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Learning for Sustainability in Horticultural Production in Arctic Norway

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Sustainability learning is gaining popularity as an important field within sustainability research, where farm sustainability can be understood as a learning process. In this study, we seek to reveal the sustainability learning process of farmers, utilizing a framework distinguishing contextual factors (where? and when?), knowledge (what?), motivation (why?), and process (how?). The article presents a participatory inquiry mixed-methods approach, utilizing results from sustainability assessments on five farms with the SMART-farm tool as a unifying starting point for further discussions on sustainability learning in farmers' interviews and stakeholder workshops. Empirically the study is set in the horticultural production in Arctic Norway, where few studies on sustainability have been undertaken. The study shows how both the complexity of the concept of farm sustainability and contextual factors influence the sustainability learning process, for instance by giving rise to a vast number of conflicting issues while working toward farm sustainability. The sustainability learning process is found to be predominantly a social learning process. The theoretic contribution of the study lies in its novel framework that can be used to reveal important aspects of the sustainability learning process, as well as to contribute to the literature on how to proceed from sustainability assessments to implementation. A key finding from the study is that farmers will require continuous assistance in their processes toward farm sustainability, but for this to be possible, knowledge, sources of knowledge, and learning platforms for holistic sustainability need to be established.

Keywords: sustainability learning, double-loop learning, SMART-farm, arctic horticulture, participatory approach

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INTRODUCTION

Sustainable farming, both as a vision and as a practice, is placed high on the political agenda, although the idea of sustainability, at the farm level remains contested in terms of its nature (what is a sustainable farm?) and its prospects (is it possible for a farm to be sustainable?) [FAO (Food Agriculture Organization)., 2014; Brunori et al., 2016; Bardalen et al., 2020; COM (European Commission)., 2020]. Sustainability challenges are sometimes described as "wicked" since they can be complex, with conflicting interpretations and uncertain outcomes (Rittel and Webber, 1973; Glass et al., 2012; Wals, 2015). The concept of sustainability rest on three pillars: environmental protection, economic resilience, and social inclusion [WECD (World Commission on Environment and Development), 1987], and for a holistic sustainable development these pillars need to perform in a concerted action.

Darnhofer et al. (2010) find that a farm's ability to become sustainable depends on several factors; key among them is the farmer's ability to learn, a process that can be understood as "the human response to tackle issues that require change" (Blackmore et al., 2012, p. 162). Understanding how to learn sustainability—i.e., learning to "*achieve and support sustainable development*" (Hansmann, 2010, p. 2877), is crucial in moving toward sustainable practices (Wals, 2007). Tàbara and Pahl-Wostl (2007, p. 1) emphasize that discussions on sustainability have "*shifted from being goal oriented to understanding sustainability as a learning process*" and numerous learning theories have been developed, each focusing on a different sustainability aspect (Blackmore, 2007; Illeris, 2018). Argyris and Schön (1978) juxtaposed learning with change, and this approach becomes the core of our theoretical framework that further draws insights from the sustainability learning literature (Hansmann, 2010), double-loop learning (Argyris and Schön, 1978), and social learning (Blackmore, 2007; Wals, 2007) to help us understand learning for sustainability at the farm level.

The purpose of this article is to address the following research question: What are the characteristics of sustainability learning in the context of horticultural farms in Arctic Norway? The article utilizes a mixed methods approach in a participatory case study of horticultural family farms in the region. More specifically, the study uses sustainability assessments to contextualize sustainability and as a starting point for a learning process toward farm sustainability (de Olde et al., 2016). Theoretically, this study enhances our understanding of how learning processes can lead to increased farm sustainability (Lankester, 2013), while empirically, it brings new evidence on farm sustainability and the underlying processes for how new knowledge becomes action regarding farm sustainability (Restrepo et al., 2018). We further suggest a way to advance from sustainability assessments to a sustainability learning process for actual change. Methodologically, this study contributes to the growing body of participatory research literature that utilizes mixed methods in a case study approach.

THEORETICAL BACKGROUND

The theoretical background draws insights from several areas: sustainability learning, social learning, loop-learning theories, and learning for sustainability at the farm level, including sustainability assessment literature.

Sustainability Learning for Change

Sustainability learning, which "aims to achieve and support sustainable development" (Hansmann, 2010, p. 2877), is a multi-level concept (learning at the individual and societal levels), in which a transdisciplinary effort (Tress et al., 2005) is fundamental (Hansmann, 2010). Changes in complex matters such as sustainability do not occur in isolation but within a system through multi-stakeholder interactions [Tilbury, 2011; Klerkx et al., 2012; Aerni et al., 2015; TAP (Tropical Agriculture Platform)., 2016]. Tilbury (2011) identifies collaboration as a key process in sustainability learning, and sustainability learning is typically associated with social learning [UNESCO (United Nations Educational, Scientific and Cultural Organization), 2002; Tàbara and Pahl-Wostl, 2007; Wals, 2007, p. 7], i.e., learning that is occurring through social interactions that also changes the understanding of participants (Folke et al., 2005; Glass et al., 2012; Beers et al., 2014). New understanding can arise from discussing existing ideas in a different social context (Beers et al., 2014). Sustainable solutions from social learning rely on processes that are flexible and iterative, encouraging learners' reflection on various perspectives (Glass et al., 2012) and thus enabling participants to understand the "*cultural, professional and personal complexities surrounding sustainable development*" (Tilbury, 2011). The complexities of sustainability learning necessitate involvement of multiple stakeholders, having different values and beliefs, and therefore "*demand[s] not just individual learning but social learning*" (Blackmore, 2007, p. 514).

Learning is a process [Ison et al., 2000; UNESCO (United Nations Educational, Scientific and Cultural Organization), 2002; Tàbara and Chabay, 2013, p. 7] leading to change (Bateson, 1972; Argyris and Schön, 1978). Change may refer to a cognitive change in the learner, which may or may not result in practical changes (Leeuwis and Van den Ban, 2008). Although the process toward sustainable development gains more momentum worldwide, it is slow-paced, especially when considering the immense and immediate challenges facing the environment and societies [UN (United Nations)., 2019]. A way to speed up the learning process for sustainability is through double-loop learning (Argyris and Schön, 1978).

The learning process begins when observing the result of an action (Argyris and Schön, 1978) and then engaging in self-reflection that then leads to either single or double-loop learning (Restrepo et al., 2018). Our approach adopts double-loop learning as described in Tàbara and Pahl-Wostl (2007), "*in which the learner becomes aware of the assumptions and values that he or she holds, and is capable of major shifts*," which is distinctly opposed to single-loop learning where the aim is to perform routine processes in a more efficient or better way (Argyris, 1992). Changes in double-loop learning further involve altering the governing variables, including changing norms and values (Argyris, 1992). In situations where more transformative changes are needed, as is the case for sustainability learning, one has to question the underlying norms and assumptions and therefore proceed through a double-loop learning approach. Double-loop learning is crucial for the long-term survival of a company, especially when faced with uncertainties, something that is also the case for the farm businesses we examine (Argyris, 1992). The literature also suggests the possibility for triple-loop learning (Eksvärd, 2010; Armitage et al., 2011; Restrepo et al., 2018), referring to reflections leading to learning about the learning process itself (Groot and Maarleveld, 2000); however, this approach is beyond the focus of this study.

Figure 1 illustrates our underlying theoretical framework which builds on a model by Hansmann (2010, p. 2879). In Hansmann's model, learning is an iterative process in which motivations and knowledge serve as first inputs, leading to both affective and cognitive outcomes, which can lead to new learning. Our framework contains aspects that affect the learning process,

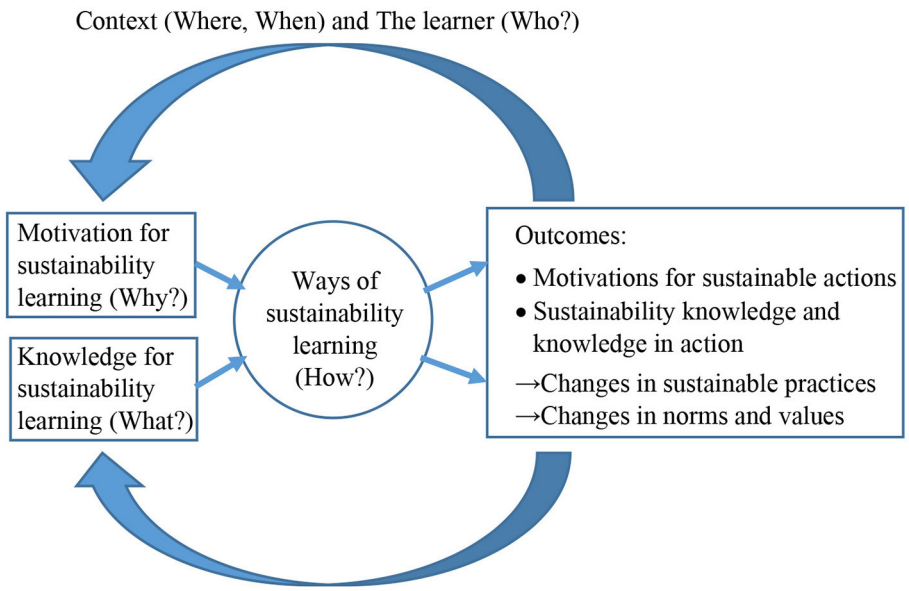

FIGURE 1 | Framework for analyzing sustainability learning.

addressing what is learned, why is it learned, and how is it learned (a notion adapted from Maarleveld and Dabgbégnon, 1999). Specifying learning outcome is also essential (Armitage et al., 2008). The complete process is framed within its context, addressing *where* and *when* is it learned, in addition to *who* learns?

The framework serves as a guide for empirically investigating the entire learning process needed to improve farms' sustainability level. *Where* and *when* refer to context, defined by time, place, and culture (Bond and Morrison-Saunders, 2013). Related to this is the notion of *who* learns. Organizations do not learn (Argyris and Schön, 1978), but rather people learn, so specifying who is learning becomes essential. *What* is the sustainability knowledge, including knowledge in action (Tilbury, 2011), and *why* refers to the motivations for learning and making changes, stemming from both internal (e.g., own curiosity and interest) and external (e.g., learning process as a means to an end) factors (Ryan and Deci, 2000; Hansmann, 2010). Finally, *how* accounts for the main process of learning, distinguishing between collaborative (learning in cooperation with others), experiential (building experience between theory and practice) and experimental (through practical experiments) (Thompson and Scoones, 1994; Darnhofer et al., 2010; Restrepo et al., 2018). The framework also includes the outcomes of the learning process, as change in sustainable practices as well as change in norms and values. Sustainability learning is the essence of this framework where single and double-loop learning (Argyris and Schön, 1978) are used to describe the level of change involved in the process of action and reflection leading to learning. This framework becomes iterative when new sustainability knowledge and new motivations for sustainable actions lead to further sustainability learning in a continuous process.

Learning for Sustainability at the Farm Level

Ever since the Brundtland commission defined sustainable development [WECD (World Commission on Environment and Development), 1987], sustainability has been studied at the farm level as a learning process (Tàbara and Pahl-Wostl, 2007; Darnhofer et al., 2010; Brunori et al., 2016). Learning has been studied at the farm level both in general and in relation to sustainability, and there is a wide range of literature studies that relates to the components of our framework (**Figure 1**).

Scholars argue that learning at the farm level must be understood as contextual (Jarvis, 1992; Blackmore et al., 2012), where the three dimensions of sustainability (social, economic, and environmental) are interconnected and affect one another differently, depending on the context. On farm level, for instance, a lot of knowledge develops daily as the farmer practices farming (Folke et al., 2005). This type of knowledge is context-dependent, and farmers can be considered experts on their own farms. This local and experiential knowledge is particularly valued among farmers and is considered especially important for farm sustainability since it is addressing local systems as a whole, considering "*the complexity of the realities in which farms operate*" (Šumane et al., 2018, p. 238). Triste et al. (2018) find that farmers' motivations also are context dependent.

A key difficulty in delimiting sustainability learning is to define the content of what is to be learned (Tàbara and Pahl-Wostl, 2007). An extensive literature on sustainability assessments has been developed to address what sustainability is at the

farm level (de Olde et al., 2018), and undertaking such an assessment is seen as "*a starting point for discussion, reflection and learning*" (de Olde et al., 2016, p. 398). A recent literature review of sustainability assessment studies at the farm level reveals that only one of the 67 examined studies discussed the implementation phase and how such assessments contribute to change (de Olde et al., 2018). A key reason for the lack of farmers' support for working toward improvement strategies is of a practical nature: it can be a time and resource consuming process for both assessor/adviser and farmer, and in addition, not all farmers are interested in interactions with other farmers or experts having to share both knowledge and farm data (Coteur et al., 2020). It is however recognized that a way for assessments to lead to more sustainable practices is to be followed by a learning process (de Mey et al., 2011; Whitehead et al., 2020).

Several studies about learning at farm level investigate the farmers' motivation for learning. According to de Olde et al. (2018), farmers' motivation to improve their sustainability practice on their farm is a prerequisite for the implementation of new sustainable practices. Triste et al. (2018, p. 121) studied farmers' motivations for participating in sustainable farming initiatives and conclude that the "*motives are diverse, manifold and directed by a diversity of underlying motivational processes*." Darnhofer et al. (2010, p. 549) find that motivations for learning are affected by the farmers' "*personality, preferences and competences*," and Ingram (2010, p. 197) in the same manner identifies that "*individual willingness to experiment, problem solve and 'trust [their] own judgement"* is evident in motivated farmers. In particular, the values held by the farmer influences what they change and what and how they learn (Blackmore et al., 2012; Darnhofer et al., 2012; Lamine et al., 2014). Darnhofer et al. (2010, p. 549) also find that farmers are motivated by "*external structures such as the social norms, technologies and the natural environment.*" Learning can be triggered by crises, such as experiencing financial or climatic hardships (Sutherland et al., 2012; Lankester, 2013).

The literature addresses how to learn sustainability, both by examining the sources of learning as well as the process of learning at farm level. Regarding sources of learning, studies indicate that the main sources for farmers' learning are: through own experience, through peer learning, and through external sources or institutions. Lankester (2013) and Restrepo et al. (2018) find that farmers value learning stemming from own experience and practice. This adheres to Darnhofer et al. (2010) who emphasize experimenting with outcome monitoring as an important source of farmers' learning. The main source of farmers' learning seems to be learning from other farmers, where concepts such as peer-learning, peer-exchange, and farmer-to-farmer learning are used (Leeuwis and Van den Ban, 2008; Cooreman et al., 2018; Kouchner et al., 2019). Lankester (2013) and Restrepo et al. (2018) highlight both active participation and observation, as well as discussions and sharing experiences and results with other farmers. In this regard, farmers consider successful colleagues as experts (Šumane et al., 2018). Farmers also use external sources or institutions in learning, such as information networks, extension services, public administration agencies, and regulatory institutions (Šumane et al., 2018; Kouchner et al., 2019). Agricultural research institutions are also important, particularly if the farm utilizes more advanced technologies (Šumane et al., 2018). Mixing various sources of knowledge is beneficial for learning (Darnhofer et al., 2010), involving both formal, knowledge from academia and industry, and informal, local and farmers' knowledge (Šumane et al., 2018).

The learning process is often represented as a combination of experiential, experimental, and collaborative learning. Restrepo et al. (2018) evaluate a collaborative learning process for sustainability among smallholder dairy farmers in Kenya, where they highlight the importance of experiential learning in a co-production process in which a learning loop model is applied. Darnhofer et al. (2010) emphasize learning through experimenting and monitoring the outcome, and Ingram (2010, p. 183) discusses that experimental learning on the farm is "*accompanied and enhanced by a process of social learning*." The learning process is continuous and reflective, where farmers "*review and reaffirm their decisions*" (Ingram, 2010, p. 197). Lankester (2013) finds that organized collective learning is important in helping farmers develop the farm in a sustainable mode. Much learning takes place in discussions with other farmers, especially when dealing with a broad concept such as sustainability, and farmers' learning benefits from discussions with various stakeholders (Darnhofer et al., 2010; Šumane et al., 2018). Oreszczyn et al. (2010) highlight how farmers' learning takes place in complex social learning systems.

Double-loop learning and single-loop learning are empirically distinguished according to the level of action and the level of reflection. Restrepo et al. (2018, p. 1267) identify single-loop learning processes, at the farm level, as processes that involve *identifying short-term solutions for specific problems* and *task-oriented problem solving* and double-loop learning processes as those processes that involve *reflecting on the problem and how aims can be achieved* and *transforming old ways of understanding*. Armitage et al. (2011) include rethinking management goals as a result of double-loop learning, while Eksvärd (2010, p. 266) introduces double-loop learning through the question "*Are we doing the right things?*," therefore implying that this process can also lead to changes in the very production system or business model of a farm. Darnhofer et al. (2017) point to the challenge of implementing changes on a farm stemming from double-loop learning because this may require a transformation in governance structures outside of the farm's sphere.

METHODS

This article adopts a participatory inquiry approach, where stakeholder involvement is central. Participatory approaches are particularly well-suited in studying complex matters such as sustainable agriculture (Eshuis and Stuiver, 2005; Bruges and Smith, 2008; Eksvärd, 2010). Stakeholders are "*those who will bear the consequences and carry out actions for change*" (Alrøe and Noe, 2016), and their involvement ensures an outcome that is more accurate, holistic, and relevant to the context (Triste et al., 2014).

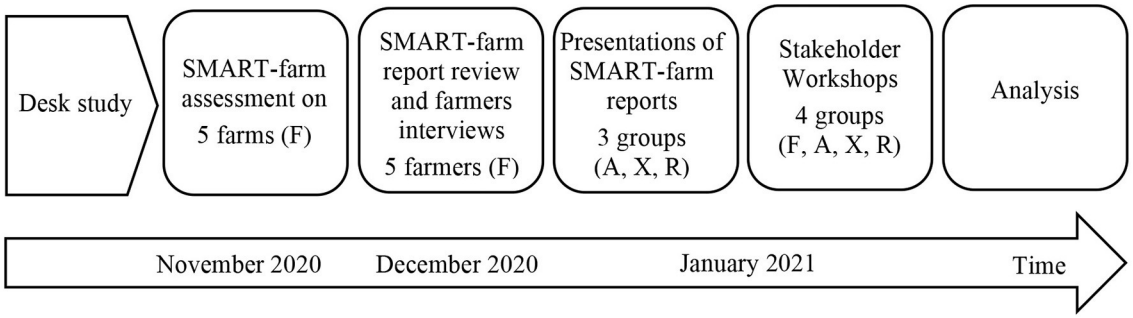

FIGURE 2 | Methods utilized and timeframe.

The study focuses on the horticultural production in Arctic Norway, where despite the governmental aims of sustainable agricultural practices and increased horticultural production, little relevant research has been conducted. The first author's extensive work experience in the local industry, in addition to a M.Sc. in horticulture, allowed for a thorough understanding of the context as well as enabled a trusting relationship with the stakeholders, the latter including farmers (F), county governor administrators (A), extension workers (X), and horticultural researchers (R). We adopt a mixed-methods approach, utilizing both semi-quantitative and qualitative methods (Keahey, 2020). The methods were applied successively over the span of 3 months, allowing rounds of reflection in-between (**Figure 2**). It should be noted that this study is a continuation of a previous study in the region where the focus was on the horticultural farmers' perspectives on sustainability (Halland et al., 2021).

To gain a clear understanding of the concept of farm sustainability in the specific context, we first conducted a desk study of sustainability in Arctic Norway horticulture (section Gaining Insights Into the Empirical Context and Farm Selection) and performed sustainability assessments on five farms (section Assessing Sustainability at Farm Level Using SMART-Farm Tool). Next, we held a SMART-farm report review session with the farmers from the assessed farms. In this review session, the five farmers were interviewed about changes made on the farm that they perceived to have improved its sustainability (section In-Depth interviews With Farmers: Changes That Lead to Sustainability Actions). Finally, four stakeholder workshops took place (section Workshops With Stakeholders: Learning for a Sustainable Future), where co-production of knowledge involving various stakeholder groups allowed multiple values and perceptions to be taken into account (Moriggi, 2020). Section Analyzing the Data describes the analysis of the findings. Throughout the phases of the process, the main author kept a diary for continuous and immediate self-reflections. The participants were informed about and consented to the terms of the research: ensured anonymity, a secure time-limited data storage, and the possibility to withdraw from the study. Due to restrictions caused by the COVID-19 pandemic, all interactions with stakeholders—including assessments, interviews, presentations, and the workshops—were conducted using the Microsoft Teams online platform. The interviews and workshops were recorded and transcribed for later analysis.

Gaining Insights Into the Empirical Context and Farm Selection

The desk study covered several sources, including: governmental documents (e.g., White Papers, Propositions, and official reports), statistics from Statistics Norway on agricultural development and from the Norwegian Agriculture Agency on production subsidies, R&D reports on farm sustainability in Norway, and relevant media coverage.

For the purpose of the study, we recruited five farmers that operate farms that produce berries, vegetables, and/or potatoes (**Table 1**). These farmers were well-known to the lead author as they were also participants in a prior study in 2019 (Halland et al., 2021). Combined, these farms represent 15% of all the land utilized for producing potatoes in Arctic Norway, 13% of the vegetable producing area, and 14% of the berry producing area. All participating farmers have long experience in farming (>10 years) and are actively involved in several initiatives concerning Arctic Norway horticulture. When undertaking sustainability assessments, it is important to note that the entire farm was assessed, and not only the part involved in horticultural production.

Assessing Sustainability at Farm Level Using the SMART-Farm Tool

The SMART-farm tool was employed in November 2020 to gain a clear understanding of the selected farms' sustainability (Schader et al., 2019). The tool is based on FAO's Sustainability Assessment of Food and Agriculture Systems (SAFA) methodology [FAO (Food Agriculture Organization)., 2014] and has a 2-fold purpose: (i) generate a sustainability report that can be used to increase the farmers' awareness and knowledge about sustainability on their own farms, and (ii) become a starting point for learning. The SMART-farm tool is developed by the Swiss agricultural research institution FiBL and registered in the Resource Identification Initiative under RRID:SCR_018197 (Bandrowski et al., 2016).

The tool assesses the farms' sustainability based on a scoring system on the environmental, economic, and social dimensions, as well as on the governance dimension (Schader

TABLE 1 | Characteristics of the participating farms.

Farm	Potatoes	Vegetables	Berries	Main market	Other income
F1	43			Wholesaler	Livestock
F2			2	Farm sales	Livestock
F3			1	Farm sales	Tourism
F4	10	6		Grocery stores	Processing
F5	9			Wholesaler	External work

Cultivated area in hectares.

TABLE 2 | SAFA dimensions and themes [FAO (Food Agriculture Organization)., 2014].

Good governance	Environmental integrity	Social well-being	Economic resilience
Holistic Management	Atmosphere	Cultural diversity	Investment
Rule of law	Water	Human health and safety	Vulnerability
Participation	Land	Equity	Product quality and Information
Accountability	Materials and Energy	Labor rights	Local economy
Corporate Ethics	Biodiversity	Fair trading practices	
	Animal welfare	Decent livelihood	

et al., 2019). SMART-farm measures the percentage of goal achievement, covering 21 sustainability themes, 58 sustainability sub-themes, and 118 default indicators (**Table 2**) [FAO (Food Agriculture Organization)., 2013]. Several tradeoffs and synergies are recognized in the assessments; the prominent ones are the tradeoffs between the performance in the Environmental Integrity and the Economic Resilience dimensions, as well as the synergies between the Good Governance dimension and the three other dimensions: Environmental Integrity, Economic Resilience, and Social Well-being (Schader et al., 2016). The assessments were conducted by the lead author, who is qualified through practical and theoretical training as a SMART-farm assessor.

The survey automatically generates a report, with pre-set objectives for each theme and sub-theme. The results are shown as the farm's percentage of goal achievement. In addition, the report further highlights aspects that have an especially positive and/or negative impact on the rating. The report is shared with the farmer (section In-Depth Interviews With Farmers: Changes That Lead to Sustainability Actions), thus aiming toward an enhanced understanding and increasing the probability that the assessment will lead to further learning. To facilitate this learning process, the SMART-farm report was translated into Norwegian in order to ensure the farmers' full understanding.

In-Depth Interviews With Farmers: Changes That Lead to Sustainability Actions

The SMART-farm report review session with the farmers included short in-depth semi structured interviews. Each interview was structured according to the four sustainability dimensions and followed directly after the discussion of the results in each particular dimension, therefore enabling relating sustainability status (as reported by SMART-farm) to previous changes made on the farm. In the interviews, we focused on the *what*, *why*, and *how* aspects of learning from our analytical framework (**Figure 1**). Each review session lasted ∼1 h. One shortcoming of the findings from these interviews is that the number of participating farmers is limited.

Workshops With Stakeholders: Learning for a Sustainable Future

The third part of the empirical investigation was four stakeholder workshops aimed at knowledge co-production and joint reflection. In total, 14 participants attended the workshops: 4 horticultural researchers, 3 county governor administrators, 3 agricultural extension workers, and 4 farmers. The study relied on selective sampling where participants had good knowledge of the context and a long work experience with horticulture and/or agricultural development in the region. Participating stakeholders had different responsibilities toward farmers, thus allowing different perspectives on farmers' learning. The four workshops contained participants from the same stakeholder group. However, acknowledging that this can be a shortcoming of the study, we chose homogenous divisions to ensure good discussions on a digital platform, allowing for freer speech and avoiding possible power imbalance between stakeholder groups. Having the farmers in a separate workshop also ensured anonymity for the farmers who had their farms assessed.

Each workshop contained two sessions (except the farmers, with whom we held individual assessment review sessions). The first session lasted 45 min, where a presentation was given of the overall findings from the five SMART-farm sustainability assessments, leaving room for questions and general discussions. The second session was a 2–2.5 h group discussions (**Table 3**). Contrary to the interviews (where the focus was on past changes), the main focus in the workshops was to provoke reflections on how to enhance existing sustainability levels. The lead author delivered the presentations and facilitated the group discussions. To ensure that the stakeholders' genuine opinions were obtained,

TABLE 3 | Overview of the workshops' implementation.

Date and time	Session	Stakeholder group	Number of participants
January 7, 2021, 11:30–12:15	Presentation	Horticultural researchers located in the region	4
January 11, 2021, 9:30–11:30	Group discussions		
January 13, 2021, 9:00–9:45	Presentation	County governor administrators from the Agricultural and Food Department	3
January 14, 2021, 9:00–11:00	Group discussions		
January 21, 2021, 1:00–1:45	Presentation	Agricultural extension workers with a special focus on horticulture in the region	3
January 22, 2021, 9:00–11:00	Group discussions		
January 27, 2021, 8:30–11:00	Group discussions	Farmers assessed with SMART-farm tool	4*

One of the farmers was unable to attend.

TABLE 4 | Common challenges from the SMART-farm reports discussed in the workshops.

Good governance	Environmental integrity
The farm does not have a plan for future improvements in its sustainability. The farm has neither carried out nor published a sustainability report within the past 5 years **(F), (X), (A), (R)**. No sales products are certified by a third-party certifier to carry an eco-label or a social label **(X), (A), (R)**. It cannot be ruled out that farm inputs come from countries where problematic social conditions exists **(F)**.	A large part of the agricultural area receives chemical herbicide applications, and comparatively many different active ingredients are used **(R)**. The crop rotation only consists of few elements and land is not maintained with a green cover during autumn and winter **(F), (X), (A)**.
Economic resilience	**Social well-being**
A relatively low proportion of the farm inputs are purchased or produced locally **(F)**. Alternative markets do not exist for all products if buyers drop out, and in general the farm sells its products to only a few customers/buyers **(X), (A), (R)**.	Only a few employees had access to external training in the past 5 years **(A)**. The farm does not take measures to prevent discrimination against women, minorities and other vulnerable groups. The farm doesn't provide extra support to disadvantaged groups **(F)**. The average working time of the farm owner is high **(X), (R)**.

the facilitator did not actively engage in the discussions, but only had a timekeeping and a subject-boundary keeping function.

The first session ended with the presentation of the upcoming tasks for the second session, and each participant had to prepare for the tasks individually beforehand. These tasks consisted of four exercises, one for each sustainability dimension. The exercises addressed common challenges from the SMART-farm assessment reports. In each workshop the participants selected one or two challenge(s) that they perceived demanding for sustainability in this context (**Table 4**). The task was then to answer the questions *what to learn, why learn*, and *how to learn* (**Figure 1**) to be able to change and improve the selected topic.

Analyzing the Data

Thematic analysis, described by Saunders et al. (2019, p. 651) as involving coding of data to distinguish themes or patterns related to the research question, was conducted in NVivo 12, where the data were divided according to stakeholder groups and sustainability dimension. Our methodological framework (**Figure 1**) served as the basis for the initial coding scheme and the data were coded for contextual factors in *when* and *where is it learned? When* (time) as in trajectory of changes (past, present, future) and *where* reflecting on the learning environment: place, policy, and societal implications. The learning process was coded for *what is learned?* (distinguishing sustainability knowledge, knowledge in action, and sustainability knowledge providers), *why is it learned?* (distinguishing between internal and external motivations), and *how is it learned?* (distinguishing sources of learning, ways of learning, and processes involved).

After the coding was completed, the analysis focused on addressing the research question through correlations between contextual factors and the *what*, *why*, and *how* of sustainability learning. Ways of learning were distinguished between individual and social learning, including social processes involved. In the last step we focused on sustainability learning processes and how the various parts of the framework were expressed. Here we also distinguished single and/or double-loop processes involved; to reveal the latter, we particularly looked for shifts in underlying thoughts, values, or assumptions.

FINDINGS

Background—The Horticultural Industry in Arctic Norway

Arctic Norway is the area in the two northernmost counties in Norway (Troms and Finnmark, and Nordland) stretching from 65°N to 71°N. Plant production is challenged by a short and cool growing season. The total area utilized for agricultural production is only 0.83% of the region's total land area, much due to the topography with its many fjords and mountains (Nøstvold et al., 2019). The horticultural

sector in the area is small. In 2019, of the total of 3,091 farms applying for subsidies, 138 farms produced either potatoes, vegetables and/or berries, with a total of 419 hectares potatoes, 50 hectares vegetables, and 24 hectares berries (Norwegian Digitalization Agency, 2019). All the farms are family farms with few external, mainly seasonal, employees. Horticultural yield is fluctuating due to annual climatic variation, and therefore, multifunctional farms with more than one production system—a condition that reduces vulnerability—is the most common way of farming. For instance, 75% of farms with horticultural production also practice husbandry. The last decade has been characterized by technical developments in horticulture production systems that are enhancing possibilities for improved production.

Norwegian national agricultural policy promotes sustainable farming (White Paper 11, 2016–2017) and aims toward the increase of horticultural production (Prop. 120 S, 2018–2019; Grøntsektoren mot 2035, 2020). Local actors with formal expertise are present in the region, for instance through the Agricultural Extension Service, and horticultural producers are actively engaging in R&D projects with regional research partners. The few large producers mainly sell through the only wholesaler that is present in the region, while smaller producers mainly sell through various farmers' markets or directly on-farm, although a few of them have on-farm processing facilities for their own produce. Local sales are stimulated by the increased consumer focus on local food over the last decade (Stiftelsen NorskMat, 2021). The agricultural industry in Norway remains highly regulated (e.g., in terms of wages and working conditions, health and safety, accounting and audits, etc.) and specific requirements related to quality control in agricultural production are found in the Quality System for Agriculture (KSL), a self-reporting system where every farmer must submit annual self-audits.

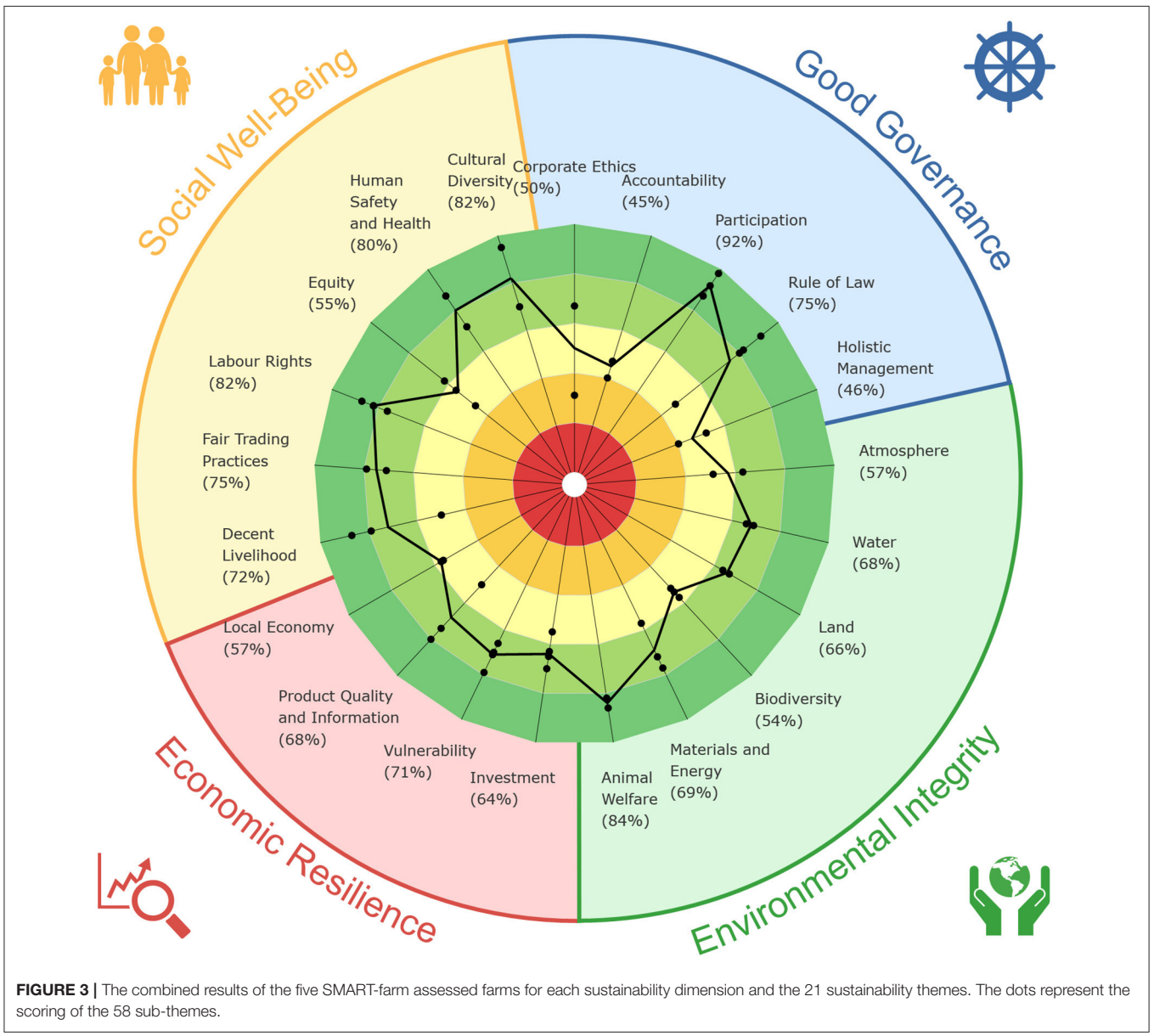

FIGURE 3 | The combined results of the five SMART-farm assessed farms for each sustainability dimension and the 21 sustainability themes. The dots represent the scoring of the 58 sub-themes.

Sustainability Assessment as the Starting Point for Discussions

Figure 3 illustrates the combined SMART-farm results of the five farms. In general, scores in the green areas (above 60%) are considered good [SMART (Sustainability Monitoring Assessment RouTine)., 2016], and it can be advisable to start the focus for improving sustainability on the themes scoring below this cutoff (in the yellow, orange, and red sectors). Although there are differences, resulting for instance from type of production (tunnel production of berries or open field potato production), availability of input locally or availability of written management plans, the trends of the different themes and sub-themes are rather consistent among the farms. Discussing these trends with the involved farmers revealed a general understanding among farmers that such trends reflected contextual conditions.

The themes with consistent lower scores might be areas that are either not so relevant in this context or are challenging for sustainability. Of the 58 sub-themes, 19 had scores of <60%-−7 in the Good Governance dimension, 5 in the Environmental Integrity dimension, 4 in the Economic Resilience dimension, and 3 in the Social Well-Being dimension. The combined results overall give an indication of the sustainability situation on horticulturally producing farms in Arctic Norway and serve as a starting point for further learning.

Findings From Farmers' Interviews and the Stakeholder Workshops: Learning for a Sustainable Future

The findings from the interviews with the farmers and the workshops are structured using the framework in **Figure 1**. Findings related to each question are presented in the following sections.

Where Is It Learned?

In the workshops, horticulture production is said to be knowledge intensive, and the horticultural farmers are perceived as: "*very interested in new knowledge and innovation, they are very forward-thinking*" (R). This perception stems from there being relatively fewer subsidies and financial innovation support schemes available, recent introduction of more technical production systems, and the necessity of risk-reduction strategies to minimize yearly yield fluctuations (mainly climate-related). The size of the farm also affects sustainability learning—for instance discussing themes in the Social Well-Being dimension one participant reflected that "*I feel that we may be a little small in relation to some of those topics, with support to vulnerable people and such*" (F). Most farms are dependent on seasonal workers but have experienced difficulties finding local workforce and are therefore increasingly dependent on foreign labor.

R&D projects including researchers, extension, and farmers are mentioned as important for sustainability learning where knowledge production for the special arctic conditions is essential. One such project was recognized as successfully expanding the table-top production of strawberries in tunnels: "*especially in such a small market as we have in northern Norway, such a project is very important, having several producers working on the same challenges* (and) *it becomes as natural to talk about economic challenges as challenges with insects, agronomy or production*" (R). Differences in size and challenges in transportation and logistics, are key factors discussed in the Economic Resilience dimension, and the local wholesaler is a decisive factor for production volume. Another feature characterizing Norwegian farmers is "trust," for example that large national input providers know the origin of their input: "*it is a lot about trust, I assume that most farmers buy from serious companies in Norway, so we think they have good control*" (F), although healthy skepticism exists. In addition, it is recognized that an agricultural policy that facilitates agriculture throughout the country, is crucial for sustained Arctic agriculture.

Many knowledge suppliers are mentioned in the workshops and interviews (**Table 5**). To further the farm in a sustainable direction, a more holistic insight on farm development is required, and one prominent feature is that there are few, if any, established learning platforms for this today: "*but where to find this knowledge (…) it is not so easy for a farmer just to call the extension service and say that I want to be better at sustainability?*" (A).

When Is It Learned?

The effect of time, both in the sense of the *actual time period of the study* and of *passing time* (changes to improve sustainability may well be seen in the future), affect sustainability learning. For instance, this study was performed during the COVID-19 pandemic which gives new perspectives on sustainability. In the workshops it was discussed how the pandemic made consumers more aware of how dependent the country is on global farm input production and distribution, and on the importance of self-sufficiency and buying local produce. This was also linked to sustainability being a valid argument for continued arctic agricultural production: "*that we should engage in agriculture in northern Norway, even though it might have been cheapest to get all the food from* (abroad)" (X). Self-sufficiency on terms of a local seasonal workforce was also discussed.

Sustainability learning as a long-term process is also evident in the discussions. One aspect is the trade-offs and economic concerns related to changing to a more sustainable production: "*In the long run sustainability will be positive for the economy, but in the short-term they go against each other in many ways*" (X). Another aspect is that: "*the time has worked*" (X), referring to that they have seen a development in farmers' attitudes. This development is closely connected to the wider public discourse on sustainability: "*we all have a long way to go, we are not there, we are consumers, the last 50 years we are raised to buy and throw away, and changing that, the whole mindset, that takes time*" (X).

Who Learns?

In this study the farmer is considered the learner. However, the farms in Arctic Norway working with horticulture are almost solely relatively small family farms, where farming is described more as a lifestyle, with high work-loads in season that to a large degree are affecting the whole family: "*it is more of a lifestyle, and you can forget about summer holidays*" (X). Often there are many family members working in close collaboration in production, as

TABLE 5 | Sources of learning, and main deliveries per sustainability dimension.

Sources	Good governance	Environmental integrity	Economic resilience	Social well-being
Individual farmer	Reports and media coverage.	Policy, reports, and media coverage. Experiments.	Monitoring decisions and market options.	Personality based
Extension	Operational planning	Experiments, monitoring, and advise in production	Economic concerns of production practices	Facilitate training
R&D	Sustainability assessments	New production systems or practical topics	Economic features related to production	
Farmer to farmer	Informal discussions, mentors	Share experience, practical collaborations, mentors	Sharing experience, mentors	Sharing work-force
Network	Branding, political force	Sharing production specific experiences	Market options, sharing resources and experience	Sharing work-force
Family	Informal discussions, strategic decisions	Younger generation with a stronger focus on environment	Economic decisions	Work/leisure, work safety, a good life
Local society	Informal discussions	Input concerning resource utilization	Arranging local markets	Local work-force, local contributions
Other	Documentation actors	Organic farming, machine-providers, documentation actors	Financial and market actors, consumers, Food Safety Authority	Labor and welfare authorities, documentation actors

TABLE 6 | Sustainability knowledge.

Knowledge	Examples
Knowledge about holistic farm sustainability	Knowledge to take sustainable choices, given the inherent complexities, trade-offs, and synergies
Agronomic knowledge	Knowledge concerning: plant protection, crop rotation, biodiversity, soil, clean seeds, fertilizing etc.
Knowledge for good management	Knowledge for good planning, managing diversity in production, making sustainable decisions etc.
Local knowledge	Agronomic knowledge for local condition including natural conditions Local and practical—tacit knowledge
Technical knowledge	Knowledge for precision agriculture and other technical advances in streamlining and easing production
Market knowledge	Knowledge for market access—e.g., sales and marketing
Relational knowledge	Personal competence for cooperation and empathy

TABLE 7 | Internal motivations for sustainability learning.

Internal factors	Example	Why does this motivate?
Knowledge seeking	Curiosity and interest in the field	Deep understanding of production and implications
Environmental consciousness	Reduce impact of production	Produce in a more environmentally friendly way
Social responsibility	Facilitate work, educate workers	Value their workers and contribute to local society
To have a good life	Plan and reduce workload	Improving quality of life and have a good family life
Improve chances of generational shift	Taking over a sustainable farm	Knowing the farm will have continued production, and making long-term planning feel worthwhile

well as in planning. Therefore, learning which aims to make the farm more sustainable needs to be distributed within the family, and, where appropriate, include employees and the seasonal workforce. In addition, in the workshops, much of the focus was on the Arctic Norway horticultural farmers, collectively.

What Is Learned?

Knowledge (including knowledge in practice) is both inputs and outputs of a sustainability learning process. **Table 6** presents the various types of knowledge found to be important for farm sustainability.

These types of knowledge are found to be varying in nature, linked to the source of knowledge, from informal (local, coming from farmers) to formal (academia, industry). Only informal knowledge is found in Local knowledge and Relational knowledge, and mainly formal knowledge is found in Technical knowledge. In all the other types of knowledge in **Table 6** we find a combination of both formal and informal knowledge.

Why Is It Learned?

The main finding is that, as the concept of sustainability is complex, the farmers' motivations for making sustainability changes at farm level are diverse. **Table 7** summarizes the main internal motivations stemming from the farmers' curiosity and interest in learning. Internal motivations are found in all the sustainability dimensions, although they are especially connected to the Environmental Integrity and Social Well-Being dimensions.

TABLE 8 | External motivations for sustainability learning.

External factors	Example	Why does this motivate?
Farm management and production	Improve product quality and decrease waste	Improve economy, quality, and reduce waste
Natural conditions	Possibilities for production	Improve economy and reduce transport
Politics and policy	Political commitment to Arctic agriculture	Enhanced potential, reduce economic risk
Society and market	Market differentiation	Freedom of choice of market solutions
Cooperation	Strong local actor securing deliveries	Reduce risk in market and production
Technology	Technology that streamlines operations	Improve efficiency, reduce resources

Table 8 summarizes the main external motivations. These are motivations where the outcome of a learning process is expected to be a means to an end. We find external motivations in all the sustainability dimensions, although only a few in the Social Well-Being dimension. The large majority of the external motivations are connected to improving the farm economy and risk reduction.

How Is It Learned?

The farmers learn in various ways, explained by one farmer as: "*talk to advisers, own experience, trial and error*" (F). **Table 9** shows the findings for ways of learning, collaborative, experiential, and experimental, in the four sustainability dimensions. The main ways of learning are collaborative and experiential. Only in the Environmental Integrity dimension is experimental learning prominent; however, this learning is sometimes also connected to experimental learning in the Economic resilience dimension. In the Social Well-Being dimension collaborative learning dominates.

Learning As a Process

The findings show several examples of sustainability learning processes, in all four sustainability dimensions. Most of the learning processes are single-loop learning, but we also find evidence of double-loop learning.

In the Good Governance dimension all four workshops (F, R, X, A) discussed the implementation of a written plan and a subsequent report for farm sustainability. There was a consensus that sustainability planning and reporting at farm level should be implemented gradually by utilizing and expanding existing documentation demands (e.g., KSL). It should also be a long-term process: "*this can be a long-term work, there seems to be an acceptance for that, as long as you (..) develop in a good direction*" (A). Learning can then have a snowball effect, where accumulating learning leads to improvements in all dimensions. It was suggested that learning can arise from adopting best practices from abroad or learning from pioneering farmers. Raising awareness is thought to be a main driver for this development: "*a massive lift in competence is needed, to change our way of thinking, because it is our way of thinking that needs to be changed first and foremost*" (X). A change in agricultural sustainability has to go hand-in-hand with the wider public discourse on sustainability. A similar implementation process has been described; in 2003 the "Environmental plan in agriculture" was introduced in Norway, the topic was very new and challenging to comprehend, causing much aggravation among farmers. Today, however there has been a significant increase in awareness: "*now everyone knows the importance of taking care of the environment* (recycling) *waste, and we register climatic change etc., so this has in a way become daily language today*" (X). This is a double-loop learning process, and it can be expected that implementing a plan and reporting on sustainability in the future will follow a similar sustainability learning path. It is also noticeable that in the Good Governance dimension, today, there are few if any formal sources of knowledge available providing a holistic focus on sustainability knowledge to the farmers.

In the Environmental Integrity dimension, the discussions were on agronomical features, improved crop rotation (F, X, A), and reducing chemical plant protection (R). The farmers' motivations are 2-fold—improved profitability: "*the main motivation, we just have to admit that, is an economic driver (..) reducing production costs and increasing yield and quality*" (F), but also curiosity and a genuine interest in the field. The ways of learning are often based on monitoring and evaluation of practical changes in production, with reflections regarding the sustainability connected to these changes. One farmer reflected on the work with reduced chemical plant protection: "*I have a focus on reducing chemical plant protection, but as it is now I can't avoid it, but I haven't used insecticides in maybe 10–15 years because I use traps, nets or covers, but covers are a plastic product, produced in* (far away), *so really, maybe it is not such a great improvement in sustainability after all*" (F). Often learning is closely related to trade-off discussions with the Economic Resilience dimension. All the processes described in this dimension could be characterized as single-loop learning processes. However, even though the focus is on efficiency and incremental changes, taking a long-term perspective, we see that small annual changes may result in larger changes.

In the Economic Resilience dimension, the discussions revolved around increased local procurement (F), securing self-sufficiency in soil, seeds/seedlings and fertilizers, and secure market conditions (X, A, R), including freedom of choice regarding market options. Many of the learning processes are based on different forms of cooperation, between farmers and extension, or more specialized cooperation like machine collaboration or sales networks to strengthen production possibilities, ease investment loads and enable better market access. In this dimension the learning processes are found to be mainly single-loop, and learning is often connected to various trade-off discussions with the Environmental Integrity dimension. Trade-off discussions can also lead to reflections resulting in double-loop learning. One farmer was concerned

TABLE 9 | Findings concerning the ways of learning in the four sustainability dimensions.

	Good governance	Environmental integrity	Economic resilience	Social well-being
Collaborative	Informal discussions, inspiring others, collaborative actions on sustainability.	Sharing experience and practical collaboration between farmers. Collaboration with research, extension etc.	Sharing experience between farmers. Collaborations between farms, market actors, customers or industries.	Farmers' cooperation, planning within family, collaboration with various external actors.
Experiential	Building sustainability awareness: assess, plan, implement, monitor, and report.	Monitoring and reflection on production efficiency, possibilities and impact.	Monitoring efficiency, thorough economic and market considerations.	Operational planning and monitoring. Social awareness and contribution.
Experimental		R&D projects, extension, and farmers' experiments.	Economic focus on agronomic experiments. Trial and error in new business models.	

with mileage, since direct sales on a remotely situated farm lead to long transportations, asking: "*is it at all sustainable to produce berries in our region?*" (F). This spurred discussions among the farmers about the farm's effects on the local economy and local society as well as on the availability of fresh quality products and added value for the customers.

In the Social Well-Being dimension the discussions focused on non-discrimination and support to disadvantaged groups (F), high average working hours (X, R), and access to training (A). Many of the motivational factors are internal, such as taking a heightened social responsibility and for the farm-family and workers to have a good life: "*we are a family business focusing on that everybody should have a good life, it's probably more about how you are as a person* (..) *it is more about personality than business thinking*" (F). Learning occurs within the family, with neighboring farms, with the local community, but also with institutions outside agriculture like the Labor and Welfare Administration (NAV). Learning based on planning, monitoring or reflecting on social concerns is also prominent. Discussions revolved around the issue of whether agriculture as a whole should take a greater social responsibility. Farming is often perceived more as a way of life rather than a career, and without awareness and good planning of working-time it is easy to be trapped in heavy work-loads: "*I think that farmers often think that time is not money, it's just a requirement that they have to work all the time*" (R). The learning processes are mainly through single-loop learning, however, double-loop learning is also present, especially through reflections revolving planning.

DISCUSSION

The following discussion seeks to answer this study's research question: What are the characteristics of sustainability learning in the context of horticultural farms in Arctic Norway? The findings show five overarching characteristics discussed in the following sections. Although separating these five characteristics, we also acknowledge that they are closely connected.

Complexity and Conflicting Issues

For holistic farm sustainability, the complexity of the concept (including the many, sometimes conflicting, issues involved) becomes central in the learning process. The interconnectedness of the farming system (Eksvärd and Marquardt, 2018) and the very nature of sustainability as a "wicked problem" (Rittel and Webber, 1973; Glass et al., 2012; Wals, 2015) adds to the level of complexity. Tàbara and Pahl-Wostl (2007), describe sustainability learning as a search for a "collective truth" that nevertheless, can also cause setbacks, if for instance policy and needs for sustainability changes are incompatible (Darnhofer et al., 2017; Eksvärd and Marquardt, 2018). In our results we find such contradictory needs, for instance between on the one hand, farmers aiming at sustainability through reduced economic vulnerability, market stability, and lower emission from transport, and on the other hand, large market actors aiming toward increased efficiency through centralization of storage and distribution hubs.

The findings reveal that the learning process, to a large degree, involves taking into account considerations for trade-offs, synergies, and long-term effects. Well-known are the trade-offs between the environmental and the economic dimensions (Schader et al., 2016). Trade-offs within dimensions are also common, such as reducing pesticides vs. using plastic fiber covers, and trade-offs between other dimensions, such as facilitating work for vulnerable groups vs. efficient use of farmers' working time. Schader et al. (2016) find synergies between the Good Governance dimension and the three other dimensions, Environmental Integrity, Economic resilience and Social Well-Being. As the SMART-farm results (**Figure 3**) show relatively low scores in several of the themes in the Good Governance dimension, this will therefore be a good point to start the sustainability learning process for the Arctic Norway horticultural farmers. Nevertheless, **Figure 3** also shows relatively high scores in most themes in the other three dimensions, and this may relate to the high policy documentation requirements already present.

Time-scale aspects remain a challenge when working for sustainability, knowing that changes need to be made in the present, while results may only be seen later, often far into

the future. This is especially challenging when planning for farm sustainability (Halland et al., 2021). In the workshops it was revealed that working for holistic farm sustainability was perceived to be better for the production and for the economy in the long run, even though in the short run it might be conflicting. One example was in improving the crop rotation system as opposed to annual efficient use of all the available land for horticultural production, as in the long-run, land can be higher yielding and less disease prone if crops are rotated. Working for sustainability is a continuous process (Brunori et al., 2016); in the long-term, periods of stability crisis, and new opportunities will fluctuate (Havet et al., 2014). Going through several rounds of learning, the farmer gains the necessary knowledge to address various conditions—knowledge that is vital for achieving long-term sustainability on the farm.

Combination of Internal and External Motivations

Darnhofer et al. (2010) acknowledge the crucial role of the farmer in farm development, and how farmers' motivation is essential for making changes toward sustainability on the farm (de Olde et al., 2018). In our findings, we see that the complexity of the concept of sustainability is reflected in the diversity of motivations for sustainability learning. Such diversity is also found in Triste et al. (2018). Hansmann (2010) stresses the motivational factor for sustainability learning, including both internal and external motivation, although he finds internal motivation particularly important since "[it] *might also support the development of pro-sustainability motivations for changing behavioral patterns in everyday life*" (Hansmann, 2010, p. 2881). In all dimensions we find both external and internal motivations, although internal or personal motivations, are mostly prominent in the Social Well-Being dimension. A farm is a business, a workplace that is generating the income for the farmer, and often also for the family and workers. Therefore, economic motivations are often either a main motivational factor or found in combination with essentially all the other external motivational factors. Although intrinsically important, economic motivations, perhaps with the exception of the Economic Resilience dimension, are seldom the sole motivational factors.

The findings also suggest that even in topics were there are strong policy regulations, especially connected to the Environmental Integrity dimension and Social Well-Being dimension, internal motivations are prominent. This result may appear to be contrary to Stock and Forney's (2014) finding that "*externally imposed legislative regulations (e.g. environmental regulations) can undermine farmers' experiences of autonomy*". Some examples relate for instance to health and safety, labor rights, and environmental impact on soil, water, and atmosphere. It is however difficult to say what came first, regulations or internal motivations. However, Hansmann (2010) stresses that also motivations for making new sustainability changes are an important outcome of sustainability learning. Thus, it might be that they work in concert, evolving as awareness and motivational outcome from a learning process. Internal motivations for holistic sustainability are not explicitly found in our study; however, it might be that they will evolve as a motivational outcome from a sustainability learning process if policy regulations concerning holistic sustainability planning and reporting are introduced. This is an issue that needs to be properly addressed in further research.

Building Awareness as a Main Cause and a Main Outcome of Sustainability Learning

Raising awareness of the concept of sustainability can be considered a main cause, and often a main outcome, of sustainability learning. The findings show that, especially for the Good Governance dimension, the process of planning for sustainability followed by subsequent monitoring, evaluation, and reporting of farm sustainability, is thought to lead to awareness of farm sustainability. Changes in policy and documentation demands, as for instance the 2020 implementation of a waste reporting requirement, may spur awareness, leading to farmers gaining new knowledge specific to their farm that may lead to farmers' active engagement in waste-reduction. In addition, although only briefly mentioned in the workshops, other studies have shown that organic farming is a source of inspiration, raising awareness about more sustainable farming practices (Lamine et al., 2014). Farmers' awareness can also be raised by external pressure from society; one example is how negative media coverage of working conditions for horticultural seasonal workers in Norway spurred actions to be taken by both the agricultural industry and governmental bodies. Crises can also act as trigger events (Sutherland et al., 2012).

In the workshops it was discussed how raising awareness could be personally quite demanding, since it will involve a mental process. Cooreman et al. (2018, p. 95) describe how this can lead to deeper learning: "*after experiencing a 'cognitive conflict,' a learner can feel stimulated to think critically about his way of looking at reality.*" Such processes can lead to double-loop learning, changing the values and the norms in the learner (Tàbara and Pahl-Wostl, 2007). Knowing how to facilitate for double-loop learning can therefore be essential in speeding up the process of sustainability learning. Eksvärd (2010) finds that the ability to ask probing questions is important for double-loop learning, and through this she concluded that: "*the first steps in transition toward more sustainable farming practice clearly involve 'un-learning' as much as 'learning'*" (Eksvärd, 2010, p. 278). Probing questions were asked in the workshops, for instance when one farmer questioned if farming practices were at all sustainable. Raising awareness might however not be directly linked to actual sustainability changes, as is for instance shown in relation to climate change adaptation (Harmer and Rahman, 2014), especially considering trade-off discussions with uncertainties of the actual sustainability of an expected outcome (as discussed in section Complexity and Conflicting Issues). Ison et al. (2000) describe change processes as moving from double- to single-loop processes, or the reverse, the outcome may express itself in either changed values or changed practices, over time.

A Social, Transdisciplinary, Learning Process

The complexity of the sustainability concept, described in section Complexity and Conflicting Issues, necessitates knowledge from numerous disciplines, in addition to local knowledge and relational knowledge, and this knowledge needs to be acquired by a variety of actors (Hubert et al., 2000). Due to these inherent complexities, sustainability learning demands a transdisciplinary process (Hansmann, 2010; Restrepo et al., 2018) where participants from different academic disciplines together with non-academic participants are working together toward the common goal (Tress et al., 2005) of producing "socially robust knowledge" and knowledge that is contextualized (Hessels and van Lente, 2008).

The findings reveal numerous examples of social learning processes in all dimensions. Social learning processes are considered essential for sustainability learning (Tàbara and Pahl-Wostl, 2007; Hansmann, 2010). The findings are consistent with the literature, where collaboration arises as a key feature of the learning process for farm sustainability (Darnhofer et al., 2010; Ingram et al., 2018). Restrepo et al. (2018) find that collaborative learning processes challenge farmers' assumptions and beliefs, and enable farmers to find relevant solutions for sustainability challenges on their farms (i.e., important in raising awareness as discussed in section Building Awareness as a Main Cause and a Main Outcome of Sustainability Learning). In Halland et al. (2021) both participation and networks were key factors for sustainability in Arctic Norway horticulture. In the SMART-farm assessment the farms also showed a very high score, 92%, on the theme Participation (**Figure 3**). Overall findings from workshops and interviews show that collaboration is important for learning, and the SMART-farm results further indicate that this is something the farmers are good at.

Optimally combining knowledge from various sources, informal and formal, is found to promote farm sustainability (Darnhofer et al., 2010; Šumane et al., 2018). Lankester (2013) argues that the famers' main source of learning is informal, and in our study we find informal farmers' networks as well as local community social networks to be important in sustainability learning, through enabling discussions concerning sustainability to be an integral part of the daily language. These findings are consistent with Cooreman et al. (2018) and Lankester (2013) showing that learning from other farmers was important for sustainability learning, for example by having "pioneer farmers," as good examples as well as contributors, especially when it comes to practical and detailed knowledge of production. The findings are also in agreement with the findings in Havet et al. (2014) where the strong integration between crops and livestock has a positive effect on farm sustainability. Moschitz and Home (2014) emphasize the importance of co-production of knowledge between research and extension with various stakeholders. The farmers in our study actively engage in R&D projects and have a well-developed collaboration with the extension service. This has been especially fruitful for new knowledge and expertise relating to arctic conditions and specialized knowledge for relevant new technologies. The findings therefore show that the Arctic Norwegian farmers have a range of formal and informal sources for the knowledge necessary to work on sustainability in the three dimensions Environmental Integrity, Economic Resilience, and Social Well-Being. However, there seems to be a lack of sources, especially formal, for knowledge in the Good Governance dimension. It could even be argued that the lack of holistic sustainability learning platforms and knowledge providers is one of the main hindrances for a sustainable farm development.

Sustainability Learning Is Context Dependent

One main characteristic of the sustainability learning process of horticultural farmers in Arctic Norway, evident in the discussions above, is how intertwined it is with contextual factors. Hansmann (2010, p. 2888) suggests that "*the ongoing, multilayered inquiries and discourses, which strive for an understanding of what sustainability ultimately means*," is the very process of sustainability learning. As there is not one fixed prescription for what sustainable farming actually is, sustainability needs to be contextualized. The importance of context becomes more evident when dealing with the interplay between special conditions; climatic, topographic, land, demographic, policy and market, where all must be understood locally. For instance, knowledge specific to special Arctic conditions was found to be lacking, and a combination of farmers' and extension experiments could remedy this situation. Restrepo et al. (2018) find that farmers value learning that is context specific and stems from practice. Also, local knowledge often contains a more holistic view of local systems (Šumane et al., 2018). It is evident that farmers' learning and transition toward sustainability needs a focus beyond the farm scale (Lamine et al., 2014), and that the learning processes of farmers and society are linked, and to a large degree bounded by policy and societal developments. One example from our findings is that attitudes toward both environmental and sustainability issues are perceived positively, both among farmers and the general public, and this makes it easier to plan for farm sustainability.

Natural conditions for food production differ, knowledge providers and actors in the value chain vary, policy and societal factors differ and, in a trajectory of time periods the situation varies, and the farmers' values and preferences differ. Subsequently, the sustainability learning process will vary according to context. Eshuis and Stuiver (2005) use the phrase "learning in context" to highlight the contextual nature of learning.

CONCLUSIONS

The article presents a mixed methods participatory inquiry approach to investigate the characteristics of sustainability learning in the context of horticultural farms in Arctic Norway. We draw on insights from sustainability learning, loop learning, social learning and learning for sustainability at the farm level. Our framework enables us to analyze important parts of the learning process (who learns, where is it learned, when is it learned, what is learned, why is it learned, and how is it learned) to understand sustainability learning at the farm level. We find that five principal aspects characterize sustainability learning in

the context of horticultural farms in Arctic Norway; however, we also acknowledge that these are closely connected:

1. The complexity of the concept of sustainability and the immense level of conflicting issues entail that the learning process constantly negotiates on trade-offs, synergies, and long-term effects.
2. The complexities are reflected in the diversity of both internal and external motivations for sustainability learning. Economic motivations are often a main motivational factor, although seldom the sole motivational factor.
3. Building sustainability awareness can be considered as a main cause for, and often a main outcome of, sustainability learning. Raising awareness can also lead to double-loop learning where the outcome is changes in farmers' values and perceptions.
4. Sustainability learning is predominantly a social learning process, where the complexities call for transdisciplinarity, optimally combining formal and informal knowledge from a variety of different sources.
5. Sustainability learning is highly interconnected with contextual factors, and what sustainability ultimately means must be understood locally.

The empirical findings raise some considerations on holistic sustainability learning. The findings reveal that knowledge required to gain a holistic insight on farm sustainability is insufficient, and few formal sources of such knowledge are available for the farmers. Nor are there any established networks or social learning platforms for holistic farm sustainability, while we also find little evidence of internal motivations for holistic sustainability. It therefore seems that there is a lack of a holistic focus for sustainability, an outcome that is consistent with Halland et al. (2021, p. 67) where a "*limitation to such (sustainable) transformation can be that the knowledge of what, holistically, sustainable food production includes is unclear.*" It could be asked if the traditional agricultural extension services and other advisors or researchers today have sufficient expertise to support farmers' learning for a holistic change toward sustainable production. In any case, it raises the question whether additional support systems or a broadened focus area for the traditional extension service is needed. From the previous discussion on motivational aspects we contend that past experiences have shown that internal motivations have grown alongside policy regulations. A stronger political commitment and subsequent policy regulation for holistic sustainability can therefore be part of the solution. Furthermore, our results illustrate that an efficient and effective holistic learning sustainability process, is a gradual transdisciplinary process, where farmers' active involvement is crucial.

Theoretically, this study contributes to filling gaps in the literature related to understanding learning processes leading to sustainability changes (Lankester, 2013). The value of the framework adopted for this study is that it emphasizes the importance of viewing sustainability learning as a continuous process in which both knowing what to learn as well as being motivated for learning are essential. This framework has proven useful in revealing characteristics of the sustainability learning process. For future studies, the framework could be incorporated with theory from Agricultural Innovation Systems (Aerni et al., 2015) to register the findings in a systemic analysis. Sustainability learning at farm level does not occur in isolation but is dependent on the complete agricultural systems. In addition, for longitudinal studies it could prove useful to better incorporate the theories of loop-learning (Argyris and Schön, 1978; Tàbara and Pahl-Wostl, 2007) or transformative learning (Moyer and Sinclair, 2020) to study real-time changes.

This study further addresses the lack of empirical studies focusing on how to go from farm sustainability assessments to sustainability implementation (de Olde et al., 2018; Coteur et al., 2020). We show how undertaking a sustainability assessment, followed by an individual discussion and a group discussion, can be a valuable way to contextualize sustainability at farm level, enabling the farmer to work on concrete sustainability improvements. This has also been proven as an effective process for raising farmers' sustainability awareness. Nevertheless, the typical farmer will need more continuous support to secure actual sustainability implementations, and therefore different sources, knowledge, and learning platforms for holistic sustainability need to be established. Knowing the complexity of the sustainability concept, establishing networks or social learning platforms for holistic farm sustainability would require new collaborations with actors working across all the sustainability dimensions. The latter relates to what Wals (2015) calls *sustainability didactics*, what is needed is then learning environments that enable learners to see the world more holistically.

DATA AVAILABILITY STATEMENT

The datasets presented in this article are not readily available in order to preserve the anonymity of the participants who consented to take part in the study under this condition. Requests to access the datasets should be directed to the corresponding author.

ETHICS STATEMENT

The studies involving human participants were reviewed and approved by NSD - Norwegian Centre for research data. The patients/participants provided their written informed consent to participate in this study.

AUTHOR CONTRIBUTIONS

All authors have participated in developing the study content and direction, and throughout the working period of the study, from January 2020 to March 2021 we had common meetings to discuss the progress. HH has been the executing part throughout the writing of the manuscript, the practical implementation of the methods as well as for the analysis. GB, LL, and IK have been actively reviewing the progress of the manuscript throughout the study's period and have delivered valuable proposals especially for theory, concept, and methods development.

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