Educating for Sustainable Agriculture:

a case study of four European postgraduate programs

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[Front Picture] Reproduced with permission from student excursion to Remeker farm, as part of the Organic Agriculture and Society course at WUR (September 2017).

THE MOTIVATION for this thesis research was simple: discover how sustainable agriculture is taught in different postgraduate programs across Europe so I myself can become an educator in this field. My experience on the MSc in Organic Agriculture at Wageningen UR has opened my eyes not only to new ways of learning but also more responsible ways of being in this world. Though this type of transformative education may seem to us commonplace, from my experience it is quite an exception. I feel it now my responsibility to create, or better to co-create, these learning environments and apply them further South, where they are urgently needed.

A note of Gratitude

To Blair van Pelt,
Who told me it was possible,
And who answered my questions
With even more questions.

To all the people who's
Experiences, thoughts and advice
Went into this work.

To Chiara Flora who walks next to me,
And to my family who trusts me,
Always.

Last but not least,
To all the anonymous Farmers
Who grew the food that has kept me alive
Throughout this whole process.

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Abstract

Sustainable agriculture arose as a response to the social and natural degradation perpetuated by the post-Green Revolution agricultural paradigm. To prepare future practitioners to respond to these inherently complex agricultural and food system challenges requires a broad appreciation of production, resources, environmental as well as socioeconomic and cultural factors. This calls for a new educational paradigm in agriculture, one that moves beyond a narrow, disciplinary focus to more systemic, learner-centered approaches. Though extensive literature exists on how to best organize curricula for sustainable agriculture, this research offers, for the first time, an overview of current practice in four postgraduate sustainable agriculture programs across Europe. Findings show that curriculum contents span beyond primary production to a focus on the global food system, through a balance of both social and natural sciences. It is also found that a systems approach is common among all programs, with experience-based and cooperative group learning being at the center of the teaching and learning process. This research highlights best practices and discusses how these progressive learning environments influence the development of learners. Recommendations are set out for learning environments which will enhance the capacity of students to serve future sustainability-oriented sectors.

Introduction

Sustainability issues centered around human and environmental health are gaining importance in recent years. Specifically, concerns about soil degradation, water availability, food quality and security, nutrition-related diseases, animal welfare and human-induced climate change are putting the spotlight on agriculture (Wezel et al., 2018, Hilimire et al., 2014, Francis et al., 2007). The current unsustainable agricultural paradigm is largely perpetuated by the technologies and attitudes of productivity that came out of the green revolution era, which have largely shaped the current state of agricultural education at university level (Meek & Tarlau, 2016). As movements towards a more sustainable paradigm of agriculture arise, this brings into question the role of education in developing future graduates capable of responding to today's challenges. Most higher education agricultural institutions are inherently teaching- and research-focused, taking a reductionist approach (Parr et al., 2007), when the challenges we are facing are complex and often require dealing with uncertainty in a wider context (Lieblein et al., 2011). Therefore, the traditional approach of dividing up knowledge into disciplines is no longer effective (Parr et al., 2007, Francis et al., 2001), neither is the division between those who produce knowledge (teachers and researchers) and those who accumulate knowledge (students).

Sustainable agriculture education thus arose alongside the sustainable agriculture movement (including organic agriculture and agroecology) as a response to the negative effects caused by 'conventional' agriculture as a key strategy for developing and implementing more sustainable agricultural practices (Hill & MacRae., 1998). This as an interdisciplinary field of study which focuses on intervening in the complexity of our current food production systems to improve its social and environmental impact (Meek & Tarlau, 2016, Hilimire et al., 2014). Educators and students of sustainable agriculture are united by their recognition that the challenges that the current agri-food system is facing requires more "systemic" approaches and perspectives (Gliessman, 1998, Altieri et al., 1998, Wezel., 2009). This type of education moves beyond the narrow focus on the production of commodity crops, which is often in stark contrast to traditional agricultural curricula (Table 1), to include the relationships between health and environment as well as policy and social justice issues in the wider food system. This expansion has also shown a move away from discipline-oriented way of teaching to a participatory 'learning system' (Table 1). Sustainability-oriented agricultural education is, at its core, meant to develop learners' capacity to understand complex relations and processes that make up our modern food system, analyze 'wicked' problems within it and develop sustainable alternatives (Meek & Tarlau, 2016). It

emphasizes a kind of learning that crosses disciplinary boundaries (David & Bell, 2009) and offers a potentially effective organizing structure with which to address many of the complex societal and environmental challenges in the agri-food system (Parr et al., 2007). Upon reflecting on a program-design which provided sufficient training for future sustainable agriculture professionals, Hill and McRae (1998) mentioned:

> Chosen lecture-topics presented agriculture as a system of interacting multifunctional components [and] demonstrated the multidisciplinary and integrated nature of sustainable agriculture. We encouraged the students to define for themselves their personal goals and to use us as allies in meeting those goals. Assignments were designed to approximate real world experiences [...]. (p 93-4).

Table 1. Distinctions between traditional and sustainability-oriented agriculture education based on Parr et al., 2007, Francis et al., 2001, Hilimire et al., 2014, David & Bell., 2009.

Traditional Agriculture Education	Sustainable Agriculture Education
Reductionist thinking; discipline oriented; components in isolation; development of specialized experts	Systems thinking; study of broad & interrelated set of relationships; balancing of content and methods from natural and social sciences
Teaching System: didactic teaching approaches where teaching staff and textbooks are the source of knowledge.	Learning System: use of multiple sources of information; focus on experiential learning that encourages self-discovery and social learning.
Teachers as holders and students receivers of knowledge; passive learning contained within the classroom & field labs.	Teachers into the classroom as facilitators of learning processes & co-creators of knowledge.
Closed learning community; specific problem solving; loss of connectivity.	Open & permeable community of learners and practitioners; increasing connectivity in education and research.

The addition of 'Sustainability' to Agricultural Education seems to have widened the content and pedagogical scope of programs to include the wider challenges and potential solutions to our current food system. By widening learner perspectives, these programs aim to develop an awareness of one's own worldviews in relation to others' and in the context of global challenges (Francis et al., 2001). They are also designed to equip learners with a wide set of skills and knowledge to face those challenges in changing environments (Meek & Tarlau, 2016, Wals et al., 2001).

There is currently extensive literature that suggests implementing pedagogical approaches that are uncommon to traditional disciplines, such as interdisciplinarity and systems-thinking, group and experiential learning and connecting theory to practice through action projects (Leiblein and Francis., 2007; Hilimire., 2014; Parr et al., 2007, Altieri & Francis., 1992, Hill & McRae, 1998).

Though this is widely shared in literature, still major differences can be found between programs in terms of their teaching and learning methods (Parr., 2006, Lieblein & Francis, 2007), content (Parr et al., 2007, Wezel et al., 2018) and underlying vision (Migliorini & Lieblein., 2016), which shows that there is no common agreement on what should be included in a sustainable agriculture postgraduate curriculum.

Recent research has offered a glimpse into the current state of higher education programs in sustainable agriculture

> "Some [...] programs are part of plant sciences departments or rural development faculties. Thus, the approach [...] may differ depending on the inner structures of universities and which topics they put forward. Some programs, for example, focus more on food sovereignty and rural development, others more on sustainable agricultural production systems and agroecosystems management." (Wezel et al., 2018, section 3.3).

Postgraduate programs in this field have been gaining in popularity in recent decades (Migliorini & Lieblein, 2016). Students come to these studies from very diverse ethnic and professional backgrounds and graduate into a wide range of positions within the local and global food sector (Meek & Talbau, 2016). It is thus worth considering the questions of what universities are delivering and whether students of these programs are being sufficiently prepared to work with the complex social and environmental challenges that concern agriculture and the wider food system today. While academic curricula are a concern of academic institutions themselves, the impact of sustainability-oriented agricultural education affects governments, organizations, academia, policy-making bodies and the wider environments in which these future graduates will be part of. How we educate students today will impact the future of agriculture globally.

Though current literature provides extensive recommendations on how to best organize and facilitate sustainability-oriented agricultural curricula, it offers limited insights into current practice in terms of implemented curriculum contents and pedagogical approaches. Such an overview is necessary to assess whether academic suggestions are applied in practice and how this influences the development of learners. This research aims to provide insights into the question of how sustainability-oriented agricultural education is currently practiced at the postgraduate level in Europe. This will be done through an analysis of i) what components are included in the curriculum of every program and how they interrelate, and ii) what pedagogical approaches are applied and how they influence student learning. The paper offers an epistemological analysis of student learning and provides practical examples and recommendations for future educators and practitioners of sustainability-oriented agricultural education.

Methods

Methodology

A qualitative methodology was chosen which made it possible to define the methods most suitable for collecting and analyzing data, as well as to explore, interact and interpret educational practice (Merriam, 1988). A case-study research method was used as it allowed the researcher to 'go deep' and to learn from current educational practice (Corcoran et al., 2004).

Selecting programs

The selected postgraduate programs have been purposefully sampled using the following criteria: be a stand-alone MSc program; contain any of the keywords 'Sustainable Agriculture and/or Food Systems", "Organic Agriculture", or "Agroecology" in the program title; use English as main language of instruction; delivered by a European university; be in existence for at least ten years. Programs were identified first through internet search through the European Association for Agroecology network, the European League of Life Sciences (ELLS) network, google search engines and asking interviewees for suggestions. While this search was taking place, a publication became available which confirmed and added upon the predetermined list (Wezel et al., 2018; Appendix Table 2). Nine postgraduate programs were initially identified and then narrowed down to four based on response deadlines and feasibility of data collection over the course of eight weeks (three programs did not respond in time, one was declined due to non-response of main coordinator, one did not yield sufficient data).

Carrying out interviews

Fifteen interviews were conducted in this research, with the choice of participants depending on current position or previous experience. 1) Purposive sampling was employed in the selection process of teaching staff who had extensive experience with teaching and/or coordinating their program. The sample included the main coordinator for each program and a professor with over five years of involvement in teaching in the program. 2) Eight students (two from each program) were randomly chosen on a first-response basis, the only requirement being that they were either a current student or recent alumni of the program. Interviews lasted from 25-75 minutes, where questions were asked depending on the position/involvement of the interviewee in the program (Appendix Table 1). Interviews usually started with more general questions about the structure and content of the program, then gradually going deeper into the learning environment. Interviewees were continuously encouraged to share specific examples from the learning environment and to speak from their own experience. Finally, questions were asked as to the strengths and challenges that each program is facing, as well as advice for future practitioners and students in sustainable agriculture education. Interviews were semi-structured to allow for new information and follow-up questions to arise when necessary. All interviews ended with an open-ended question asking interviewees whether there was anything else they would like to share about the program. Interviews started with more open, general questions about the structure and content of the program, then gradually going deeper into the learning environment. Interviewees were invited to share specific examples from the learning environment and to speak from their own experience. Finally, questions were asked as to the strengths and challenges that each program is facing, as well as advice for future practitioners and students in sustainability-oriented agricultural

education. Interviews were semi-structured to allow for new information and follow-up questions to arise when necessary. All interviews ended with an open-ended question asking interviewees whether there was anything else they would like to share about the program.

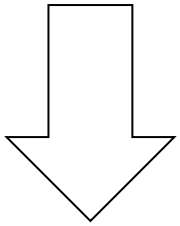
Data collection & analysis

The data collection methods included direct observation of formal classroom activities and excursions, which allowed an 'inside' perspective of the teaching/learning environment as well as a monitoring of student participation and motivation. Due to financial limitations, this was only done in two out of four cases which were more feasibly accessible to the researcher. For all four programs, data was collected from semi-structured interviews and secondary data source material such as course guides and curriculum design documents. Due to lack of information on what is currently practiced in sustainable agriculture postgraduate programs, an inductive approach was taken (Goddard, 2004). This research began with observations, with theories formulated and compared with existing peer-reviewed literature towards the end of the research. Interviews were recorded and data was transcribed and anonymized. An open coding approach using a line-by-line analysis was employed in order to allow themes and topics to emerge from the analysis and to build categories (Yin., 2009). A second-order analysis was conducted and codes were constructed and organized based on the theoretical framework set forth by Hilimire et al (2014) on designing curricula for sustainable agriculture education.

Table 2. Examples taken from the coding process. After coding data in "in vivo codes" (wording used by participants), a second order analysis was applied and codes were constructed based on terms found in peer-reviewed literature.

1st order analysis

In Vivo Codes	**Words taken from interviews**
Experience	We focus on learner experience; students gain practical experience; more interactions and student engagement; they learn better through immediate experiences in the food system; experience firsthand; experience an existing farming system.
Complexity + Systems	these issues are complex; we design agile assignments which reflect the complexity of the challenges; take up different perspectives; look at complex challenges as a system of relationships; brings complexity of food system into the classroom through systems approaches.



2nd order analysis

Constructed Code	**Properties (from peer-review literature)**	**Phrases taken from interviews**
Experiential learning	learning by doing; integrate new knowledge into past experiences; action research and action learning; shortens the distance between practice and theory; shift their focus from universal principles to site-specific applications; moving from an introspective focus to challenges that face society; learning be placed in a context; concrete situations in the field as the starting point for the learning process.	Focus on learner experience; learn by looking at things, identified own learning gaps; gain practical experience; exposed to different perspectives; student more engaged; chance to students to orient themselves; work in the field; more interactions; apply knowledge; move away from controlled environment.
Systems Learning	Perspective to deal with whole systems; emphasis away from individual units; integrates various aspects of food systems; whole network of ecological, social and cultural relationships.	all interrelated; these issues are complex; reflect complexity in assignments; use of open questions to guide journey; challenge students to take up different perspectives; adequate space for discussion; explore the whole supply chain.

Cases

University of Hohenheim (Hohenheim) – MSc in Organic Agriculture

The MSc in Organic Agriculture and Food Systems is a two-year program, running in its current form since 2008, with students currently numbering at around 40, from 18 different nationalities. The main objective of the program is to prepare experts with practical skills and knowledge on organic food system management, focusing on primary food production, food technology and quality control. The program includes interdisciplinary teaching/learning methods and offers an interaction between animal sciences, plant sciences, economics and engineering, as well as between academia and the employment sector. The program has been designed based on the premise that studying organic agriculture requires a holistic and practical approach. It has also been structured in a way which addresses the needs of the organic sector in Germany, based on feedback given by major employers in the initial phases of the program design. For this reason, there is a strong link to the practice, through regular interaction with stakeholders from the organic sector and through the mandatory action project which focuses on working on a real life project for an external client.

During the first year at Hohenheim, the compulsory modules cover many different aspects of Organic Agriculture and Food Systems from plant and animal production to food processing and socio-economic and socio-cultural aspects. There is a strong emphasis put on what is happening on the farm all the way to processing, and this is explored through discussion sessions, research seminars, real life case studies and excursions to organic farms, processing firms and food retailers.

Wageningen University and Research (WUR) - MSc in Organic Agriculture

The MSc in Organic Agriculture has been established in its current form since 2006, with the aim of incorporating a systems approach to both research and education. A major learning objective of the program is to prepare students for interdisciplinary teamwork in a wide variety of different settings, from academia, to the private and public sector. The program exposes around 85 international students per year to a wide range of aspects of organic agriculture and the wider food system, with a major focus on transitions towards a sustainability. Group work and real-life case studies foster an interdisciplinary approach, with a balance struck between social and natural sciences.

The study environment has an international character and makes use of case-studies and project opportunities in both the developed and developing world. The tight collaboration with various different chair groups (e.g. Farming Systems Ecology, Soil Biology and Rural Sociology group) offer students a diverse and multi-disciplinary learning environment. The design of the program offers the option to choose between an Agroecology (natural science) or Sustainable Food Systems (social science) specialization track.

ISARA-Lyon (ISARA) - MSc in Agroecology

The MSc in Agroecology program at ISARA-Lyon, running from 2010, aims to prepare students to address food system challenges by combining scientific knowledge with professional and practical experiences. The program is comprised of around 25 students per year, from international backgrounds. The curriculum also has an international focus, ranging from EU to tropical environments and covers a range of topics from agroecosystems functioning to consumer protection. The MSc has been designed to offer students a wide perspective of the food system, and to enable them to develop creative solutions for sustainable farming and marketing of organic products. It applies a multidisciplinary approach in which natural science is combined with social science and economics, with the aim of developing the ability to handle complexity and change. Within group projects, students are given autonomy to guide their own learning processes. Though the Agroecology faculty is small and does not offer a wide choice of research projects to work on, the opportunity to study at partner universities around the world is a key feature of the program as it allows students to specialize in a range of themes explored at other universities.

Norwegian University of Life Sciences (NMBU) - MSc in Agroecology

NMBU's MSc in Agroecology is a trans-disciplinary and student-oriented educational program that was established in 2008. Student groups range from around 20 students from international backgrounds. The goal of the program is to provide experiences that are useful to help students embrace complex realities. The learning environment has been designed around the Kolb cycle (1984) educational strategy, to incorporate experiential learning and on-farm learning and encourages students to become good communicators and facilitators, who can effectively connect theory to practice and contribute to future food systems including production, economy, environmental impacts, and social equity issues.

Though the program starts by looking into local food and farming systems, the scope of the program at NMBU is also very broad, with students being exposed to overarching themes such as Sustainable Production Systems, Global Food Security, Global Change Ecology and Restoration Ecology. Much like the program at ISARA-Lyon, the Agroecology faculty is relatively small, with limited research done within the university so students are encouraged to study at partner institutions. The program encourages the integration of theory and practice by focusing on action learning and action research related to agroecology and sustainable food systems. A main learning objective to prepare students for a wide range of positions related to multiple land use, organic agriculture and food networks.

Data Analysis

Curriculum Contents

The four programs showed similarities in the way they are structured. They use a fixed number of ECTS requirements, with various degrees of flexibility for students to tailor their own study program. Having a tailored and dynamic program allows students to have more control over their learning path and focus within the breadth of available topics (Bawden & Wals, 2000). After having completed the compulsory modules, the student can choose their elective modules from a range of available natural and social science disciplines. Then, they are required to narrow down their focus and deepen their expertise by carrying out a thesis and internship project in a particular field. This type of program structure is better suited to adapt to the evolving learning interests and needs of students, which can be fast-paced and unpredictable (Hilimire et al., 2014), and also allows students to change direction as novel courses arise out of the rapid technological and socioeconomic developments that are occurring in the agricultural and food sector (Meek & Talbau, 2016, Hill & McRae, 1998). An analysis of the curricula of all four cases has shown an expansion of the conventional agricultural curriculum to include themes that go a) beyond natural sciences to cover wider socioeconomic dimensions and b) include integrative themes where the focus of analysis becomes a system rather than a specific element or problem.

a) Beyond natural sciences

The thematic basis the of the four curricula consists of knowledge about the integration of soils, plants and livestock within a farming system. Students analyze interactions among these three key sub-compartments (WUR – "Integrated Natural Resource Management" course) and learn about different agroecological cropping practices and biological pest control management (ISARA – "Agroecological Cropping Practices" course). The natural science side of every program is complemented by themes and methods from the social sciences, which introduce a dimension of agriculture that is usually not included in conventional agriculture curricula. Students are invited to go deeper into an analysis of the agri-food system, to understand the motivations and politics around transitions to more sustainable systems (Hohenheim, 2017-18 Curriculum Document). They look specifically into the sociological, political and economic aspects of how and why individuals, groups, and industries make certain choices throughout the food system, including the areas of production, processing, trade and consumption. (NMBU course learning objectives). According to Altieri and Francis (1992) this move beyond ecological principles and practices of farming systems to emphasize the linkages between agronomic and sociological disciplines is seen as crucial for meeting the goals of agroecology education. The complement of qualitative research tools such as surveys and interview alongside descriptive statistics enables students to further develop their research skills and scope, understand the societal relevance of the topics under study and prepare them to move into their future employment (Leiblein et al., 2004). Alongside the incorporation of sociological methods and disciplines, a range of skills is developed in students, including presentation and group facilitation skills (ISARA), qualitative research techniques (WUR & NMBU) and feedback competences (Hohenheim). As a professor put it,

> "We focus on the skills, knowledge, attitudes, and capacity for future vision that will prepare students to become competent graduates who have multiple capabilities for

improving difficult situations. We place more emphasis on the development of students as creative and assimilative persons who can connect theory to practice." (Professor Interview, June 21st, 2018)

When asked about their future employment prospects, eight student and alumni responded with a range of directions including food policy and legislation, international development and research in both academia and development in the private sector. The same variety can also be found in the thesis project topics from every program (Appendix Table 4). This wide range of career interests and the diversity in backgrounds is reflected in the range of themes and skills included in the compulsory courses of every program (see Table 4).

Table 3. *Distinction between course themes and skills focused with a primary production focus, or a wider food system-focus. The production-focused modules' perspective spans from farm to landscape, whereas the food system-focused courses go beyond the farm gate and spans the wider supply chain and food system.*

	Production-focus	**Food System-focus**
Themes	Principles of Organic Food Systems	Markets & Marketing of Quality Food
	Organic Livestock Farming & Production	Social Transformations for Sustainable Food Systems
	Integrated Natural Resource Management	Agroecosystem policies and nature conservation
	Agroecological cropping practices	Action learning in farming and food systems
	Biological Interactions in the Soil	Economics & Environmental Policy
	Organic Livestock Farming & Production	Food Safety and Quality Chains
	Organic Plant Production	Food Security & Rural Development
	Agroecosystem Management	International Food & Agricultural Trade
	Agroforestry in Tropical Climates	Academic & Professional Skills Training
Skills	Soil sampling & nutrient analyses	Interpreting food legislation and regulations
	Nutrient & energy flows	Community engagement and outreach
	Sowing & transplanting	Project management & facilitation
	Crop identification & planning	Qualitative research methods
	Farm systems design & modelling	Negotiation & presentation skills

a) Use of integrative themes

In the courses "Integrative Natural Resource Management" (WUR) and "Agriculture & Landscape Management" (ISARA), students learn to take a whole farming system as the focus of analysis. This requires studying larger units than individual crops or crop yields and invites an understanding of how different biophysical elements on the farm relate to each other (e.g. through drawing nutrient cycles and energy flows) and also how farm management decisions are linked to the wider socio-economic factors within a specific context. By choosing broad themes and highlighting the relations between them within one course helps students understand that the challenges of our current agricultural paradigm are both interrelated and far wider than merely technical problems (Altieri & Francis, 1992).

Other courses taken from these four programs include relationships between farming systems and society, applications of farm system modelling tools and their role in rural development and designing multi-stakeholder strategies for more sustainable food production systems. These courses include, for example, looking at policy implications, mapping out power relations and understanding the mechanisms and impacts of subsidy schemes, analyzing the role indigenous knowledge or farmer experience and how it can be used alongside technological innovations in novel food production systems. Using this "larger frame of reference" in sustainable agriculture programs helps learners "acquire a broader vocabulary and appreciation of a wider range of information resources that help them understand the linkages among components and the total complexity of agricultural systems" (Altieri & Francis, 1992). These interlinkages are made possible through connecting a range of curriculum components which makes use of multiple disciplines, skills and approaches (Figure 1).

Synthesis of Curriculum Component Interrelations

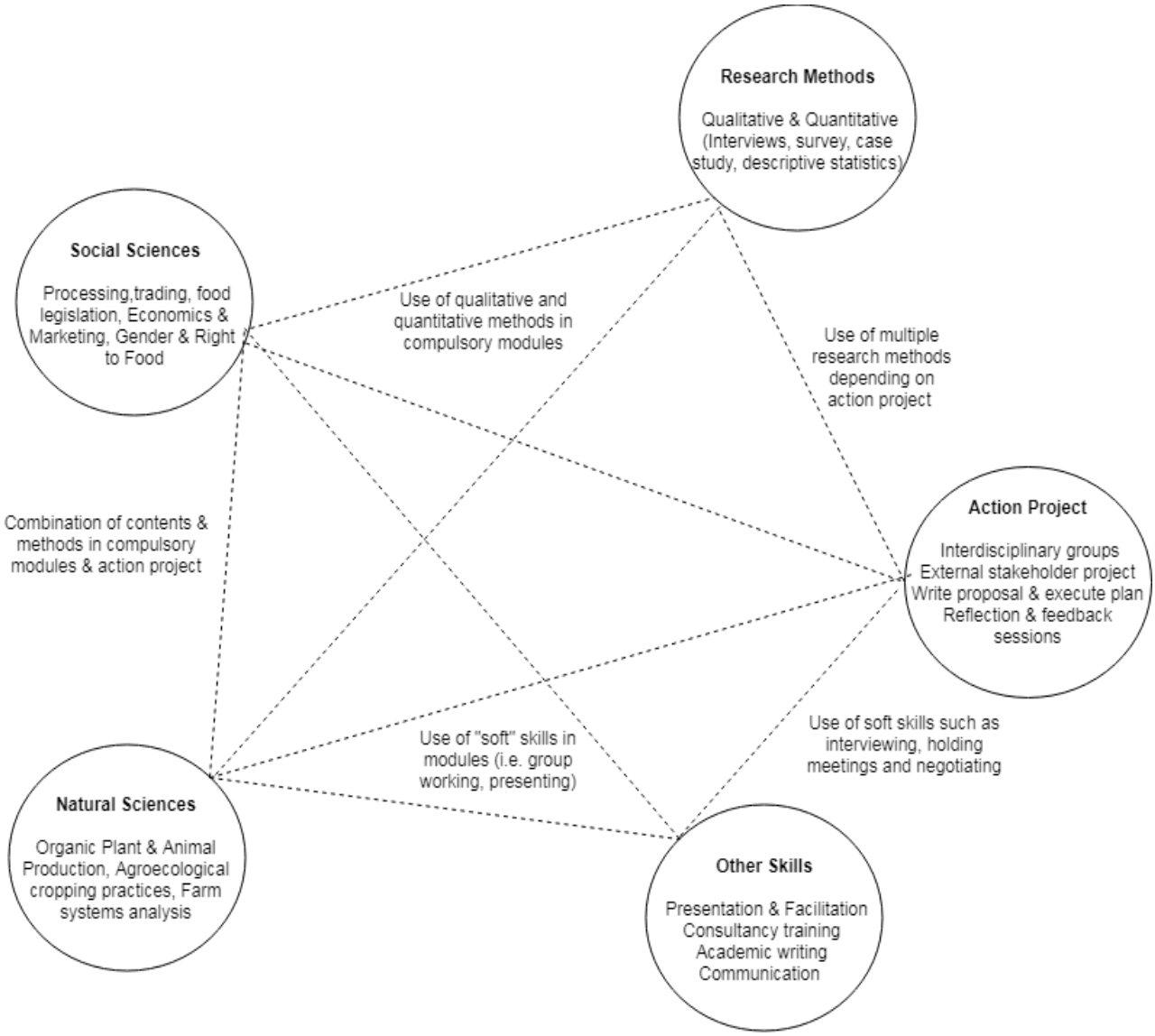


Fig. 1. *A breakdown of the relationships between compulsory components taken from the compulsory modules of all four MSc programs.* ***Social Science & Natural Science:*** *themes and research methods from both disciplines used in courses and interdisciplinary group projects.* ***Action Project:*** *includes interdisciplinary knowledge and research methods from natural and social sciences and "soft skills" taught in skills training modules.* ***Other Skills****: are taught through professional skills trainings, course assignments and group projects where students practice employability and academic skills.*

Pedagogical Approaches

Experiential learning

All four programs coordinators and teaching staff mentioned the use of concrete experiences in the field as the starting point for the learning process; in fact, experiential learning is found to be the cornerstone of sustainable agriculture education university programs (Ostergaard et al. 2010; Parr & Trexler, 2011). Designed to create contact with practitioners and thus help students link theory to practice (Parr & Trexler, 2011), these experiences take place in various points across the food system, from farms to packaging and distribution centers and from retailers to food regulatory bodies. For example, at WUR this is done by going on self-guided excursions and exploring local food- and farm-scapes which allows students to analyze the local food system and the relationships between different actors in the foodscape. Upon returning, students reflect and share their experiences to their classmates and teachers in facilitated discussions. By being involved in these meaningful learning experiences, learners move closer to the real world challenges that they will be confronted with as professionals in the agri-food sector (Leiblein et al., 2004).

> We consider experiential learning to be vital for enabling students to acquire the competencies needed for them to constructively be able to support a sustainable development of farming and food systems. A learning process based on experiences allows students to observe, act and interact (Migliorini & Lieblein., 2016).

In ISARA-Lyon, student groups start off with a one-week excursion to a specific region where they get a chance to interview different actors to understand the various agricultural, economic and environmental constraints and potentials of that agroecosystem. According to these learning approaches break down the false separation between school and community learning spaces (Meek& Talbau, 2016) and allow the inclusion of 'different' forms of knowledge (e.g. farmer knowledge and experiences), to enter into classroom (Lieblein & Francis, 2007).

At NMBU, students are also grouped from the outset and are given a project where they need to go out of the classroom and explore an existing farming system to understand how it fits within the local food system and the surrounding landscape. Where off-campus experiences are not feasible, experiential learning also takes place through bringing practitioners inside the classroom to share examples from practice, as well as through visiting or maintaining student farms as a way to develop practical skills.

> "The experience of going out into the field was most fun and where I learned the most. It helped me calibrate … to realize what I need to learn next, what my learning gaps are and what I need to do to fill them. Immediately after being on the field, I started making connections: this farmer wants to improve soil fertility and he has sheep and a barn. So, I need to know more about nutrient cycling!" (Alumni from NMBU, May 27th, 2018).

The experiential approach is meant to encourage students to take initiative and "shape their own learning path" (Waldenstrom et al., 2008). In fact, this is the guiding principle of the MSc in

Agroecology program at NMBU, where the teaching staff aims to "change focus from the subject to the experience of the learner" (Professor Interview, June 21st, 2018), by focusing on teaching/learning through the immediate experience in excursions, group projects and interactions with different stakeholders. At ISARA-Lyon, this is done through designing individual and group assignments in collaboration with farmers and other food system professionals, which allows students to develop more technical competences.

The action project at Hohenheim and WUR is also designed with external stakeholders to shorten the distance between theory and practice. Clients from the agri-food sector submit a project, such as developing a bee-friendly agroforestry farm in the Netherlands or testing consumer perceptions on a particular meat substitute. Groups of students, now acting as consultants, then go through the various stages, from writing a proposal to carrying out stakeholder interviews and research all the way to presenting the final results to the client. The purpose of this exercise is for students to gain practical experience from the beginning by being exposed to different ways of working. Reflecting on this type of exercise in a sustainable agriculture postgraduate program, Lieblein et al. (2008) found that by engaging in complex situations that did not have ready-made answers, this broadened students' perspectives and "fostered real-world relevance". Feedback from both teaching staff and students highlights that students become more engaged while developing their group-working skills and other employability skills.

> For many students, it is the first time they experience writing a structured report, and this provides good practice for the thesis and internship phase (Professor Interview, May 25th, 2018).

All programs mentioned that an integral part of the program is taking students on an excursion at different moments throughout the course. This is good for students who never had an experience on a farm before as it offers a real-life perspective of the different practices in different sectors of the food system (Wageningen). At ISARA, excursions allow students to experience the wider food system and interact with various actors in the agro-food system, e.g. farmers, policy-makers, producers, retailers, etc. Student feedback from Hohenheim (taken from 29th May, 2018) mentions that while excursions are very valuable experiences, they should somehow offer a more interactive and participatory way of dealing and learning from each other.

> The excursions are limiting because farmers share knowledge and students receive. I would prefer if it was a closer connection […] not just one day but visiting for a longer period and working together on a problem so that we can really experience these real life situations. (Student from Hohenheim, May 29th, 2018)

An interview from NMBU stated that "a single visit to a farm is never a complete example of reality". Excursions on the Agroecology program are often completed by students working on farm for one whole day, in order to get a better understanding of the reality of the farmers and to thus be able to come up with more realistic solutions to their challenges. Reflecting on this experience, an alumna shared that

> When you go on an excursion and speak to people there, then it's not just an excursion anymore! When you have interviewed them and had a few more interactions then it becomes a more practical application. This made the learning more concrete and prepared me better when doing applied work during the internship phase.

By both acting and reflecting on their actions, learners are thus able to assimilate the new knowledge and experiences and thus start to impact upon the world around them (Tassone, 2018).

Interdisciplinary and Systems Approach

Creating an interdisciplinary learning environment based on a systems approach is almost a natural outcome, when complex food systems issues are dealt with. This type of learning requires the object of analysis to be a system rather than isolated components (Hilimire et al., 2014) and emphasizes the integration of different disciplines and practices into the learning process. Recent literature shows that this approach is one of the founding principles of sustainability-oriented agricultural education (Parr et al., 2007), as it offers a way to analyze modern multi-dimensional food system challenges and develops in students the ability to solve whole system problems (Salomonsson et al., 2009). As a member of both the teaching and coordination staff of one of the MSc programs mentions,

> With a topic as broad as Organic Agriculture, it's almost impossible to divide it into small parts and study it only from one perspective - it's all interrelated – we cannot separate soils science from food policy. The nature of the topic lends itself to a systems approach" (Coordinator Interview, 21st May, 2018).

In all four programs, the linear 'food chain' metaphor is abandoned for one that emphasizes the whole network of ecological and sociocultural linkages, to offer a systems perspective from production to processing to market. For example, on the 'Organic Agriculture and Society' course at WUR, instead of dividing content into the classical disciplines, both lectures and learning activities are designed around open questions such as

> Which food do we need, grown by whom and where? What kind of sustainability do we want? How can we close cycles in agriculture? How can manage and govern regional and global food systems? How can we turn knowledge into action? (taken from 2018 Course Documents)

Further, these open questions are complemented by exercises such as bridging the "Think-Do Gap" (WUR) and "Rich Picturing" (NMBU), which allow groups of learners to imagine "ideal" scenarios come up with the incremental actions needed to get from the current reality to the imagined one. Interviews from ISARA-Lyon mention that posing these types of open questions to students such as "What is a truly agroecological farm?", and encouraging them to design new farming scenarios around "How can such a farming system be realized?", motivates them to integrate knowledge and action, and to come up with original answers. Throughout the process,

they become better able to combine, for example, specific agronomic practices with wider landscape management tools as well as existing policy structures (Coordinator Interview). According to Sriskandarajah et al. (2010), the use of open questions leads to enhanced reflexivity and moves the learning process beyond merely raising awareness to making connections between theory and real world applications.

> This offers absolutely essential preparation for students because it's how it is outside of university - none of these things happen in isolation. If we focused on management practices without looking at how the EU policies affect management practices, that would be an ineffective way to prepare students. It is important to see it from a systems perspective […] because these issues are complex. (Coordinator Interview, June 2nd, 2018)

Another example of bringing this approach into the learning environment is by designing group assignments around real-life case studies. This allows for students to apply theoretical learning to practical challenges and to place a single case or practice within its wider context (Salomonsson et al., 2009). By examining the power relations surrounding a seed bank project in Germany, students could gain a better understanding of how the structural and economic dimensions related to the wider issues of small-holder farmer autonomy and food sovereignty in the region. Within the group work, every student could bring their own contribution depending on their cultural and professional background. An alumna of the MSc in Agroecology mentioned that "the case study projects worked well because it allowed us to apply knowledge and concepts from different disciplines … and forced us to come up with more realistic solutions to the challenges we were looking at" (ISARA Alumna Interview, June 5th, 2018). According to Meek and Talbau (2016) this approach provides an opportunity to learners to "connect interdisciplinary knowledge to transformative systems changes".

Exposure First

Through exposing students to a breadth of themes and experiences around the food and farming system, exposure to complexity comes first and this encourages curiosity and motivates students to learn specific skills and theories for problem-solving (Hilimire et al., 2014, Lieblein & Francis, 2007). Students in all four postgraduate programs are exposed to different themes from the very beginning (production, processing, consumption, etc.), through both formal lectures or excursions, and interact with different stakeholders (farmers, policy-makers, producers, etc.) inside and outside the classroom. Initial discussions and group work projects are often designed to be agile for students to be able to bring in the richness of their own knowledge and experiences. For example, one course started with an interactive session where teachers brought in a grocery bag with supermarket products as a starting point for a discussion. Through the facilitated interactions that arose, students shared their own perspectives and experiences around these foods and various food system practices and philosophies were touched upon. The stories and experiences shared came with a diversity of values and perspectives as well as technical knowledge about different domains in the agri-food system. This approach has been described by Meek and Talbau (2016) as "attempting to foster student's systemic awareness grounded in their own experience". Further,

this type of 'icebreaker' activity early on in the course served to bring the group together and facilitate better listening and discussions which opens learners up to the collaborative co-creation of ideas and possible solutions (Sriskandarajah et al., 2010).

The introductory courses of all four programs encourage students to appreciate multiple perspectives through being confronted with common situations and analyzing the different relationships or "systems of interest". Through group projects focused on real-life case studies, students start to integrate different perspectives and disciplines very early on in the program. This encourages them to develop skills in systems thinking (Sriskandarajah et al., 2010) as they learn to recognize and analyze the interconnections between different scenarios. Supporting literature mentions that the exposure-first approach allows learners to develop their own questions and hypotheses, and this is a powerful way to support student engagement and investment in their learning (Lieblein & Francis, 2007). Further, it has been found that adults with very different learning styles all thrive on practical examples and hands-on experiences (Kolb, 1984).

A recent alumna of the MSc in Hohenheim stated that starting with this generalist approach to the subject "helped me figure out what am I interested in and what I want to focus on in later in my program". This learning approach closely resembles the T-shape approach, where different disciplines are connected horizontally in order to look at the subject from a wide perspective, and then deepened (vertically) into the core subjects each students wants to focus on.

> The idea is that students get the basics of the natural science topics and basics of social science topics within the first block of their studies. We do this to make sure that the group is on the same page – that they all have basic level of information on all the different topics and that they understand what the breadth of the topics are within the scope of the program. (Coordinator Interview, May 24th, 2018))

Then, once students have experienced different topics within the natural and social sciences, they are better able to decide which direction they want to follow. A current MSc in Organic Agriculture student mentioned that it was really helpful to understand whether to choose a natural science or social science path for their thesis and internship. Another student mentioned that it helped narrow down their focus when searching for future employers. A program coordinator involved in designing the initial program mentioned that the broad exposure approach prepares students to look at the agri-food system from very different perspectives, which is preferred by employers.

> The organic industry needs people with an understanding of how plants grow, what restrictions farmers have in their daily life as well as an understanding of the economic framework they are working in. We can only get this when we start with a broad approach in the modules. (Professor Interview, June 9th, 2018)

Cooperative group learning

Interviews from all four programs express that working in interdisciplinary groups is vital to the teaching and learning process as it prepares students for later in their career, where they are likely to be working with professionals from a wide range of backgrounds. Parr and Trexler (2011) find peer-to-peer learning to be a crucial element in food systems programs, an approach that can stimulate creative thinking and problem-solving. At NMBU, students work in groups for the length of the whole semester. The learning objective is to work with a farmer or external stakeholder with the aim of contributing to the improvement of the present situation on the farm, in a food-systems perspective. This is carried out in groups based on the premise that knowledge is created through this exchange of skills and expertise within learning teams (Francis et al., 2001). Group projects at ISARA and Hohenheim are also designed to guide students through an active learning process where they are usually exposed to a variety of sustainability challenges (i.e. sustainable production and intensification, agroecology, societal equity and power imbalances) where they need understand their inherent complexity and explore possible alternatives. This process encourages communication between learners. Each student in the group is encouraged to personalize the knowledge gained during the learning process and take a position within the group on their own ideas for sustainable solutions.

> By sharing, in dialogue with others [...] students can become part of a highly productive and rewarding process. The student can learn from others, can challenge what he or she hears, can reconsider his or her own knowledge and insights and, in case, can adopt new ways of viewing certain issues. Together, these steps can yield interesting discoveries and can serve as a transformative process. (Tassone et al., 2018)

Alumna feedback from the MSc in Agroecology at NMBU states that "this process was good when could use diversity in the group - e.g. someone spoke the language of farmers or had experience in a specific practice, and was hard when different group members had different ideas, visions or learning styles" (May 23rd, 2018). Given that there is enough social cohesion in the group (Wals & Jickling., 2002), a type of "formal social learning" (Wals, 2007) can occur that comes through this mirroring of perspectives, values and ideas with others in the group which can act as a catalyst for learning (Sriskandarajah, 2010). It has been found that the group learning approach allows a much deeper engagement with the case than if students were working individually (Hilimire et al., 2014). Feedback from teaching staff who have been implementing this approach mention that the group project approach can be intense as

> [...] the role of the teacher becomes more of a facilitator or a coach. Since there are no straightforward answers, it can be scary for students because they don't know how to approach the group work. For a teacher, group projects then become more like guiding a learning journey rather than setting a clear assignment. (Professor Interview, June 2nd, 2018)

According to Ison (1990) and Hilimire et al. (2014), when instructors act more as facilitators participatory group processes, traditional academic boundaries tend to blur and this helps students, teachers and external practitioners to become part of a wider community of learners. According

to survey data, this process allows for a deeper participation for both educators and students through the application and sharing of diverse knowledge, experiences and perspectives (Table 5).

Table 4. Comparison of recommendations proposed by Francis et al. (2001), and Hilimire et al. (2014) and suggested practices from academics' and students' survey.

	Francis & Hilimire	Survey Direct Quotes
Experiential Learning	Learning must be placed in a context, responsive to student's needs and relevant to real-life situations. By exposing students to practical contexts they learn by doing; integrate new knowledge into past experiences; Experiential learning shortens the distance between practice and theory; shift their focus from universal principles to site-specific applications; moving from an introspective focus to challenges that face society;	Focus on learner experience; students learn by looking at things and identify own learning gaps; go on excursions and work with farmers; by being exposed to different perspectives student become more engaged; gives a chance to students to orient themselves in the program; Bring lectures outside the classroom; learning through role play and interactive sessions; flipped classroom activities; apply knowledge through real-life case studies.
Interdisciplinary approach	Sustainable agriculture education requires an emphasis on systems as opposed to individual disciplines. Dealing with complex challenges and will enhance the integration of different disciplines. A shift is needed from narrow to systems questions that emphasize the whole network of ecological, economic and sociocultural linkages, from production to processing and from markets to consumers.	use of open questions to guide discussions; interdisciplinary group work and case studies that link ecological, economic and sociocultural aspects with natural sciences; incorporate group assignments that require a multi-disciplinary approach; use open questions that reflect complexity and guide journey; challenge students to take up different approaches & perspectives;
Exposure First	To learn how to deal with such complex and dynamic issues, students need to start from immediate conversations and experiences and connects students to what they already know. It is important to take sustainable agriculture education outside the classroom and into the agroecosystem where students can learn from interacting and applying their knowledge.	start with excursions to explore landscape from multiple perspectives; immediate exposure to food and farming systems; engage with stakeholders from the beginning; start by exploring local food- and farm-scapes; expose students to a breadth of themes and topics to allow them to orient themselves; start by providing an overview of all the different modules and themes.
Group Learning	When students work in groups, they shift their focus from universal principles to site-specific applications. This allows for deeper participation and exposure to different ideas and communication styles. Group work can encourage development of creative thinking and problem-solving skills.	Group project on farm design; performing SWOT analyses and group presentations; group assignments based on real-life case studies and peer-review sessions; students see concepts in application and share their diverse knowledge and perspectives; allows students to bring in a diversity of ideas and take initiative for their group project.

Discussion

The analysis above shows that the themes currently included in sustainable agriculture curricula go beyond primary production and the natural sciences, to include methods from the social sciences as well as trainings for the development of other professional skills and competencies. A unique feature of these programs is that they manage to integrate issues of food production, climate change, social justice and gender and aim for the development of very diverse sets of skills in students; which is quite ambitious for a postgraduate program. The pedagogical approaches highlighted include innovative approaches designed to capture the complexity of current challenges and prepare students to potentially transform future agri-food systems, which also match with educational strategies suggested in literature (Hilimire et al., 2014, Lieblein et al., 2007, Wals 2001). The learning that takes place thus goes beyond the scope of the contents and the pedagogical activities, as reflected in the student comment below

> It is only appropriate that a course tackling the complexities of sustainable agriculture would be inherently complex itself. For the past two months I have been learning more about my interests, skills, motivations, and myself, than I ever expected from a course with "agriculture" in the title. However, it makes perfect sense. Sustainability of the agroecosystem encompasses the whole organism, looking at the farm as the complex living being it is. (NMBU student feedback, from Migliorini & Lieblein, 2016)

According to these case studies, this broader and more integrated curriculum has been designed to make learners more aware of the complexities of agriculture and the wider food system, as well as more open to different perspectives and systemic approaches. This is consistent with recent literature on what to include in sustainable agriculture curricula (Hilimire et al., 2014, Parr et al., 2007, Altieri & Francis 1992). Both practitioner interviews and student feedback indicate that the capacities that students often develop are associated with second-order changes (Sriskandarajah et al., 2010) such as learning about their own learning system, learning about different worldviews and reflecting on their own ways of being and acting in the world (Ison et al., 2007). This "meta-learning" is what transforms students' way of perceiving the world around them and acting in more responsible ways within it (Sriskandarajah et al., 2010, Wals et al., 2001).

This accessing of higher degrees of learning is something shared with Education for Sustainable Development, where the topic of sustainability opens up the curriculum to the inclusion of complex societal issues. Further, it caters for widening the content scope and developing skills for action and reflection (Wals et al., 2001). Instead of teaching students what they should do, these programs provide the tools to analyze current challenges by asking critical questions, co-create possible solutions, act autonomously and reflect on their action. This type of education focuses on capacity building that will allow students as more reflexive professionals and citizens to understand what is going on in their environment and determine for themselves what needs to be done (Wals & Jickling, 2002). As a program coordinator mentioned, "We are exposing students to deeper learning and equipping students with tools to respond to complex changing environments" (June 5th, 2018). This access to deeper levels of learning is a profound change of epistemology that is crucial (Ison, 1990) since the potential of sustainable agriculture depends on a learning system that is able to bring about a change of attitude and reflective action. Therefore, sustainability within

the agricultural curriculum becomes more than simply an add-on to the curriculum but brings about a change in student ethos and praxis. These signs of deeper learning (Sriskandarajah, 2010) are reflected in the table below:

Table 5. A summary taken from fifteen interviews on the effect of these programs on student learning. Professors and program coordinators gave their thoughts based on formal feedback from students and their observations of student development. Students and alumna shared their reflections from their own experience. This table was cross-checked with nine current MSc in Organic Agriculture at Wageningen students for reliability.

	Ontological (realities)	**Axiological (values)**	**Epistemological (ways of knowing)**
Exposure first	Direct experience, on-farm experiences, Exposed to reality of farmers & other stakeholders including policy-makers & retailers	Exposure to different worldviews, ideologies & ways of being	Questioning own worldviews and ways of being; knowing different stakeholders' positions and motivations
Interdisciplinary & systems learning	Work with complex bio-physical and sociocultural aspects; Take in and apply information from different disciplines	Exploring food & farm connections from different perspectives, including cultural, ethical and socio-economic	Learn to look at issues through multiple perspectives, Learn for creating systemic solutions; including different ways of learning.
Experiential Learning	Learning happening outside the classroom, Studying issues to design solutions, Working on projects with real stakeholders (farmers, external companies, etc.)	Going beyond merely observing to being involved in real-world challenges	Learning by doing, Learn to reflect and improve on action, Develop competence for purposeful action Learn to imagine new scenarios and create actionable steps towards them
Group learning	Working with group of people from diverse cultural and professional backgrounds	Direct confrontation with other ways of being & working, mirroring ideas & experiences	Learning about collaborating in group processes, valuing different ideas and ways of working

To continue to develop these kinds of capacities in students and create programs which embody sustainability in the curriculum, it is clear that learning cannot be limited to the classroom or to one-way transfers of disciplinary knowledge. Rather, it requires a "hybridity and synergy between various between multiple actors in society [...] and an increased permeability among units, disciplines, generations, cultures, institutions and sectors" (Wals et al, 2001). The four programs analyzed in this case study show an advancement from first-level learning, which is non-critical, non-reflexive and perpetuates more of the same way of being which keeps the system in place, to second-level learning which steps outside the usual frame of reference and requires new meaning making and allows values, beliefs and paradigms to be critically examined (Sterling, 2001). From speaking to professors and program coordinators, it became clear that the motivation to design a learning environment that will encourage learners to explore their own competences, values and perspectives was born out of their own experience and worldview. Though these programs are well-established in their respective institutions, they are often a minority in their vision and

approach to education, detached from most of the other faculties and from ample institutional support. This may mean that student development and potential transformations that occur within these programs may encounter resistance from a wider system that remains unchanged, thus change being held in place (Sterling, 2011). Rather than a change of paradigm, these innovative programs may just end up tinkering with existing boundaries.

A third-level type of learning may also be possible, one that facilitates an understanding and a reconstruction of paradigm. This engages and involves the whole person (Meek and Talbau, 2016) and requires whole system re-design, deep, conscious reflection and a paradigmatic reordering which can only happen in education if it involves society as a whole – that is, changes in culture that would create a "pull" for education. This type of learning may be achievable, as Sterling (2001) suggests, but would call for a whole system shift by changing paradigm, purpose, policy and practice. This is however beyond the scope of this research. The type of learning approaches highlighted in this study may act as a stepping stone towards this participatory and transformative educational paradigm, and sustainability-oriented agricultural education as it is practiced in Europe can provide an example for that. With the majority of higher education agriculture programs currently continuing the lowest-level learning, if we are to face the challenges of our time, we need to build the momentum that will, at the very least, *begin* the process towards the kind of 'transformative learning' highlighted from these programs. The examples outlined in the previous sections as well as the table of recommendations in the next section can provide a starting point for this transition.

Recommendations

Everyone a teacher, everyone a learner

"It is a myth to think that there is a single right vision or a best way to sustain the earth or what kind of earth should be sustained" (Wals et al., 2001). As previously discussed, education can move away from teaching the right answers to being a means to develop self-actualized members of society who tap into their own potential and jointly create solutions. To this effect, this section puts forward suggestions and recommendations (Table 7) shared by practitioners of sustainability-oriented agricultural education, with the hope of building momentum towards this new educational paradigm.

> "It is not just about what you want students to learn but also about how you want students to go through the process of learning it. We do not want students to leave the class feeling like they have the answers. We want them to have an idea of where and how they can find the answers, and to be able to keep asking questions and think critically about sustainability in a wider context." (Professor Interview, June 2nd, 2018)

This requires educators to go from system of control, such as lectures and structured discussions in class, to a system where teachers don't always know what's going to happen or how students will respond, as happens during experience- and discovery-based learning. To this effect, one course coordinator shared:

> "Don't be afraid to leave your comfort zone as a professor. Apply the systems approach. Learn from students. Provide them the space where they can tell other students about their own experience and reflect - students can learn quite a lot from each other. Have a lot of group-work without neglecting individual work." (Professor Interview, June 21st, 2018)

But the burden is not all on teachers and coordinators. To make the most out of the program, students "must enjoy to design things, to try to find solutions to complex problems, to discover solutions to modern challenges." (Coordinator Interview, June 5th, 2018). According to student interviewees, this requires a combination of good academic competences, good communication skills and entrepreneurial skills. Students need to be prepared to interact with the environment around them, to take responsibility for their work and challenge their own beliefs and perspectives.

> When students are encouraged to examine their attitudes towards the subject matter and how new information and skills can be applied to real-world situations, they can become enthusiastic and even passionate about the topic and are able to translate their visions into action (Sriskandarajah et al., 2010).

Table 6. Recommendations for future sustainability-oriented agriculture programs as shared during interviews with practitioners, students and alumni from the four postgraduate programs.

Maintain links to practice & the employment sector.	Helps students connect theory to practice and develop valuable skills through field work, excursions & case studies. Motivates action and capacity building. Action projects with external companies and research projects help students. understand how their skills knowledge can be applied in real-life.
Use diversity in cultures and backgrounds in the classroom.	Allows students to tap into the knowledge and experiences of others. Create spaces for sharing during lectures, discussions, group work and excursions. This can help develop communication and other soft skills that support students in their paths after graduation.
Take a systems approach to education and research.	Emphasize the relationships between agriculture, society and the environment. Allows students to be flexible and open up to different approaches. This helps them to train in different fields and ways of thinking/working.
Offer a diversity of examination methods.	Varying examination tools through a combination of written exams, oral exams, assignments and group work projects can be beneficial for students with different competencies and keeps students more engaged.
Fixed curriculum, flexible program.	Offers students a fixed framework with compulsory modules and fixed requirements, but with a lot of flexibility for to personalize their learning path. This can prepare students to become independent and self-motivated learners.
Be a Teacher-Facilitator.	Teachers should guide students to bring their own input and ideas into the process. The limited part should be the traditional 'knowledge transfer'. The bigger part should be the co-creation of knowledge and development of skills.
Develop independent learners	Students need to be encouraged through agile assignments to interact with different people and the environment around them, to work in teams and to challenge their own beliefs and perspectives.
Exposure to global & local perspective	Introduce the main themes of every course in the context of global challenges while developing problem solving tools aimed at both the global and local level.
Facilitate participatory & reflective learning environments	Encourage students to build on their own experience through participatory learning. Action projects bring together students from different backgrounds and develops diverse knowledge and skills. Actively create space for reflection and discussion within courses for students to digest new knowledge and experiences, e.g. through short group presentations after excursions, individual and group reflection assignments, etc.
Listen to student feedback	Collect and apply student feedback as this helps in the further development and effectiveness of the program. Keep a flexible curriculum to allow for continuous changes depending on feedback.

Conclusion

This overview of current educational practice highlights a range of progressive teaching and learning approaches which match with suggestions from current literature on sustainability-oriented agricultural curricula. These include broadening the content scope from primary production to the wider food system as well as an integration of research methods and learning objectives from both the social and natural sciences. Within these progressive learning environments, learning is shifted from the subject to the learner with the aim of developing their capacity for critical thinking, collaborating and turning theory into action. Though a brief epistemological analysis shows signs of deeper learning in students (Table 6), more research is needed to examine how these educational environments influence learning and whether they are adequately preparing students to respond to the challenges of our current agricultural and food systems. This research can offer a starting point for such further analyses. Further questions that come out of this study include: Are these sustainability-oriented agricultural programs delivering what they promise to in their program or institutional mission? Are the chosen educational strategies appreciated by students? Are these programs supported at the institutional or societal level or do they operate within the margins? Where do graduates end up and how are they contributing to the movement against the current unsustainable agricultural paradigm and towards a more ecological and inclusive alternative? To answer these questions, it is essential to confront the 'traditional' educational system from a post-modern perspective.

To end, we are currently at a crossroads in higher education. We can either choose to keep the same systems running by producing more of the same ways of thinking and interacting with the world, or we can co-create educational environments that work towards deeper learning and a fundamental reorientation of our current paradigm. May this work be met as a step towards the latter.

Limitations

Some considerations need to be taken into account when interpreting the findings and recommendations that arise of this case study:

a)Reliability and validity were substituted for "dependability" and "authenticity" according to the framework set forth by Lincoln and Guba (1985) for credibility in qualitative research. Thus, the following questions were considered:

> **- Can data sources be trusted?** Both professors and coordinators who took part in this study expressed a deep investment in their own programs and in their motivation to improve the field sustainability-oriented agricultural education.
> **- Has there been sufficient engagement with data sources?** There has been engagement with a sufficient number and variety of informants, but not through prolonged interactions. Spending more time on every case would allow a deeper immersion in its issues and opportunities.
> **- Has there been sufficient triangulation of raw data leading to analytical statements?** This was addressed by triangulating data from interviews, curriculum and course documents as well as the researcher's own observations in order to validate statements made. Further, throughout this research, evaluative or descriptive statements were supported by specific examples or by quotes from raw data.
> **- Has a critical friend challenged the outcomes of these findings?** Two reviewers (thesis supervisors) and a critical friend were asked to give feedback and to question the research processes and outcomes.
> **- Is the account of the research sufficiently detailed to give the reader confidence in the findings?** A well-documented audit trail has been created during the data collection and analysis phase. Comparing findings from academic literature to quotes from raw data also aimed to bring credibility to the results.

b) Bringing in personal bias into the research is inevitable when interpreting data for qualitative research (Yin, 2009). The research thus cannot claim external validity, since the type of analysis carried out required a subjective interpretation of events. One factor which may have influenced the study's overall validity is the reactivity of the researcher with the providers of information. Conducting face to face interviews may have influenced the data collection through the researcher's own affinity with certain kinds of people, ideas and settings. This is also holds true for the data analysis phase where the researcher's personal qualities, views and interests may have seeped into the data collection itself. An improvement could be to have a third-party validate interview transcriptions and to confirm transcriptions as well constructed codes with the original interviewees.

3) The availability of sources and kinds of data may also have influenced the findings of this research. The researcher only accessed a number of limited curriculum documents, depending on what teaching staff were willing to share. Thus data was taken from what was available, excluding everything else. It is also acknowledged that a single interview cannot be a complete representation of reality. There are probably many important aspects on which data was not collected on. Interviews may have only captured part of the complete picture; a semi-structured approach was

used however to allow room for spontaneous conversation and for information to arise that was not planned. Lastly, this research only took into account examples from Europe and so it would be useful to expand its geographical reach so as to enrich the understanding of educational practice in sustainable agriculture higher education programs worldwide.

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Appendix

Appendix Table 1. List of Interview Questions

What does the program look like?	What is the structure of the program? What is the distinct focus/characteristic of the program? Does it belong to a distinct department? What is the size of program in relation to University? Does it have tracks & specializations? Fixed or compulsory courses? Does it require a thesis? Is the study connected to other studies in the university? Does it connect to outside stakeholders? Backgrounds/destinations of students? Data on student admissions/graduates? What are the students prepared for? What is the vision of the program? What is the predecessor? How was it created? What is the mission of the university/program? How does this program fit? What are the learning objectives of the program? What are the learning outcomes?
What is taught?	When was the curriculum established? What is the core of every program (i.e. compulsory modules)? What are the themes and issues dealt with in the curriculum? What is the rationale behind the chosen themes? What are the skills and abilities aimed for/developed in students? What are some other skills that students can develop? What do you perceive as the impact of these contents on student learning? What are some recent thesis topics?
How is it taught?	What are specific teaching and learning strategies used in the program? Go into specific course: How is the learning environment? Practical/Theoretical examples? What is the role of the teacher? What are some best practices? What do students learn from the process, from your perspective/ student feedback? How are the professors trained? (Organic or Conventional?) For every teaching method: can you share one specific example?
Open questions	What can we learn from each other moving forward? What is one best practice and what was the effect of it on the learning environment? What is one challenge and how can we improve it? What are some challenges experiencing? What do you imagine for future food programs? How can we achieve this? What is 1 piece of advice you have for future students and educators of sustainable agriculture

Appendix Table 2. List of available Sustainable Agriculture Master programs in Europe (taken from Wezel et al., 2018).

Level	Name	Universities and Institutions	Language
Master	Agroecology and Food Security (from Sept. 2018 onwards Agroecology, Water and Food Sovereignty)	University of Coventry (UK)	English
Master	European Master of Agroecology (double degree)	ISARA, Lyon (France), Norwegian University of Life Science, NMBU (Norway),	English
Master	Agroecology—Organic Agriculture (double degree)	ISARA, Lyon (France), Wageningen University (The Netherlands),	English
Master	Agroecology	Norwegian University of Life Science, NMBU, Aas (Norway)	English
Master	Organic Agriculture	Wageningen University (The Netherlands)	English
Master	Organic Agriculture and Food Systems (double degree)	Aarhus University (Denmark), University of Hohenheim (Germany), BOKU (Austria), Warsaw University (Poland), ISARA, Lyon (France)	English
Master	Sustainable International Agriculture	University of Kassel-Witzenhausen (Germany) and University of Göttingen (Germany)	English
Master	Agroecology	Swedish University of Agricultural Sciences (Sweden)	English
Master	Agroecology	Harper Adams University (United Kingdom)	English
Master	Master Interuniversitaire en Agroécologie	University of Gembloux (Belgium), Free University of Brussels (Belgium), University of Paris-Saclay, AgroParisTech (France)	French
Master	Agroecologia: Un Enfoque para la Sustentabilidad Rural	International University of Andalusia (Spain), Pablo de Olavide University (Spain), University of Cordoba (Spain)	Spanish
Bachelor, Master	Agroecology	University of Zagreb (Croatia)	Croatian
Bachelor, Master	AgroecologyAgroecology	Mendel University, Brno (Czech Republic)	Czech
Bachelor, Master	Study in Agricultural Ecosystems and Agroecology	University of South Bohemia (Czech Republic)	Czech

Appendix Table 3. Compulsory and elective modules from each case study program.

	Hohenheim	Wageningen	ISARA-Lyon	NMBU
Compulsory Courses	Organic Food Systems & Concepts (6) Economics & Environmental Policy (6) Global Agri-food Systems: Conventional, Organic, and Beyond (6) Organic Livestock Farming & Product (6) Project in Organic Agriculture & Food Systems (12) Processing and Quality of Organic Food (6) Markets & Marketing of Quality Food (6) Organic Plant Production (6) ECTS 54	Integrated Natural Resource Management in Organic Agriculture (6) Social Transformations towards Sustainable Food Systems (6) Masterclass Organic Agriculture (3) Academic Consultancy Training Project (9) Academic & Professional Skills Training (3) ECTS 27	Agriculture & landscape Management (6) Agroecological cropping practices (6) World Agroecosystems & Agricultural Use (6) Management of Agroecosystems: policies and nature conservation (6) Group project management (12) ECTS 36	Agroecology: Action learning in farming and food systems (30) Research Methods (6) ECTS 36
Elective Courses	Biological Pest Control (6) International Food and Agricultural Trade (6) Food Safety and Quality Chains (6) Organic Farming in the Tropics and Subtropics (6) Gender, Nutrition and Right to Food (6)	Organic Agriculture and Society (6) Biological Interactions in the Soil (6) Ecological Design and Permaculture (6) Agroecology (6) Analysis and Design of Organic Farming Systems (6) Quantitative Research Methods (6) Education for Sustainable Development (6)	Electives offered by partner Universities	Sustainability & Rural Development (6) Tropical Agriculture Human Nutrition & Food Systems (6) Agroecology & Economics (6) Ecological Engineering (6) Systems analysis & Action-based research (6)

Appendix Table 4. Randomly selected theses from each program; topics are as wide as the food system itself.

- The People Left Behind: The Agricultural Sector in the Context of Dutch Depopulation and its Policy (WUR, 2017)
- Determining factors and trajectories analysis to support system diversification: mixed orchard animals and mixed orchard vegetables systems. (ISARA, 2016)
- Consumers' attitudes on the organic laser marked fruit. (WUR, 2018)
- Conception of agro-ecological cropping systems combinations, explored explicitly at farm scale and for the protection of groundwater quality. (NMBU, 2017)
- Taming nitrogen : recognizing N2O emissions in fertilization practice. (NMBU, 2017)
- Multi-scale diversity in agroecosystems to improve pest control and system resilience. (Hohenheim, 2018)

Appendix Table 5: Further recommendations as highlighted by practitioners and students through the interviews. These can be applied to sustainability-oriented education in general.

Best Practices	**Explanation**
Maintain good communication between modules.	Keep one person (or team of people) orchestrating each module who is taking care of the teaching quality and who communicates with other modules to avoid overlaps.
Communicate from the beginning to manage student expectations.	Students arriving to these "progressive" programs should know from the beginning what the plan is and how going through this process will help them reach their goal, as it may at times be overwhelming.
Implementation of peer review	Students review the proposals of other students and give specific feedback. This works in the Action Project module because it's easier for students to give targeted feedback.
Envisioning Activities	Students envision ideal scenarios or solutions and come up with steps on what they need to do to reach it. Teachers offer guidance on what tools are needed and support the process by giving constructive and timely feedback.
Make use of Presentations	This is a good way for students to learn because it forces them to do the reading and to get experience presenting complex materials, which they will be required to do in their professional life.
Built in Reflection mechanisms	Students should go through constant reflection cycles. This can be done in different ways: at end of the day through short group presentations, through individual and group reflection assignments and by filling in a learner document with learning expectations at the beginning and learning outcomes at the end of every course.
Expose students to a balance of Organic and Conventional systems	It is constructive for students to be confronted with the strengths and weaknesses of both systems if they are to go out into professional world with a complete picture.