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Biocultural learning – beyond ecological knowledge transfer

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Education sciences research has showed that learning is a complex interaction between individuals and their surrounding world. The simplification of learning complexity has been commonly assumed in local and traditional ecological knowledge (LEK/TEK) research. Based on a modern learning theory, this article describes learning complexity behind the LEK/TEK held by fishers and farmers in Sweden. It leads to the introduction of the concept of biocultural learning that contributes to this field by giving details to this complexity. From a biographic approach, this research combines case studies, in-depth biographical narrative interviews, participant observations and the analysis of personal blogs and family pictures as data collection methods. This combination reveals the interconnection between professional knowledge about nature, identity construction and emotional bonds to nature. This article highlights the value of giving professional status to LEK/TEK and discusses the need to promote and strengthen biocultural learning in different society sectors.

Keywords: professional knowledge; workplace learning; biocultural learning; nature; LEK/TEK research

1. Introduction

Education sciences have made a large contribution to the scientific understanding of the complexity involved in learning processes per se. In this respect, education sciences research has showed that learning is not only a simple knowledge transfer process, but rather a complex interaction between cognitive, psychodynamic and sociocultural processes.

For instance, the complexity and intrinsic relationships between individual and social processes involved in learning are well known and recognised. In particular, in workplace learning research, Illeris (2003, 2004) has described three main dimensions of learning (i.e. cognitive, emotional and environmental). This outlines how the individual learning processes are triggered by the external work environment (e.g. technical, sociocultural and organisational). However, research on professional or workplace learning that concerns people not only living in, but also working in, nature is still limited from an educational science perspective (with few exceptions, e.g. Mukute [2009]; Slade [2013]; Garavito-Bermúdez, Lundholm, and Crona [2016]; Garavito-Bermúdez and Lundholm [2017]; Garavito-Bermúdez and Boomstra [2019]).

Having nature as a workplace assumes particular interactions with multiple species of animals, plants, fungi and microbes transforming and shaping "the human"

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compared to an ordinary workplace; in line with the human–nature relationship (see especially e.g. Bull [2009]; Nadasdy [2007]; Karlsson [2016]). This lack of research is important in the light of the ongoing political and science discussion on the importance of holders of local and traditional ecological knowledge (LEK/TEK) in conservation measures in relation to e.g. biodiversity. Specifically, the discussion concerning questions such as what kind of knowledge is LEK/TEK and how is it learned?

Outside the education sciences, however, the knowledge about nature held by local communities has been the object of research within several disciplines and research fields, such as environmental and sustainability sciences. Within such research fields, the ecological knowledge held by local users has been seen as a cumulative body of knowledge, beliefs and practices evolving by adaptive processes through generations by cultural transmission (Berkes 1999, 8; Berkes, Colding, and Folke 2000, 1252). This means that the complexity of the learning processes has not been sufficiently recognised, but has instead been simplified.

By selecting two case studies within fisheries and farming, the aim of this article is threefold: (1) to apply an educational science perspective on learning processes among people having nature as their livelihood, place of residence and as a workplace and thus contribute to the lack of educational research in this area; (2) to argue for that so-called local ecological knowledge held by e.g. local fishers and farmers represents, in most instances, a professional knowledge on ecosystem complexity: and (3) finally discuss the findings in relation to research on LEK/TEK outside the education sciences, and thus show the full complexity of the learning processes taking place. The selection of two case studies (Swedish fishers and farmers) was fundamentally based on (i) the reduction in biodiversity in marine and freshwater and farmland biotopes dues to fishing and farming intensification, and lower fisheries and farmland heterogeneity and (ii) the value of biocultural diversity of fishing and farming for biodiversity conservation and sustainability.

A discussion of the findings addresses the implications of simplistic, romantic and Eurocentric (i.e. Western science) views on knowledge generation, characterised by previous research on LEK/TEK and biocultural memory. Hence, it introduces the concept of biocultural learning to state the complexity in learning processes beyond knowing about and working in nature. The research answers the main research question of what role is played by the different learning dimensions (cognitive, emotional and environmental) in the generation, maintenance and updating of knowledge about nature among Swedish fishers and farmers. This article highlights the implications of what the complexity of learning processes means for sustainability. Such conclusions are expected to facilitate and support transdisciplinary knowledge production among different society sectors and actors through dialogue and inclusion.

2. Previous research

2.1. Workplace learning

The modern theorisations of learning took place between late 19th and early 20th centuries by the development of two ways of understanding learning. One based on knowledge generation as mental processes (cognitivism), and another on knowledge generation as behaviours (behaviourism) (see, e.g. Schunk [2012]). These two streams became the principles for the work achieved by learning theoreticians. Behavioural theories of learning dominated the first half of the 20th century, but became challenged by the need to include internal processes (e.g. thought, beliefs, feelings). Cognitive theories became more accepted as a result of their focus on the acquisition of knowledge and skills as mental processes influenced by the external environment. The technological development reached during the late 20th century brought new methods for understanding how the brain functions, while performing mental operations involved in learning and memory. Parallel to it, the neuroscience of learning has shown the role of the brain in learning and behaviour, and how motivations and emotions are represented in the brain. Research on learning continues to develop and agrees largely on the complexity of internal and external processes involved in learning. Illeris' theorisation of learning (Illeris 2003, 2004) is based on such general agreement made by the education research community after more than a century of research on learning. For this reason, Illeris' theory of learning is the point of departure for this article.

Learning is in Illeris' words: "all processes that lead to relatively lasting changes of capacity, whether they be of a motor, cognitive, psychodynamic or social character, and which are not due to genetic-biological maturation" (Illeris 2003, 397). The relevance of this integrated definition, according to Illeris himself, is avoiding any separation between learning, personal development, socialisation and qualification from different angles. It offers a broad orientation in Nordic, Continental European, Russian, British and American approaches. Illeris' learning theory (see, e.g. Illeris 2003) integrates the cognitive, emotional or psychodynamic (as internal processes) and environmental dimensions (as the external processes). In particular, the cognitive dimension is described as knowledge and skills behind learners' understanding, abilities and attitudes. The emotional or psychodynamic dimension encompasses feelings and motivations. The environmental dimension comprises participation, communication and cooperation. Specifically, learning in working life, the cognitive dimension refers to learning content, the emotional or psychodynamic dimension denotes learning dynamics and the environmental dimension connotes both the technical–organisational and the social–cultural features of the learning contexts (Figure 1). The interaction between internal and external processes (the individual and the environment) that takes

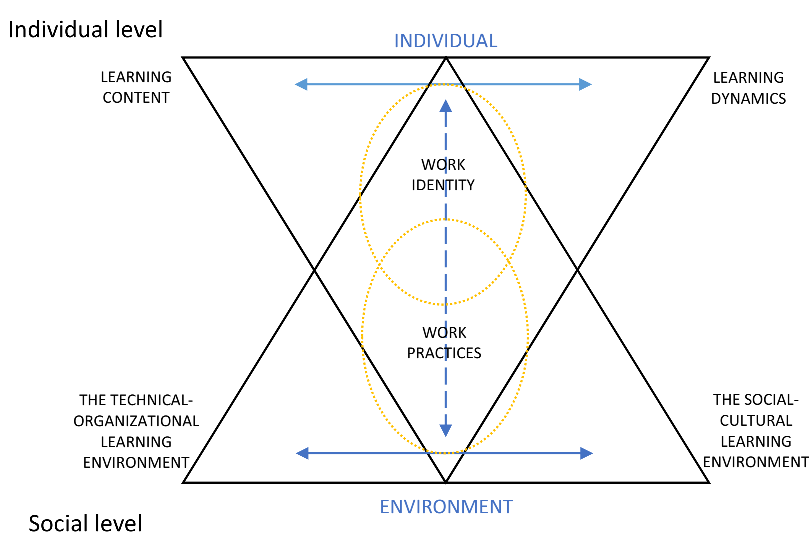

Figure 1. Learning in working life by Illeris (2004).

place in learning influences the construction of work identity and work practices according to Illeris (2004). In Illeris' words, identity "concerns the way the individual perceives him/herself as working individuals, and how he/she is perceived by others as part of a working fellowship" (Illeris 2004, 436–437). The complexity of learning is illustrated by Illeris (2003) in his integrated model of learning in working life (Figure 1).

The notions of agency (see, e.g. Billett [2008]) and reflection-in-action (see, e.g. Schön [1987]) encompass the Illeris' learning theorisation described earlier; they are particularly involved in the construction of professional identity. On the one hand, Billett's research on the role of agency on professional learning highlights the interconnections between the social (i.e. societal norms, practices and values and their enactment) and the individual (i.e. inter-psychological processes). He affirms: "neither the social suggestion, nor individuals' agency alone is sufficient to account for the processes of engaging in the simultaneous processes and remarking the cultural practices that constitutes work" (Billet 2008, 53). The individual and the social are relationally subjected to different ways of exercising individual and social agency. Of particular importance is the notion of individual's agency, which underlines the personal contributions of engaging, making sense and enacting the socially derived knowledge about work at particular moments; in time and in particular work situations. On the other hand, the notion of *reflection-in/on-action* by Schön (1987) emphasises that personal reflection during and on work practices confers professionalism and status. Personal reflections on own practices are an important component involved in the performance of knowledge and practices from the learning perspective. Finally, professional knowledge and practices are influenced by scientific literacy. Scientific literacy is considered as "the knowledge and understanding of specific concepts and processes required for personal decision-making" (National Science Educational Standards 1996, 22).

2.2. Environmental and ecological knowledge

Natural environments (lakes, arable lands, forests, savannas, etc.) are also workplaces and contexts of significance for professional learning and sustainability. LEK/TEK has largely been the object of research into sustainability, environmental and natural management sciences for decades (e.g. Poizat and Baran [1997]; Neis *et al.* [1999]; Berkes, Colding, and Folke [2000]; Olsson and Folke [2001]; Davis and Wagner [2003]; Fazey *et al.* [2006]; Zukowski, Curtis, and Watts 2011). Despite many efforts to describe, understand and integrate LEK/TEK knowledge into environmental policy and management, it has rarely been granted professional status. Instead, it has been largely simplified, romanticised and compared to Eurocentric knowledge (i.e. Western science) (see critical views against such positions, specially e.g. Suchet [2002]; Banerjee and Linstead [2004]; Briggs [2005]).

Within LEK/TEK research, local and traditional ecological knowledge has been defined as "a cumulative body of knowledge, practice and belief, evolving by adaptive processes and handed down through generations by cultural transmission, about the relationship of living beings (including humans) with another and their environment" (Berkes 1999, 8; Berkes, Colding, and Folke 2000, 1252). This largely accepted definition has transgressed to new research fields such as biocultural memory (or biocultural refugia). The concept of biocultural memory has been used as a synonym of accumulated ecological knowledge or social–ecological memory referring to ecological knowledge and practices that are regenerated, retained and revived through collective memory by communities of users (see, e.g. Barthel, Folke, and Colding [2010]; Singh, Pretty, and Pilgrim [2010]; Socies-Fiol and Cuéllar-Padilla [2017]). In particular, Barthel *et al*. affirm that traditional natural resource strategies are "passed on" by social interaction within families, communities, settlements and professional groups through songs, aphorisms, objects and embodied everyday practices. Thus, social–ecological memory would be part of any community, whether a traditional ecological system or a contemporary community. In line with Barthel *et al*.'s work on biocultural refugia (social memory related to food security) (Barthel, Folke, and Colding 2010; Barthel, Crumley, and Svedin, 2013a,b), Calvet-Mir *et al.* (2016) describe the content of home garden knowledge, which concerns users' understanding of crop sowing and harvesting, water management, fertilisation, pest and disease management, seed selection and storage, crop uses and new technologies. Furthermore, these scholars frame different modes of transmission of home garden knowledge: (i) from parents (vertical transmission), (ii) from parental generation other than the parents (oblique transmission), (iii) from the same generation (horizontal transmission) and (iv) from younger to older generation (retroactive transmission).

After this presentation of previous research on the professional knowledge about nature (within and outside education sciences), the next section describes the research methods used in the research for this article.

3. Research methods

This qualitative research focuses on two case studies (see, e.g. Creswell *et al.* [2007] and Gerring [2007]) constituted by two different professional communities (fishers and farmers) and different work strategies (i.e. small-, medium- and large-scale). In this research, the case study method helps to illustrate more general principles based on an "example of real people in real situations," penetrating situations "in ways that are not always susceptible to numerical analysis" (Cohen, Manion, and Morrison 2007, 253). The findings from the selected cases of Swedish fishers and farmers could be generalisable at the "analytical or theoretical level," and "empirical or demographical level" (see, e.g. Lundholm 2004).

The cases included in this research were part of doctoral and postdoctoral projects. Case studies were chosen fundamentally for two reasons:

1. Biodiversity in marine and freshwater and farmland biotopes are decreasing due to fishing and farming intensification, and lower fisheries and farmland heterogeneity.
2. The value of biocultural diversity of fishing and farming for biodiversity conservation and sustainability.

3.1. Participants

A total number of 27 participants constituted the sample within the two cases selected. Case studies were constituted by 20 fishers and 7 farmers in four different geographical areas: Lake Vättern (14 fishers), Blekinge Archipelago (six fishers), Norrtälje's (five farmers) and Uppsala's farmlands (two farmers). These 27 professional fishers and farmers participated voluntarily in the mentioned projects that took place between

2009 and 2016 and 2017 and 2019, respectively. The criteria for the selection of participants were localisation and professional group (fishing and farming) in line with criteria for the selected case studies presented earlier.

A total of 20 fishers (of 57 that were contacted) participated voluntarily. All the fishers were men between 27 and over 72 years old (in 2009) in Lake Vättern, and between 34 and 69 (in 2013) in Blekinge Archipelago. All perform high-tech, small-scale fishing. This type of fishing is performed in small boats for two to five people with a GPS, an inboard diesel motor, a VHF radio and sonar. American crayfish, Arctic char, European perch, common whitefish, European eel, herring and cod are some of the target species caught and sold by the participants. Catching is done using selective nets, fish traps and trawls, and crayfish are caught using cages.

A total of seven farmers (of 12 that were contacted) agreed to participate in the research project. Farmers have different production scales and were localised in the municipalities of Norrtälje and Uppsala. Three participants were men and four were women, all of them aged between 43 and 64 years old (in 2018), two performing in small-, three medium- and two in large-scale farming. The artisanal and high-tech farming performed by the participants comprises mainly agriculture, husbandry and forestry, sometimes in combination with educational and training activities (schools and universities). Farmers work principally with the production of dairy, meat, wool, eggs, honey, herbs, wood, cereals, leather and ointments. Some farmers work full time in farming, and other farmers combine part-time farming with other professions.

The backgrounds of the fishers and farmers participating are varied (see Appendix Tables 1 and 2 [online supplemental data]). However, two types of backgrounds were identified: those with a family tradition of fishing (15 fishers) and farming (five farmers), and those who have no familial connections to the fishing (five fishers) and farming (two farmers) professions. All of them have upper secondary education, and several have college degrees in different areas (four fishers and six farmers).

3.2. Data collection and analysis

The data collection is constituted by in-depth biographical narrative interviews, participant observations and the analysis of personal blogs and family pictures. Such data provides a large understanding of fishers' and farmers' life stories and how such stories are related to the contexts to which they belong. This combination of methodological tools facilitates an understanding of the interactions between the cognitive, emotional and environmental dimensions of learning.

According to Bron (2017), biographical methods and interviews have many meanings. In education sciences, the term life history is commonly used to describe the focus on people's life stories. Bron describes this approach as: "The biographical story consists of several narratives told in a specific time and space that together form the whole story of life as part of a person's biography" (Bron 2017, 21). She considers biographical stories as a set of narratives told in a specific time and place forming part of people's biography.

Biographic narrative interviews with fishers and farmers were undertaken and recorded in meetings at fishers' and farmers' homes, workplaces (i.e. fish shops) or coffee shops, and lasted one to three hours. All fishers and farmers were mainly interviewed individually (with the exception of two fishers in Lake Vättern, father and son, and two farmers in the municipality of Uppsala, husband and wife). Interviews were recorded and transcribed manually. Some participant observations were made during fishing and farming at fishers' and farmers' outdoor workplaces and homes.

Interview questions of significance for this article concern the following themes:

a. Participants sociocultural background (e.g. What is your name and age? How and why did you start fishing/farming professionally? Have you any family members in this profession?);
b. Knowledge about target species and ecosystem processes (e.g. What target species do you work with? How have the ecosystems changed in recent years? Which factors of perturbance negatively affect the ecosystem?);
c. Feelings for the profession and nature (e.g. How does it feel to work outside and have nature as your main workplace? Do you think your profession challenges you and, if yes, how? What is important to you when you work?).

A biographical approach is used for the analysis of data from interviews, as well as fishers' and farmers' personal pictures and blogs. By analysing verbal and visual narratives, research questions are answered. A biographical approach through the analysis of narratives allows an understanding of fishers' and farmers' lives in relation to their social settings. This means the interplay between the individual (e.g. meaning and agency) and the social (e.g. structures and norms) (Robertson 2002). Fishers' and farmers' life narratives show fundamental events and circumstances responsible for their professional learning in and about nature. Such events and circumstances are mainly related to fishers' and farmers' previous life and work experience from an early age. The analysis of fishers' and farmers' life narratives enables us to see the complex interactions between internal psychodynamic processes and external processes embedded in learning. The anonymity of the participants is managed by using a code. The code denotes participants' profession by FIS for fishers and FAR for farmers. It is followed by a number referring to the order of interview (from 1 to 20 for fishers, and 1 to 8 for farmers) and the first letter of the place to which participants belong. V for Lake Vättern, B for Blekinge Archipelago, U for Uppland and R for Roslagen. An example of this code is FIS1V that indicates that a particular quote corresponds to fisher 1 in Lake Vättern.

The next section shows the main findings. It focuses on the internal (cognitive and psychodynamic dimensions) and external (environmental dimension) processes involved in professional learning about nature among the participants, i.e. Swedish professional fishers and farmers.

4. Results

Biocultural learning refers to learning complexity in and about nature, particularly to the dimensions and processes involved when people have nature as a workplace. Biocultural learning is a conceptual tool and the main result derived from the application of Illeris' learning theory (Illeris 2003, 2004) (see Figure 1). Figure 2, thus, illustrates the internal (cognition and emotion or psychodynamic) and external processes (environment: the technical–organisational and sociocultural and physical features) at the individual and social levels, respectively, embedded in learning in and about nature. Such dimensions and processes influence the development of local and work

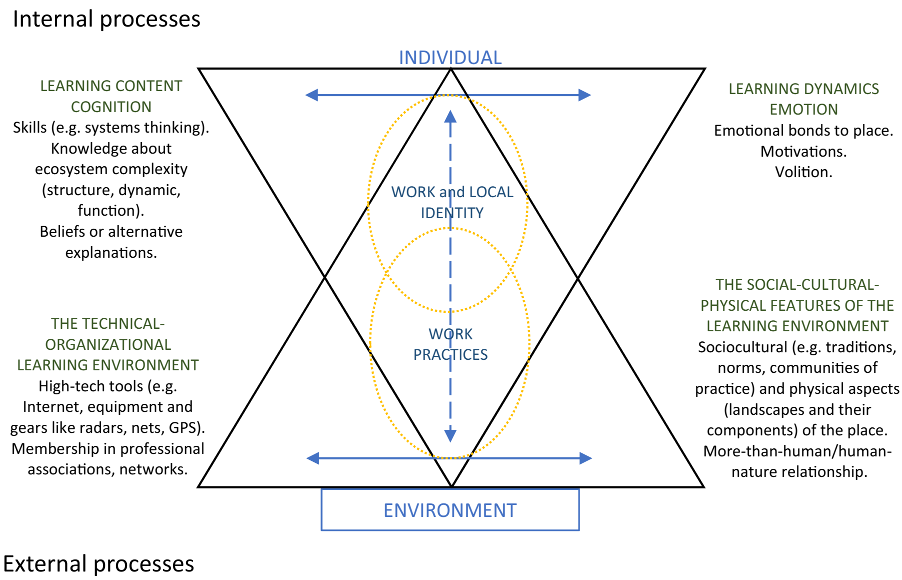

Figure 2. Biocultural learning.

identity among fishers and farmers, which are important for sustainability work practices.

The following paragraphs describe the research results in relation to the different parts of Figure 2. The results, thus, give substance to the learning processes and dimensions by Illeris (Figure 1) when individuals have nature as their work environment.

4.1. *Internal processes: the cognitive dimension or learning content*

The cognitive dimension of learning when people have nature as a workplace concerns knowledge about nature, specifically about ecosystem complexity (structure – i.e. biodiversity, dynamics, function). It also involves beliefs and alternative explanations about ecological processes not noticeable by everyday experience through observation. Systems thinking is one of the main cognitive skills needed and developed for the understanding of ecosystem complexity and ecological processes. In consequence, the results focus on knowledge about nature (LEK/TEK) as the core of professional ecological knowledge.

Knowledge about nature held by fishers is mainly about ecosystem complexity. This knowledge concerns the dependency of their work on target species in terms of work practices and performance. Fishers involved with a wide range of target species have a large knowledge about ecosystem structure and dynamics. This knowledge comprises the identification of feeding interactions between species (including the variety of life forms), and feeding interactions changing over time. Thus, it relates to target species' competition for food resources and habitats (among others), and the flows of biomass in response to direct and indirect feeding (and other) types of interactions. Energy fluxes determined by feeding interactions are described by some fishers such as FIS7V. He described particular changes over time in the body-mass of secondary carnivores such as Atlantic salmon, Arctic char and common whitefish, making them thinner and longer. The following excerpt illustrates this:

> At specific stages in the life of the Arctic char and whitefish, they eat plankton. In turn, whitefish eat plankton and bottom organisms and stuff, but some whitefish become extremely large, over 2–3 kg, and they eat common whitefish and smelt or stuff like that. Not everyone, but there are a few … so they eat almost the same as Arctic char. Large fish can eat both common whitefish and smelt, but there are large variations in the 'fish species'. Excerpt 1. FIS7V.

Fishers also described several elements directly and indirectly affecting the feeding interactions among their target species and the flows of biomass in the lake; fishers mentioned disturbance factors such as climate change, water quality, cormorant populations and overfishing. They described significant circumstances and events (e.g. the construction of factories and a waste water treatment system, storms and cold winters) as reconstructions of their own or other memories. Furthermore, they seem to connect such memories with information from Swedish Board of Fisheries' fishing reports. The next excerpt illustrates FIS1V's statement concerning the influence of low levels of phosphorous on fish. According to him, low levels of nutrients affect the amount and quality of plankton and zooplankton, which is the food of fish such as common whitefish (one of his target species):

> There are different species that are affected (decreased) by different external factors. Common whitefish for example, and other fish, are also affected by water treatment plants … there is too little food and nutrients for fish to survive. Water is too clean. Excerpt 2. FIS1V.

Similarly, knowledge about nature among farmers regards ecosystem complexity. Farmers who combine different farming activities (i.e. agriculture, animal husbandry and forestry) involving several target species (e.g. chickens, cows, sheep, horses, bees, herbs) (see Appendix Table 2 [online supplemental data]) generate a wide knowledge about ecosystem structure and dynamics. Farmers' knowledge about the feeding interactions of target species is part of everyday work knowledge. In the next excerpt, FAR1R described the significance of manure for soil and hay harvests; this last item is important for heifers. Moreover, she mentions the interconnection between heifers (target species) and some species of plants that benefit from open pastures grazed by grazing animals:

> Manure is an important ingredient in organic farming. The fertilizer contains important nutrients that enable a good harvest of feed and food. The manure should be able to release the nutrients and build on the humus content in the soil. Furthermore, heifers contribute to biodiversity by go in the summer and graze on various pastures around Broströmmen [a specific place]. Heifers make sure that the grass doesn't compete with species like cat foot and blue violet by grazing on the meadows down towards Brosjön. It maintains also open spaces for other rare plants like cross-owl, St. John's wort and night violet to grow. Excerpt 3. FAR1R.

Another example of farmers' knowledge about ecosystem structure is presented in Excerpt 4. In this, FAR7R described the interconnection between different species existing on her and her neighbour's farm, including target species (sheep, bees, horses, cherry trees). According to her, several tree species and other plants on her and her neighbour's farms benefit from pollination by her bees. In turn, these plants and seeds are bred for her animals (e.g. sheep, horses):

> I have a farm with several plants and a lot of herbs. Then our neighbour also has apple, cherry and other fruit trees. But just that my sheep and horses graze on sly, dry sagebrush… They eat up hazel, seeds, aspen and hay. Then, it becomes airy, nice and easy for bees to pollinate raspberries and everything. Excerpt 4. FAR7R.

Furthermore, farmers' knowledge about structure also regards target species behaviours, particularly for farmers working with animal husbandry. This knowledge is of significance for animal care. Excerpt 5 shows the experience of FAR6R who has adapted his work practices to chicken's (target species) behaviour:

> When working with animals you realize that the animals are guided by instincts. It is also recognized that breeding has made that some instincts among certain breeds no longer exist. For example, the brown hybrid chick I have, they are completely cuckoo in the head. For an ordinary old breed hen, she goes inside when it starts to be afternoon and the sun goes down. She goes inside and sits on the stick because it is natural to jump up into trees so that the fox or predator can't come and take her when it gets dark. But the brown chickens have lost such instinct. It continues to go out in the evening and graze. I have to chase them in. Excerpt 5. FAR6R.

4.1.1. The nature of farmers' and fishers' knowledge about nature

The knowledge about nature held by fishers and farmers concerns the understanding of ecosystem complexity (i.e. ecosystem structure that includes biodiversity, and ecosystem dynamics). Such knowledge is derived from science literacy and their own experience. All the excerpts presented earlier illustrate examples of systems thinking, which is significant for generating an understanding of ecosystems. It can be considered as a cognitive skill that fosters the identification of interconnections between living and non-living components constituting ecosystems. In turn, scientific literacy seems relevant for the development of systems thinking among fishers and farmers, which is largely derived from their formal education (schooling). All the fishers and farmers participating in this research have completed at least upper secondary school education; some of them even have higher education degrees (see Table 1 and Table 2 in the Appendix [online supplemental data]). The next excerpt shows an example of scientific literacy among them as one of many statements from fishers and farmers regarding knowledge about nature non-derived from experience. In this, FAR4R explains the influence of queen's pheromone levels in wane in wild bees based on what science shows, in contrast to his experience of introducing a new queen (something that rarely happens in nature simultaneously) to the colony:

> It's the queen who camps all eggs. If the colony has a good or bad queen depends on how the colony works as a whole. Bees know when the queen begins to grow old; her pheromone levels begin to wane and ends. When she flies from the swarm a new queen can arrive. Bees take care of everything by themselves. I don't need to do so much when the queens get older. In many of my colonies, it happens to have two queens at the same time. It doesn't use to happen with wild bees. Usually, the old queen would have swarmed with half the biomasses before this new queen was hatched. Sometimes

the new queen begins to lay eggs and the old queen is gone, the next time I go there to take a look. Excerpt 6. FAR4R.

Fishers' and farmers' understanding of ecosystem complexity includes beliefs or alternative explanations, for instance, to feedback loops. Beliefs characterise not only fishers and farmers' knowledge but also scientists. The next excerpt shows the uncertainty embedded in ecosystem-based strategies that challenge different professional groups (fishers, ecologists, policy-makers) for managing the reduction in Arctic char populations in Lake Vättern:

> Well that's difficult, because no one knows what needs to be done. Arctic char's reproduction cycle doesn't work as it should after all measures taken by policy-makers in the lake, and nobody knows why. It seems that it doesn't help to stop fishing this species, neither changing the size of the net nor the amount of net, the population continues to decrease. It has been many years since they started with all the measures, and what has happened? It has only gotten worse and worse. I know some fishers who suggested hatching fry of Arctic char in artificial conditions and putting them back in the lake when they have become big enough. They believe it would help populations recovering. In that way, the fry has perhaps passed their most critical period. But there was such resistance against it. There was an ecologist from the Swedish Freshwater Laboratory who said that over his dead body it would happen. But I mean, we have been sitting in other species like American crayfish in the lake that don't belong here, and it has gone well. In this case of Arctic char, we are helping a species that belongs in the lake. I think it would be a good thing to do. Excerpt 7. FIS9V

Furthermore, all farmers and fishers seem to constantly evaluate the knowledge and strategies developed through and for work performance by reflecting on their own work practices. So, fishers and farmers are able to incorporate new knowledge about nature and sustainable work strategies. The incorporation of new knowledge seems to depend on its relevance and coherence with fishers and farmers' previous knowledge. Thus, scientific literacy is a relevant aspect, but is not the only one influencing fishers and farmers' knowledge about nature. Experiential knowledge also has an important impact on what fishers and farmers know about nature. Experiential knowledge is derived from work practices in nature, sometimes from early ages (e.g. apprenticeship). Fishers and farmers depend on the experiential knowledge they generate on nature. The next excerpt shows the views of FIS14V on the experiential knowledge needed, and its significance for a good professional performance, which allows fishers to have nature as their livelihood:

> It's 99% skill to catch a fish. Then you can have sometimes luck. But you don't have control over the size of your catch. You might get a four kg or a 19 kg fish. For me, fishing has basically nothing to do with luck when working with it as a profession. For instance, my colleague who is 70 years old, he can't have been lucky all his life, but he is skilled. And these old guys (professional fishers), they are super-talented. They can manage to see things in nature that an ordinary person don't see, e.g. how weather, currents and wind influence fish behaviours, and thus to manage to have a good catch. There is a lot of components or pieces that a fisher tries to get together… even by having such skills you never know 100% for sure how your catch will be. Excerpt 8. FIS14V.

Fishers and farmers' experiential knowledge about nature is sometimes not explicit, but mainly embodied in everyday work practices. Many fishers and farmers talk about their embodied knowledge about nature and its relevance for work performance. The next excerpt is one of many examples illustrating the tacit and embodied nature of experiential knowledge about nature:

> Knowledge sits in my body. I can't sit here now and explain all of it, but when I am at the place then I know. It's like a feeling. Take for example when we go out fishing during the night. We are five men aboard and we always ask ourselves: where shall we go tonight? One can say, here! Another one says, there! I say, I believe we should go there, that's where the herring is tonight. OK! let's try. We all agree. Most of the times it's me and another colleague who have the same opinion. Nine out of ten times we are right when we get to the place. So, we have experienced the movements that give you the feeling for it. It's about feelings. This knowledge is important. I think this knowledge is threatened nowadays when all the fishers are getting very old, and the recruitment of new fishers (apprentices) is so low. Unfortunately. Excerpt 9. FIS18B.

The above statement also highlights the importance of apprenticeship on knowledge generation and maintenance. According to fishers and farmers with a familial connection to fishing and farming, apprenticeship is influenced by low recruitment of young and new professionals. Something that, in turn, threatens the generation and maintenance of professional knowledge about nature.

4.2. Internal processes: the psychodynamic dimension or learning dynamics

Nature plays an important role in the fishers' and farmers' knowledge about nature. For them, nature is understood not only as a physical place for working and living, but a social and emotional space to attach to and be attached to. All fishers and farmers state that nature plays an important role in their lives, no matter whether or not they have a familial connection to farming or fishing. For some of them, specific environments (e.g. a lake, the Sea, a piece of arable land, a farm) are places to which they belong. Fishers and farmers showed a strong self-identification with their target species (e.g. eel-fishers). The next excerpts show some examples of place attachment and self-identification:

> Nature has enormous significance for me. It is my whole host. I live in a forest plot … I pick blueberries on my plot. I think we (people) look differently at nature. Some only see nature as a resource to exploit. Contrary, I have a very humble attitude to nature. I have always had it really. We have never had any farmers in the family. It has been self-chosen. Excerpt 10. FAR7R.

> For five generations, my ancestors have known that the eel is from the Sargasso Sea. How did they know it in the 17th century? Over generations, the knowledge about eel and the ways of catching it (with slings and braided baskets with a stretched) have been told in my family. There was so much eel before (now it is endangered). I live on a street called Skuregränd. The people who came to this place and fished eel were called 'the forest people'. We have a certain dialect so 'forest' comes from 'scourge' (skure in Swedish), and 'skogsfolk' (forest people) become 'skure'. I and several others are called 'skurefolk'. It was that people who came to this place for fishing four centuries ago, and I come from that family. An eel-fisher family. I'm one of them. We are just some people who still live here and who have inherited this profession. Excerpt 11. FIS16B.

As it has been shown, place is not only characterised by its physical features, but also by its social features. Learning processes about nature at the professional level are determined by the interaction between individual internal and environmental external processes in a determined place and time. Thus, place and time are closely related to how fishers and farmers' knowledge about nature is generated, maintained and updated. Fishers' and farmers' knowledge about nature and work practices is not static; it is linked to the past, the present and the future. An example of that is the use of the Internet, social networks and other high-tech tools allowing fishers and farmers to increase their understanding of nature in a totally different way than before. At the same time, the existing work knowledge and work strategies that characterise small-, medium- and large-scale fishing and farming today are closely connected to, and embedded in, traditional work practices within such communities:

> I grew up with fishing, and even today, for me that's a way of living. It's like a culture. I was born at home on an island. My dad started fishing with passive gear like I do today. And when old men fished herring, they went out early in the morning and arrived home. Then women came down and picked up herring and the nets. Women helped their men (fishers)… the whole family was involved in fishing. Excerpt 12. FIS20B.

After the above description of the individual and internal processes embedded in the cognitive and psychodynamic dimensions of learning about nature, the next paragraphs describe the external processes of learning that concern the environmental dimension. Such processes concern particularly the role of apprenticeship and communication (with peers and scientists).

4.3. External processes: the environmental dimension, or the features of the learning environment

The environmental learning dimension embeds the technical–organisational, and sociocultural and physical features of the learning context. The use of high-tech tools (e.g. Internet, equipment and gears) by fishers and farmers, like their membership in professional associations and social networks are key aspects for increasing their understanding of nature. Parallel to this, the sociocultural (e.g. traditions and communities of practices) and physical features (e.g. landscapes) of the learning environment are significant aspects for knowledge generation, maintenance and updating. One of the major elements behind the generation of knowledge about nature by fishers and farmers is apprenticeship. Many fishers and farmers stated to have inherited the professions from their fathers or mothers. In fisheries, the apprenticeship happens between grandfather, father or a related old man and a young boy or man. In farming, it happens even between grandmother or mother to a young girl or woman. The next excerpts are two of those examples:

> My father and grandfather were fishers. They were peasants both of them. They had a farm as livelihood; they also fished. I was with my dad out on the lake and fished when I was 5 years old. It's probably quite common in the fishing profession. You take over after your father. It's probably not easy to jump in and become a professional fisher, otherwise. You must have so much knowledge. It's not enough having a fishing license and equipment. You have to know where to put the wears and what kind of wear you

need to have a good catch. This kind of knowledge is very experience-based. Excerpt 13. FIS3V.

I am born here. I have been here with my mom and dad. I didn't want to be a farmer, but I have always loved animals. I got a little pony when I was 12 years old. I went to an agricultural high school, because I wanted to be a veterinary. I said to my mom and dad: you haven't a son (they have three daughters), no man to take over this farm, but I can do that. In my family, this farm has passed from women to women over generations. Excerpt 14. FAR1R.

Communication is another major element in the generation, maintenance and updating of fishers' and farmers' knowledge about nature. Communication with peers and scientists is largely common, particularly among fishers and farmers with a non-familial connection to the profession. The next excerpt shows the case of FIS5V, who did not have a familial connection to the fishing profession and worked as a mechanic for several years before he started to fish professionally. He found the opportunity to become a fisher and to have a livelihood as a fisher late in life:

I have two friends who were professional fishers in Lake Vättern. I could buy fishing equipment and take over within the profession in that way. But I hadn't knowledge of fisheries or anything like that before I started. But I have always been interested in nature. I am raised on a farm. I had to get the license, so I had to quit my job first and start right away. It was a bit difficult for me to get profitability, when I haven't so much knowledge. My friends and I didn't work together. Everyone has their own boats, so I asked for advice. I had to learn, the long hard way (laughter). Excerpt 15. FIS5V.

In line with the above statements, it seems that fishers and farmers with non-familial connections to the profession also have a large dependency on other sources of information such as the Internet compared to those with a familial connection. The next excerpt shows a clear example of it. According to FAR6R, communicating with scientists, and reading scientific rapports and books have been of significance for the knowledge he has on chickens:

My knowledge of chickens was quite non-existent when I started with egg production. I have taught myself. I guess I'm pretty good at my work now, because I have some communication with experts in the chicken field. I sit quite isolated here, so I have read quite a lot of poultry literature. The Swedish University of Agricultural Sciences has produced the lot, especially when it comes to feed for organic chickens. Then my analytical ability has been good, being able to count stuff. But I'm not a salesman, I'm a technician, but in my former career I learned that it is important to focus on the customers' needs. I'm pretty good at finding solutions. I think it's important to learn about what people did in the past, because most of the knowledge already exists. I love craftsmanship. So my main guide is a handbook of poultry care from the 70s. It helps me a lot, for instance, it has good advice about fish silage and how much should I add of it in chickens' food in order to obtain eggs of quality. Excerpt 16. FAR6R.

The above paragraphs have shown the external processes involved in learning, thus the significance of the environmental dimension for the generation, maintenance and updating of knowledge about nature among fishers and farmers.

The next section discusses the presented findings in relation to previous research on LEK/TEK and biocultural memory. Based on the presented findings, it introduces the concept of biocultural learning as a conceptual tool for the scientific understanding of the complexity embedded in professional learning processes among people having nature as their livelihood, place of residence and workplace.

5. Discussion

The findings are summarised as follows. The cognitive, emotional (or psychodynamic) and environmental dimensions of learning play important roles in the generation, maintenance and updating of knowledge about nature among Swedish fishers and farmers. Knowledge about nature is generated and updated individually by fishers and farmers at the cognitive level. This knowledge refers to the understanding of ecosystem complexity (i.e. ecosystem structure including biodiversity and ecosystem dynamics). Systems thinking is a relevant mental skill required for, particularly, fishers' and farmers' understanding of ecosystem complexity. It is considered as a capacity of mental abstraction that allows the identification of interactions between living and non-living components constituting ecosystems, and ecological processes. Such knowledge is a mixture of different forms of knowing derived from science literacy (i.e. formal education, information acquisition by reading books, the Internet, scientific rapport) and experience (i.e. communicating with peers and scientists, and apprenticeship by membership in social networks and associations), in line with Garavito-Bermúdez *et al.*'s research (Garavito-Bermúdez, Lundholm, and Crona 2016; Garavito-Bermúdez and Lundholm 2017; Garavito-Bermúdez and Boomstra 2019). In particular, the knowledge derived from experience or experiential knowledge is embodied (tacit) in work practices. Furthermore, fishers and farmers constantly evaluate the knowledge and strategies developed by and for work performance. These findings highlight the role of individual agency (see, especially, e.g. Billet 2008) actively exerted by fishers and farmers through developing their professional knowledge, work strategies and work performance. Fishers' and farmer's agency and reflection on everyday work (see, e.g., Schön 1987) are key elements making possible knowledge and attitude change (i.e. learning) that leads to sustainable fishing and farming strategies.

For fishers and farmers, nature means not only a place for working, but a place for self-identification. Early experience in nature and everyday work practices seem essential for fishers' and farmers' generation of positive emotional bonds with nature. Fishers and farmers are emotionally attached to the place they know and feel belonging to; thus, nature is significant for them, their families and future generations. Moreover, the development of sustainable fishing and farming practices seems to be connected to the positive emotional bonds to nature, and identity (local and professional). Both place attachment and identity are embedded in the interconnections between the internal (emotional or psychodynamic dimension) and external processes (environmental dimension). Belonging to a professional community of stakeholders is significant for the generation of professional knowledge by fishers and farmers (the sociocultural and physical features of the learning environment). In this sense, the social recognition of belonging to a certain local and professional community is central for identity construction, and independent from having a previous familial connection to the profession and place. These findings are in line with previous research in education science concerning the interactions between ecological knowledge, place attachment and identity (see, e.g. Garavito-Bermúdez and Lundholm [2017]). In addition, they relate to anthropological research on sense of locality among local communities (including Inuit) in Northwest Greenland (see, e.g. Nuttall

[2004]) and the sense of locality and place attachment significance for sustainability (see, e.g. Sejersen [2004]).

Within education sciences, this article contributes to the theorisation of learning processes characterising professional knowledge when people have nature as a workplace. For this, it develops and extends Illeris' learning theorisation (Illeris 2004) (Figure 1) by introducing the concept and model of biocultural learning (Figure 2). By applying and extending Illeris' learning theory, this article increases the scientific understanding of learning complexity involved in professional knowledge about nature (LEK/TEK). The concept of biocultural learning adds new elements involved in learning dimensions (internal and external processes) that have not been contemplated before. The cognitive dimension – described as knowledge and skills behind individual's understanding, abilities and attitudes by Illeris (2003) – includes furthermore beliefs or alternative explanations for real phenomena that do not always have a religious or spiritual content. Furthermore, it comprises cognitive skills such as systems thinking, understood as the ability to identify interconnections among systems components, and to synthesise them into a unified view of the whole (Senge 1990). It is mainly developed through scientific literacy derived from formal education (schooling) settings. The emotional or psychodynamic dimension – that encompasses feelings and motivations influencing cognition (Illeris 2003) – also comprises emotional bonds to the physical (e.g. landscape, architecture, objects), social (e.g. professional peers, communities) and cultural (e.g. traditions, religion) features of the workplace. It embeds the sense of belonging to particular communities and landscapes (e.g. urban and rural). The environmental dimension – that comprises participation, communication and cooperation (Illeris 2003) – concerns not only the communication and participation with other humans, but with multiple species and non-living components (e.g. sun, soil, water, air, fire) presented at the workplace. Thus, this article underlines the significance of interconnectivity of life and social geographies in learning research, particularly within workplaces. Such new elements encompass the research on more-than-human, human– nature relationships and human–animal studies (see, e.g. Bull 2009; Nadasdy 2007; Karlsson 2016). For instance, fishing environments and fish itself are important for the construction of "fisher" (as a professional), "fishing" (as a life style) and "fishing culture" as a family tradition by individual fishers and their communities. This finding is also in line with the significance of the physical place on community culture, and the significance of community local culture on place meaning (see, e.g. Stedman 2003; Garavito-Bermúdez and Lundholm 2017).

By stating that LEK/TEK is core professional knowledge about nature that results from biocultural learning, this article highlights the role of scientific literacy and the contextual character of knowledge generation embedded in professional outdoor practices. The findings presented in this article provide significant elements giving a professional status to work practices in nature, and to those who have nature as their workplace. Such insights argue against romantic views of LEK/TEK as a sacred knowledge largely based on spiritual beliefs and world views (see critical views by e.g. Cocks [2006]). Moreover, the findings of this research contrast with a well-established definition of the LEK/TEK held by local stakeholders "as an accumulated body of knowledge, beliefs and practices evolving by adaptive processes through generations by cultural transmission" (Berkes 1999, 8; Berkes, Colding, and Folke 2000, 1252). Using and reproducing this definition within the research on TEK/LEK and biocultural memory implies two false assumptions: (1) that learning is merely a process of knowledge transfer; and (2) that LEK/TEK is only generated by cultural transmission. In addition, Berkes, Colding, and Folke (2000) describe LEK/TEK as a way of knowing nature that is similar to Western science by being based on observations. Similarly, these scholars consider LEK/TEK as an historical tradition encoded in rituals and cultural practices of everyday life by people "outside" Western science, in contrast to scientific knowledge that is understood as an abstract tradition held by people "inside" Western science. These last assumptions disclaim the historical and sociocultural features of scientific inquiry and scientists' professionalisation processes (see, e.g. Restivo [2017]; Lucier [2009]), and the role of formal education or schooling (that is based on scientific inquiry) on the professionalisation of user ecological knowledge.

Consequently, this article shows that LEK/TEK and biocultural memory should be understood and studied as a cognitive element inseparable from users' professional and local identity and place attachment (see, e.g. Garavito-Bermúdez and Lundholm [2017]); in contrast to previuos research (e.g. Barthel, Folke, and J. Colding [2010]; Singh, Pretty, and Pilgrim [2010]; Socies-Fiol and Cuéllar-Padilla [2017]; Calver-Mir *et al.* [2016]). Even if the selected cases are demographically limited to two professional groups (fishers and farmers) in two particular Swedish contexts (fisheries and farming), the findings presented in this article could be generalisable at the theoretical and empirical levels (Lundholm 2004). This means that the theorisation of professional learning (processes and dimensions) developed by Illeris (2003, 2004), and extended in this research to the particular cases of professionals having nature as their workplace, are theoretically applicable to other professional groups and sociocultural contexts. This statement is based on decades of research on learning in education sciences that has largely showed that human cognition development and structure do not differ by ethnicity, geographical localisation, gender or class, even if these aspects influence learning contexts and conditions. In this particular case, different ways of knowing nature (derived from scientific literacy and experience) are coexistent in human cognition development and structure. Additionally, the variety of knowledge about nature enables individuals to perform particular work or labour (e.g. fishing, hunting, farming, herding).

6. Conclusions

This article applies and extends the learning theorisation model developed by Illeris (2004) (Figure 1) and introduces the concept of biocultural learning as a theoretical tool allowing us to illustrate the learning dimensions and processes involved when people have nature as a workplace (Figure 2). Such learning theorisation is not exclusive to communities of local users of natural resources. It could be applied to a variety of professional communities of practice in different society sectors (public and private). Thus, people are related to, and influence directly and indirectly, nature in personal and professional ways. The concept of biocultural learning by itself provides new insights and understanding about the complexity embedded in learning processes aimed at social transformation for sustainability. Such complexity should be considered in the present and future sustainability research and practice, particularly that concerning LEK/TEK and biocultural memory (refugia), as well as in general environmental science. In line with this, this article contributes to the discussion regarding the need to promote and strengthen biocultural learning as lifelong learning for sustainability.

Another main conclusion from the findings and discussion presented in this article is the significance of giving professional status to work practices in nature (e.g. fishing, farming, hunting and reindeer herding), and to the professional knowledge generated through it (e.g. ecosystem complexity, including biodiversity). Such status is highly important for generating and promoting dialogue and cooperation between society sectors and institutions. The benefits of integrating the professional knowledge about nature held by local users of natural resources is largely comparable to other professional knowledge within a variety of professional groups (e.g. teachers, medical doctors, nurses). The integration of such professional knowledge as LET/TEK means, per se, a step forward for transdisciplinary knowledge production which is highly demanded for the achievement of global sustainable development goals (see, e.g. UN [2019]). Democratic processes and social inclusion are major prerequisites for transdisciplinary knowledge production and decision-making for sustainability; and are potentially spaces for promoting and strengthening biocultural learning.

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Supplemental data

Supplemental data for this article can be accessed here.

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