Interdisciplinarity and awareness raising – two necessary challenges for sustainable education on the Water-Food-Energy-Nexus and the food value chain

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Introduction

In 2008, Lehmann and his colleagues introduced their publication with

> "In a world where systems are increasingly larger, [...] and where societal rather than technical issues play increasingly bigger roles, problems cannot be solved by applying a technical solution alone. It thus becomes important for engineers to be skilled not only in terms of their particular technical field but also in their ability to identify non-technical aspects of problems, the interaction between these aspects, and possible solutions. Introducing and integrating these aspects into engineering education is certainly not an easy task and requires innovative approaches."[1]

For more than a decade, the need for a holistic approach has been recognised, where "societal rather than technical issues play increasingly bigger roles". However, interdisciplinary developments in education are not yet wide spread[2] and are considered challenging[3]. Similarly, long-term consequences and sustainability have only recently emerged in classroom settings. Furthermore, migration and urbanisation as well as the related socioeconomic and cultural challenges and developments add complexity, for which young professionals should be prepared during their academic study. In Egypt, especially food security and a healthy environment, but also many other dimensions and indicators of sustainability are closely linked to water availability, salinity, and pollution[4,5]. With almost no precipitation, but plenty of sun irradiation the Nile, and to a lesser extent partially renewable ground water are currently the predominant source of water, pumped increasingly using renewable energy sources[6]. The successful design, operation and maintenance of these PV or wind driven agricultural pumping and irrigation systems require sufficient knowledge in at least four distinct fields: water and energy engineering, agriculture and economics. To do so sustainably, environmental and ecological dimensions are added, thus making food security a truly interdisciplinary challenge.

To address the topic of sustainability in the Water-Energy- Food nexus from two different perspectives, two independent ERASMUS+ co-financed curricula development activities were initiated by two partially overlapping consortia of Egyptian and European

Universities. One project, **DeVilag** focussed on the educational needs and opportunities to further sustainable agriculture by the approx 7 million smallholder farmers, representing the vast majority of agricultural labourers and the majority of land use in the Nile Delta. The second, **SureMap** focussed on the educational needs of larger enterprises that start farming operations in the western dessert, under the umbrella of the 1.5 Million Feddan (630 kHa), the New Delta, the Toshka or New Valley Project and similar governmental schemes to increase agricultural output, export opportunities and food security. The projects resulted in 6 new or improved MSc programs, two diplomas and two improved undergraduate degrees in engineering, agriculture and environmental sciences that all pivot on the concept of sustainable development, and integrate new didactical approaches like online teaching and problem oriented learning.

Materials and Methods

Data collection tools and approaches used

The methods and approaches were chosen primarily to base the curriculum development on a sound basis and to inform educators on perceived needs, beyond anecdotal evidence from a small peer group. They were designed to be descriptive or hypothesis generating, rather than to provide statistically validated, representative data. Accordingly, they were designed to capture maximally diverse opinions. This followers the rational that educators continuously adapt and develop educational content according to background knowledge, own interest and motivation, as well as classroom dynamics, and the choice of projects and topics by the students, in problem oriented learning (POL) or Project-Based (PBL) settings (based on Lehmann et al 2008[7]). Identifying and showcasing a whole variety of needs can in itself be used as an educational tool.

Evidence gathering was pursued through a farmer focussed stakeholder needs analysis that also included other representatives of the agro-food value chain's quadruple helix. It was supplemented by a thorough review of internationally and locally available curricula characterising them for innovative content and didactical approach. The stakeholder and curricula surveys were then combined in a gap-analysis that provided the basis for curriculum and teaching material development.

The curricula mapping exercises relied on extensive internet searches using keywords combined by Boolean operators in the search engines DuckDuckGo, Ecosia and Google. Topic specific key words like water, irrigation, energy, renewable energy, agriculture, food etc. were combined with educational content specific ones, like bachelor, masters, PhD, diploma etc. Further keywords used to characterise the programmes, were grouped as "project based" (key words included projects, experiential learning, skills, hands-on, experience), "field specificity approach" (key words like holistic inter- and multidisciplinary), "relation to industry" (incl keywords like internships, career, companies, field-visits, industry), and "research focus" (with keywords like research, thesis, publish, analysis). Results were discussed within the consortium and additional suggestions sought within available expert networks. All identified curricula and programs were then further analysed, characterised and classified, including the assignment of one or more predetermined thematic foci. Curricula that were not available in English, Arabic, Greek, Italian, Spanish, French, German or Swedish) were cursory analysed for innovative structures or course titles using Google Translate, but excluded for more detailed analyses and benchmarking considerations.

The design of the stakeholder review data collection tools reflects the necessity to determine the most suitable tools for varying socioeconomic and cultural settings and

different target groups. It was guided by recent developments in mixed methods research (MMR) that combines different analysis methods and study designs especially in social research, and applied disciplines. In the last 15 years, MMR approaches have gained momentum and numerous new fora have been established like the J. of Mixed Methods Research[7]. None of the studies described here aimed to obtain representative data, neither within the participating universities, nor amongst the stakeholders, experts or farmers, since this would have been beyond the scope of the study.

The methods aimed to facilitate an extensive needs analysis that can be compared and contrasted with the description of current teaching content and the didactical status quo. Initially, the primary needs analysis, implemented through the **DeVilag** Project was envisaged as a hypothesis-generating tool, and to validate approaches and techniques, including focus groups and "farmers meetings", for large-scale employment during the second study, implemented through the **SureMap** project. The stakeholder reviews all relied on the possibility of physical interaction, to clarify questions while filling in the questionnaires in a classroom setting, hence had to be adapted due to the onset of the COVID-19 pandemic for the second survey. Nevertheless, both phases of the survey applied a mix-method approach, collecting qualitative and quantitative data to maximise breadth and scope of the study. The data was collected from the following target groups thus duly covering the quadruple helix of stakeholders:

- Farmers (contractual and non-contractual)
- Agricultural Companies
- NGOs, trade associations, and unions
- University Professors, Graduates, and Students
- Government Establishments

The easiest target group to be reached were students, followed by their educators, teachers, and professors. Since post-graduate students in Egypt are routinely employed as junior teaching staff, the distinction was made by the role respondents played in the particular setting, rather than their seniority. Teaching and lecturing assistants were classed as staff, even though they might have been enrolled elsewhere in MSc or PhD programs, while those enrolled in targeted courses or programs were classed as students. For the university constituency, mainly structured questionnaires were used, consisting of multiple choice or likert scale analyses, with limited open answer questions. The aim was more easily analysable and interpretable data, while open sections enabled respondents to add additional or clarifying information whenever they felt this to be necessary. To cater for the experts' and non-farming stakeholders' severely limited time resources, structured interviews were used. They facilitated categorisation, enabled rudimentary statistical analysis, and provided sufficient flexibility to focus on the interviewee' areas of interest and expertise.

To capture a maximally diverse range of opinions, and counter arguments, as well as to put respondents more at ease within a familiar setting, an even more qualitative approach, based on focus group discussions (FGD) was chosen to survey farmers. The method allows to acquire input from large numbers of participants, and were moderated by experts in rural sociology, based on predetermined questions. Although moderators deviated from FGD scripts according to need and to capture unforeseen developments, limited comparison of focus groups was possible. Following the FGDs, farmers had the opportunity to voice their opinion in a more private setting, thus allowing the articulation of minority views or ones that contradict those expressed by community leaders.

To capture the expertise from both consorta, all questionnaires, interview guidelines and focus group trigger questions were developed in English and subsequently translated into Arabic. The development process included a phase of "background reading", followed by

the suggestion of appropriate questions. After merging duplicates, questions were then reviewed for clarity, precision, and priority, and a selection made to balance topics covered, with the depth and detail enquired, while limiting the length of the questionnaire. The thus developed tools were then once again reviewed by experts from the consortia, and translated into Arabic, and verified by 12 bilingual faculty members. Prior to dissemination on the farmers generally, the FGDs were tested on a pilot group of non-contracted famers. Similarly, face validity was ascertained for students' questionnaires. However, while cultural diversity and language use amongst students was sufficiently coherent in all investigated settings, this was not the case for farmers, hence rephrasing, "translation into local dialect" and explanations were found to be frequently necessary, also leading to subtle adaptations during implementation.

Targeting of survey respondents

Farmers in Egypt can be categorised into several relevant groups, including contract and non-contract farmers, smallholders and larger enterprises, as well as farmers in the old lands (mainly near the Nile or in the Delta) or the new lands, newly reclaimed desert. Significant numbers, especially of micro or small-scale farmers don't conclude contracts with wholesalers or traders before the planting season, but sell products at local and regional market places, post-harvest. Larger operators and specialised farmers (eg. organic) select crops based on pre-concluded contracts and export opportunities. The DeVilag related survey and curriculum development were mainly focussed on needs of micro-farms and the sustainability of smallholder farming. They are more likely to seize operations and migrate to the cities or beyond, whereas SureMap concentrated on larger operations in desert areas, designated by the Egyptian Government for development.

The qualitative survey conducted for farmers was based on 20 FGD rounds; 7 with contractual farmer groups and 13 non-contractual farmer groups. This was followed by a more traditional survey of an additional 103 farmers in the categories - smallholder farmers and large-scale farm operators.

The farmers' surveys were conducted in eight governorates. Alexandria, Kafr Al-Sheikh, Beheria (including Beheira and Beheira Oasis), Matrouh (including Moghra and Siwa Oases) and Sharqia are located in Lower Egypt, while Giza, Fayoum, and Aswan are in Upper Egypt. The student and staff surveys were focussed on the six universities participating in DeVilag or SureMap. Students and staff from other universities were also allowed to fill In the online surveys, but were not actively recruited.

To ascertain that the needs assessment also includes information from the whole quadruple helix of government and policy makers, NGO's, cooperatives and associations, manufacturers, traders and other commercial operators, a targeted networking effort was launched to interview decision makers and opinion leaders. Target specific interview questionnaires were designed to structure the interviews and maximise data acquisition during off and online visits that usually lasted approximately 30 minutes.

Results

The stakeholder review, curriculum development activities and training sessions were all implemented in two consecutive waves that initially were envisaged to build on one another but had to be adapted to the conditions caused by the COVID pandemic. The second wave's focus shifted largely to online activities, thus reducing comparability.

Focus group participants were mainly male, accounting for 86% of non-contract (NCF), and 66% contract farmers (CF). Reflecting the apparent farm-size distribution, 67% of CF operated on 6 ha or more and only 7% rented their land, while 69% of NCF operated on

2 ha or less, with 12% renting the land. Irrigation depended predominantly on Nile water (70% and 87% respectively). Large farms dependent also on deep wells especially in areas of the Egyptian Government's 1.5 Million Feddan and the New Delta developments. CF were much more likely to know about sustainable agricultural practices, including composting and the use of organic fertilizer, water saving irrigation techniques and proper crop planting times. On the whole NCF needed prompting on such methods, often believing they could only be applied at large scale. Educational levels and the highest certificate obtained also largely correlated with knowledge on sustainability concepts. One predominant conclusion by all FGDs was that there is a link between economic parameters (ability to generate sufficient income) and the desire to maintain rural life. This is now complemented by an emerging trend linking higher education with small scale farming suggesting a shift to smallholder farming for leisure.

> *No one who has land arranges to leave the countryside. Only those who are educated, physicians and engineers who are staying in cities … They rent places to live and stay there the whole week and come back during weekends and vacations. (Contracted Male Farmers, Beheira)*

It also highlighted the differing needs of small scale operations in the Delta, where environmental and water pollution, overpopulation, market seasonality, growth opportunities, access to markets and the ability to scale dominated. For large-scale operations in the desert, off grid energy availability and storage, access to water and its salinity, crop storage and transportation, export opportunities, availability of fertilisers and pesticides, as well as related quality standards were identified.
Especially amongst CF there was general consensus that graduates must be educated in the field and in direct contact with the farmers, in addition to their regular academic training. This should include topics like organic and sustainable pest control methods, and the safe transportation and crop handling, but also the ability to identify the farmers' challenges and needs themselves, stipulating an approachability as a decisive factor.

> *University students must be trained in the field and be the direct connection between the farmers and the agriculture research centres.*
> *(Contracted male farmers, Beheria Oasis)*

> *We need them close by us and to speak our language.*
> *(Contracted Male Farmers, Kafr el Sheikh).*

NCF were in general much less likely to receive consultation and advice from agricultural engineers, and more likely to rely on peer-networks or information from agricultural sales persons. They also complained regularly that the agriculture advice received was at times incorrect, although often, no examples were given. It was therefore not possible to identify whether the information farmers received was in fact incorrect, or if this perception was based on suspicion, misunderstandings or lacking knowledge of the farmers. However, it underlined the need to cover cultural, perceptional and language barriers during the education of water and agricultural engineers, and to match consultation and extension services with the capacities -financial and otherwise- by tailoring recommendations and suggestions to the farmers' needs and realistically judged capabilities.

> *"We want specialists to come and deal with us regularly, not just give orders and leave"*
> *(Contracted Female Farmer, Fayoum)*

In the first wave of the student and academic survey, 205 students and 59 faculty members across three Egyptian Universities participated, with 34% of students and 39% of staff being associated with private universities. Students were 54% at undergraduate level, and staff evenly distributed between seniority levels (from demonstrator to professor). Undergraduate students and those enrolled in a public university were predominantly female (59%), while faculty was predominantly male (62%). About 30% and 50% of students enrolled in private and public universities respectively had not been introduced to the concept of sustainability or sustainable agriculture, while 97% of staff had, with seniority being correlated to availability of information. This suggests an increasing awareness in academic professional circles, but less so in the general public. This is supported by the finding that over 75% of teaching staff and over 96% of students obtained their knowledge in a university setting.
Based on the level of knowledge identified in wave one, a further 336 students and 115 staff were surveyed to determine their insights on the needs identified from stakeholders. Their characteristics in age and gender distribution were very comparable to wave 1, although there was a marked increase in participants with science, business and engineering backgrounds. The main needs identified were water and irrigation related challenges, lacking skill sets, urbanisation pressures, climate change adaptation and energy related issues. For the 103 additional farmers surveyed (90% male, 52% land owners, 23% with no formal education) however, challenges related to desert land reclamation, water and irrigation, supply chain, environmental and crop pollution and export opportunities as well as lacking skill sets and funding, including financial incentives were the top 5 priorities respectively. Not surprisingly other stakeholders from the quadruple helix including government and policy makers, civil society, and industry representatives weighted the challenges according to their field of activity. Sampling in banks, agri-food businesses, NGOs, cooperatives, governmental and trade organisations was through networking and by recommendation, thus resulting in relatively small sample sizes. The majority of respondents focussed on their area of expertise, hence no statistical evaluation was carried out. Once common theme was however, the realisation that solution to most of the identified challenges and especially those related to sustainable development, required interdisciplinary skill sets, to facilitate synergistic cooperation.

The curriculum mapping identified 412 programs that are at last partially suitable for benchmarking. The majority of them are taught in Europe, North America or Australia and to or the Middle East - covering all thematic foci considered relevant. Interestingly the educational level varied considerably, with a relative predominance at Masters' level, and non degree courses. Interestingly, some highly interdisciplinary topics like green supply chains, carbon and water footprinting were rare and often lacked a holistic approach. In Egypt, the majority of topics were covered through newly developed courses in more traditional degree programs - commonly as electives.
35% of the programme identified were judged to integrate a project based approach, 25% were considered to foster relations to industry, 19% included research elements and only 17% were considered interdisciplinary. Unsurprisingly, 57% of vocational training courses had very strong links to industry, and 43% included project based elements, but all lacked research activities. PhD degrees on the other hand were regularly project based, with a strong research focus. Interestingly, PhD and Masters' programs were 2-3 times more likely to be interdisciplinary than general certificates, diploma or vocational trainings.

The comparison of assumptions expectations and the knowledge available in educational settings and especially the content of curricula, with the needs communicated with the stakeholders identified three areas of similar importance that require development. The

Fig. 1 Educational offerings with a focus on agro-food related sustainable development topics identified through online searches and limited academic stakeholder surveys.

general integration of skill development into curricula has started, but although intended (learning) outcomes are generally specified, testing and verification should improve to ascertain an acceptable level at the end of any program. One approach is the integration of problem oriented learning (PoL), but requires extensive training of many educators and the development of suitable examination methods. Similarly, the integration of sustainability considerations in agriculture and engineering curricula is also ongoing, but would benefit generally from a more interdisciplinary approach that allows consideration of all four dimensions of sustainability – ecological, economical, socio-political and cultural. Last, but not least, it became apparent that thus far curriculum content largely caters for the needs of economically lucrative markets, like large scale agricultural operations and export oriented farmers. However, many of the 2030 sustainability goals will not be reached, if the needs of less lucrative markets, like rural communities, smallholder and persistence farmers fail to be considered. Most of the analysed curricula seem to lack this dimension hence within the project it became a focus of development.

On this basis, a total of 73 different courses and their educational content were developed in nearly 100 online meetings. Relying on local teaching staff and international input to ensure that the content is both, suitable for local conditions and of adequate quality. Until now, two Masters' degrees, a diploma, as well as specialisations at Bachelor's level in agriculture, food processing, water and energy engineering were developed and implemented in two governmental and two private universities, each containing courses that focus on smallholders needs. An additional diploma and four Masters' in environmental sciences, water and energy engineering as well as agriculture that all follow an interdisciplinary approach and share similar courses have been developed and are due to start implementation. Concurrently, 14 training programs for teaching staff were implemented covering didactical and technical topics, but also material and content development for online teaching and Massive Open Online Course (MOOC) development as well as plagiarism, IP and copy right considerations.

Discussion and Conclusion

Adaptation to challenges posed by recent societal and environmental changes requires cultural and behavioural changes at the individual, community and country level as well as globally. One approach to facilitate change builds on educational development and the adjustment of didactical approaches and teaching content. Two ERASMUS+ co-funded curriculum development projects attempted to further the concepts of sustainable development in the water-energy-food (WEF) nexus, based on needs analyses and stakeholder surveys. They identified interdisciplinary competences and personal or soft skills for professionals and didactical approaches for educators as development opportunities that should be considered in curriculum development. Interestingly, a recent study, published by Moazen Kloor and colleagues (2021)[9], recommended that both "content-based and skill-oriented curriculum approaches" should be "considered as a general principle in the revision of agricultural extension and education" curricula. Based on the feedback from the quadruple helix of stakeholders, numerous curricula and teaching courses were developed that address sustainable development in agriculture, engineering and environmental sciences, with one focus on smallholder farmers and small entreprises in the Nile Delta and Old Lands and the other on large scale desert land reclamation in the 1.5 Mio Feddan and New Delta initiatives of the Egyptian Government. Concomitantly, staff members at participating Egyptian universities were trained in the development of online teaching materials, including the production of educational videos and Massive Open Online Courses (MOOCs). A very similar approach has recently been published by Mehany and colleagues (2022)[10] who described a Sustainability and Resilience Education Framework for Interdisciplinary Course Development that also uses 4 dimensions of sustainability. Furthermore, the results and drawn conclusions were recently supported by findings of Baptista et al[11] who identified best practices Masters' programmes in Sustainable Agriculture that included of interdisciplinary courses of agricultural practices. However their definition was somewhat more restricted, being

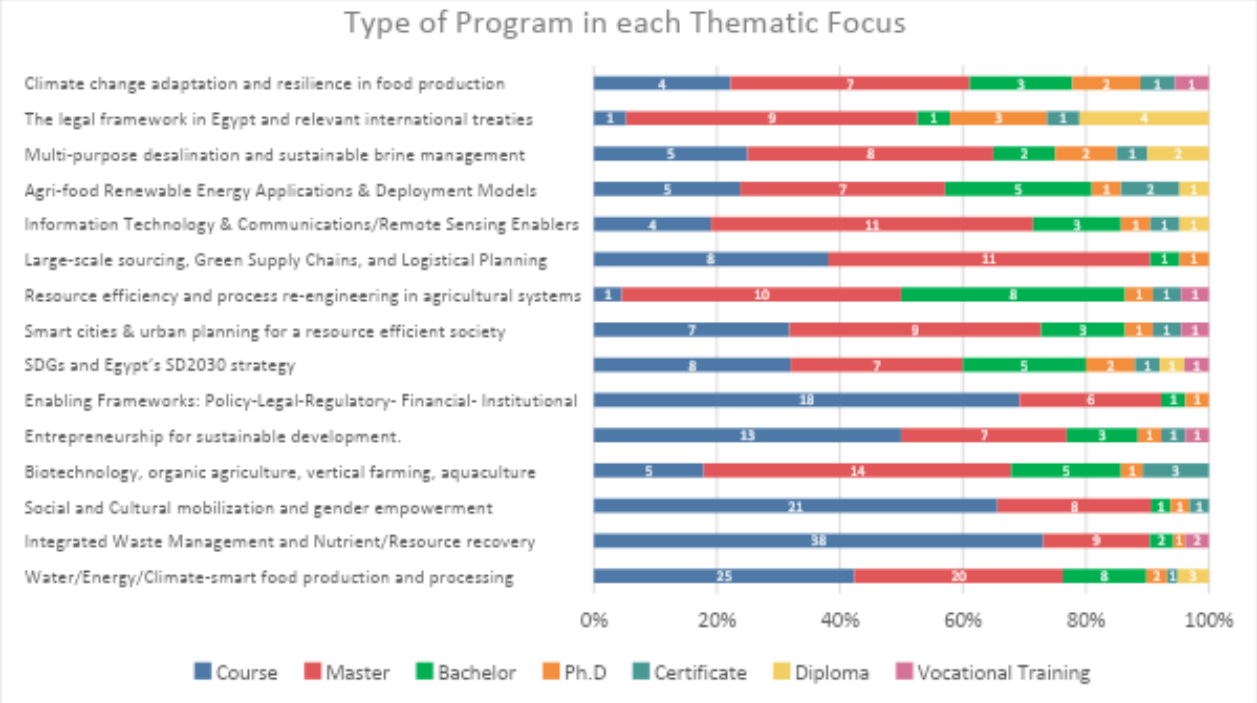

Fig. 2 Level of education at which the different topics are offered for professional development.

limited to agricultural practices, and technologies and systems linked to climate change adaption and mitigation, but it seems plausible that this can both be extended to related fields in engineering and environmental sciences as well as economics. This is also supported by the identified skills that professionals in the agro-food value chain need in the transition towards a sustainable agriculture.[12] Interestingly, Sørensen and colleagues linked them to the ability of educators, to "encourage a student's perspective that moves beyond generic discipline-based skills and instead builds on heterogeneity, inclusion, and use of different actors' knowledge, practices, and experiences, and the ability to respond and be proactive in a constantly changing world". The developed degree programmes thus can make a contribution to Egypt's move towards reaching the SDGs. However, staff awareness and training as well as student recruitment remain major challenges that are linked to lacking awareness by parents and school leavers regarding the opportunities and challenges related to sustainable development. With the organisation of COP27 in Egypt, this is likely to change in the near future, putting Egypt in a strong position for sustainable development.

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