USING THE OPEN DATA FARM AS A DIGITAL TWIN OF A FARM IN AN INNOVATIVE SCHOOL SETTING TO INCREASE DATA LITERACY AND AWARENESS

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Abstract.

In recent years, the number of digital applications and data streams has steadily increased, but knowledge and expertise in dealing with them has not increased to the same extent. The Open Data Farm is intended to make a significant contribution to education and training in order to increase data literacy in agriculture.

The Open Data Farm (ODF) represents a twin of a real agricultural business as a 3D model in which existing data streams in various branches of the business are visualized. The teaching and research centre Hofgut Neumühle (LVAV) in Rhineland-Palatinate is used for this purpose. The aim of the model is to record operational data and material flows from their various sources and to visualize them dynamically in order to make them tangible for third parties.

This type of visualization creates an understanding of the data and data flows in the companies. The content of the open data farm is supplemented by technical information from the farm knowledge platforms. The information displayed in three-dimensional space is thus supplemented by direct technical information. In addition to the terms in the Farmwiki, practical examples for solving digital applications in agricultural practice are also linked. This ensures that only editorially prepared and professionally verified content is communicated on the Open Data Farm.

The central aim of the Open Data Farm is to create a real visual farm twin with which theoretical content can be combined with existing data streams for training and further education.

By using augmented reality (AR) to expand the learning content in the ODF in practical lessons, the teacher is given a tool for independent and individualized expansion of the learning content. The individualised learning of pupils is given greater consideration. With the development and

use of the 3D model in the school, lessons on the topic of digitalisation in agriculture become an interactive virtual learning experience through the use of virtual tours using virtual reality (VR) technology. Through immersive learning, students gain a better understanding of the complex interrelationships and applications in the field of digitalisation. In addition, the ODF's virtual environment provides hands-on experience in the classroom, regardless of location.

The ODF is actively integrated into the school curriculum of edu@farmwissen in agricultural vocational training in order to increase the data competence of agricultural trainees. As an essential virtual and interactive component of the edu@farmwissen teaching material, the ODF is designed to be action-orientated and used in a didactically valuable way. The technologies (AR/VR) and the 3D model are integrated into the content of the lessons and serve to fulfil pedagogically and didactically valuable learning objectives. The VR content supports the subject matter and adds data literacy to the curriculum. The use of ODF with VR technologies in the classroom is reflected.

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Keywords.
education, digital twin, data literacy, AR, VR

Introduction

Agriculture as a primary sector faces immense and diverse ecological, economic as well as technical challenges. Increasing pressure on production methods and external factors such as constantly changing and dynamic production conditions, new digital technologies as well as the strict legal framework conditions pose a great challenge for farmers. In addition, there are obstacles that make the use of digital technologies more difficult (Schleicher and Gandorfer 2018) (Bartels et al. 2020). These include, for example, high capital investment, interface problems and higher competencies in dealing with digital applications. A far-reaching change in future agricultural management is the transition from analogue to digital solutions. The presentation of digital solutions in relation to sustainable agricultural practices is considered essential. Since 2019, the Federal Ministry of Agriculture and Food (BMEL) in Germany has created fourteen digital trial fields on agricultural in which digitalization of agriculture is promoted in different areas (Verbraucherschutz 2018). As part of the Southwest Experimental Area, the Hofgut Neumühle Teaching and Experimental Station for Livestock Husbandry is being developed and set up as a so-called OpenDataFarm in a model trial (Neumühle n.d.). Farm (private) data as well as publicly available data are linked and presented in a virtual model that is freely accessible. The different communication technologies and the use of different sensors make it possible to generate important environmental data and information. Since agriculture, as an essential part of the food industry, belongs to critical infrastructure, the infrastructure of such a system must also be taken into account with regard to failure safety and possible attack potentials (Reuter et al. 2019). This is why knowledge of data and operational data, its use and infrastructure is important for farmers. In addition to visualization, informing about digital technical terms, demonstrating practical examples and qualifying through teaching materials in schools, teaching and further education take an important position against the background of the so-called FarmWissen strategy. The strategy's goal of bundling knowledge about digitization on a central platform all over Germany and at the same time presenting it in a more attractive and practical way can be linked to the OpenDataFarm (Kraus et al. 2022). In particular, we are trying to adapt the content of the strategy for modern and digital teaching in agriculture. In this country, curricula and teaching are usually very static. Frontal teaching still predominates and digital techniques are very slow to find their way into everyday teaching (Wirtz and Wirtz 2021). However, it has been proven that people learn more successfully when several sensory

channels are addressed simultaneously. The use of a digital twin in the form of ODF in agricultural education enables students to gain a direct insight into practice and better understand complex relationships. By interacting with the digital twin, students can play through various scenarios, make decisions and observe their effects in real time. This teaching method not only promotes an understanding of agricultural processes, but also the development of problem-solving and decision-making skills among learners. The handling of operational and public data as well as sensitivity to resilience play a major role in this pilot project. The aim is to increase the handling and understanding of data and its quality. In addition to the knowledge transfer aspect, OpenDataFarm serves as a test site for new innovative developments regarding applications in the areas of IoT sensor technology, edge computing or robotics. The need for personalized learning models emanates from the observation that modern education systems fail to meet the needs of modern students (Ağca 2023, Furini et al. 2022).

OpenDataFarm concept for visualizing public and operational data

The establishment of a digital farm and field twin in form of the so-called OpenDataFarm represents an important component within the framework of knowledge transfer of the Experimentierfeld Südwest. The aim of the OpenDataFarm is to firstly serve as an educational platform that demonstrates combining publicly available data with private, farm specific operational data. Secondly, to drive further developments and allow for the open exchange and creation of innovative ideas, concepts, and solutions to current challenges in the field of smart farming, the OpenDataFarm will be constructed as a living lab.

For this purpose, the OpenDataFarm visualizes the data and resource flows of a real farm and its agricultural fields. This farm is the Teaching and Research Institute for Animal Husbandry (LVAV) Hofgut Neumühle, which is located in Münchweiler an der Alsenz in Rhineland-Palatinate. In addition to crop farming, grassland, and versatile animal husbandry, the LVAV Hofgut Neumühle takes on additional tasks in inter-farm training, further and advanced education, the implementation of practice-relevant trials and consumer education (Landfried 2022). Not only because of the existing data history, the totality of data and the digital infrastructure, the farm is excellently suited for the implementation of the pilot project but also to ensure the transfer of knowledge and the further development of digital solutions with real operational data, a free use of operational data of an agricultural enterprise is necessary. Since farm data contains sensitive information, and publicly available data is very limited, the state teaching and research institute LVAV Hofgut Neumühle was convinced to participate and provide their data for this project. They recognized the important role they could play in driving forward both the transfer of knowledge and the testing of digital technologies in campaign of digitizing agricultural practices as they already have an established innovative environment with the appropriate IT infrastructure and precision farming technology. Here there is the opportunity to work, research and impart knowledge with selected specific operational and public data in the form of open data. The farm data is collected in an independent database that is being developed in cooperation with the BeSt-SH trial field. The aim is to combine and save all data, regardless of the farm, source, data format or manufacturer, and then to visualize it in a model. The database is designed for all farm branches, even though data from the field of crop production was visualized in a first step. The open-source idea is pursued in the development of the database. The step-by-step development of the database structure is published with the help of detailed digital documentation on suitable platforms such as Github and is thus accessible and supportable for external persons.

In order to present high-quality data, the first step was to define trial fields according to type of use, distance to a weather station and data basis. For these trial fields, the farm data were then linked with the public data. Initially, agronomic data, geoinformation, weather data and remote sensing data from satellites and drones were used as data sources. Agronomic data in the sense of yield and application maps, geoinformation from the State Office for Geology and Mining as digital terrain models and WMS services with soil data, live weather data from Agrarmeteorology Rhineland-Palatinate and free remote sensing data from the Sentinel2

satellites. The drone and handheld LiDAR data were used to create a virtual 3D model of the LVAV Hofgut Neumühle. The individual data sources were additionally supplemented with operational data of the farm. As an example, georeferenced soil samples can be mentioned in the geoinformation. Certain data sources were also further processed to increase the information content and to enable an attractive presentation. The visualization of the OpenDataFarm is done with the help of a 3D model of the farm (figure 1). The vision is for the viewer to be able to move around the model and directly view data from the different operational areas. This form of representation also plays an important role regarding virtual and augmentative reality (AR/VR) in education. The 3D model is also used for new innovations in the test area of robotics. The georeferenced 3D model of the real farm could thus serve as a virtual test region for autonomously driving field robots. The first concrete tests are currently being planned.

By presenting public and private farm data and linking it to knowledge transfer, an overall concept is created that can lower the inhibition threshold towards digital applications by showing entry opportunities for farms that are still less affine and digitized, but also the added value for farms with a high degree of digitization. Use in the classroom or lecture hall is also conceivable. Here, implemented plant protection measures or fertiliser applications could be demonstrated in their natural environment using the georeferenced data and maps, and their results analyzed. The presentation of data in relation to terrain, exposure and external factors is a great advantage when assessing data quality.

In this pilot project, the OpenDataFarm is additionally the centre for the integration of state-of-the-art technology for the collection of environmentally relevant data through weather sensors, IoT sensors and regarding the establishment of a resilient infrastructure to enable sustainable management in the future.

Fig.1 3D-model of the LVAV Hofgut Neumühle as basis for the visualization of the OpenDataFarm

Digital twin for education purposes in edu@farmwissen

In view of the increasing complexity of working environments in agriculture and the constant increase in data on and about farms, ways are being sought to visualize this wealth of information in a way that is appropriate for the target audience. The Open Data Farm represents a digital twin of the LVAV Neumühle experimental farm and visualizes various real data and material flows.

By using the ODF via the Internet, regardless of time and place, students are given the opportunity to access the information even after class. Digital twins and the use of AI can be key pillars of future personalized learning environments (Furini et al. 2022). Digital twins are virtual representations of real objects and data that can be interacted with in a virtual environment. It is

hoped that an interactive and independent approach to the open data farm will increase motivation and participation in dealing with data and its significance for agricultural processes. The Open Data Farm (ODF) plays a pivotal role in agricultural vocational training at edu@farmwissen, where it is actively integrated into the school curriculum to enhance the data competence of agricultural trainees. As an integral component of the teaching material, ODF is designed to be action-oriented and utilized in a didactically valuable way. The platform seamlessly integrates technologies such as augmented reality (AR), virtual reality (VR), and 3D models into lesson content, thereby fulfilling pedagogically and didactically valuable learning objectives. In particular, VR content supports the subject matter while adding data literacy to the curriculum, thereby providing trainees with a comprehensive understanding of agricultural practices. The integration of ODF with VR technologies in the classroom enables trainees to apply theoretical knowledge to real-world scenarios, thereby fostering critical thinking and problem-solving skills. By leveraging these innovative tools, edu@farmwissen equips its students with the data-driven expertise needed to succeed in the modern agricultural industry.

Integration of modern technologies for collecting environmental information

The focus of German agriculture is particularly on the precise and sustainable management of the soil. In future, Smart Farming should make this possible by collecting and analyzing process and sensor data (Reuter et al. 2019).

To this end, automated, executable advisory services based on intelligent networking and the combination of public and detailed site-specific data are offered by the GeoBox-Infrastructure as part of various projects such as Smart Soil Information for Farmers (SoFI). The aim is to promote resource-efficient and environmentally friendly fertilisation and soil cultivation with a view to avoiding soil compaction and reducing climate-damaging emissions. The decision-making aid is based on data sets generated on different intensive measurement plots within the framework of the project and covers the range of agriculturally used soils and pedological criteria in south-west Germany. Experimental plots of the OpenDataFarm also serve as intensive measurement plots. From these data sets, methods are developed for the use of simple and complex soil water balance models, but also the continuous recording of soil hydrologically relevant parameters to verify the simulated soil moisture. So-called Long Range Wide Area Network (LoRaWAN) sensors (IoT sensors), which forward their data via the open community-based platform "The Things Network", are used as additional sensor technology. This enables a cost-effective and flexible spatial distribution of sensors over the area. The potential soil moisture is calculated using the SIMPEL simulation model. For this purpose, current weather data, soil properties and data from soil estimation, which are all publicly available, are used as a basis. The areas provide an overview of the potential soil moisture and make it possible to compare areas in terms of this and provide orientation for practising farmers. The validation of the simulation models then takes place via the data sets of the intensive monitoring sites. In order to make the data and model results publicly available, the integration of the results into the GeoBox-Infrastructure takes place, which represents the digital infrastructure and contributes to the resilience of agriculture (Wald et al. 2021).

In addition, the intensive use of regional sensor data in Smart Farming provides farmers with improved bases for decision-making and opens up new scope for action for the administrative bodies responsible for environmental and climate protection. It is becoming apparent that modern technologies can make an important contribution to the expansion of environmental information. However, it is also clear that natural processes from biotic and abiotic factors cannot be completely controlled. By incorporating sensor data, remote sensing data, soil data, current weather data and simulations, predictable and unpredictable influences can be partially compensated for (Eberz-Eder et al. 2021).

Integration of field testing and 3D models in education

An additional aspect of OpenDataFarm is the integration of field trials. In addition to the possibility of bringing this into teaching via the platform and showing students visually prepared data, it enables practicing farmers to find out about the trials carried out and their results. In addition, the experimental methods presented provide a basis for implementing similar or identical field trials on their own farms. Scientific trials and the visualization of simple demonstration trials can be carried out in the digital twin. As the OpenDataFarm not only covers the field of arable farming, but also special crops such as viticulture, fruit growing and beekeeping, it opens up a broad spectrum. The trials are initially limited to the field trials carried out in the Experimentierfeld Südwest project, but the platform fundamentally follows the open source concept so that external partners, whether from the private or public sector, can also present and incorporate their results.

The field trials conducted in the Southwest Experimental Field project are mainly carried out using so-called on-farm research. With this method, the field trials are integrated into the farmers' normal operations. The trial planning is usually complex and external factors have a greater influence than in plot trials. However, the cooperation between farmers and researchers provides a high added value, which usually results in the observation from different perspectives. By demonstrating new technology, varieties or cultivation techniques, new farming methods can be developed. The acceptance of trial results is particularly high due to the practical conditions (Crofoot, 2010) (Hoffmann et al., 2007).

The AR and VR concept also plays an advantage in the OpenDataFarm, because the experimental technology used can be experienced immersively in three-dimensional space and is supplemented by further information on the technology used, experimental methods and the results through links to the other FarmWissen platforms. In the field of teaching, training and further education, the OpenDataFarm can thus supplement theoretical lessons with practical examples in a virtual setting (Fig. 2).

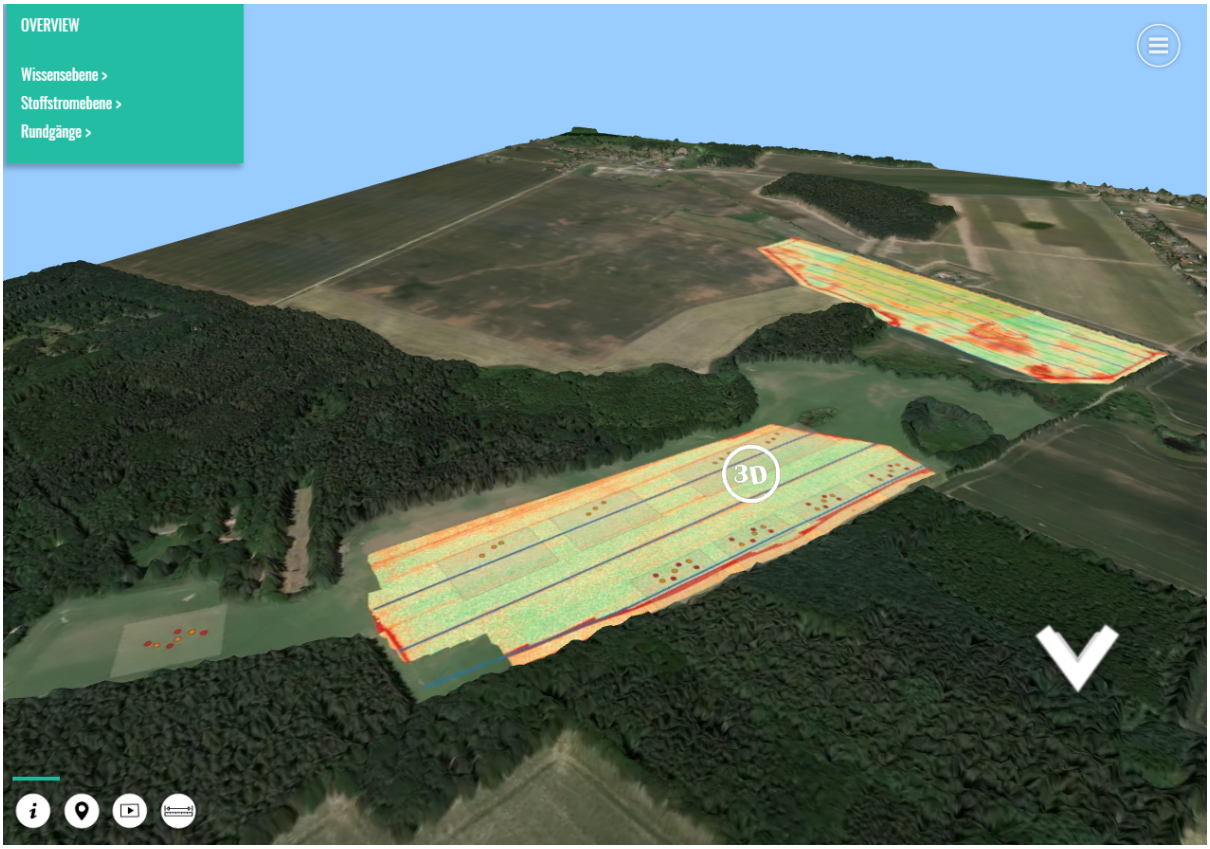

Fig. 2 Presentation of test plots in the OpenDataFarm

The following mock-up illustrates exactly how 3D models can be used in teaching, training and further education. The use of LoRaWAN sensor technology is being tested in the Southwest Experimental Field and represents a digital solution in the area of soil. A soil profile was created and transferred three-dimensionally to the OpenDataFarm in order to raise awareness of this topic. As can be seen in Fig. 3, the model is then supplemented with information on surveying using LiDAR, soil maps and IoT sensor data via LoRaWAN. The ODF platform will seamlessly integrate with IoT devices, enabling real-time monitoring of soil health, crop growth, and environmental conditions, allowing for precise decision-making and optimal resource allocation.

The open data resources provided by ODF will facilitate the development of innovative curricula that incorporate cutting-edge topics such as precision agriculture, sustainable farming practices, and environmental sustainability.

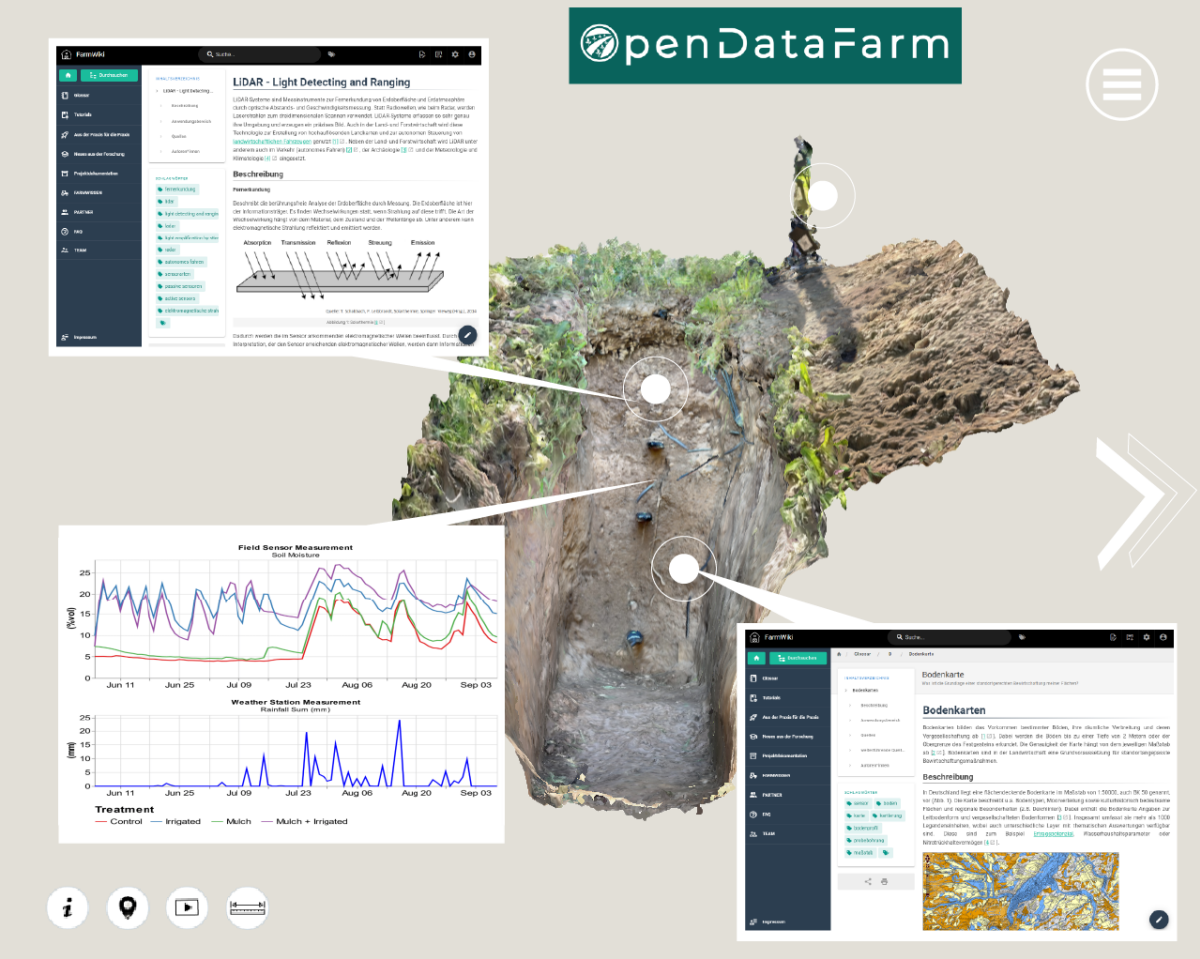

Fig. 3 Soil profile with LoRaWAN sensors and linked information

Knowledge transfer to expand skills in the application of digital technologies in agriculture

Increasing the skills of farmers and consultants to new technology or software providers, and researchers is essential if digital technologies are to realize their full benefits in practice. Great attention should be paid to fostering collaboration from all of the above levels in implementing new technologies for future development and research (Ingram et al. 2020). New ways need to be created to transfer research results into practice (Jánszky et al. 2019). Structured knowledge transfer is essential for communicating the knowledge gained from research into practice.

It is important to make the results visible (Michaelis et al. 2019). Visualization on the OpenDataFarm embeds research results in a practical way. Users see the content in a familiar

environment and are free to seek information according to their interests. Central to this is presenting topics in a more practical way. This achieves a focus on the objective and implementation (ibid.). The OpenDataFarm serves as a demonstration on how to deal with public and operational data and further knowledge on digitalization in agriculture. It is one component of a whole knowledge transfer structure. „FarmWissen“unites the OpenDataFarm, practical examples and a FarmWiki. FarmWissen represents a knowledge transfer platform for digitalization in agriculture. This is characterized by cooperation with other experimental fields, research, consulting and practice. The aim is to bundle knowledge about practice-established and future-oriented digital applications and technologies on a central platform throughout Germany and at the same time to present them in a more attractive and practical way. This is because barriers accompany digitization to acceptance. High investment requirements, concerns about data protection and sovereignty, and incompatibility between systems are among the biggest barriers (Schleicher and Gandofer 2018). The FarmWissen strategy addresses these challenges with a clear presentation of the benefits of digital applications and technologies. In addition, there is the possibility of individual as well as location- and time-independent knowledge transfer on subject-specific content.

The practical examples specifically answer practical questions from agriculture. They are unique in their form. Detailed step-by-step instructions with a detailed list of ingredients, similar to a recipe, explain the advantages of the technologies used. In the description of results, the author of the practical example evaluates the economic, ecological and social potential as an expert. In this way, each user can decide whether the practical example is suitable for him or her and his or her business and whether it will generate the desired added value (Fig. 6).

Fig. 4 Schematic representation of a practical example on FarmWissen

The platform is accompanied by a FarmWiki (FarmWiki 2023), in which a detailed explanation of the individual ingredients (e.g. terminal) of the practical examples takes place. Complicated technical preparations for individual examples are additionally explained with image and video material in detailed tutorials.

With the digital farm "OpenDataFarm", as the third component of the FarmWissen strategy, the

platform visitor is enabled to interactively experience the previously described ingredients (e.g. yield map) on a virtual farm. The goal of this data visualization is to increase the understanding of digital information, underlying data streams and material cycles of a farm.

To successfully establish it in practice, a knowledge transfer approach must already take place in teaching and training as well as in classes and studies. By developing additional exercises for online courses within freely available learning management systems (LMS), such as OpenOLAT or Moodle, teachers have the opportunity to access content on digitization in agriculture and use it as exercises on digital technologies in the classroom. This gives future practitioners an overview of digital possibilities right from the start, which also serve as further training in everyday professional life on FarmWissen. In the future, the exercises will be available as documents with step-by-step instructions, instructional videos or within the virtual classroom by means of 3D models. In this way, lessons are made exciting and can be actively experienced, arousing interest in digitization in agriculture. The practical examples offer another opportunity for use in the classroom. For example, project work is already being carried out in which all students design a practical example using a template for a technology of their choice. During the elaboration, the students have to deal intensively with the material, so that their digital skills are increased. In addition, the creation of new glossary papers is suitable as project work for students. Studying and summarizing scientific sources to create an article also strengthens digital literacy here. This means that practitioners are already qualified in the use of digital technologies right from the start and are prepared for the use of digitization to optimize and support work measures.

Discussion

The OpenDataFarm pilot project is the central point of contact for knowledge transfer within the scope of the project (Kraus et al. 2022). Through the use of state-of-the-art technology and forward-looking research, approaches to solutions for the diverse challenges of digitization are demonstrated. The core objective is to facilitate the entry into digitized agriculture and to lower the inhibition thresholds in order to make the primary sector of agriculture future-oriented and resilient (Schleicher and Gandorfer 2018, Reuter et al. 2019).

In order to implement the concept of the OpenDataFarm, the LVAV Hofgut Neumühle is excellently suited as a model farm due to its data history, the entirety of existing data and the existing digital infrastructure, but also due to the already advanced degree of digitization and the proximity to teaching (Neumühle n.d.). It should be emphasized here that the basic idea of using digital technologies, applications and information on resource and environmentally friendly methods, as well as sustainable management, are the focus. If possible, the concepts should be transferable to other forms of operation. The added value from the combination of private and public data will be demonstrated to the user in different ways as part of the knowledge transfer and the qualification in dealing with data will be increased, as well as the general competence for digitalization in agriculture strengthened (Kraus et al. 2022). Through the direct transferability to the own farm, time and especially cost savings can ideally be generated for the user. The sensor technology used to generate environmentally relevant data can be expanded at will and enables cross-industry added value for other production areas (Wald et al. 2021). The implementation of increasingly strict regulations can be supported by data that is generated anyway, for example through digital decision-making aids. In addition, the OpenDataFarm initializes a Living Lab for future research projects. The latest technologies, for example from the field of robotics, can be tested and transferred into practice.

Overall, the project contributes to lowering the inhibition threshold towards digitalization in agriculture, although the challenges are very diverse. The overall knowledge transfer structure "FarmWissen" on the one hand facilitates the entry into digitization and on the other hand strengthens the ability to deal with digital solutions for already highly digitized farms (Kraus, et al. 2022). The overall concept clearly pursues the platform idea, which enables cooperative approaches and collaboration. This is ensured by the attractive practical presentation of the

visualized data via 3D models. The link with agronomic data provides the user with a vivid impression, which facilitates the transfer to his own farm. The 3D modeling additionally allows the use of VR and AR in teaching. This forms an important building block with the handling and evaluation of data quality. The natural reference gained in this way, such as slope, exposition or adjacent vegetation of the data, allows them to be evaluated and analyzed under consideration of all influencing factors. The LVAV Hofgut Neumühle and the project consortium ensure the transfer of knowledge. This will strengthen competence building among practitioners, as well as in vocational, technical and higher education institutions for the use of digital applications and technologies. Finally, experts have the opportunity to share their findings via the platform and practitioners are enabled to obtain targeted information about digitization in agriculture. The OpenDataFarm combines visualization, demonstration, information and qualification. The Open Data Farm (ODF) plays a crucial role in agricultural vocational training at edu@farmwissen, enhancing the data competence of trainees through interactive and action-oriented lessons. By integrating VR technologies into the curriculum, ODF supports subject matter understanding, adds data literacy, and fosters critical thinking and problem-solving skills among students.

Overall, the OpenDataFarm project aims to strengthen competence building among practitioners, as well as in vocational, technical, and higher education institutions for the use of digital applications and technologies.

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References

Ağca, Rıdvan. (2023). Using digital twins in education from an innovative perspective: Potential and application areas. Education Mind. 2. 10.58583/Pedapub.EM2306.

Al-Akkad, A., L. Ramirez, A. Boden, D. Randall, and A. Zimmermann. 2014. Help Beacons: Design and Evaluation of an Ad-Hoc Lightweight S.O.S. System for Smartphones. Edited by M. Jones, P. Palanque, A. Schmidt and Grossman. Vol. Proceedings of the SIGCHI Conference on Human Factors in Computing Systems (CHI'14). New York: ACM.

Bartels, N., J. Dörr, J. Fehrmann, K. Gennen, E.-C., Härtel, I. Groen, J. Henningsen, T. Herlitzius, et al. 2020. Abschlussbericht Machabrkeitsstudie. Machbarkeitsstudie zu staatlichen digitalen Datenplattformen für die Landwirtschaft. Kaiserslautern: Frauenhofer IESE.

Crofoot, A. N. Presidential Address – Advantages of on-farm research. Conference Proceedings, New Zealand Grassland Association, 2010, https://www.grassland.org.nz/publications/nzgrassland_publication_13.pdf, 12.02.2023

Dörr J, Nachtmann M (2022) Handbook digital farming: digital transformation for sustainable agriculture. Springer, Berlin Heidelberg. ISBN 978-3-662-64377-8

Eberz-Eder, D., Wölbert, E., Hinze, J., Schaffner, S., Ferdinand, J.-H., Wald, L.: Farmwissen an innovative concept and platform for competence enhancement in Smart Farming, Book of Abstracts Conference on Precision Agriculture (ECPA) 2023 in Bologna (Italy). Edited by Maurizio Canavari Giuliano Vitali Michele Mattetti,

Eberz-Eder D., Kuntke F., Schneider W., and Reuter C. 2021. Technologische Umsetzung des Resilient Smart Farming (RSF) durch den Einsatz von Edge Computing. Vols. 41. GIL-Jahrestagung, Informations-und Kommunikationstechnologie in kritischen Zeiten. Bonn: Gesellschaft für Informatik e.V.

FarmWiki. 2023 edited by Agricultural Public Service Center Rheinhessen-Nahe-Hunsrück. Accessed 15.03.2024. https://farmwiki.de/.

Furini, M., Gaggi, O., Mirri, S., & Montagero, M. (2022). Digital twins and artificial intelligence: As pillars of personalized learning models. Communications of the ACM, 65(4), 98-104.

Hoffmann, V.; Probst, K.; Christinck, A. Farmers and researchers: How can collaborative advantages be created in participatory research and technology development? Agriculture and Human Values, Springer Verlag GmbH, 2007, Jg. 24, S. 355-368, doi:10.1007/s10460-007-9072-2

Ingram, J., and D. Maye. 2020. “What are the implications of digitalisation for agricultural knowledge?” Frontiers in

Sustainable Food Systems, 66. doi:10.3389/fsufs.2020.00066.

Jánszky, B., and F. Herrmann. 2019. Auf Augenhöhe: Wissenstransfer zwischen Forschung und Praxis der ökologischen und nachhaltigen Land-und Lebensmittelwirtschaft (Teilschlussbericht 1 des BÖLW). Berlin: Bund Ökologische Lebensmittelwirtschaft e.V. (BÖLW).

Kraus, M., J. Menne, D. Eberz-Eder, S.-L. Schaffner, and J.-H. Ferdinand. 2022. FarmWissen. Die Wissenstransferplattform zur Digitalisierung in der Landwirtschaft. Vols. 42. GIL-Jahrestagung, Was bedeutet Künstliche Intelligenz für die Agrar- und Ernährungswirtschaft? Bonn: Gesellschaft für Informatik e.V.

Kuntke, F., Reuter C., Schneider W., Eberz-Eder D. and Bernardi A.. 2020. Die GeoBox-Vision: Resiliente Interaktion und Kooperation in der Landwirtschaft durch dezentrale Systeme. Vols. Mensch und Computer 2020-Workshopband. Gemeinschaft für Informatik e.V.

Michaelis, T., Herrmann F., Klischat U. and Wolf B. 2019. “Wissenstransfer innovativ weiterdenken .” Workshop im Rahmen der 15. Wissenschaftstagung Ökologischer Landbau. Kassel.

Neumühle, Lehr- und Versuchsanstalt für Viehhaltung Hofgut. n.d. Hofgut Neumühle, Kompetenz in landwirtschaftlicher Tierhaltung. Edited by Dr. Karl Landfried. Accessed 02 05, 2022. https://www.hofgut-neumuehle.de/.

Schleicher, S. and M. Gandorfer. 2018. Digitalisierung in der Landwirtschaft: Eine Analyse der Akzeptanzhemmnisse. Edited by A. Ruckelshausen, A. Meyer-Aurich, K. Borchard, C. Hofacker, J.-P. Loy, R. Schwerdtfeger, H.-H. F. Sundermeier and B. Theuvsen. Bonn: Gesellschaft für Informatik e.V.

Schneider, W. 2017. “Neben Chancen auch Risiken der Landwirtschaft 4.0.” GetreideMagazin, 1-15.

Verbraucherschutz, Bundesministerium der Justiz und für. 2018. Richtlinie über die Förderung der Einrichtung von Experimentierfeldern zur Digitalisierung in der Landwirtschaft. Bekanntmachung, Bundesanzeiger, Bonn: Bundesministerium für Ernährung und Landwirtschaft, 1-7.

Wald, L., Eberz-Eder, D., Trapp, M., Weimper, J. and Kuhl,M. 2021. Smart Soil Information for Farmers (SoFI). Öffentliche Bereitstellung von Mess- und Simulationsdaten der Bodenfeuchte in der GeoBox-Infrastruktur. Bonn: Gesellschaft für Informatik e.V.

Wirtz, L., Wirtz, S. Unterrichten in Gesundheitsfachberufen- Pädagogisches Handbuch für Lehrende; 1. Auflage; Urban&Fischer; Elsevier; 2021