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Article

What Skills Do Agricultural Professionals Need in the Transition towards a Sustainable Agriculture? A Qualitative Literature Review

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Abstract: Agriculture is facing mounting challenges across the globe and must move towards more sustainable practices to combat climate change and meet changed production requirements. Education has been acknowledged as highly important in a sustainable transition, but there is no clear agreement about what skills are needed for professionals in the agricultural system. The purpose of this paper is to identify and analyse skills needed for professionals in the agricultural system to engage in the transition towards sustainable agriculture and elaborate on the implications of this for a transition towards sustainable agriculture. The review is based on a qualitative semi-systematic literature review of 20 peer-reviewed articles concerned with sustainability, skills, and agriculture. Five categories of skills were identified and analysed, including systems perspective, lifelong learning, knowledge integration, building and maintaining networks and learning communities, and technical and subject-specific knowledge and technology. As the identified categories of skills have emerged from different contextual settings and a diverse group of actors, these five categories encourage a broad and inclusive understanding of skills that can be translated into different contextual settings, scales, and professions within the agricultural system. The article concludes that professionals engaged in the transition towards sustainable agriculture need skills that encourage a perspective that moves beyond generic discipline-based skills and instead builds on heterogeneity, inclusion, and use of different actors' knowledge, practices, and experiences, and the ability to respond and be proactive in a constantly changing world.

Keywords: sustainability; agricultural professionals; sustainable agricultural systems; sustainable education; skills

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1. Introduction

What skills are needed for professionals in the agricultural system to engage in sustainable agriculture, and how are these skills represented in the scientific literature today? Agriculture and food production are facing mounting challenges across the globe and must move towards more sustainable practices to combat climate change, environmental degradation, hunger and malnutrition, food safety and security, and a still-growing population [1–3]. Sustainable agriculture and our future food production play an important role and need to be perceived within a broad and integrated perspective that accommodates the three pillars; the environmental, economic, and social dimension, while at the same time keeping within a safe operating space of the planetary boundaries [1]. This insight has resulted in various policy documents and strategies in the past decade, e.g., the EU Commission's 2020 Target, FAO, and the United Nations 17's sustainable developments

goals (SDG's), all acknowledging the key role played by agriculture in global sustainable transition and development [4,5]. While agriculture is the prime target of the United Nations' Sustainable Development Goal of 'zero hunger', it indirectly affects most of the other goals, as food security and food safety are implicit prerequisites for a '*world free of hunger*' [5], a vision of the United Nations General Assembly and the 2030 Agenda for Sustainable Development 2015. To achieve these goals, several scientific and political reports have emphasised the need for agricultural professionals who can deal with the pressing sustainability challenge, and acknowledge education as an important tool in transforming the future of the planet [5–7].

There is a common agreement that moving towards a sustainable future requires a shift in perspective. It is, therefore, critical for sustainability scholars to understand this paradigm shift and orient their work in line with advanced theory and practice from fields relevant to sustainable agriculture and food systems [8]. However, education for sustainable agriculture is a vast research field that holds many discussions about theory, practice, and the educational outputs, as the conceptualisation of sustainability, problems, and the degree of change required in the transition differ significantly depending on different learning institutions and individual people [6]. Most often, education for more sustainable futures, especially within the agricultural sector, is identified by its subject content, while it is also important to acknowledge the learning processes that underpin sustainability [9]. It is, therefore, suggested that some of the key processes promoting learning for sustainable transitions and developments are, among others, collaboration, engaging with whole systems, innovation in the curriculum, teacher and learning experiences, and active and participatory learning [9–11]. Furthermore, the literature highlights the importance of a broad understanding of different kinds of knowledge in a sustainable transition, such as farmers' own experiences and knowledge [12–16]. Even though this is beginning to be well acknowledged, a recent study by Charatsari and Lioutas [17] found that the agronomists in their study were lacking some skills to promote sustainable agriculture and support farmers in making the transition towards more sustainable practices [17]. It is likewise recognised that education for sustainability and agriculture must move beyond dichotomies of objective true and false, and view practices as diverse, subjective, and contextual [18]. These recent examples highlight the need to step up efforts in education for sustainability and environmental and agricultural programs and challenge the normative skill-based course approaches [18,19]. However, there are many different definitions and terminologies regarding what constitutes skills for sustainable agriculture, and scientific research demands a more comprehensive description of skills and the implication in terms of developing the curriculum and future educational programmes [20]. Furthermore, the need to cultivate students' skills in higher education for sustainable agriculture (and food systems) has also motivated discussions about how teachers and students can be competent 'change agents' in the sustainable transition of the society [3,6,21]. Professionals in the agricultural system included in this paper are mainly people working directly with agriculture such as farmers, advisors, mentors, etc., or people involved in sustainable food production strategies, education, and/or research.

The definition and operationalisation of skills, competencies, and knowledge have been dealt with by different theories of knowledge and in educational literature. These definitions often concern differences between the concepts of knowledge, skills and competencies; simplifying knowledge as relating to theory, whereas skills relate to practice, with the link between the two being competencies. However, in the scientific literature, the terms become blurred in practice, and there is no consistent theoretical (or practical) use of skills, competencies or knowledge. We have decided to apply the definition of skills in this review as an interrelated complex of knowledge, competencies, and attitudes that enable positive and collaborative action and problem solving [22]. Furthermore, skills are primarily used in this paper in an educational context. This means that the categories of skills identified are skills that can be integrated into an educational context.

Besides skills, sustainability is a complex concept that is sometimes considered ambiguous because it means different things for different people in different situations. Regarding agriculture, many definitions can be found, but most of them, including those in the articles reviewed here, are connected to the three pillars of sustainability: society, economy, and environment. In this paper, we employ sustainability as a concept that includes a broad perspective, the three pillars of sustainability, and resonates with the definition stated in the report of the world commission on environment and development in 1987 by Brundtland: 'meeting the needs of the present generation without compromising the ability of future generations to meet their needs' [23], and with the definition of feeding the world population while at the same time keeping within a safe operating space of the planetary boundaries [1]. Sustainability in the Brundtland sense means different things in different contexts and the knowledge needed to tackle the UNSDGs is therefore complex and local and must be negotiated in its context. This requires transdisciplinary and interactive work by farmers, advisers, suppliers, researchers, policymakers, and/or other experts—whoever influences or has a stake in the situation. Hence, sustainability in the Brundtland sense is more of an overall direction given by, e.g., the UNSDGs, and then dealing with the social processes of getting there.

Moving towards a sustainable agricultural system, however, is a highly complicated process [24,25], and several articles in the past decade have discussed and argued for different strategies. One of the consistent conclusions is that there needs to be a more holistic approach to addressing the complexity in which an agricultural system is embedded [20,26]. This paper aims to synthesise and discuss the current scientific discussion about the skills that are required to engage with a changing world and move towards sustainable agriculture.

2. Materials and Methods

The purpose of this review was to undertake a thorough identification and analysis of the skills needed for professionals in the agricultural system, represented in the scientific literature. To this end, we developed a semi-systematic and qualitative literature search inspired by Wong et al. [27]. This approach was employed as it allows for the study of a topic that has been investigated and conceptualised in various ways by several groups of researchers within different disciplines [27]. A semi-systematic literature search is particularly relevant when undertaking a qualitative analysis to map themes and other different perspectives (e.g., theoretical, philosophical, and practical) represented in the scientific literature [27]. As sustainable agriculture is a vast research field and we aim to cut across disciplines and professions within this field to identify broad represented skills, such an exploratory approach was selected. One potential contribution of this analysis, using a semi-systematic literature search approach, could be the ability to map out a relatively new research field and identify skills needed in more sustainable agriculture, synthesise the state of knowledge, needs and demands, and create an agenda for future research.

This literature review was carried out as part of the EU Horizon 2020 Nextfood project as part of a mixed-method report on the skills required in the context of the agri-food and forestry system [28]. For a successful literature search, a three-step methodology was adopted to capture relevant sources and ensure a rigorous and repeatable method: (i) the generation of keywords and search strings, (ii) a semi-systematic search, and (iii) extraction of skills.

2.1. Generation of Keywords and Search Strings

Based on a keyword generation process among the Nextfood project consortium partners, a group of interdisciplinary and international researchers, 21 keywords associated with sustainability, agrifood systems, and education were identified, grouped into clusters, and developed into three search strings. These searches were conducted between December 2018 and March 2019 in different scientific databases for a broad subject coverage: Web

of Science, Scopus, EBSCO, and PROQUEST. This search was followed up by a literature search in July 2020 to provide an updated literature review.

The search strings created were: (1) (skill* OR competenc* OR knowledge) AND (agricult* OR agroecolog* OR agri-food*) AND (sustainab* OR resilien* OR environment*), (2) (skill* OR competenc*) AND (agricult* OR agroecolog* OR agri-food*) AND (sustainab*), and (3) (Skill* OR competenc OR learning*) AND (Sustainab*) AND (Farmer* OR Agronomist*).

2.2. Semi-Systematic Literature Search

The literature search was undertaken by adopting a qualitative and semi-systematic approach. This strategy is used to identify phenomena, concepts, or knowledge gaps within the literature [29]. In this case, our research question required the qualitative collection of data. An integrative review approach was useful, as the purpose of the review was not to cover all the articles ever published on the topic, but rather to combine perspectives to create new connections [29]. The inclusion criteria for the initial search included peer-reviewed articles written in English and published in the ten years between 1 January 2010 and 31 December 2019. The three search strings produced (1) 1238, (2) 522, and (3) 514 results. These articles were scanned for relevance by three researchers, who have different scientific backgrounds and nationalities, by their title and keywords and had to include a relevant number of the selected keywords. This step produced a list of 60 articles reviewed for eligibility from their abstract. This step resulted in a list of 27 studies split between the researchers and read in full, leading to the exclusion of a further seven studies that were not relevant for the final research purpose of identifying the skills necessary for actors in the agricultural system. The majority of the relevant selected peer-reviewed articles had a context within agriculture, and some of the articles were concerned with the broader food system perspective. Through this review process, a final list of 20 relevant articles was produced and is shown in Table 1.

Table 1. The 20 peer-reviewed articles that this literature review built upon.

1. Cerf, M., Guillot, M.N., Olry, P., 2011. Acting as a change agent in supporting sustainable agriculture: How to cope with new professional situations? Journal of Agricultural Education and Extension, Volume 17, Issue 1, Pages 7–19
2. Cerutti, Alessandro, et al., 2017. On the use of Life Cycle Assessment to improve agronomists' knowledge and skills toward sustainable agricultural systems. Visions for Sustainability, Volume 7, June 2017, pages 38–53
3. Charatsari, C., Lioutas, E.D., 2019. Is current agronomy ready to promote sustainable agriculture? Identifying key skills and competencies needed. International Journal of Sustainable Development and World Ecology, Volume 26, Issue 3, 232–241
4. Darnhofer, I., Bellon, S. Dedieu, B., Milestad, R., 2010. Adaptiveness to enhance the sustainability of farming systems. A review. Agronomy for Sustainable Development, 30(3), 545–555
5. Davidson, E., 2015. More Food Low Pollution (Mo Fo Lo Po): A Challenge for the 21st Century. Journal of Environmental Quality, 44, pp.305–311
6. Duru, M., Therond, O., Martin, G., (. . .), Bergez, J.-E., Sarthou, J.P., 2015. How to implement biodiversity-based agriculture to enhance ecosystem services: a review. Agronomy for Sustainable Development, 35(4), pp. 1259–1281
7. Dwyer, J; Berriet-Solliec, M; Lataste, FG; Short, C; Marechal, A; Hart, K., 2018. A Social-Ecological Systems Approach to Enhance Sustainable Farming and Forestry in the EU. EUROCHOICES Volume: 17 Issue: 3 Pages: 4–10
8. Francis, C.A., Jensen, E.S., Lieblein, G., Breland, T.A., 2017. Agroecologist education for sustainable development of farming and food systems. Agronomy Journal, Volume 109, Issue 1, Pages 23–32
9. Herrera-Reyes, Ana; Martínez-Almela, J., 2018. Project-Based Governance Framework for an Agri-Food Cooperative. Sustainability, Vol.10(6), p.1881

Table 1. *Cont.*

10. Hilimire, Kathleen., 2016. Theory and Practice of an Interdisciplinary Food Systems Curriculum. NACTA Journal, Vol.60(2), pp. 227–233
11. Ilieva, R. T. and Hernandez, A., 2018 Scaling-Up Sustainable Development Initiatives: A Comparative Case Study of Agri-Food System Innovations in Brazil, New York, and Senegal. SUSTAINABILITY Volume: 10 Issue: 11 Article Number: 4057
12. Kerry, J; Pruneau, D; Blain, S; Langis, J; Barbier, PY; Mallet, MA; Vichnevetski, E; Therrien, J; Deguire, P; Freiman, V; Lang, M; Laroche, AM., 2012. Human competencies that facilitate adaptation to climate change: a research in progress. International journal of climate change strategies and management Volume: 4 lssue: 3 Pages: 246–259
13. Laforge, J. M. L., & McLachlan, S. M., 2018. Learning communities and new farmer knowledge in Canada. *Geoforum*, *96*(June), 256–267
14. Lankester, A.J., 2013. Conceptual and operational understanding of learning for sustainability: A case of the beef industry in north-eastern Australia. Journal of Environmental Management., 119, pp. 182–193
15. Mica Bennett & Steven Franzel, 2013. Can organic and resource-conserving agriculture improve livelihoods? A synthesis, International Journal of Agricultural Sustainability, 11:3, 193–215
16. Moschitz, H; Home, R., 2014. The challenges of innovation for sustainable agriculture and rural development: Integrating local actions into European policies with the Reflective Learning Methodology. Action research Volume: 12 Issue: 4 Pages: 392–409
17. Nguyen, T.P.L., Seddaiu, G., Roggero, P.P., 2014. Hybrid knowledge for understanding complex agri-environmental issues: Nitrate pollution in Italy. International Journal of Agricultural Sustainability, 12(2), pp. 164–182
18. Šūmane, S; Kunda, I; Knickel, K; Strauss, A; Tisenkopfs, T; des los Rios, I; Rivera, M; Chebach, T; Ashkenazy, A., 2018. Local and farmers' knowledge matters! How integrating informal and formal knowledge enhances sustainable and resilient agriculture. JOURNAL OF RURAL STUDIES Volume: 59 Pages: 232–241
19. Triste, L., Debruyne, L., Vandenabeele, J., Marchand, F., Lauwers, L., 2018. Communities of practice for knowledge co-creation on sustainable dairy farming: features for value creation for farmers. Sustainability Science, Volume 13, Issue 5, Pages 1427–1442
20. Warbach, JD; Geith, C; Sexton, A; Kaneene, T., 2012. EIGHT AREAS OF COMPETENCY IN DECISION MAKING FOR SUSTAINABILITY IN METRO FOOD SYSTEMS. Transylvanian review of administrative sciences Special lssue: SI Pages: 145–157

2.3. Extraction of Skills Identified in the Literature Search

The analytical formation of categories of skills was performed by identifying from each article any mentioned skill or phrase that might emphasise a skill, competence, and/or knowledge required. Every necessary potential skill identified was compiled in an initial list. For example, '*understanding complexities in agricultural systems*' [30] is identified as a need for a systems perspective, and includes skills to navigate in a broad agricultural system.

This list identified a total of 164 skills. A mapping process was performed to group them into tentative themes. Therefore, words and phrases pointing to similar concepts and/or meanings were categorised into the same theme. This process led to the 164 skills identified from the peer-reviewed literature being condensed into five categories of skills, which are listed in Table 2.

3. Results

It became clear that the skills emphasised in the scientific literature selected for this review are more about directing the perspective in order to succeed in making a transition towards sustainable agriculture, rather than training professionals in specific skills. What stood out in the literature is that sustainability is associated with managing the present and future agriculture, and that this requires a broad and holistic approach in learning and practising sustainable agriculture. The categories of skills identified and listed in Table 2 are not necessarily in the order of those most emphasised in the literature; instead, they provide a thematic categorisation of most emphasised topics. Accepting that the following categories of skills should not be perceived as fixed categories, it is important

to make clear that no single category pre-exists any other; rather, they are interdependent and overlapping. Table 2 presents the primary contribution of the 20 articles in the five identified categories of skills. Some of the articles may have inspired other categories without being referenced in the specific category.

Table 2. Table 2 presents the five identified categories of skills and the primary contribution of the 20 articles.

3.1 Systems perspective	Francis et al., 2017; Hilimire, 2016; Cerf et al., 2011; Cerutti et al., 2017; Duru et al., 2015; Laforge and McLachlan, 2018; Warbach et al., 2012; Dwyer et al., 2018
3.2 Lifelong learning	Davidson et al., 2015; Cerutti, 2017; Francis et al., 2017; Charatsari and Lioutas, 2019; Šūmane et al., 2018; Bennett and Franzel, 2013; Darnhofer et al., 2010; Duru, 2015, Hilimire, 2016
3.3 Knowledge integration	Herrera-Reyes et al., 2018; Triste et al., 2018; Duru et al., 2015; Bennett and Franzel, 2013; Kerry et al., 2012; Cerf et al., 2011; Laforge and McLachlan, 2018; Šūmane et al., 2018; Moschitz and Home, 2014; Nguyen, Seddaiu and Roggero, 2014; Lankester, 2013; Darnhofer et al., 2010
3.4 Building and maintaining networks and learning communities	Laforge and McLachlan, 2018; Šūmane et al., 2018; Herrera-Reyes et al., 2018; Charatsari, 2019; Ilieva et al., 2018
3.5 Technical and subject-specific knowledge and technology	Duru et al., 2015; Cerutti et al., 2017; Cerf et al., 2011; Darnhofer et al., 2010; Herrera-Reyes et al., 2018; Ilieva et al., 2018

3.1. Systems Perspective

There is common agreement that knowledge about systems is crucial to understanding the complexity of sustainable agricultural practices. However, there is no clear nor common understanding of what a system is or how to define it, or what a systems perspective requires from knowledge, awareness, or skills if that potential is to be fulfilled. This section explores the complex and abstract body of 'systems perspectives' highlighted in the scientific literature. Therefore, a systems perspective should not be considered a closed concept. Instead, we want to explore its diversity to understand what a systems perspective is in future sustainable agriculture. When categorising the skills within this category, it became clear that the literature perceives systems and systems perspectives differently and from different scientific positions/paradigms. Overall, we identified the systems perspective as twofold: as a broad and holistic perspective of a system, including different stakeholder groups, sectors, and/or disciplines, and as a micro perspective including a limited disciplinary focus. Our scientific openness to a systems perspective resulted in this perspective being identified in almost all the articles in the literature review in one way or another. The literature represents the systems perspective through concepts such as 'systems thinking' [2,11] or by descriptions that we have condensed and/or interpreted as a systems perspective. A systems perspective is represented in the literature as a tool that supports effective learning to address complex problems in the contemporary food and agricultural system [2] and as an awareness of situations as multi-dimensional which needs to be taken into consideration [31]. Examples of such tools include *embracing the advisory situation as a whole*, or that *advisers need to be aware of the various dimensions of the situation so that they can identify the diversity of situations they encounter, and adjust to it* [31]. Besides these broader representations, a systems perspective is also represented as a system within a more 'closed' system, such as ecological processes, ecosystem services, or agroecological principles (however, this one has many different and contradictive definitions attached that we do not go into here), or as the integration of technical knowledge, which in this context means integrating different disciplines into practice. This involves only including technical

disciplines and thereby excluding social disciplines and society in general [13,30]. This is a common tendency in the literature concerned with the technical and environmental implications of sustainable agriculture.

Furthermore, systems are used as a concept to describe practices, for example, agricultural systems, farming systems, and food production systems—all referring to agricultural practices in a system. This perspective is grounded in traditional conventional agronomy, involving systems that focus on soil systems or ecosystems. These systems are very important for practitioners working on farms, for example, to understand bio-mechanisms in the soil. Nevertheless, the literature also emphasises that there is a need to zoom out from these on-farm knowledge practices and include a broader perspective that includes society, locally and globally, to manage future sustainable agriculture.

From a broad and holistic perspective, the literature highlights, e.g., the need for knowledge institutions and education to incorporate systemic perspectives or 'systems thinking' and experimental approaches that not only include specific technologies or specific disciplines, but also incorporate multiple stakeholder groups, various perspectives, and different institutions [11,32,33]. This emphasises a perspective that crosses disciplines, stakeholders, and institutions. 'Systems thinking' is particularly used as a way of thinking in systems, for example, as a learning strategy for students [11]. In other articles, a 'systems perspective' is not directly demanded, but the importance of being aware of complexities is, for example, the complexities involved in 'real-life' practices [30], including the importance of involving perspectives and knowledge from farmers' own experiences and individual practices [14,31] and being aware of the surrounding society [34]. To 'incorporate awareness of complexities' has been coded as a systems perspective, as it involves the perspective of real-life practices and the inclusion of individuality, context, and society. Individuality, in this case, is important because it represents heterogeneity, which is an unavoidable factor when dealing with sustainable agricultural systems.

Another example of how a system perspective is presented comes in the article by Laforge and McLachlan [32]. They represent systems as not limited or isolated within different sub-systems, but as inclusive and diverse in their existence. Laforge and McLachlan [32] give an example of the situation in which farmers, and their learning communities, are involved about a systemic perspective: *These learning communities are situated within systems of government regulations, international legal frameworks, infrastructure, weather patterns, soil conditions, seed genetics, food traditions, and cultural values, as well as knowledge around growing and eating a wide diversity of foods* [32]. This example shows the complexity and diverse reality of the system in which farmers and other professionals in the agricultural sector are involved, and of which professionals need to be aware to navigate a future sustainable agricultural system. An agricultural system in this review is therefore defined as a broad and inclusive system that can be both contextual and individual as well as structural and global. Most importantly, an agricultural system is dynamic and heterogenic in its representation, and professionals have to be able to navigate through this system to deal with the transition towards more sustainable agriculture.

The concept system is also used as a political argument and as a stepping-stone for talking about alternative vs. conventional food systems. It becomes clear in the literature that there is a contradiction and disciplinary clash between conventional agriculture and alternative agri-food movements. For example, the article by Francis et al. [11] describes agroecology as a discipline with a systemic perspective that addresses criticism of the present agricultural paradigm with arguments such as there being a need to *replace 'Monoculture Mentality' with diverse and creative thinking* [11] and *evolve from a short-term 'Anthropocentric' focus to 'Ecosystems' thinking* [11]. This perspective highlights different scientific paradigms and disciplines, which are negotiated in these articles. Firstly, there is an assumption that a systemic perspective is presenting a change in perspective from what we have done and thought about agricultural practices to what we would like to do and think about them in future.

Nevertheless, the concept of systems and a systems perspective continues to be defined in relation to scientific paradigms and disciplinary traditions, as well as to context. Therefore, a systems perspective needs to be broadened and perceived as situated in individual contexts to include the skills and competencies needed in a transition.

3.2. Lifelong Learning

Lifelong learning in this literature review is identified as an ongoing process of learning and adapting to a changing world on both local and global levels. The need for lifelong learning and continued education has been well-documented in the literature as being important in a transition towards a more sustainable agricultural system, not only for farmers and other practitioners but also for the private sector, retailers, and crop advisers [35]. In particular, the ability to be adaptive is a general competence that is argued for in the literature. This adaptiveness involves different perspectives depending on the context, profession, and/or scale in time and space, which is explored in this section: firstly, being able to enhance and challenge one's knowledge and understanding of sustainability from a long-term perspective, deal with or learn how to adapt to uncertainty and complexities in future, and be proactive through experimenting.

The articles concerned with lifelong learning are also studies about learning, understanding how learning happens, and for whom learning is important to engage in a sustainable agricultural system. Awareness of this learning perspective has particularly increased in studies concerned with stakeholder education and learning within agricultural and food systems. However, lifelong learning is not a new phenomenon but is changing in perspective from only being associated with learning institutions and education to being part of everyday life practices. However, lifelong learning is not perceived in the same way in the literature. Some represent lifelong learning through institutional and formalised practice, while other articles represent it through hands-on practice, real-life practices, network communities, and a mindset of being proactive.

In some of the articles, lifelong learning is characterised as a practice linked to institutionalised settings, in universities or other educational institutions, for professionals in the agricultural system. These articles argue that continued education and lifelong learning are important for students in higher education [11] as well as professionals already engaged in agriculture systems, to continually increase and enhance knowledge about sustainability and qualified sustainable transitions across sectors, professions, and disciplines [30,35]. For example, in the study by Francis et al. [11], they conclude that placing responsibility on students to encourage autonomous learning and prepare them to deal with uncertainties and complexities in future agricultural practices is essential for their future engagement with new knowledge and self-reflection [11]. Another study by Charatsari and Lioutas [17] argues that there is a need to develop lifelong learning programmes for agronomists to enable and motivate them to facilitate farmers' personal and entrepreneurial change, and to facilitate the creation of constellations of actors, such as linking farmers with other producers, institutes, suppliers, and consumers [17]. In this perspective, lifelong learning is directed at agronomists to enhance their own ability to facilitate change for individual farmers. This might be understood as a more practice-oriented focus, while the first example is lifelong learning to facilitate self-reflection and new knowledge at the student level.

The second recognised theme within this category is about being able to deal with, or learn how to adapt to, uncertainty and complexities in the future. The ability to live with change and uncertainty [15] and have the capacity to respond to changing natural and agronomic conditions [36] is greatly emphasised in the articles. Various events are challenging agricultural systems, such as more stringent quality requirements, new environmental regulations, debates on genetically-modified crops, extreme climate events, the revision of the Common Agricultural Policy and consequences of the financial crisis. These all create uncertainty, risks, and opportunities about the future agricultural system [37]. However, living with uncertainty is not a new discipline for farmers, who are used to uncertainty about weather prediction and market prices, for example. However, with globalisation and

issues related to climate change, uncertainty has become more diverse as the categories expand and put pressure on the pace of change [37]. This does not ignore the fact that the agricultural system is and always has been undergoing some sort of change, but the change is no longer just about production and economic development but involves new non-economic interests. Another example of how the need for skills to be able to adapt to constant change has increased is ensuring a flexible farm organisation that increases the options for new activities for the farmer and his or her family [37]. The last theme identified in this category is the ability to be proactive through experimenting. Skills related to lifelong learning for and with a sustainable agricultural system are about reacting to new demands and changes, locally and globally. However, it is as important to learn how to be proactive towards change through skills such as being able to carry out basic experimentation, and problem-solving [2,13,17]. This calls for skills in thinking innovatively and being creative.

Lifelong learning is about adaptiveness and being able to react and respond to changes, as well as being proactive. This requires actors and actor groups to enable an ongoing process of learning and knowledge along the path to transition, including different actors at the local farm level and actors at a global agricultural systemic level, as well as actors in educational programmes. Furthermore, it also requires a willingness to engage in ongoing changes and knowledge developments, which often involve adapting to innovation and new technologies. This perspective will be further elaborated in the results section concerning technical and subject-specific knowledge and technology.

3.3. Knowledge Integration

More and more studies highlight the need to integrate different kinds of knowledge to overcome the challenge and move towards more sustainable agriculture. All the articles in this review are concerned with 'knowledge' in one way or another to describe the needs and potentials to move towards more sustainable agriculture. However, we do not intend to fully present what 'knowledge' covers in these articles, but rather explore the need for knowledge integration. The articles particularly show that it is necessary to integrate farmers' own experiences and knowledge to create more sustainable rural areas and manage a sustainable transition [14,16] or even describe a gap between the theoretical knowledge base and practical, local experienced knowledge [13]. This category of 'knowledge integration' will examine the need for knowledge integration highlighted in the literature and explore the related skills and competencies.

In the literature, 'knowledge' is used to describe what is relevant to know in order to deal with a sustainable transition. Most of the articles relate knowledge to different scientific disciplines, especially agronomy and technical knowledge, or other kind science-based knowledge. This is also referred to as formal knowledge and is related to what is called informal knowledge, which is experienced knowledge, such as hands-on knowledge and know-how. The literature has different ways of expressing these two perspectives of knowledge, and notions such as local knowledge [36,38], farmers' own knowledge [15,31,32], and tacit knowledge [16] are also used in the category of informal knowledge. Then, there is interdisciplinary knowledge [35], however, which still refers to science-based knowledge and knowledge gained in an institutionalised educational setting. The literature expresses a need for these two kinds of knowledge to be integrated, and some articles call this need a necessary change in how knowledge is perceived from a thing that can be transferred to a process of relating and negotiating meaning [12]. Another article describes this integration of knowledge as hybrid knowledge [39]. Besides these two-sided perspectives of knowledge, there is also a theme about knowledge in relation to learning. One article highlights how putting farmers' knowledge back at the centre means that independent and social learning is happening, which can advance a more progressive sustainability agenda in the food system [32]. With this focus, the article also sheds light on and problematises the conventional knowledge represented by most of the institutional venues as something that is not promoting a sustainable agricultural system for the future [32]. Another article emphasises that knowledge can be experimental or about different knowledge systems,

such as systems perspectives, and, for example, that local knowledge can be based on different conceptualisations of the world compared with science-based knowledge about farm management [37]. Another article takes as its starting point a social co-creation process of learning rather than a fixed knowledge transfer [40]. This perspective points towards the integration of informal, local knowledge to achieve a broader and more diverse understanding of the world, in opposition to existing educational institutions.

However, it is not simply about adjusting to new knowledge practices. This is emphasised in the article by Cerf et al. [31] as they investigate and discuss the role of being a change agent in a new professional situation. The study points out that change agents (advisors) need to step out of their historically built professionalism and develop new ways of integrating scientific and technical knowledge with farmers' knowledge to enable farmers to develop a new understanding of their unit of action and how to materialise it in farming practices [31]. Such new approaches are not only based on new forms of verbal interaction but also imply new ways of mobilising the field visit or the experimental data and evaluation criteria [31].

There are different levels of complexity when examining farmers' knowledge versus science-based knowledge. One article by Šūmane et al. [15] focuses on two interrelated kinds of knowledge: local knowledge and farmers' knowledge. Here, local knowledge encompasses dynamic and complex bodies of know-how, practices, and skills, developed and sustained over time based on local people's experiences in their environmental and socio-economic realities. Farmers' knowledge is a sub-set of local knowledge that enables them to farm in specific local conditions. It is based on their practical experience and often linked to a practical skill. As agriculture is highly dependent on the local environment, local farmers' knowledge is of particular importance as it contains an intimate understanding of the particular set of local cultural and natural resources [15].

However, the tendency is that knowledge per se is related to disciplinary or scientific knowledge, and the literature is asking for the integration of the experienced knowledge and know-how with individual, contextual knowledge. Some articles define these two categories of knowledge as formal and informal, while other articles define them as scientific knowledge and experienced or local knowledge. Nevertheless, knowledge is firstly formalised into institutionalised contexts, know-how, and practical experiences, and experimental knowledge is categorised as being outside these institutions. This division challenges the divided relationship between traditional educational practices and real-life practices and advances a need to move beyond this rigid division and present new knowledge paradigms that emphasise a more dynamic, fluid, and inclusive basis where interdisciplinary knowledge, practice and know-how, and proactive and innovative experimentation are included. Nevertheless, it is interesting to ask the question about how knowledge is perceived and what kind of knowledge is accepted in which contexts, as well as what knowledge implies concerning a sustainable agricultural system.

3.4. Building and Maintaining Networks and Learning Communities

The importance of networks and learning communities is frequently highlighted in the literature and includes practices of sharing knowledge and experiences to move towards a more sustainable agricultural system. Networks and learning communities as a category in this review cover the skills for building and maintaining networks, as well as building and maintaining learning communities within these networks. This category builds upon articles which connect learning communities and networks of associated stakeholders, such as farmers, with a positive influence in the transition towards a sustainable agriculture. Furthermore, there is not a coherent linkage between networks and learning communities and sustainable agriculture, but different understandings of the objective and/or effects of these networks. Firstly, the 'network and learning community' phenomenon is grounded in contextual settings, which means that they may look very different from context to context, depending on the profession and the setting or situation. However, there is a common theme within this category, namely the proactive effect of creating networks,

and networks and learning communities in the context of sustainability become activistic and innovative, as social relationships in these networks are shown to foster collective action [14,41]. The literature points out that the potential and need for building and maintaining networks and learning communities provide opportunities for farmers who want to develop an alternative pathway towards a sustainable agricultural system in contrast to conventional farming practices [15,32], as these networks have the potential to cultivate new ideas and voices that have not been listened to before, such as female farmers and those from urban, non-agricultural backgrounds [32]. A consistent trend in the literature is that networks and learning communities within sustainable agricultural do not just contribute to professional knowledge sharing and giving advice to one other but encourage and address a shift towards an alternative (and more) sustainable agricultural system. Furthermore, these networks are not to be understood as an isolated knowledge network, but rather as mutually depending on a broader system. For example, one article highlights the potential of these networks indirectly influencing at a food system level in terms of political issues, such as the policy of seed ownership [32]. In this article, they use a metaphor to describe a network and the inherent potential and responsibility to move knowledge and opportunities to where they are needed. They depict the network as the ecological and mutual symbiosis between fungus and plants called mycorrhiza. This metaphor becomes facilitatory for an exploration of how underground rhizomes support farmers' learning communities in the same way as fungal structures reach out and act in the soil to support vascular plants [32]. The article concludes: *in an era of digital technologies, mycorrhizal connections and associated learning communities need not be situated in place; however, they can be fluid, diversified, and self-organised and may create the impression of unseen, subterranean connections among actors within a global food and farming movement* [32]. Herrera-Reyes et al. [14] explored the relevance of farmers' knowledge and social learning practices in the construction of alternative pathways in sustainable agriculture and the strengthening of project-based governance [14]. In this study, social learning communities include interpersonal relationships, feelings of belonging, trust and commitment, and friendship, all essential for a learning community. Furthermore, actions that lead to learning from collective actions contribute to social cohesion in an organisation, and these actions are linked to the exchange of information, experiences, and mutual help [14]. In addition, another study by Ilieva and Hernandez [41] highlights the effect of grassroots innovations in contrast to top-down governance projects and interventions [41]. In this study, grassroots initiatives have an impact on socioeconomic inequalities by introducing innovations, such as Community Supported Agriculture (CSA), an initiative where the local community financially supports local farms and farmers [41]. Network building is also about building stronger social sustainability that likewise affects the economic and environmental dimensions of sustainability. Another important part of building networks and learning communities is the need to build and grow partnerships by linking participants with different power relations across government and market institutions. This partnership has the potential to translate key values that might be neglected or taken for granted in terms that can be advantageous for mainstream actors in the socio-technical agricultural system [41].

In the literature, learning communities are identified as improving skills, such as the ability to solve internal conflicts and build knowledge capacities [15,17], and thinking across institutions, power hierarchies, and markets. However, building and maintaining networks within the agricultural system is not a single thing or arrangement that can easily be studied or operationalised, and skills related to this category are not univocal but multiple. The skills related to this category are, thus, to possess the ability to integrate networks and learning communities locally in the contextual setting, socially engage with others, and be willing to share experiences and knowledge as a common good.

3.5. Technical and Subject-Specific Knowledge and Technology

In the literature review, technical knowledge is emphasised as fundamental but changing in perspective, and in this section, we explore this transformation of technical knowledge and technology in relation to a sustainable agriculture. It is not within the scope of this article to examine what specific technology or technical skills professionals and farmers need to operate in and manage the sustainable transition at the farm level, but rather to analyse the representation and emphasis this receives in the scientific literature.

The need for more sustainable agriculture is often related to adverse environmental effects such as biodiversity loss, climate change, erosion, and pollution of air and water. This focus often leads to solutions that increase the level of provisions of ecosystem services, such as focusing on solutions such as soil fertilisers or other biological regulations of the soil [13]. Technical knowledge is often associated with a specific practice and is something that students are taught at technical universities [30]. It is shared in local as well as global learning communities, especially by farmers and advisors. Thus, in this literature review, we do not deny that the development of robots and other kinds of software initiatives will have a huge impact on future practices in agriculture, but this is not something that is emphasised in the literature selected for this review and therefore is not examined here. However, technical knowledge is emphasised in the literature as something that changes in perspective in line with the demand for more sustainable agricultural practices. The articles emphasise a shift in perspective, from putting productivity first and sustainability second to focussing on sustainability, in the Brundtland sense, as parallel and inclusive. This builds on the insight that only a sustainable agricultural system can be productive in the long term and meet the UNSDGs. In this change, 'change agents' and advisors find it difficult to navigate a new role and relationship with the farmers, and this uncertainty leads to doubt about their expertise in terms of technical skills and competencies. Previously, advisors and change agents have perceived themselves to be experts at providing technical knowledge to farmers to help them innovate their practices [31]. However, a changing system also requires a changing relationship between actors in the system who rely on each other's practical experiences, experimentations, and scientific research.

Since the 1970s, technology and technical innovation have dominated the agricultural sector and succeeded in increasing income and yields, both in relation to crops and animal production. Thus, in the past decade, more and more critical voices have pointed out the consequences of optimisation and maximisation of income and the need to decrease our environmental footprint [37]. The articles in this literature review present a perspective towards sustainable agriculture that is critical of the previous dominant normative understanding and use of technology and technical solutions at the farm level. This criticism particularly points to the goal of stability, income maximisation, technical fine-tuning, or biological optimisers by controlling processes, reducing the range of natural variation in the farming system, and stabilising farm output to ensure an efficient and stable supply of goods and services [37] as problematic. As well as the 'one-size-fits-all' recommendations and the transfer mode that is mainly a top-down process towards farmers [13], it presupposes that the world is understood as stable and that farmers are a homogenous group. However, this reductionist perspective is encountering many critical voices expressing a need to balance it with concepts such as adaptability, resilience, and flexibility [37]. To do this, the articles by Francis et al. [11] and Ilieva and Hernande [41] highlight the importance of subject-specific knowledge that focuses on alternatives to improve soil health and intensify soil capacity, through agroecological principles with crop rotation, organic inputs, and soil covers [41]. Agroecological principles are here defined within a broad perspective, including both environmental, economic, and social dimensions of managing a farm. The study by Ilieva and Hernande [41] illustrates how environmental conditions are intertwined with social conditions and poverty, as some countries experience Sahara-like conditions where there once was forest, and the effect on the socioeconomic status in that area. Through land and farming managing techniques, such as reforesting and soil restoring techniques, these areas will be improving in all three dimensions [41].

Technical knowledge is acknowledged as a discipline that needs to be discussed and developed in collaboration with companies, practitioners, and scientists. One article expresses the importance of alliances between organisations (for sustainable agriculture) and research centres and universities to promote technological advances related to organic farming, as there is a need to develop new sustainable strategies that do not depend on harmful chemical substances [14]. Specific skills within technical knowledge and technology are not emphasised as the main problem—rather, it is emphasised that technical skills include reducing the ecological footprint of agricultural production, using soils and biomass as carbon sinks, watershed management, enhancing biodiversity on a landscape level, tightening nutrient flows (i.e., nitrogen and phosphorous), and reducing pesticide use. Moreover, technology and technical knowledge likewise tap into the huge developing area of software technologies. For example, one article highlights that there is a potential in focusing on using versions of LCA (life cycle assessment) software to understand the importance of metrics in accounting for environmental sustainability [30]. In this sense, technology is also software and a method for understanding sustainability in higher education.

There is a tendency to mention technical knowledge as an independent and unavoidable factor when dealing with sustainable transition in the agricultural system. However, none of the articles reflect on technical perspectives in a process of redefining technical knowledge in a sustainable agricultural system. It is thus important to raise questions about what technical knowledge, skills, and competencies look like in future sustainable agricultural practices, and whether there is a need to unpack the concept of 'technical' and 'technology' with sustainable agricultural systems to acquire a better understanding of the components, practices, and materialities that make up what they are in relation to the matter of reference.

4. Discussion and Conclusions

This literature review was designed to identify and analyse skills needed for professionals in the agricultural system to move towards, and navigate within, sustainable agricultural practices. We have analysed how skills are represented in the articles, and the implications this may have in practice, as well as in future sustainable practices. In a thorough qualitative reading, we identified five main categories of skills that were given thorough consideration in the literature. The five categories were 'systems perspective', 'lifelong learning', 'knowledge integration', 'building and maintaining networks and learning communities', and 'technical and subject-specific knowledge and technology'.

This review built upon a qualitative semi-systematic literature review, which means that it included a limited and systematic selection of articles. This method was chosen to obtain a more thorough analysis of how skills are represented in relation to sustainable agriculture in the scientific literature. It became clear that this topic of skills needed in sustainable agriculture is still an evolving and developing field of research. This review provided an analysis that not only categorised but also provided insight into how skills and categories are emphasised and represented in the scientific literature in relation to sustainability. This insight is interesting as it sheds light on the manifold usage of complex concepts such as 'system' or 'network' or 'technical knowledge' and what constitutes these concepts.

A systems perspective responds in particular to the required need for a broad and more 'whole-picture' perspective that is generally acknowledged as important in agriculture of the future. We need to move beyond known practices, silo thinking, quick fixes, or best practices as well as the linear learning approach, and integrate the complexities of agricultural practices. The skills that relate to this category are the ability to zoom out from individual practices on the farm level, including different actors and various perspectives, as well as to understand the relatedness of different practices. This also requires a personal willingness and openness to understanding the possibilities of a broader perspective. The category of 'lifelong learning' highlights the importance for actors on different levels to engage in an ongoing process of learning and adapting knowledge along with the transition.

In the review, lifelong learning is emphasised as already relevant in the early years of study as it fosters early self-reflection and attitudes towards a constantly changing practice. It is also relevant for agricultural professionals who have been practising for several years, perhaps especially so for them. The skills embedded are innovative and creative thinking and being able to experiment, but also problem-solving, critical thinking, and the ability to receive and create space for support from employees, family, and/or local society. Besides these, lifelong learning also encourages a discussion about learning as a practice that needs to be reviewed, as studies show that we need to discuss how we educate the future generation of professionals for a transition towards sustainable agriculture. There is growing interest in developing a more iterative and multi-dimensional understanding of learning and educating. Awareness of this perspective has grown in studies (including the articles in this review) concerned with the education and learning of actors within agricultural and food systems. Especially, we see a turn in these studies, from classical learning theories based on positivist imaginaries of knowledge acquisition and scientific inquiry as objective and extractive activities, towards subjective and contextual ones [42]. However, the dominant learning model within agricultural studies has been, and remains, a linear process from scientist to student or farmer [42]. This warrants further exploration of the transition towards a more learner-centric educational approach where real-life practices, context, and subjectivity/heterogeneity are the basis for the understanding and operationalisation of skills and curriculum.

Integration of knowledge, especially formal and informal knowledge, is shown to be essential in the literature. However, knowledge is understood as a broad term that relates to the specific context it is defined in. This category emphasises the need to integrate different kinds of knowledge experienced and obtained by different actors in agriculture. We identified two overall categories of knowledge emphasised in the literature, formal and informal knowledge; however, it is important to make clear that this division does not provide an entirely accurate picture of the different knowledge types that exist among agricultural professionals. Formal knowledge represents scientific and generic knowledge and informal knowledge represents contextual and individual experienced knowledge. Within these two categories, there are many different variations and expressions of knowledge by different actors that can also be placed between or across the here-defined formal/informal division. The skills within this category enable the actors to combine scientific knowledge with experienced and context-specific knowledge, and to understand and operationalise global issues and solutions with individual local and contextual settings. This category of skills is especially important for future agronomists and 'change agents' who need to facilitate change at the farm–society level. Integrating knowledge can be facilitated in networks, and networking and creating and maintaining networks and learning communities is the fourth category identified in this literature review. 'Creating and maintaining networks and learning communities' is a category that particularly covers new farmer networks and learning communities that foster alternative and proactive initiatives through knowledge sharing. In the literature, networks are described as something that has the potential to cultivate new ideas and give voice to a broader and more diverse group of farmers, such as female farmers and farmers from urban, non-agricultural backgrounds. This is particularly important because the transition towards a more sustainable agricultural system requires a shift in perspective and the inclusion of different voices and perspectives. Future agriculture will include a more diverse group of actors, whom not all are familiar with, for example, long farming traditions, but come from diverse scientific backgrounds. Therefore, it is simply not possible to describe different actor groups, such as farmers, as a homogenous group. The articles in the literature review already represent a diverse group of farmers and other actors, as they are placed in different contextual settings. The skills identified in this category are for actors to have the ability to build diverse knowledge capacities, seek out new or existing networks, share knowledge with different actors, and understand the value and potential of these networks.

The fifth category was 'technical and subject-specific knowledge and technology'. This category exists because technical knowledge and subject-specific knowledge, such as theory within agronomy, ecosystems, and economy, are essential when working with and within the network of agriculture. However, we also raise a question about what skills are needed in this category of technical knowledge. This question is relevant as discussions about sustainability often result in a technical solution or future sustainable agriculture that depends on technical and technological solutions. In this review, we do not examine in depth what the technical solutions are and what they should look like. Rather, we highlight the need to learn how to navigate the technical and technological developments that are constantly evolving.

This review highlighted ambivalence to sustainability skills as they do not fit the classical understanding and idea of what skills are, and how these should be integrated into educational settings. Agricultural education today should not only encompass technical knowledge, but also the social skills and competencies within a systems perspective, continuous learning, integration of knowledge and networking, and motivation and openness to engage in a dynamic and changing world. These categories emphasise the need to go beyond skills as something related to subject-specific disciplines and include a broader knowledge capacity. As already mentioned, these categories are not to be understood in isolation, but rather as interdependent. Furthermore, the implications of the results for practice means that these categories are extracted from different contexts and have to be operationalised in other contexts that make sense for that specific case, practice, and context. In this sense, we argue that transdisciplinary development is necessary for our common sustainability agenda.

The particular contribution of this review is to offer an understanding of 'sustainability skills' in the context of agriculture as being relational and context-dependent. Sustainability, and the definition of sustainability in relation to agriculture, is defined within many different perspectives, scientific disciplines, and practical experiences/values in the scientific literature and practice. However, the definition of sustainability is still a relevant debate—especially when discussing 'sustainability skills' in an educational context. Thus, we find it very important to highlight that sustainability is dynamic and inclusive, allowing contextual differences and relationships to exist. The categories of skills identified in this review have the potential to go beyond skills as something static and discipline-specific and push forward a discussion about how skills need to be interpreted and integrated into future educational programs and curricula. Furthermore, we conclude that integrating a fruitful and successful transition requires a diversity of actors with different perspectives, experiences, and scientific knowledge. Another finding was that sustainability as a concept becomes blurred in the review as the articles represent different dimensions of sustainability and highlight examples that relate to their specific cases. That sustainability is not clearly defined in these articles is not a problem in itself; thus, we acknowledge potential in exploring how the scientific literature represents and describes sustainability as a concept. We recommend continued research into future education programmes, Environmental Sustainability Education (ESD), and curriculum development for future programs, and the integration of these perspectives and categories in discussions about how 'sustainability skills' can be assessed, evaluated, and operationalised in education and life-long learning processes.

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