraught relationship between receiving information and communicating information. Instead of concepts like dissemination or transfer of knowledge,

recent work focuses on the idea of circulation as a better way to explain how knowledge is socially transmitted. Circulation also expands traditional history of knowledge endeavors from focusing on 'knowledge that' about the physical world to embracing the humanities and how knowledge circulates among sciences and humanities. Instead of a narrative that emphasizes success and progressive accumulation of knowledge, circulation offers a more complex narrative recognizing that what specific knowledge is individually or socially validated and subsequently circulated is subject to numerous cultural influences (Hammar and Ostling 2021). History offers a plethora of examples of humans ignoring particular bits of information because they did not mesh with existing narratives or sometimes due to cultural narratives about who espoused the information (cf Keller 1985; Miller 2019; Gándara-Chacana 2022). This phenomena is the basis for Kuhn's (1962) famous treatise on paradigm shifts and it is why it is possible to find evidence of 'modern' thinking in historic, even ancient, materials.

2.1.4 Shared knowledge

The process of circulating knowledge can, over time, generate shared knowledge within a culture. Shared knowledge represents the entanglement of evolutionary adaptations for how our brains function as individuals within strongly social settings (Boyd et al. 2011; Laland and Rendell 2013; Leeuw and Folke 2021; Little et al. 2023). Modern humans perceive that our thoughts and memories are extremely individualized despite evidence across decades revealing that much of our knowledge, intelligence, and memory are social and collective (Bartlett 1932; Bruner 1991; Edelson et al. 2011; Roediger and McDermott 2011; Dudai and Edelson 2016; Sloman and Fernbach 2017; Falandays et al. 2022). Shared knowledge endures across time and space and therefore is the quintessence of biocultural roots of knowledge. Indeed, "Our very success as a species is undoubtedly in part attributable to our uniquely huge distributed memory store of cultural knowledge" (Laland and Rendell 2013).

Shared knowledge is often place-based and subsequently offers connections across social—ecological systems. "Human communities construct their specific shared knowledge systems, as well as beliefs and values about the environment which surrounds them, depending on how they interact with these environments" (Schwermer et al. 2020). How people interact with and come to know a physical place is often communal. People express relationships with place through a variety of narrative forms, including "myth, prayer, music, dance, art, architecture" and subsequently, "places and their meanings are continually woven into the fabric of social life, anchoring it to features of the landscape and blanketing it with layers of significance that few can fail to appreciate" (Basso 1996). Specific places can become integral to both individual and group identity and can signal ingroup/outgroup status. This is often demonstrated in the question posed to new acquaintances, "*where* are you from?" Large dataset analyses reveal strong correlations among mountain landscapes, socio-cultural variables, and various individual personality traits including conscientiousness and openness to experience (Götz et al. 2020). A case study of Black Rock, New Mexico highlights how a single place resonates differently across cultures and across time and that this can lead to conflict as well as to cultural blending (Dodge 2007). Further, culturally embedded knowledge and narratives (e.g. myths) may be maintained even if the physical place changes or if individuals leave a place. Cosmologies / religions, which are often core to individual and group identities, are perhaps the most ubiquitous examples of shared knowledge crossing time and space.

3 Knowledge and narratives

The knowledge sources we have described are entangled with each other as they consistently try to maintain culturally coherent narratives (Fig. 1). Rooted in biocultural processes that blend an individual with their social context, narratives are "mental representations that summarize relevant causal, temporal, analogical, and valence information" (Johnson et al. 2023), which create a "version of reality whose acceptability is governed by convention" (Bruner 1991). Narratives can be considered complex systems that reflect "nonlinear interactions between brain, body, discourse and environment" (Pianzola 2018). Further,"narratives contain stories, actors, scenes that reflect and help maintain the cultural identity of a group or community or express a desired or feared vision of its imagined future" (Helgeson et al. 2022).

While narratives have been deeply and broadly studied across disciplines, there remains a dearth of attention to knowledge acquisition and its role in narrative development or application. In the extant literature, when knowledge is linked to narratives it tends to be in the form of 'knowledge that' or what we think we know of the world (cf Bruner 1991; Crow and Jones 2018). Yet, 'knowledge from' (schemas) and narratives are locked in a highly recursive relationship. Narratives operate at conscious and unconscious levels and are inextricably woven into where, when, and how humans acquire knowledge, which influences what knowledge is embraced as 'truth' about any particular topic, which then shapes new or modifies existing narratives relevant to that topic.

In this way the amalgamation of knowledge sources reflect and influence individual and shared narratives about SES. Although they do change over time, like individual schema, once established, cultural narratives are fairly persistent. In comparison, SES are dynamic and are rapidly changing. The question at hand is what role humans will choose to play in shaping and adapting to SES transformations. Ehrlich (2000) proposes that humans attempt to "consciously evolve" such that people "openly attempt to increase the rate of cultural evolution in the area of understanding our evolutionary background and the biases it produces." Using the human cognitive propensity to create narratives presents opportunities to think about how humans might "consciously evolve" to intentionally develop more appropriate narratives to live in and adapt to changing SES. Toward that goal, Conviction Narrative Theory (cf Johnson et al. 2023) and the Narrative Policy Framework (cf Crow and Jones 2018; Schlaufer et al. 2022) offer theoretical and empirical bases for consciously considering narratives, and potentially changing narratives, as part of decision-making processes. Additionally, the Frameworks Institute (https://www.frameworksinstitute.org/) and the Narrative Initiative (https://narrativeinitiative.org/) are organizations that focus on intentionally changing dominant narratives to address various issues. While they do not explicitly discuss knowledge acquisition, these organizations do emphasize the need to well-understand existing narratives as the basis for creating a new or a counter-narrative, which then must be intentionally disseminated so that new knowledge may be acquired.

The traits of human knowledge acquisition documented in this paper have allowed problematic narratives to develop and be sustained over time. While there are numerous potential examples, we selected three narratives that present significant barriers to meeting SES challenges. Our focal narratives include those that (1) conflate wicked and tame problems, (2) posit a false human—nature duality, and (3) resist biocultural evolution as a way to understand human cognition and behavior. These exemplify knowledge acquisition pathways, align with our stated characteristics of narratives, and have deep cultural roots that has enabled them to contribute to historic and contemporary practices that are

not conducive to addressing SES-based challenges. Applying what we know about knowledge acquisition to shift or counter these narratives may be one way to catalyze a more positively resilient human future. After delineating our focal narratives, we offer examples of where narrative shifts may be happening along with noting constraints on these shifts.

3.1 Conflating wicked with tame problems

Scholars have delineated multiple types of problems, to include social messes (Ackoff 1974; Horn and Weber 2007), divergent and convergent (Schumacher 1977), simple, complicated, and complex (Glouberman and Zimmerman 2002), as well as wicked and tame (Churchman 1967; Rittel and Webber 1973). At one end of the spectrum, social messes, divergent, complex, and wicked problems are amorphous and do not have singular definitions or solutions. In contrast, convergent, simple or tame problems such as constructing a rocket or developing a pesticide, can be solved. While wicked versus tame is often set up as a dichotomous relationship, Head's (2022) review offers a more nuanced view, suggesting a spectrum of problem configurations ranging from wicked to tame and that considering any issue of concern in concert with its decision-making context are key to determining how wicked something may be. Pertinent to our work, the dichotomous versus spectrum approach reflects differing narratives about the nature of problems with associated ties to knowledge acquisition. The more recent spectrum-based perspective also suggests a shift in narrative over time. Our key point, however, is that there is a tendency to try to push problems toward the tame end of the spectrum in seeking simple and/or permanent resolution. Daviter (2017) notes a paradox in approaches for engaging with wicked problems, "In stark contrast to the widely shared notion that solving wicked problems is not a viable option, a sizable part of the more recent debate appears to promote strategies that are designed to accomplish exactly that."

Enlightenment ideals established a social narrative that knowledge acquisition should rely on linear, hierarchical, and reductive approaches, which are suitable for addressing tame problems but can be counterproductive when applied to wicked ones (Ison et al. 2015; Cockerill et al. 2017; McKay et al. 2020). Given the evidence for how humans acquire, store, and retrieve knowledge, the dominance of the Enlightenment model makes sense. Because tame problems can be clearly defined, the cause and effect relationships are typically visible and accurate and often lend themselves to binary thinking. This helps to instantiate schema emphasizing reductive approaches that identify causal relationships as the 'best' way to solve problems. The undeniable success in addressing a diverse array of tame problems coupled with decreased experiential knowledge of biophysical systems has promulgated a narrative suggesting that humans can fully understand, predict and even control social and biophysical systems (Cockerill et al. 2017). This is often expressed in demands for controlling or eliminating various hazards (e.g. flood, fire) within SES and then placing blame when those hazards manifest (Andrasko 2021, Weir, Neale, Clarke 2021). The persistent power of this narrative is epitomized by the conviction of Italian seismologists for not accurately predicting the risk posed by a 2009 earthquake and the public outrage following their subsequent acquittal (Nosengo 2012; Abbott and Nosengo 2014). SES focused issues reside at the wicked end of the problem spectrum and therefore, require management approaches that allow adaptation as conditions change rather than focusing attention toward a singular endpoint. While wicked problems cannot be addressed using

the same processes that solve tame problems, the limits to how humans acquire knowledge resists recognizing and accepting this, even among professionals.

3.2 False human-nature duality

The idea that humans have limited cognitive ability is not new. Miglietti (2020) writes about Swiss naturalist Johann Jakob Scheuchzer who advocated in 1731 that humans need "self-knowledge" to recognize that we cannot possibly know everything we might want to know and that what we do know is always imperfectly known. This caution about human cognition was overpowered by Enlightenment narratives emphasizing the human ability to understand, and subsequently control, the physical environment, which spawned narratives separating humans from "nature" (Cockerill et al. 2017). This cemented a strongly anthropocentric worldview that marginalized other 'ways of knowing' including more biocentric or indigenous worldviews (Aho 2019; Relva and Jung 2021). In reaction to Enlightenment rationality and the clear environmental consequences of the Industrial Revolution, Romantic era narratives doubled down on segregating humans from nature in an attempt to benefit both (Cockerill et al. 2017; Cockerill 2021). This was further entrenched as the field of ecology emerged and intentionally segregated humans from the physical environment (Kingsland 2019). This segregation continues to be perpetuated in research (Dalrymple 2022) and in contemporary debates about SES management. In his pivotal work, Dryzek (1997) documents that five of seven dominant environmental discourses subordinate nature to humans. Additionally, culture is often treated as exogenous to SES, yet culture is where shared knowledge accumulates and so must be integral to thinking about how to manage or adapt to SES (Caldas et al. 2015). Any narrative of humans as exceptional and exempt is in direct opposition to the integrated, evolutionarily egalitarian reality of SES. In fact, Dunn (2021) suggests that if human society is to have a long-term future, we must recognize that "there is no boundary between us and nature."

3.3 Resistance to biocultural evolutionary explanations

Akin to the human-nature divide narrative, there are disciplinary narratives that segregate evolution-based from social-cultural based understanding of human thought and action, representing a form of "intellectual apartheid" (Wilson et al. 2014). Those on one side of this divide resist accepting biocultural evolution as foundational to understanding humans generally and how we know things more specifically. In writing about what the future holds for humans, Dunn (2021) emphasizes that we ignore evolution at our own peril. Likewise, Cockerill et al. (2017) posit that, "ignoring the reality of evolution represents a significant barrier to developing realistic ways to implement resilient, adaptive approaches" for living in SES. Still, this reluctance to engage with the very root of human existence is evident across multiple disciplines. Venkatraman (2013) highlights resistance from economics and other behavioral social sciences to embrace neuroscience to help explain decision-making. As Carroll et al. (2017) note, "…scholars in the humanities face heavy institutional resistance to conducting biocultural research." Despite its clear connection to human cognition and culture, linguists and philosophers of language tend to discount evolutionary explanations for language (Dennett 2017). There are, of course, exceptions and Dennett (2017) notes several linguists who embrace evolutionary thinking while Spink and Cole (2006) offer insight into applying evolutionary psychology in library science to consider how and why people seek information. There are multiple explanations for resistance, including

that embracing biocultural evolution requires acknowledging that much of human cognition is unconscious, challenging narratives of free will. Mesoudi (2017) posits that another reason for resisting evolutionary rationales is based on a "reluctance to consider continuities between human behavior and the behavior of other species." These rationales reflect Enlightenment and Romantic era narratives that established a human-nature divide and posited that humans are superior to other species and hence not subject to the same laws of biology. In more recent history, evolutionary concepts were misinterpreted and misapplied to support various social injustices and therefore became "a pariah concept" for considering human behavior (Wilson et al. 2014). There is no small irony in having a dominant narrative supporting empiricism that simultaneously rejects the abundance of empirical evidence from biocultural evolution. This does, however, reflect the power of various cognitive processes described in this paper, including misplaced accommodation of information that is incongruent with existing schemas. It also reflects the power of shared knowledge as disciplinary narratives constrain change (Wilson et al. 2014).

3.4 Using narratives to shift narratives

If humans seek a long tenure on Earth, the status quo is not tenable. One way forward is to consider how and where people acquire knowledge to create narratives and to then use that knowledge to intentionally shift problematic narratives. This approach requires that researchers and practitioners be aware of prevailing schema and concomitant dominant narratives. To be clear, we are not proposing narrative shifts to advocate for any particular position. Our point is that many current narratives present significant barriers to addressing contemporary wicked problems and if humans are to successfully navigate modern SES via mitigating impacts and/or adapting to variation, these narratives must change. There are signals that groundwork is being laid to support such shifts for the focal narratives we have described and we offer several brief examples. It is beyond the scope of this paper to deeply assess these cases, but by bringing them together we hope to prompt discussion and reflection in considering how they demonstrate linkages across knowledge acquisition, narratives, and meeting SES challenges.

Because the complexity of SES is often beyond human cognitive ability to fully grasp, computer models are necessary to understand SES-focused problems. Cooperative modeling projects report that helping people see (i.e. knowledge from observation) inherent complexity is a key benefit to using this approach in SES management. As a specific example, a water planning project in the Middle Rio Grande basin in New Mexico included cooperatively developing a model to create 'what if' scenarios. The model revealed multiple unintended consequences, including reduced river flows, if various conservation options were implemented. These results reframed perceptions of water management as a relatively tame problem to recognizing it as a more wicked problem. Because influential people with a strong desire to address water issues were engaged in the modeling process, the model results catalyzed a shift in socially transmitted knowledge about water management, which did affect narratives related to long-term planning (Cockerill et al. 2006).

Relevant to the human—nature divide narrative, across disparate disciplines there is increasing attention focused on the reality that humans are integral to social-ecological systems (Cockerill et al. 2017; Herrero-Jáuregui et al. 2018; Colding and Barthel 2019; Vos et al. 2019) and that any ideal of human agency as being separate from the biophysical world is misplaced (Tábara 2023). Schill and colleagues (2019) argue that humans need to alter their narrative from a human dominant view (e.g. *Homo economicus)* to thinking of

humans as "enearthed"— that is integrated with and dependent upon the biosphere. Water management in Aotearoa, New Zealand offers an applied example where culturally shared knowledge has attempted to re-shape a national narrative about being part of SES. According to Te Ao Māori (Māori worldview), mountains and rivers are perceived as ancestors, not as impersonal objects. Kaitiakitanga is "the ethic of protecting the environment for its own sake, as well as for present and future generations to use and enjoy" (Aho 2019). *Te Mana o te Wai* refers to the vital importance of water, emphasizing the special connection tangata whenua (people of the land) have with it. When managing freshwater it imposes a hierarchy of obligations, prioritizing first the health and well-being of the water, followed by human health needs (i.e. drinking water) and then enabling other water uses to provide for people's social, economic and cultural wellbeing (Ministry 2017, 2020, 2023). Since 2014 *Te Mana o Te Wai* has been recognized as nationally significant and has been included in the National Policy Statement for Freshwater Management and related regulations (Ministry 2017).

This increased recognition of living in SES bodes well for moving away from narratives emphasizing human-nature duality toward more complex narratives decentralizing humans. Despite promising developments, however, challenges remain. For example, at the time of writing, the New Zealand government has walked back national policies based on *Te Mana O Te Wai* and returned to primary national resource management legislation that aims to "promote the sustainable management of natural and physical resources" (Resource Management Act, 1991). Based on findings in literature reviews about SES frameworks and models, a false human-nature duality persists in the tendency to focus on the social *or* the ecological rather than their integration (Binder et al. 2013; Herrero-Jáuregui et al. 2018; Cockerill 2024). Likewise, there are issues with balancing benefits of quantitative, empirical methods with the messy, qualitative reality of many SES relationships (Herrero-Jáuregui et al. 2018; Vos et al. 2019; Nagel and Partelow 2022). Overemphasizing empirical approaches can perpetuate treating SES-based concerns like tame problems (Cockerill 2024).

Suggesting the seeds of another narrative shift, there is increasing cross-disciplinary attention to biocultural evolution. Authors of the 2023 paper *Multilevel Cultural Evolution* represent fields of engineering, business, psychology, public policy, computer studies, public health, and biology as they offer ways to apply biocultural evolution to addressing social issues (Wilson et al. 2023). Similarly, the paper *Earth Systems to Anthropocene Systems* represents diverse disciplinary fields in proposing an evolution-based system of systems paradigm to address societal concerns and the target audience includes those "engineers and scientists who are unfamiliar with evolutionary mechanisms" (Little et al. 2023). This academic attention is aligned with numerous popular publications that embrace biocultural evolution. Over time, this has the potential to reduce the resistance to including biocultural evolution as core to thinking about living in SES.

Within contemporary SES-specific research and practice, however, there is scant attention paid to biocultural evolution and its role in how SES are perceived as well as how management options are viewed (but do see Schellnhuber et al. 2005). Reviews of SES as a frame for thinking about resilience or sustainability do not explicitly address the evolutionary roots of and limitations to human knowledge acquisition processes. At the same time, research and practice engaged in trying to better manage or adapt to changing SES increasingly acknowledges the power of narratives in how people perceive a particular issue and how they are likely to behave. These efforts reveal that acquiring knowledge about other people's perspectives or narratives can positively influence group interactions (Eyal et al. 2018; Chabay et al. 2019; Davenport and Rentsch 2020; Relva and Jung 2021). When

viewed through a biocultural lens, this is not surprising as storytelling (one kind of narrative), may be at the root of human intelligence (Coen 2019) and is likely key to how we have evolved into the social species we are (Boyd 2018). If employed with an appreciation for biocultural evolution and knowledge acquisition processes, narrative elicitation and storytelling approaches have the potential to introduce new narratives that normalize the concept of wicked problems as well as establish humans as natural and hence subject to biocultural evolution.

One promising narrative elicitation approach is to tap into bioculturally-derived factors that resonate deeply, and often unconsciously, with people. Examples of these factors include identity affirmation, expressions of power or status, collaborating with peers, and caring for next generations. For decades, scholars have proposed using recognized evolved human traits to catalyze behavioral changes necessary to address environmental concerns (Heinen and Low 1992; Penn and Mysterud 2007; Vugt et al. 2014; Wilson et al. 2014). We suggest that applying narrative elicitation techniques intentionally designed to access deep-seated human attributes could influence schema formation and thereby influence how knowledge about SES-related concerns is received, which would subsequently affect perceptions about mitigation or adaptation options. As a specific example, narrative elicitation could take advantage of the human desire for causal explanations. There is evidence that simply asking people to share their views about a contested topic does little to moderate those views, but asking people to generate a narrative to explain causal relationships about how something works, may reveal a knowledge gap that can moderate attitudes (Sloman and Fernbach 2017). "The beauty of causal explanation is that it takes explainers outside of their own belief systems" (Sloman and Fernbach 2017). Applying this understanding of human cognition is at the root of using fuzzy cognitive mapping to engage people in SES-related decisions (cf Gray et al. 2012, 2015). Applying a narrative approach that asks people to explain cause and effect can be useful in getting people to more readily acknowledge the complexity inherent in SES and to better see how and where social systems are fully integrated with ecological systems.

4 Conclusion

This broad overview provides insight on knowledge acquisition and its relevance to thinking about narratives within an SES context. Specifically, we highlight that humans acquire knowledge through both conscious and unconscious means and how we know anything is as much a social phenomena as an individual one. The interweavings of knowledge from self, from observations, via social transmission and shared culture are core to how narratives are generated, perpetuated, altered, or rejected. The biocultural evolutionary roots of how human brains work via schema explain why narratives are ubiquitous, powerful and persistent. Indeed, this paper is rife with narratives, those we explicitly interrogate, as well as many that are implicit, perhaps even beyond our consciousness. It is this power that makes narratives a promising tool to catalyze change. The narratives that conflate wicked and tame problems, promulgate a human-nature divide, and resist embracing the reality that we are biological and cultural beings are deeply embedded and schema continue to enforce them. Yet, examples provided here also suggest that shifts in these narratives may be underway and if these shifts progress, that can promulgate schema formation or adaptation to re-enforce new or counter narratives. Actively encouraging such shifts is essential if a human goal is to positively engage in coevolving SES.

In thinking about ways forward, our work also embraces a historical perspective and highlights that people have been thinking about knowledge, narratives, and the human place in the world for a long time. The repetition of ideas over decades or even centuries, demonstrates both the complexity inherent in human cognition and the power of biocultural evolution in determining what knowledge is accepted or rejected at any given point in time. Like individual schema, repetition is key to shaping and shifting cultural narratives. Of course, as knowledge circulates, what rises to the fore at any point in time changes, so when old ideas arise as seemingly new ideas, they are not exact replicas. Therefore, revisiting ideas, concepts, and approaches under new and different contexts has the potential to trigger different schema or prompt new schema to develop. In exploring how we might leverage linkages among evolution, knowledge, and narratives we embrace the idea that "What anchors a culture is an incredibly complex dynamic between a society's cognitive dynamics, its network structures, and its environmental context, all interacting within the path-dependent trajectory that shaped its dynamics" (Leeuw and Folke 2021). We propose that identifying and trying approaches to apply everything we understand about knowledge acquisition and its role in shaping individual and cultural narratives can allow us to reframe, re-shape, and ultimately re-imagine a more resilient human future.

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