Introducing IoT for the small farms

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Contents

1 Executive Summary 3

2 Challenges and Solutions 3

3 Result 4

4 Course description 6

4.1 Intercultural Communication & Academic Entrepreneurship in Agricultural Engineering 6

4.2 Technical Basics of Smart Farming 7

1 Executive Summary

Activity 4.3 concentrated on piloting, testing, and refining innovative learning modules that integrate digital agriculture, intercultural collaboration, and entrepreneurial thinking. A major achievement was the development and delivery of the module *Intercultural Communication & Academic Entrepreneurship in Agricultural Engineering*, which combined Smart Farming concepts with innovation management, communication skills and business development practices. Students participated in international learning experiences in the United States and Japan, engaged with universities, companies and innovation hubs, and produced comparative analyses of agricultural innovation ecosystems. These experiences deepened their understanding of how Smart Farming technologies evolve within different socio-technical environments.

Complementing these activities, the project implemented a digital learning prototype on GNSS technology to explore the feasibility of scalable online teaching formats. Feedback from pilot users confirmed the value of concise, practice-oriented digital content, while also reinforcing the limitations of MOOC-style formats for smallholder farmers. This confirmed the relevance of the strategic shift toward university-level audiences.

Across all pilot tests, the modules proved effective in supporting students' understanding of Smart Farming technologies, fostering innovation competencies and strengthening international collaboration. The refinement phase resulted in clearer explanations, improved visual materials and modular formats suitable for blended and mobile learning. Activity 4.3 thus delivered pedagogically robust and internationally transferable learning materials that strengthen digital and entrepreneurial education in agricultural engineering, providing a solid basis for future training and mobility initiatives.

2 Challenges and Solutions

During the implementation of Activity 4.3, it became increasingly clear that the originally planned objective, which was to develop a harmonized Smart Farming and IoT learning module specifically tailored to smallholder farmers through a MOOC format, required significant adaptation. While a prototype digital learning unit on GNSS was successfully developed and piloted, the broader concept of a universal Smart Farming/IoT MOOC for smallholders proved less feasible and ultimately not aligned with the realities encountered in agricultural practice, education systems and regional farming structures.

One central reason for this shift was the high regional specificity of smallholder agriculture. Small-scale farming systems across Europe and beyond differ substantially with respect to climate, crops, operational structures, resource availability, technological preconditions and regulatory frameworks. As a result, the educational needs, technological entry points and adoption challenges of smallholders are highly heterogeneous. A single MOOC designed to address "smallholder smart farming" at a general level would have had limited practical relevance and risked remaining too abstract to support meaningful learning outcomes for farmers operating in diverse contexts.

Furthermore, the project's research activities indicated that digital agricultural technologies are not adopted uniformly, and smallholders often prioritise solutions that address immediate, context-specific challenges. This heterogeneity mirrors the structure of agricultural education itself: advisory systems, vocational pathways and upskilling mechanisms differ greatly between countries and regions. As a consequence, there is no universally applicable pedagogical model for Smart Farming education at the smallholder level. A centralised MOOC would not adequately accommodate the diversity of farming practices, technological infrastructures or cultural perspectives that shape learning readiness.

Additionally, repeated survey and feedback activities demonstrated that the demand for structured digital training among small-scale farmers remains limited, largely due to time constraints, operational priorities and variable digital literacy. While many farmers express interest in specific technologies or practical demonstrations, participation in extended online learning formats such as MOOCs is considerably lower than anticipated. This insight reinforced the conclusion that a universally deployed Smart Farming MOOC for smallholders would have attracted only a narrow segment of the intended audience.

In response to these findings, the project consortium, particularly the participating universities, redirected the focus toward higher education learners, where interest in digital agriculture, openness to innovation, and capacity for independent learning are significantly higher. This strategic shift enabled the development of academically robust modules that integrate Smart Farming technologies, intercultural communication and innovation competencies. The collaboration between institutions enabled the creation of internationally relevant course structures, rather than a single, generalized farmer-oriented MOOC.

At the same time, the development and testing of individual digital units, such as the GNSS learning module, remained valuable for understanding how digital content can support practice-oriented knowledge transfer. These smaller-scale digital components can later be adapted or localised for future farmer-oriented training activities.

Overall, the modification of the original objective reflects a realistic and needs-driven adaptation to agricultural diversity, educational heterogeneity and the practical constraints of smallholder learning environments. By shifting to university-level modules while piloting selected digital components, the project ensured high-quality outputs that remain aligned with the overarching goal of strengthening digital competences in agricultural engineering and supporting long-term innovation capacity in the sector.

3 Result

Activity 4.3 focused on the pilot implementation, evaluation and refinement of innovative learning modules designed to foster digital competences, interdisciplinary collaboration and entrepreneurial thinking in agricultural engineering. This activity ensured that the educational materials developed within the project were tested under realistic teaching conditions and aligned with the needs and expectations of learners in higher education and professional agricultural contexts.

A key achievement of Activity 4.3 was the development and delivery of the Intercultural Communication & Academic Entrepreneurship in Agricultural Engineering module. The module combined elements of digital agriculture, innovation research, communication studies and entrepreneurship education. Students engaged with the technological, economic and societal dimensions of agricultural innovation, developed business model concepts, and received training in pitching techniques and entrepreneurial presentation formats. By integrating intercultural elements and interdisciplinary group work, the module enabled students to understand how agricultural technologies are embedded within global socio-technical systems and how innovation processes differ across cultural and regional contexts.

A core component of the module was an international learning experience in the Midwestern United States, where students visited partner universities, innovation ecosystems and leading agricultural companies. These visits provided students with first-hand insights into regional agricultural structures, technological developments, and institutional environments that shape the adoption of Smart Farming technologies. In discussions with academic experts, industry representatives and extension professionals, students explored how regional conditions such as farm size, labour availability, regulatory frameworks, innovation incentives and digital infrastructure influence the deployment of digital tools. The student research reports produced after these visits highlighted significant differences between the U.S. and European agricultural innovation landscapes, particularly regarding openness to experimentation, private-sector involvement and the role of extension services. These analyses contributed to the further refinement of the learning module and demonstrated the educational impact of immersive, international learning settings.

The module also included a collaboration with a partner university in Japan, where students from both institutions worked jointly on innovation challenges related to agriculture, sustainability and One Health. This intercultural exchange fostered interdisciplinary thinking and helped students understand the global interconnectedness of agricultural systems. By jointly developing prototype solutions and presenting them in pitch sessions, students practiced innovation skills while learning to navigate cultural differences and diverse disciplinary approaches. This strengthened not only their technical and conceptual competencies but also their global awareness and communication skills.

In parallel, the course *Technische Grundlagen, Smart Farming* introduced students to the technical foundations of digital agriculture, including guidance technologies, machine communication, sensing systems and data-driven field operations. This module provided the necessary technological background for the international components of Activity 4.3 and also functioned as an independent learning experience for participants aiming to gain deeper insights into Smart Farming technologies.

To complement the university-level teaching activities, the project developed and piloted a digital learning unit in the form of a Massive Open Online Course (MOOC) focusing on GNSS technology in Smart Farming. The pilot session presented the principles of satellite-based navigation, typical application areas, operational advantages and practical limitations. It included visual explanations, a quiz component and a structured feedback mechanism. The pilot tests with agricultural practitioners demonstrated that clear visualisations, concise explanations and examples from everyday practice substantially improve understanding. At the same time, the evaluation also revealed typical barriers among practitioners, such as concerns about signal stability, equipment costs, data handling and the need for hands-on demonstrations. These insights informed subsequent refinements of the digital module.

Across all pilot activities, several overarching findings emerged. Students responded positively to formats that combine theoretical concepts with practical application, international exposure and entrepreneurial thinking. They particularly valued opportunities to interact with external stakeholders, including companies, research institutions and innovation hubs. The interdisciplinary and intercultural elements of the modules were perceived as enriching and motivating, as they provided context for understanding how Smart Farming technologies function within broader innovation ecosystems.

The pilot tests also highlighted a structural challenge that shaped the strategic focus of Activity 4.3: while Smart Farming technologies hold considerable potential for farmers, the direct demand for structured digital training among agricultural practitioners remains relatively limited. Many farmers face time constraints, infrastructure limitations or competing operational priorities that make participation in continuing education difficult. This reinforced the decision to concentrate the pilot implementations primarily on university-level learners, where readiness, interest and digital literacy were higher. These learners also serve as future multipliers who will carry knowledge into advisory roles, industry positions or farm management.

The refinement phase of Activity 4.3 resulted in substantial improvements to the learning materials. Explanations of complex technical concepts were clarified, diagrams and examples were expanded, and modules were restructured to allow flexible use in blended and mobile learning formats. Navigation within digital resources was streamlined, and the teaching materials were enriched with practical scenarios that illustrate both the potential and the limitations of Smart Farming technologies.

Overall, Activity 4.3 successfully produced and tested a comprehensive set of innovative learning modules that combine digital agriculture, intercultural collaboration and entrepreneurial education. The activity strengthened the pedagogical quality, international relevance and practical applicability of the project’s educational outputs. It laid a robust foundation for future curriculum development, supported international networking and created learning experiences that prepare students to actively shape technological and societal transformation processes in agriculture.

4 Course description

4.1 Intercultural Communication & Academic Entrepreneurship in Agricultural Engineering

Module Description Link:
https://campus.tum.de/tumonline/WBMODHB.wbShowMHBReadOnly?pKnotenNr=4430887&pOrgNr=15646
Module Level: Masters
Duration: one Semester
Credits: 5

Learning Outcomes: After successfully completing the module, students will be able to understand and navigate the complexity of global challenges in agriculture and the agricultural engineering sector. They will be equipped to analyze these challenges in diverse agricultural systems, cultural settings, and international, interdisciplinary academic contexts. Participants will develop an awareness of the importance of different perspectives in agricultural engineering, enhance their ability to think critically and innovatively, and apply problem-solving strategies in an international and multidisciplinary environment. By engaging in collaborative group work, students will strengthen their intercultural competence and gain valuable experience in working within global teams.

Content: Agriculture faces numerous global challenges, including climate change, food security for a growing population, ecological sustainability, greenhouse gas reduction, conservation of natural resources, biodiversity protection, and water pollution mitigation. While the agricultural sector contributes to some of these issues, it also plays a crucial role in developing sustainable solutions. Agricultural engineering, in particular, offers technological advancements that can enhance efficiency and sustainability in diverse agricultural systems.
This module provides insights into various agricultural structures worldwide, explores the significance of agriculture across different regions, and examines how different countries, institutions, and industries approach agricultural challenges. It also emphasizes the importance of effective communication in multicultural settings, preparing students to collaborate internationally and develop solutions through teamwork.

Teaching and Learning Methods: The module content is delivered through lectures, seminars, and discussions led by guest lecturers from various academic and industry backgrounds. Experts from different universities, research institutions, and companies will provide insights into global agricultural challenges and engineering solutions. While past seminars have included perspectives from Germany, Japan, and the United States, the module aims to integrate a broader international outlook. The seminar sessions occur either at the TUM campus or a partner university, which will be announced in an information session before the module begins. Discussions, group activities, and case studies will provide students with opportunities to apply their knowledge, refine their intercultural communication skills, and develop entrepreneurial approaches to agricultural challenges.
Readig List:

- Handbook Digital Farming (Jörg Dörr, Matthias Nachtmann) https://doi.org/10.1007/978-3-662-64378-5
- Agrarkommunikation (Matthias Kussin, Jan Berstermann) https://doi.org/10.1007/978-3-658-36341-3

4.2 Technical Basics of Smart Farming

Module Description Link:
https://campus.tum.de/tumonline/wbModHb.wbShowMHBReadOnly?pKnotenNr=1181135
Module Level: Bachelor
Duration: one Semester
Credits: 5

Learning Outcomes: After participating in the module, students will be able to

- distinguish between the terms “digitalization,” “smart farming,” and “precision farming”
- describe the theoretical concepts behind these terms
- name use cases for the respective concepts and assign new use cases to the respective concept
- describe the technical basics of smart farming
- identify new systems based on the technical systems taught and outline and differentiate their functionality from existing ones (e.g., farm management information systems and newly emerging digital offerings)
- Identify the necessary skills for dealing with specific use cases or issues in smart farming (e.g., procedure for setting up a sensor network) and, under guidance, familiarize yourself with such a specific use case and discuss it.
- Confidently use the technical system covered in the exercise (e.g., use of an agricultural drone)

Content:
- Distinction between the concepts of digitalization, smart farming, and precision farming
- Historical stages of development of smart farming
- Technical fundamentals and theoretical concepts
  - Global Navigation Satellite System (GNSS)
  - Computers and binary systems
  - Structure and application of data networks in outdoor and indoor farming
  - Connectivity (RFID, LoRa, WiFi, Bluetooth, etc.)
  - Digital field records and farm management information systems
  - Wireless sensor networks
  - Drones in agriculture
  - ISOBUS and AgroXML
  - Automatic steering systems and field robotics
- Use cases:
  - Market overview of field records
  - Robots in indoor and outdoor farming
  - UAVs for wildlife rescue, field assessment, and application of agricultural inputs
  - Barn 4.0 in horse husbandry
- Integrated exercises:
  - Drones (hardware, software, flight planning, field assessment)
  - Wireless sensor networks (connecting a wireless sensor to a Raspberry Pi)
  - Robotics (programming self-driving robots)

Teaching and Learning Methods: In the lectures, students are introduced to the fundamental concepts of “digitalization,” “smart farming,” and “precision farming” using established definitions. These concepts are then explored in greater depth and illustrated through practical application cases.

In the integrated exercises, students develop the competence to identify the skills required to address a selected application scenario and to acquire these skills under guidance in order to work on the scenario in a solution-oriented manner.

The exercises begin by establishing the theoretical foundation, including the selection and configuration of the appropriate hardware and software. This configuration is then implemented practically in the laboratory (e.g., planning and simulating a flight with an agricultural drone, connecting a sensor to a microcontroller and configuring data transmission). Finally, the chosen technology is applied under real-world conditions at an experimental farm (e.g., executing the planned drone flight over trial plots, collecting a small dataset using the sensor on the experimental fields).

The exercises are offered in the form of supervised group work, with each group working on different topics depending on the availability of hardware and software (e.g., drones, sensors, field robots). The methods and results of the group work are exchanged among the groups to provide all students with a solid understanding of the respective technical systems.

Readig List: Standards in this field have not yet been established. Recommended reading includes articles from agricultural engineering publications (www.landtechnik-online.eu).