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# Innovative Engineering Education In The Wake Of Smart Agriculture. Revision Of The Agricultural Engineering Curriculum

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# INNOVATIVE ENGINEERING EDUCATION IN THE WAKE OF SMART AGRICULTURE. REVISION OF THE AGRICULTURAL ENGINEERING CURRICULUM


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## ABSTRACT

Global developments request ever more productive agricultural production systems to ensure food security. Agricultural production must be environmentally, socially sustainable and economically efficient. Innovative digital technologies are central to sustainable production systems. This poses challenges to the education of agricultural engineers, as technologies for real world challenges result from highly interdisciplinary innovations.

Agricultural engineering (AgEng) as academic discipline is not universally established, which leaves voids in educational curricula and formal training areas. A substantial conflictual dualism remains between the biological and engineering domains. There are currently no homogeneous pathways through which these domains merge on common scientific and cultural foundations, cumulating in consistent training areas. The diffuse institutional situation damages the position of AgEng as an academic discipline. The ambiguity of AgEng has become evident during the evolution of Smart Agriculture (SA), where digital technologies deeply interact with conventional agricultural technologies.

In the course of rapidly spreading SA technologies, the present paper formulates a rigorous approach to defining competence formation in AgEng to integrate cross-competences, which can be offered through lifelong learning (LLL) opportunities.

## 1 INTRODUCTION

Global demographic developments, climate change and political crisis call for more efficient agricultural production systems in order to ensure food security on global level. At the same time, contemporary agricultural production cannot simply intensify, but must produce environmentally, economically and socially sustainable (European Commission 2023). This poses clear targets and challenges to the education of agricultural engineers, as the solutions to such real world problems are characterized by highly interdisciplinary challenges and innovations.

Digital technologies of the socalled Smart Agriculture (SA) are central to address the challenges posed to agriculture (FAO 2022). Remote sensing, geo-localization, automated harvesting, monitoring and precision pest management are only a few technologies proposed under the term SA (VDI 2021). The present article looks into educational aspects and competence formation that this development has on the discipline of AgEng.

### 1.1 Agricultural Engineering: Definition and status

Conceptually, AgEng's primary goal is providing technological solutions to sustainable biological production systems (Holden et al. 2020). Aggregated goals are the preservation of nature, environment and landscapes. Central capacities of AgEng are the development of agricultural machines, technologies and production systems, thus, the technological soul of agriculture (Lazzari and Mazzetto 2016).

For the European Society of Agricultural Engineers, EurAgEng, "Agricultural engineering combines the disciplines of mechanical, civil, electrical and chemical engineering principles with a knowledge of agricultural principles according to technological principles. A key goal of this discipline is to improve the efficacy and sustainability of agricultural practices" (EurAgEng 2023). Comparable conceptualizations are drawn in non-European contexts, as in India (Singh 2015) or the USA (ASABE 2023).

The tools and skills to achieve these goals are partially provided by other engineering disciplines. Engineering and agriculture are highly dynamic professional and scientific sectors, especially since the emergence of digital technologies and processes. On academic level, many of the innovative research topics have a strong interdisciplinary character. In this context, scientific fields tend to expand their scope, creating competing skills and overlapping roles.

In consequence, the sphere of action of the agricultural engineer is compressed by the expertise of other fields of engineering, which tend to be better defined and structured, often moving discussions to focus on specific aspects of a problem. This, however, leads to a shortage of far-reaching visions.

Thus, while the mission of AgEng as a discipline is clear, its practical educational implementation is confuse. As a result, AgEng as a discipline lacks coherent development. Digitization poses further challenges to AgEng as it requires the re-ordering and potential enlargement and further collaboration with other disciplines.

The CIGR, the International Commission of Agricultural and Biosystems Engineering, maintains an open definition, promoting "sustainable biological production systems while protecting nature and environment and managing landscape through the advancement of engineering and allied sciences" (CGIR 2023). However, the adjective 'agricultural', to describe a core task, fell out of use. Fig.1 below displays the current seven CIGR subjections that cover the field of agricultural and biosystems engineering (CGIR 2023).

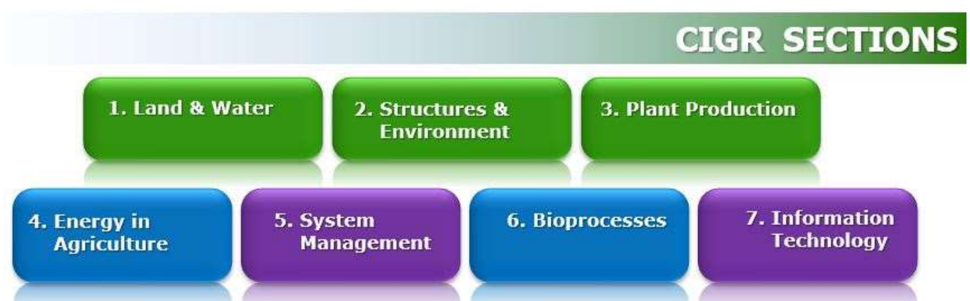


*Fig. 1 The seven sections of the International Commission of Agricultural and Biosystems Engineering, CIGR*

A comparable structure is pursued by the Italian Association of Agricultural Engineering, AIIA, which maintains seven sub-sections (AIIA 2023). Despite the tutelage by various associations, AgEng, as scientific subject and professional qualification, lacks representativeness and visibility in research and education institutions. There is a clear risk of thematical overstreching and conceptual blurring.

This is demonstrated by the plain absence of specific items relating to AgEng in the vast list of the European Research Council, ERC, categories. The term engineering is widely present, however not in combination with agriculture (ERC 2023). The adjective ‘agricultural’ is apparently problematic, as it doesn’t focus anymore on a specific domain of interest (DomInt), i.e. cultivated lands or animal husbandry. It rather addresses a too wide concept of ‘biological production systems’. DomInt’s intend portions of the real world over which we have knowledge or interests, driven by application purposes. Today, educational and academic institutions have difficulties to relate to AgEng DomInts as these are often crossing through various scientific and cultural foundations (Singh 2015).

## 2 METHODOLOGY

The diffuse position of AgEng in academia and institutions risks further deterioration inflicted by emerging SA technologies, which are brought forward by diverse engineering branches and information technologies. This practice paper seeks to conceptually develop educational units and curricula around AgEng, building on cross-competences and transversal capacities, in order to develop a conceptual model of rigorous competence formation in AgEng.

### 2.1 Conceptualization and competences of AgEng

To structure the position of AgEng in science, we may consider the correlated Scientific Disciplinary Sectors (SDS) with inherent DomInt’s. Central DomInt’s for AgEng are agriculture, engineering, biology, informatics and others. The DomInt determines a portion of the real world over which we have knowledge or control interests driven by application purposes. The DomInt of AgEng focalizes on production systems with environmental and biological elements that are difficult to control. Obviously, AgEng concerns several DomInts, as productive biosystems, mechanical engineering or digital technologies. DomInts, their areas and topics, are part of specific SDS, which are conceptual spaces that contain also investigation methodologies and objectives. Combining these elements, SDS represent recurring investigative approaches of enquiry, analysis and study, driven by specific application purposes and with modes of representation and documentation characterized by its own terminology. In Italy, where the scope of university education is structured in cognitive areas, for instance medicine, engineering, agricultural sciences, economics, these areas channeled in distinct SDS. The competences and cross-competences, expertise and skills of AgEng are actually divided into three distinct SDS, relating to the application fields of a) hydraulics and hydrology, b) machinery and plants and c) rural constructions, territory and landscape.

Inside a given DomInt there is thus a synthesis of several cognitive activities, deriving from a variety of expertises of various professional fields that characterize through an interdisciplinary approach the aspects of interest of the real system. The concept of “macrodomain of prevailing interest” (MD) considers the general and prevailing standpoint by which an analysis on the same real world is carried out. In each macrodomain, the related standpoint determines the purpose of the analysis with corresponding methodological approaches. The example of maize cultivation (Fig.2) indicates the many different standpoints by which the enterprise can be analyzed.

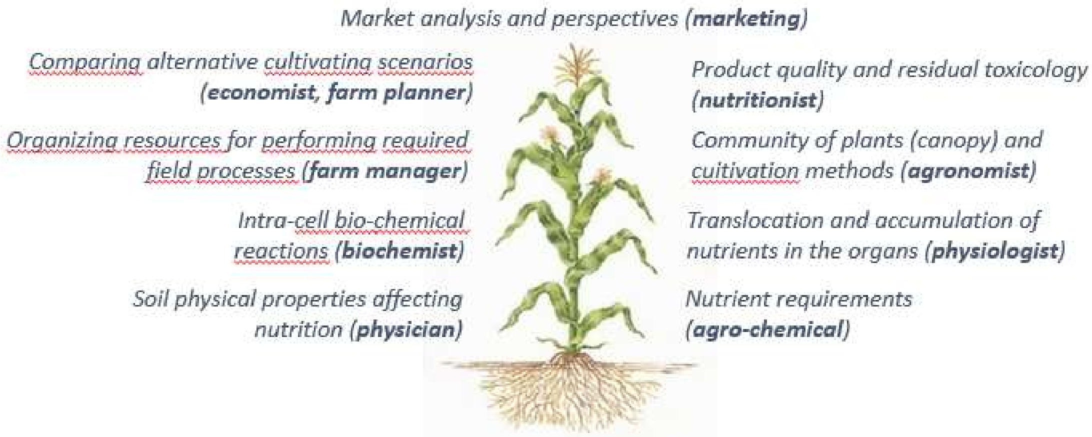


*Fig. 2 Example of maize colitivation with respect to possible macrodomains of prevailing interests (MD)*

The example in Fig.2 shows, how in respect to the specific interests, MD's differ. If prevailing interests concern e.g. nutrient requirements, the physical and chemical MD will prevail over others. Accordingly, for analysing the organization of field processes, social and organizational MDs will dominate. This doesn't mean that other MD's are neglected, as they scrutinize the complete system. MD's shift their emphasis according to prevalent interests.

MD's relate to decision-making by identifying one predominant viewpoint through which a system can be analyzed according to prevailing purposes. With regard to AgEng, four main MDs are significant (Fig.3).

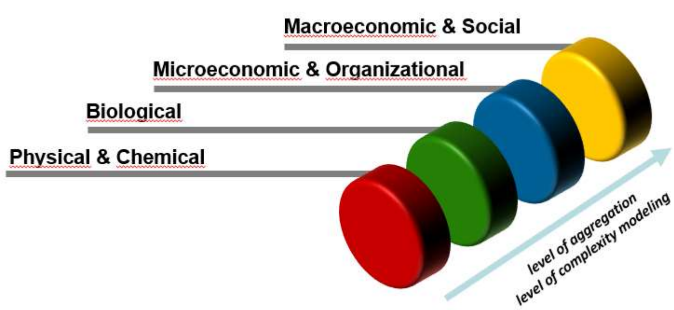


*Fig. 3 Four macrodomains of prevailing interests (MD) relevant in AgEng*

The outlined four MD's are the prevailing persperctives on relevant tasks in AgEng. Such methodological foundations are useful to clarify educational challenges, for instance with reagard to mountain agriculture. To form competent agricultural engineers, university courses must offer educational paths that create new knowledge around a given DomInt. Universities grant and promote the formation of autonomous sets of skills and cross-competencies supported by different levels of experience (internships, mentoring, collaboration with enterprise networks). The higher the interdisciplinary profile of the DomInt, the more robust the training in cross-competence topics, the more AgEng university courses offer real world capacities.

Structurally, AgEng courses are firstly articulated on teachings focused on sector-related expertise, while ensuring a proper level of cross-experience topics. Fig.4 displays the different thematic weighting of various MDs in university courses or programs.


*Fig. 4 The design of courses and programmes according to macrodomains of prevailing interests*

Fig.4 outlines very well, how in highly specialized courses a given MD tends to dominate over the others. In the case of an engineering course, the physical and chemical MD is predominant. In the past, some highly specialized bachelor programs were held in Italy, which eventually had little success. A lack of professionalism and falling interest was the result. AgEng courses should always ensure an equilibrated profile, avoiding over-specialization, as an universalist approach relates better to everyday tasks in agriculture.

Bringing this logic into university programs, the schematic overview of bachelor (left) and master courses (right) looks as displayed in Fig.5 below.

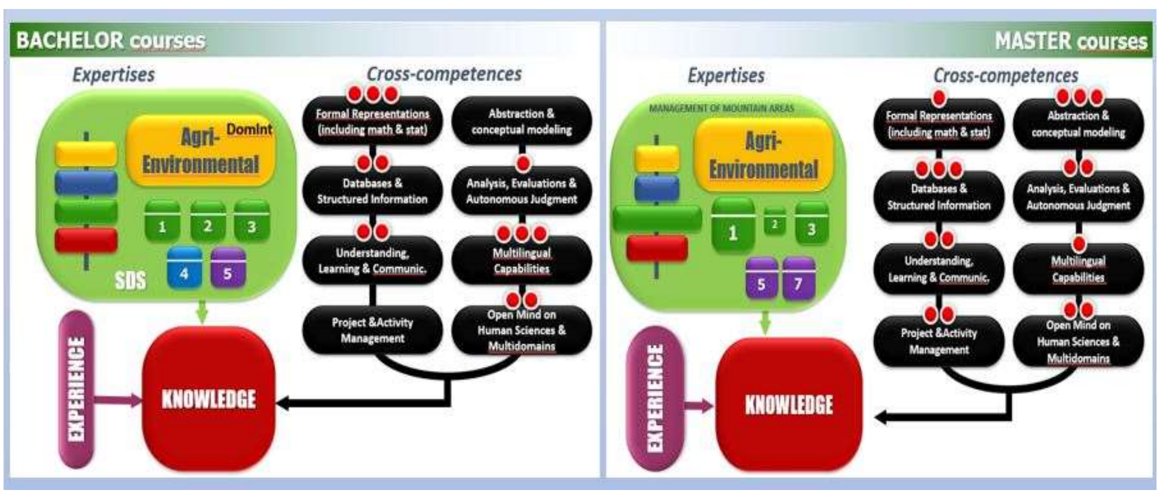


*Fig. 5 Schematic juxtapositon of AgEng Bachelor's and Master's degree programmes with different thematic focuses. Red dots indicate relative importance.*

Structurally, the left and right scheme of bachelor and master courses are equal, but weightening the various elements results differently. The four blocs in each scheme are related to each other: Expertises, cross-competences and experience generate, as final target, knowledge. Expertises consist of the agri-environmental DomInt (topics, methodologies, objectives) with orientation from five CIGR sectors and balanced MD's. This bloc (SDS) is juxtaposed to cross-competences of various weight (red dots). Experience is gained through autonomous activities as working placements, stages, mentoring programs or professional collaborations.

The bachelor's degree is build around balanced MD's and the CIGR sections 1 to 5. Additionally it introduces a first selection of cross-competences. This set up leads towards holistic and rigorous competence formation in AgEng. It describes the basic level of AgEng competence, but represents and underlines the broad picture of tasks within the discipline.

The master course with agri-environmental focus addresses specific tasks and developments as different MD's indicate. There is a focus on CIGR topic one to advance students' specialization on natural resources. This corresponds with a nuanced weighting of cross-competences towards abstract thinking and independent reasoning.

## 2.2 Smart agriculture: Curricula integration and cross-competences

The need for new educational elements in AgEng has become particularly evident with the appearance of SA, where digital technologies deeply interact with the traditional technologies of the agricultural sector, even with significant impacts in many application domains (crops, orchards, animal, soil, water, soil etc.) and related major impacts on the quality of management at farm level.

SA solutions enhance the management quality of decision making processes in agriculture as they allow to make decisions based on targeted information previously collected through monitoring procedures (Mazzetto, Riedl, and Sacco 2016). This

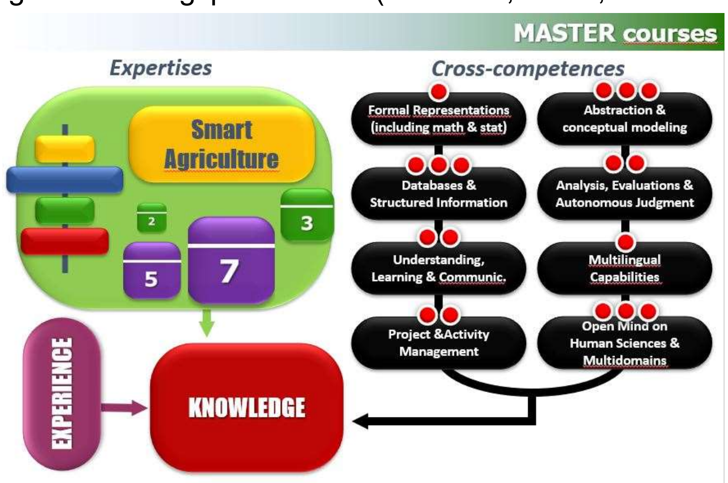


*Fig. 6 Combination of skills and cross-competences in SA in the framework of a master program*

adds complexity to the curricula and training of AgEng professionals, especially in context of an ever proceeding digitization and automatization of the agricultural technology chain. Digital skills can be integrated into existing AgEng education through both, expertises (DomInt's, MD's) and cross-competences. Following the previous structure Fig.6 provides an overview on the setting of a master course around SA technologies, including differing MD's, DomInt's, CIGR sections and cross-competences. Cross-competences take an even bigger share in the SA master program as there is a need for flexibility and stabilized transversal skills. The focus lies on the management and organisational MD, as well as on the 7$^{th}$ CIGR panel, information technologies. While the Agri-Environmental master requires many cross-competences, the drafted master in SA poses even more weight on cross-competences.

A promising option to include innovative cross-competences into the AgEng curriculum, is  the use of lifelong learning (LLL) modules or courses. The practice project USAGE, Upskilling Agricultural Engineering in Europe, has developed LLL opportunities on SA technologies tailored to agricultural engineers and practitioners (USAGE 2023; Vidric et al. 2023). USAGE conceptualized and developed diverse educational programms and products mainly on topics of the digital transformation. The short and tailored manner of USAGE LLL products fits ideally with cross-competences required in AgEng bachelor and master conceptualizations. USAGE produced a handbook that lays out the pathway to combine different LLL modules to a joint AgEng master program of the affiliated unitversities (Paulus et al. 2022).

## 3 RESULTS AND CONCLUSION

The present paper underlines that through a rigorous approach, academic competence formation in AgEng is possible. A stabilized curriculum on bachelor and master level, based on expertises, cross-competences and experience helps the discipline to address real world challenges and gain more visibility. Such stabilization will foster synergies and collaboration between sectors, rather than feeding unnecessary competition.

Emerging SA technologies require ever more cross-competences and interdisciplinarity. SA technologies refer to core capacities of AgEng and provide therefore an important incentive to strengthen and modernize the curriculum of AgEng. The discipline often suffers the competition with experts from other domains; which is normal when a domain is open to interdisciplinary approaches. The focus needs to remain on the primary goal, i.e. the technological soul of biological production systems, determining the exact role and contribution of each actor in the various steps of the process.

As a discipline AgEng needs for stable curriculum based on clearly defined segments (expertise, cross-comp, experiences) and flexible upgrading opportunities to cope genuinely with real world requests. Thus as a complete and transversal discipline, AgEng is able to develop far-reaching visions for technologies in productive biosystems. Considering the experiences from the project USAGE underlines how innovative LLL courses and learning modules can successfully teach cross-competences in the realm of AgEng and SA in comparably short time.

## 4 SUMMARY AND ACKNOWLEDGMENTS

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