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Educational and training innovation opportunities in the aquaculture and fisheries sector of Hungarian secondary agricultural education

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Abstract
Among the challenges of the aquaculture sector, the present study tries to focus on the necessary modernisation and innovation of the Hungarian sector education by strategically outlining the possibility of a niche secondary-level fisheries PILOT (experimental) training. It is obvious that the "launching" of such a shortage training level is a very complex and long-term task, but in our opinion not unfeasible. To this end, we are considering the development of a multi-stage action plan, the first milestone of which will be a thorough situation survey of the aquaculture education community. The study applies a deductive approach to specific areas of education and training within the general trends in aquaculture, covering the main traces of PILOT training in fisheries as a niche discipline. Our first paper, targeted at educators, focuses on the results of a questionnaire survey of 94 educators. Our main objective was to assess the presence of aquaculture-related knowledge content and associated methodologies in the classroom and the general digital literacy of educators. Our objectives also focus on the general digital readiness of vocational trainers and on the patterns of "professional marketing" opportunities that aquaculture professionals can express.

Keywords Aquaculture · Vocational training · Secondary education · Sustainability · Trainers · Hungary

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Introduction

In the aquaculture and fisheries sector in Hungary, the design and implementation of PILOT training requires a very long and complex exploratory research. In this paper, we explore and describe the micro and macro environment in which our future training will fit perfectly. In the course of our research, it became clear that the limited amount of theoretical studies and empirical studies related to our specific topic is a serious limitation to our objectives. In order to develop a literature framework, we started a literature search on the Web of Science (WoS).

Very few studies have been carried out on the subject of vocational training in aquaculture at the secondary level. An exploration was attempted using synonymous search terms (aquaculture vocational training, education, secondary education, fishery vocational training etc.), with no results in the WoS filters relating to education as a discipline, but the number of papers relating to fisheries was also limited compared to other disciplines. In view of this, our study neglects the possibility of synthesising with other literature and the lack of similar empirical studies, which would allow for comparison. As regards the structure of the theoretical part, the first major thematic unit of the introduction chapter focuses on the broader (sectoral) context, while the second panel draws attention to the more specific educational and training framework.

Key trends in the aquaculture sector

According to the FAO (2022), world fish production (live weight) reached 214 million tonnes in 2020, 60% above the 1960s average. In 2020, aquaculture production will reach its highest level ever at 122.6 million tonnes (FAO 2022). In 2020, 58.5 million people were working full-time, part-time and casual jobs in fisheries and aquaculture, of whom 21% were women. By sector, 35% of the employed worked in aquaculture and 65% in fisheries (FAO 2022). Less than 1% of the nearly 20 million people employed in aquaculture in Europe, North America and Oceania work as fishermen or fish farmers. Interestingly, until 2015, employment in fisheries and aquaculture in Europe showed a downward trend, but between 2015 and 2020, there was a 3% increase in fisheries and a 5% increase in aquaculture (FAO 2022). EU production figures have recently increased by around 24%, with Spain (21%), France (15%), Italy (14%) and Greece (10%) among the most important aquaculture-producing countries, accounting for 74% of EU (European Union) aquaculture production.

From 2021, the EU set out a vision for the further development of aquaculture that will contribute to both the European Green Deal and the economic recovery following the Covid-19 pandemic. The new guidelines build on strategic experience at the EU and national level and take into account recent developments, including research, innovation and the use of EU funding. They also respond to the calls of the "farm to fork" strategy to accelerate the transition to a sustainable EU food system, recognising the potential of sustainable aquaculture to produce food and feed with a low carbon footprint. In order to achieve this vision, attention must be paid to the various challenges and opportunities for EU aquaculture to achieve the following interlinked objectives:

- Creating resilience and competitiveness
- Participation in the green transition
- Ensuring social acceptance and informing consumers
- Increase knowledge and innovation

The Strategic Guidelines identify 13 areas where further work is needed to ensure the sustainability, competitiveness and resilience of EU aquaculture. The guidelines set out concrete recommendations and propose concrete actions for the Commission, EU Member States and the Aquaculture Advisory Council.

The EU's strategic objective, in relation to Hungary, is linked to a forestry and fisheries sector that contributed 3.9% of GDP production in 2021. Within the livestock sector, the fisheries sector has shown a steady increase in its contribution to GDP, despite the fact that the sector is generally outdated in technical terms. The gross production value of domestic fisheries in 2021 was 69 million Euro with the sector's output value rising steadily for several years. For many years, the edible fish production of the fisheries sector has made a small contribution of 0.01% to the gross value added of the national economy. It can be assumed that neither the output nor the production value of the sector will change significantly in the coming years, because compared to other agricultural sectors, the fisheries sector is small and has been producing fish in approximately the same size of farmland and in almost the same quantity for years (MA-HAL 2022). Overall, it can be said that the aquaculture sector in Hungary is predominantly characterised by freshwater fish and fishing activities and it can also be said that it has to cope with the same major problems as the European sector as a whole (Urbányi et al. 2023). From the point of view of our study, the most relevant of the 13 EU strategic guidelines is the need to increase knowledge and innovation, and it is in the context of these that we focus on the need to reform vocational education in the sector, which is threatened by labour shortages that cannot be offset by technical solutions and increased mechanisation.

Education and training guidelines in fisheries

The FAO's thesis is that it is important to invest in education to ensure that more evidence-based information reaches consumers in order to address the different perceptions that affect the growth of the aquaculture sector. If we want to promote aquaculture products, it is important to understand how consumers currently use information to communicate their consumption preferences, including their origin (Duisenbekova et al. 2024; Beyer et al. 2023). The European Aquaculture Society held its annual conference in Rimini in autumn 2022. The conference motto "Innovative solutions in a changing world" fits well with the EU orientations described above, and one of its sessions focused on educational issues, which are also emphasised by the FAO.

Comparing aquaculture education with agricultural (farming) education, there are two major differences in the acquisition of knowledge:

- There is a long and strong tradition of agricultural training in Europe, in contrast to aquaculture training, which is still in its infancy; there is a lack of sufficient numbers of high-quality courses, both at the secondary level and in adult education frameworks.
- The output needs of agricultural training, the educational platforms adapted to them, are well defined and operate along precise labour market needs, in contrast to aqua-

culture training, where market needs are still being identified; in some cases, only definite needs are encountered. For these reasons, aquaculture education in Europe shows a varied picture (Urbányi et al. 2023).

Relevant to this adult learning framework is AQUA-TNET, a thematic network for Aquaculture, Fisheries and Aquatic Resource Management, which plays a leading role in cooperation between stakeholders to improve quality and develop the European dimension by stimulating and supporting innovation within disciplines and by improving lifelong learning opportunities. The network regularly provides relevant information on ongoing reforms in higher education and vocational training in Europe, to some extent successfully encouraging its partners to learn about and use lifelong learning strategies (Seixas and Eleftheriou 2020). This strong motivational sponsorship (Khademi-Vidra 2014, 2017; Imbeah et al. 2020) can be observed in the aquaculture-related continuing education systems of a few European countries. An example of such a system, which is very efficient and demand-specific, is the Austrian system. To identify and describe specifically the range of European vocational training institutions in the field of secondary vocational training in fisheries, we have a very difficult task. At the EAS 2022 conference (Rimini, Italy), a special session was devoted to the problems of training and education in the aquaculture sector. The focus of the session was on how to fit the professional qualification needs of the very diverse aquaculture sector to the European Qualifications Framework (EQF) and how to match the different levels of training to the needs of the practitioners in the sector. It was also mentioned that it is difficult to formulate uniform good practices, partly due to the diversification of the sector and partly due to the lack of information, as there are no databases on the different National Training Institutions and their levels (Padros et al. 2023). The only living and effectively functioning traditional school model in our narrow, Central and Eastern European region that we have detected is the Training Institution of Trebon in the Czech Republic.

Trebon in the Czech Republic is home to one of Europe's most professional vocational schools for fisheries and fish farming. The school's main training is full-time and takes place over 2 years. The basic requirements for admission are successful completion of a 3-year course in fishing, a teaching certificate and a standard entrance examination in Czech language and mathematics. On completion of the course, the student will have a secondary school leaving certificate. During his/her studies, the student will learn about freshwater fish farming, fish farming production technology, aquarium and ornamental fish species farming, the biology of aquatic organisms in aquatic ecosystems, mechanisation in aquaculture and fisheries, waste management and preventive measures that increase the risk of fishing losses. It also covers aquarium and ornamental fish farming, angling, fish diseases, angling techniques, biology, mechanisation in fisheries, fisheries, waste and the environment. The general education subjects are Czech language and literature, mathematics, English, chemistry, hydrobiology, physics, computer science, economics and organisation and social sciences. After completing their studies, students can find employment as fisheries technicians in the primary production of fisheries production, as workers in fishing organisations etc. It is also important to mention that the school cooperates with the largest fish farming and processing companies in the Czech Republic. The Czech aquaculture sector is parallel to the Hungarian aquaculture technology in its traditions and current technology. The production environment, the breeding technology used and the infrastructure used are identical to the Hungarian production. The only difference is that in the Czech Republic, it takes 4 years to produce market carp (approx. 2 kg body weight), whereas in Hungary, it takes 3 years.

Thus, it can be stated that the training methodology proven and applied in the Czech Republic serves as a good model for Hungarian developments and as a starting point for the development of the Hungarian Aquaculture Training Strategy.

Training traditions in the domestic fishing industry

Domestic fisheries education has a history going back nearly 100 years. It is a good illustration of the conditions that preceded it, in order to meet the personal needs of the development of fishing, to "designate individuals to be sent abroad for the practical learning of fishing 'tricks'". In 1906, the Fisheries Administration Department was set up as a separate department within the then Ministry of Industry to deal with fisheries matters. As one of its first activities, the Royal Hungarian Experimental Station of Fisheries and Wastewater Treatment was established in the same year, followed shortly afterwards by the Station of Fisheries and Wastewater Treatment, which operated within the framework of the Budapest Veterinary College. These two institutions can be considered the pioneers of fisheries education, as their declared mission was to carry out theoretical work (including education) in addition to practical tasks. This situation persisted until the end of the Second World War.

After the Second World War (Table 1), an educational structure was developed to meet the needs of the socialist economy, which enabled dozens of professionals to take part in practical and theoretical training and consultancy abroad. This period was characterised by a triple pillar of education: apprenticeship, intermediate fish farming education and higher fisheries education. Apprentices were trained at the Agricultural Vocational School in Tata, the 13th biggest city of Hungary (both full-time and part-time). Intermediate training was also provided in Tata and was less successful, as technician certification courses were correspondence courses and the employment of intermediate cadres on farms was not yet widespread. The tertiary fisheries training was provided by the universities at the level of plant engineer and agricultural engineer. After the change of regime, fisheries education also changed. Secondary education virtually disappeared, while apprenticeships (which in their heyday had 25–30 students per year) also became less popular.

Universities continued to provide fisheries education, further strengthened by the decision to transfer doctoral (PhD) training from the Hungarian Academy of Sciences

Table 1 Domestic fisheries education in Hungary (1945-)

Period	Name of training, level, institution
1945–1989	- Professional practice - Intermediate fish farming education (agricultural vocational schools) - Post-secondary fisheries education (university)
1990-	- Basic fisheries training in agricultural vocational schools. The last training was in 2015; since then, the training has been discontinued - There was no secondary-level fisheries training in Hungary - Tertiary level fisheries training is available within the general agricultural engineering (MSc.) and agricultural engineering (BSc.) degree programmes at the level of specialisations (5 and 7 subjects respectively) - Since 1994, PhD training has been transferred to the universities, during which period 35 colleagues have obtained their PhDs in aquaculture at the Hungarian University of Agricultural and Life Sciences and its predecessor institutions

(MTA) to universities in 1994. EU accession brought further changes. Hungary, as an EU member state, introduced the so-called Bologna system of higher education, whereby students are awarded a bachelor's degree (BSc., equivalent to a college degree in agricultural engineering) in the first stage, usually after seven semesters (3.5 years), and then a master's degree (MSc. = master's, i.e. university degree in agricultural engineering) after further four semesters (2 years). Despite serious efforts, and despite the adoption of accredited training, the training of fishery apprentices has practically disappeared. Fisheries education cannot be divided up today on the basis of the traditional training structure. Today, apprenticeship training would still be available mainly at the Jávorka Sándor Agricultural and Food Vocational School and College (Tata), but the institution is subject to strict rules, and the training is conditional on a sufficient number of students applying. Unfortunately, this critical number of students has rarely been "cobbled together" in recent years, so the number of graduates from the school has been reduced, even though they are much needed. The sector is characterised by the presence of "trained fishermen" who learn the ropes from their older colleagues who have graduated from Tata. All the higher agricultural education institutions offer courses in fisheries management.

A new trend in higher education is the so-called dual training, whereby companies finance (partly or fully) the student's training, but expect him/her to complete a degree and diploma in a pre-defined field. This has not yet spread to the fishing industry and the breakthrough is still to come. The Hungarian educational system includes a special type of training (which the EU is not able to interpret and place the diploma on the labour market), and this is the training of fisheries engineers (currently called Fisheries-Fisheries Management Specialist Training). Its characteristic is that a minimum of BSc (vocational qualification) can apply for the 2-year training, where you can receive the training in 3×1 weeks per semester. The reformed education system has brought with it the introduction of courses and training under the so-called OKJ (National Training Register), including the Fish-Fish Farming Training, which has a 3-year school-based training period and 800–1000 h of extra-school training. This training is currently being restructured and reformed. Fishing education also includes a relatively large number of further training courses and courses, many of which, although they do not award certificates or diplomas, provide high-quality training. Universities and research institutes are mainly affected by the trend in national education policy towards training foreign students. In the past, more foreign students have graduated from Hungarian educational institutes. However, recently, under the so-called Stipendium Hungaricum scholarship programme, the government has created a BSc. This initiative is to be commended as it provides a further opportunity for foreign students to develop their skills under the guidance of Hungarian educational and practical professionals (in modern terms, this is the transfer of knowledge), and these students return home bringing the sector's reputation to the Hungarian universities and colleges. Higher education institutions that provide theoretical training in the school system also provide practical training, but in close cooperation with sectoral (FM) and academic institutions. This duality serves well, especially at MSc and PhD levels, as it provides students with practical knowledge in addition to theoretical knowledge.

Finally, it is important to stress that our education would be worth nothing without the support of practitioners and their companies. The wealth of knowledge, the knowledge of fisheries management, is available in the practical sphere, which is why we need to cooperate as widely and as deeply as possible, and dare to assess the expectations and needs of practice, because this is the basis of practice-oriented training, and this is how we can

expect to produce qualified professionals who will be able to stand their ground in the labour market and enhance the reputation of our sector.

Digital competences, novel motivational patterns, innovative methodologies in aquaculture

To implement future PILOT training at the school level, we need an active, knowledgeable, open-minded teaching team; a motivated and interested student body; and a supportive and inclusive school environment. Digitalisation can be a form of connecting teachers and students (which of course does not replace but can complement face-to-face interactions, human relationships and learning situations). Researchers have developed a number of conceptual frameworks to comprehensively clarify what digital competence involves and have developed various appropriate measurement tools. There are some self-assessment tools for teachers' and school leaders' digital competence (Cabero-Almenara et al. 2020; Rieckmann 2018). However, most of these tools focus on pre-service teachers (McGarr and McDonagh 2019; Brandt et al. 2019; Koehler and Mishra 2009), and even recent contributions point to the need to consider educational contexts other than primary and lower secondary education (Vare et al. 2019; Roll and Ifenthaler 2020).

The literature on teachers' digital competences and competence development takes a variety of approaches (e.g. Bencéné Fekete 2021, Almerich et al. 2016; Cabero-Almenara et al. 2020; Cattaneo et al. 2021; Belaya 2018). The competences involved are multifaceted: they include technological competences and pedagogical components (Rudnák 2023), all of which are related to the context of teaching (Industry 4.0; see also Ghomi and Redecker 2019; Cabero-Almenara et al. 2020; Teo et al. 2021). The technological component of digital competences includes skills needed to use computers, mobile devices and applications (Hajiyeva et al. 2023; Cattaneo et al. 2021; Belaya 2018). Teachers need to develop their digital skills, including the use of software and hardware (Guzman and Nussbaum 2009). Lindsay (2016) notes that teachers also need to master mobile ICT technologies, as learning-teaching processes are increasingly taking place in informal contexts where learning can take place anytime and anywhere.

The studies reviewed (Rosenberg and Koehler 2015; Kontio and Lundmark 2021) further emphasise that vocational learners and trainers need digital problem-solving skills in addition to the relevant skills. Furthermore, it is important to analyse and evaluate information (this is called information literacy). Part of digital development should include a review of self-efficacy related to skills: it is essential that the educator reflects on and tries to understand his/her actions in the digital environment (Cattaneo et al. 2021). Digitalisation, the rise of online platforms, has not only had an impact on the educator society, but has obviously rewritten the paradigms of youth and consumer culture as a whole.

To summarise this thesis briefly and succinctly in the context of aquaculture, it can be said that young people have become active consumers, often making conscious food choices and establishing their adult fish consumption habits in adolescence (Beyer et al. 2023). The young generation therefore has a very different experience of education today than even those who sat in the classroom 10–15 years ago. This is partly due to the increasing demand for rapidly developing digital technologies in an accelerated and globalising world, and partly due to the impact of Covid, online education at home. Young people are inundated with a constant stream of information from online platforms that they cannot and do not want to absorb: they decide whether to be interested or move on based on impulses acquired in seconds. Young people need to be attracted to the sector with buzzwords that

capture the imagination of a thinking teenager (they learn about it at school, they are often asked these questions on social media, they receive constant updates on their smart phones etc.). There are already digital attempts in aquaculture education to attract young people and orient them towards a career in the sector. One such initiative was the Kyrgyzstan FishKA education project, which involved academics in an online course that provided students with a creative way of learning about the fisheries and aquaculture sector in Central Asia and Kyrgyzstan in particular. The teachers participating in the project had previously attended digital competence development courses, where they learned the basics of interactive and inquiry-based digital learning, as well as the use of digital learning environments and ICT skills (Tarasova 2021) Through these examples of good practice, it can be seen that what is needed today is not only professional lexical knowledge and practical experience, but also the digital competences that enable the theory and practice of aquaculture to be presented in an online space and to be taught in an innovative way.

Teachers' experiences and methodological suggestions for sectoral sensitisation of young people

Game-based learning has emerged in recent years as an interesting didactic tool to promote science learning (Sanders et al. 2023; Manzano-León et al. 2021; Stanitsas et al. 2019; Gardner and Strayer 2017). The goal is always to create a playful educational environment where students enjoy the experience while learning (Gil-Quintana and Prieto Jurado 2020; Wilson et al. 2018; Young et al. 2012; Barab and Dede 2007). Game-based learning involves (re)designing learning activities based on educational and discipline-specific issues, using educational games that have applications within and beyond educational settings (Herrero et al. 2020; Stanitsas et al. 2019; Plass et al. 2020). The use of analogue games and digital simulations has increased learners' motivation and interest in learning about environmental issues (Fox et al. 2020). Different educational experiences have been used in game-based learning on fisheries sustainability and ocean literacy (Arboleya-García and Miralles 2022; Fauville et al. 2019). Often, these educational practices are based on knowledge of marine biodiversity and environmental issues (Kelly et al. 2022; Ghilardi-Lopes et al. 2019) or introduce role-playing to analyse the perspectives of people interested in ocean conservation: fishermen, marketers, environmental managers etc. (Schmäing and Grotjohann 2023; Schmäing and Grotjohann 2023; Arboleya-García and Miralles 2022; Parrondo et al. 2021; Koenigstein et al. 2020; Fernández-Polanco et al. 2010).

The educational strategy developed to promote responsible consumption education and to support sustainable small-scale fisheries and sustainable fisheries followed an approach based on gamification of educational content/knowledge. Thus, the Spanish experts designed three specific games (face-to-face and online board games). Based on cooperative learning, the games refer to the environmental and social impacts of different types of fisheries while the learners acquire knowledge about natural marine resources. An online interactive cooperative game, *Sustainable Fish Consumption* (*Consumo Pescado Sostenible*), was created using the Genially app, following the style of an interactive virtual recreation room (Paredes-Rodríguez et al. 2023; Huang et al. 2020). This game demonstrates the sustainable use of marine resources through artisanal fishing and provides students with appropriate training to enable them to make choices for sustainable fish consumption. The game offers an empathetic eco-social perspective, referring to the impacts on local fishermen fishing in distant seas and the balance between their professional and private lives. The classroom implementation of the game facilitates students' collective reflection through

feedback in the missions/challenges from Octopus, the Ecos(i)Food project logo, who acts as a virtual hidden teacher. All students can win the game by working more effectively in a cooperative environment. This game provides an ethical context from which students can see the consequences of consumer choices in the conservation of marine biodiversity. In another didactic proposal for game-based learning, the *Fishing Alphabet* virtual game (*Rosco Pesquero*), students had to select the appropriate word related to fishing and responsible consumption to progress through each letter of the alphabet (Paredes-Rodríguez et al. 2023; Huang et al. 2020). The word choices in the game in these instructional phases were selected according to the science curriculum. Thus, they were related to the tools and types of small-scale fisheries, marine species important in regional fisheries, fish markets, environmental impacts and the basic elements that an eco-label should contain. The third game, *Juego de Memoria Recursos Pesqueros de Asturias* (*Memory Game of Fishery Resources of Asturias*), was based on traditional card-pairing games, with species selected based on socio-economic and cultural importance (Torralba-Burrial and Dopico 2023).

Material and method

In order to achieve our long-term goals (implementation of PILOT training at the secondary level), we started to explore the educational and training environment of the sector. To this end, we first interviewed trainers in agricultural education as a starting point for the planned multi-target group studies. Our aim was mainly to assess the extent to which fish and wetland knowledge is present in the current curricula and the extent to which teachers are open to the possibilities of improving the content and methodology of aquaculture education. Currently, there are five Agricultural Training Centres in Hungary with 61 member institutions (Khademi-Vidra and Bakos 2023), of which the online survey was conducted in the schools of the Southern Agricultural Training Centre between 13 and 17 November 2023. The number of questionnaires evaluated was 94. Fifty-two percent of the responding teachers were female and 48% male. The age distribution of our sample reflects the ageing of the professional teaching population (Tables 2 and 3).

Our target group for the questionnaire survey was agricultural teachers. The questionnaire was voluntary and anonymous. The survey is not representative, but it is indicative for our target group. The questionnaire consisted of ten open and seven closed questions. The open-ended questions were designed to assess the actual and real situation and specific perceptions and suggestions on the topic under study. For the closed questions, we used nominal variables. For processing the questionnaire database, we used the statistical software package IBM SPSS Statistics 20.

Table 2 Age profile of the surveyed expressed in percentage

Age (year)	Distribution (%)
20–30	4
31–40	15
41–50	36
51–60	33
60 +	10

Table 3 Teaching experience of the surveyed expressed in percentage

Teaching experience (year)	Distribution (%)
1–5	19
6–10	14
11–20	24
21–30	28
31–40	12
40+	3

Our exploratory questionnaire study was structured around the following research questions:

- Q1: To what extent is aquaculture included during the lessons (which includes pond fish farming, intensive (precision) fish farming and natural aquaculture (including angling)?
- Q2: What digital competences do respondents have and how do they integrate digital skills into their learning and teaching processes?
- Q3: What traditional and modern methodologies/tools are most effective in engaging learners?
- Q4: How could industry professionals help promote aquaculture among teachers?

Due to the exploratory nature of the research, the specificity of the sample and the lack of similar research results, we refrain from hypothesising in this research. The main findings drawn here will serve as a starting point for hypothesising further surveys based on a larger sample. Research among young people in vocational education and training will also build on this.

Results and discussion

Towards the future: opportunities for fisheries PILOT training

Today, it is clear that a paradigm shift in aquaculture education and training is needed as soon as possible. There is no school-based (secondary) vocational training adapted to the dynamic development of the sector in terms of content and form, education has not yet been developed in Hungary in response to market needs, and the sector lacks a quality skilled workforce. In view of all this, we thought that by launching a PILOT training programme, we could revive a long-abandoned training tradition, in the "twenty-first century" of course. In the Hungarian educational system, most of the vocational secondary schools in the field of agricultural training belong to the five Agricultural Vocational Training Centres run by the Ministry of Agriculture, which are present in a maintenance capacity. In cooperation with the ASZC of Szekszárd, located in the south of the country, we thought over the idea of the training.

In the curricula of the current Hungarian secondary agricultural vocational training courses (e.g. Food Technician, Small-scale Food Producer, Food Inspection Technician, Butcher and Meat Preparation Technician, Environmental Technician, Agricultural

Technician etc.), subjects and knowledge areas specifically related to fish and wetland biota are negligible. This fact was confirmed by our study, since only 10% of the teachers interviewed deal with aquaculture in their teaching.

The current Hungarian situation is not unique. Although it has been previously reported that information and data are incomplete (Padros et al. 2023), the aquaculture and fish production sector in the Central and Eastern European region is facing similar problems. One of the obstacles to the development of the Romanian aquaculture sector is the shortage of professionals, which could lead to a drastic decrease in fish production in Romania in the future. A major paradigm shift is needed across Europe to overcome the shortage of professionals in the aquaculture sector. Young people who are not familiar with the sector from a family background, or who have no experience of fish and the aquatic environment through angling, need to be made more accessible. This marketing activity should start as early as possible, with demonstrations from pre-school age onwards, where young children can learn about fish and the systems for rearing fish and have the opportunity to taste fish as a food. These experiences can make young people love aquaculture (Hamza 2023).

Based on the answers to our open questionnaire, the following topics and content are directly and indirectly addressed by the aquaculture curricula:

- *Legal, economic, business, environmental, technical, commercial*: taking into account the wider environmental and economic context of aquaculture. This includes the legal framework, economic processes, business economics, trade and environment.
- *Fish feeding, fishing machinery design and operation*: fish feeding is a key part of sustainable aquaculture. The course details methods for providing adequate feed. It also introduces the construction of fishing machines and the principles of their operation.
- *Impact of agricultural practices on natural waters and habitats*: the impact of aquaculture on natural waters and habitats is an important and topical issue. The course details how aquaculture activities affect the environment and what farming practices are needed to maintain the ecological balance.
- *Biology curriculum*: the biology curriculum covers many aspects, such as the anatomy and characteristics of fish in the case of the animal phylum, and wetlands in the ecology curriculum from a conservation and environmental perspective.
- *Fish farming*: fish farming details the methods of artificial fish farming, the appropriate environmental conditions and their preparation for human consumption.
- *Ecology curriculum*: the ecology curriculum explains in detail the biological properties of natural waters, including the water cycle, chemical composition, pollution and the body structure of aquatic organisms.
- *Faculty and supplementary education*: participation in school faculties gives students with a deeper interest in aquaculture the opportunity to gain more in-depth knowledge of fish farming and related subjects.

The combination of these fragmented learning materials, while not concentrated, provides students with an opportunity to gain a broad understanding of the different aspects of aquaculture and a more complex, integrated view of the economic, environmental and biological dimensions of the industry.

Forty percent of the respondents are open to covering aquaculture more explicitly in their curricula in the future, and 4% are already planning to cover aquaculture in their subjects (Fig. 1).

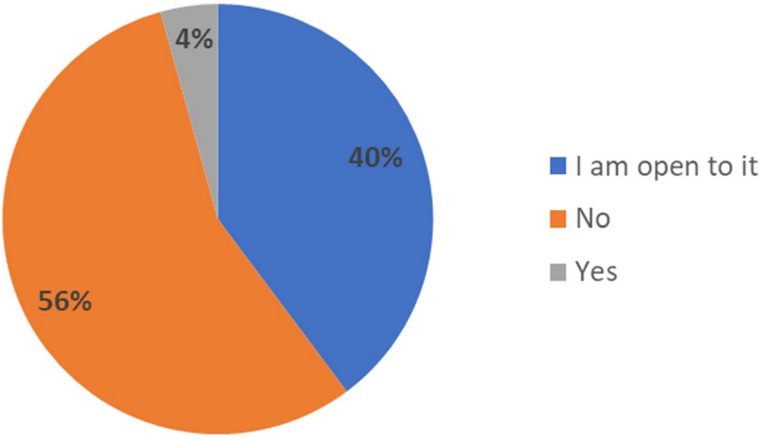

Fig. 1 Do you plan to cover curricular content related to this sector in your future teaching? Source: own research, 2023 ($n = 94$)

In the context of tightly packed curricula, educators face significant constraints in diversifying existing teaching materials. However, if provided with adequate time and resources, the teachers we interviewed expressed a keen interest in delving into several critical areas within the realm of aquaculture in their subjects:

- *Establishment and operational maintenance*: detailed insights into setting up facilities such as aquariums, fish ponds or aquaculture farms are crucial. This includes understanding the necessary infrastructure and technical requirements, alongside methods for water quality maintenance and troubleshooting (e.g. operation and repair of both stable and floating seaweed cutters).
- *Practical training and vocational guidance*: enhancing students' practical skills through active participation in fish farming activities. Vocational guidance aspects could cover the entire spectrum of the fishing profession, from farm-level operations to market access strategies.
- *Fibre forages, grasslands and innovative practices*: expanding learning materials to encompass the role of fibre forages and grasslands in aquaculture, and introducing innovative practices aimed at sustainability and ecological balance. The curriculum could also address riparian conservation and its impact on wildlife.
- *Fish farming in agriculture*: the integration of fish farming into agricultural curricula, with a focus on the interplay between aquaculture and traditional agricultural practices. Topics might include fish production and processing.
- *Market dynamics in aquaculture*: an analysis of market demands, preparing students for the evolving market needs. This would cover areas like product diversification, export–import processes and strategies in business and marketing, extending from breeding technology to trade.
- *Comprehensive understanding of aquatic life*: an in-depth exploration of the biota in native natural and artificial wetlands, focusing on inter-species relationships, with particular attention to protected native fish and plant species. The impact of aquaculture on biodiversity in natural waters could also be a significant topic.

- *Fishing—angling*: a detailed exploration of angling, including methods, equipment, sustainable practices and aspects that enhance its appeal to students.

These topics are instrumental in fostering a multifaceted understanding of aquaculture and its diverse applications. In conjunction with the topics previously mentioned, this expanded focus will significantly contribute to the professional and scientific development of students in the aquaculture sector.

Below, we describe what other aquaculture-related content the responding teachers would like to teach in the context of theoretical and/or practical education and what didactic tools they would use:

- *Recreational activities and tourism opportunities in aquaculture*: lectures and presentations on the different fishing activities and the tourist attractiveness of fishing. Interactive maps or digital presentations showing ideal fishing spots
- *The role of wetlands in habitat management*: field surveys of local wetlands. Development and presentation of habitat management plans
- *Fish and other aquatic life, environmental conditions*: hands-on living laboratory demonstrations on fish life and environmental needs. Field trips to local wetlands
- *Vocabulary, vocabulary cards, online exercises*: interactive vocabulary exercises and games with aquaculture-related terms. Use of vocabulary cards to stimulate competition and learning between students
- *Fishponds, recreational ponds, garden ponds—creation, management, maintenance*: information presentations and workshops on the creation and maintenance of different types of ponds. Practical applications, where students can design a plan to create and manage their own pond
- *Wetland protection, water quality studies*: theoretical and practical studies on wetland condition and water quality. Water quality measurements and analyses with students
- *Fish feed production*: practical demonstrations on the fish feeding process (e.g. mixers, grinders, presses). Study trips to places where fish meal and feed are produced
- *Aquatic communities, aquatic flora, aquaponic vegetable production*: demonstration of aquaponic systems and practical applications. Field work to observe aquatic plants and animals
- *Determining biological oxygen demand*: laboratory exercises for measuring biological oxygen demand. Exercises in simulated environments to study the effect of biological oxygen demand
- *Water sampling, testing, impact on living organisms*: practical training in water sampling (e.g. water quality testing with a measuring box and laboratory tests). Study of the effects on living organisms, including the effects of different pollutants
- *The impact of fertilisers and pesticides on living water*: classroom presentations and discussion on the environmental impact of fertilisers and pesticides. Exercises in simulated environments to demonstrate the effects
- *Foreign language-related vocabulary and interesting curricular content*: classroom vocabulary and reading materials on aquatic life and nature conservation. Project assignments where students produce their own foreign language materials
- *In the framework of adult education—training as a fisherman, fish farmer or fish keeper*: traineeships in fishing, fish farming or fish keeping. Theoretical courses and exams in the professional fields

These creative topics can contribute to developing students' broad and practical knowledge of aquaculture. The interactive and practice-oriented approach can enable students to learn and apply their knowledge in a real-life environment. The proximity of the Southern Agricultural Training Centre, for example to Baja, a city in the south-west part of Hungary and its surrounding area, is perfect for learning about natural habitats on the spot, and the forest of Gemen along the Danube offers further opportunities for field studies.

Digital teacher competence is essential for today's teaching and learning work. Ninety-eight percent of the teachers surveyed use ICT tools in their teaching (Fig. 2).

The responding teachers with digital skills and abilities, if given free rein to teach aquaculture-related knowledge and not having to adapt to time frames and curricula, would develop the following creative and interactive aquaculture teaching materials and didactic elements:

- *Interactive online platform*
  - Digital learning materials: interactive online learning materials that include professional videos, vocabulary building content, animations and case studies
  - Online simulations: allowing students to try out aquaculture processes in a virtual environment
- *Live field sessions*
  - Farm visits: to places where aquaculture is actively practised (e.g. pond farms, fish ponds and fish farms, special exhibitions and to see and help the maintenance, animal care, veterinary team etc.). Students can participate in the processes and meet the professionals directly

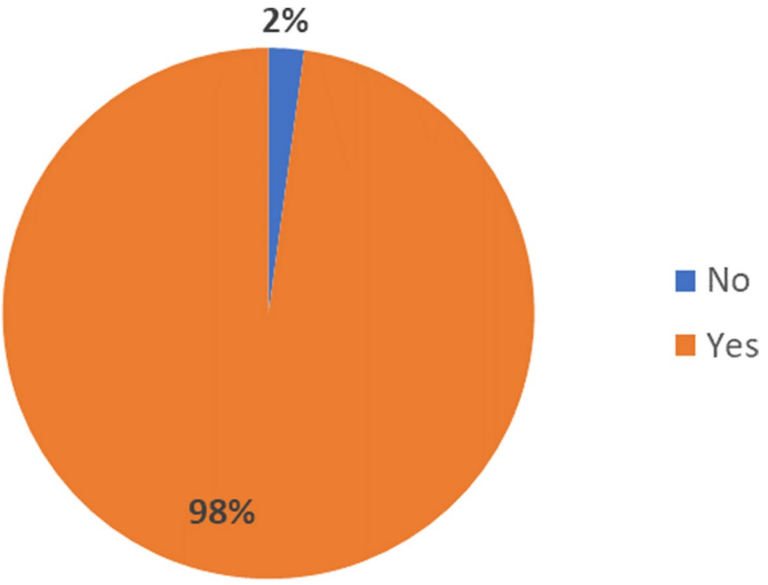

Fig. 2 Do you use ICT tools (e.g. internet or offline applications) in your teaching activities? Source: own research, 2023 ($n=94$)

  - Visit fishing clubs: learn about fish and bait in the context of fishing. Learning about fish anatomy using skeletons
  - Water testing exercises: in natural aquatic habitats. Students will gain direct experience in measuring water quality and assessing living conditions of organisms
  - For example: "After a short lesson and awareness-raising session, I would take the students to a nearby water body, preferably one with a nature trail. While learning about the wildlife there, I would have a discussion with them on the topic. Then we would work on aquaculture through a project task involving data collection, information use, problem solving, etc." (Teacher of 5 years)

- *Project work and group work*
  - Project-based learning: developing your own student projects on different aspects of aquaculture. For example, creating a fish farming plan
  - Group work: where students will work together in groups on different aspects of aquaculture
  - For example, "… I would think mainly in terms of a class teacher. As there is a wetland nearby, there would be tasks related to the habitat on the spot. I would definitely think in groups. There would be pre-assignments using LearningApps or the smart box. The first task for each group would be the same: A student's view of the Boronka Reservoir—what would you show a tourist? This would be a short, 2–3 min introduction from the groups. This would be followed by tasks related to the wetland. On the spot, there would be tasks that would require simple tools (e.g. net, thermometer, litmus paper, etc.). After the excursion, groups would make a poster, a 2–3 min video or a montage of their experiences and knowledge. The groups would decide. The evaluation would be formative, based on criteria agreed beforehand". (Head teacher of 26 years)
  - For example, "In the first lesson we will go over the anatomy and characteristics of fish (MOZAIK 3D model). In the second session, we will review native fish species. Then we would move on to fishing (small student presentations), then wetland conservation (visit to a local wetland e.g. White Lake in Gátér). For this we would do a project, each group would identify a problem related to wetlands, carry out a water analysis using the BIESEL method: physical, chemical (oxygen, nitrate, nitrite, carbonate) and biological characteristics, then propose a solution to the problem". (Teacher of 6 years)
  - For example, "I would set up an aquarium and a mini fish pond with groups of students, testing them regularly from the installation of the organisms to their maintenance". (Teacher of 38 years)

- *Lectures and guest lecturers*
  - Online presentations: from various aquaculture professionals
  - Guest lecturers: experts, fishermen, fish farmers who share their personal experiences with students

- *Training/education*
  - Hands-on training on domestic freshwater crop and livestock production, involving working farms and their experts
  - Theoretical background of national and international good practices in online training
  - For example, "My colleagues are very creative and I would also bring in an external tutor. I would contact fish farmers and pond operators in the region. 60–70% of the

training would be on the ground. We would use cooperative techniques in a classroom setting, taking advantage of interactive whiteboards and Moodle". (Teacher of 26 years)
  - For example, "The aim of the training is fish farming itself, emphasising the importance of aquaculture on a theoretical and practical level. It is essential to teach it and to set the objective of making the sector competitive. To be aware of the need to provide and learn to provide nutritious food, products and services, with special attention to the conservation and protection of the natural environment".

- *Virtual reality (VR) and 360° videos*
  - VR applications: allowing students to experience virtual fish farming or fishing processes
  - 360° videos: from aquaculture sites, allowing students to immerse themselves in the field environment

- *Social media and blogs*
  - Student blogs: about students' aquaculture experiences, research and discoveries
  - Social media group: where students can share what they have learned and their experiences with each other and with professionals

- *Challenges and competitions*
  - Online quizzes: for knowledge of aquaculture issues and practices
  - Innovation challenges: where students have to find innovative solutions to aquaculture challenges
  - For example, "Online data collection: list of important fish species and other aquatic organisms in Hungary; collection of photos, videos, possibly own photos, drawings; PPT: situation of our waters, endangerment, environmental protection; group quiz on Kahoot" (Teacher of 25 years)

The teachers' responses indicated that they would cover a wide range of topics in the field of fisheries, fish farming and aquaculture, including the situation in Hungary and Europe. They stressed the importance of native wetlands and their management, as well as economic forms and activities. In addition, fishing technologies, machinery and their use would be included in the teaching materials. Respondents would also go into further areas, such as observing the operation of seaweed cutters and fish traps, wetland conservation, water quality studies and the use of modern technologies such as drones and sonars. They also stressed the importance of aquaculture and its links with environmental protection.

These knowledge content and multimedia, hands-on approaches allow students to enjoy learning about the world of aquaculture while actively participating in the learning and teaching process and gaining real-life experience.

The teachers who responded mentioned a wide variety of methods and tools to engage students' interest, based on their teaching experience. The most common approaches are summarised below:

- *Hands-on activities and field visits:* focus on active participation and personal experience through hands-on activities, field visits and factory visits

- *Digital tools and online content:* the use of IT tools, digital learning materials, online exercises and interactive presentations to help learners navigate the digital world and create more interesting and engaging learning experiences
- *Project work and group work:* group work and project work allow students to work together and learn a topic in detail
- *Visual aids and visualisation:* the use of a variety of visual aids, films, short films, presentations and visual aids to help students understand the material and create memorable experiences
- *ICT and interactive teaching methods:* using information and communication technologies, interactive teaching methods, quizzes and online interfaces
- *Game elements and gamification:* incorporating game elements, using gamification methods that motivate and challenge learners
- *Purposeful and differentiated teaching methods:* using short, purposeful teaching materials and differentiated teaching methods, taking into account different levels of prior knowledge of learners

Teachers' responses show that they recommend mainly practice-based, proactive learning and teaching methods in the classroom, where children can be directly involved in the learning process themselves, to stimulate young people's interest. In addition to the above, the promotion of aquaculture among young people can be encouraged through professional study trips, thematic workshops, student days, career guidance days, summer camps, forest schools, project weeks and preparation for professional competitions.

The crucial role of sectoral support organisations was also highlighted, for example, the organisation of programmes to raise awareness of aquaculture among young people through various chamber events and professional days, through creative and informative social media content (e.g. Facebook Campaign, TikTok videos, Youtube channels etc.). These approaches, used together or in combination, can be effective in engaging learners and transferring the learning material. Flexible and varied teaching methods allow each learner to find the most motivating and effective way of learning.

Opportunities for cooperation between schools and practitioners

Sixty-eight percent of the teachers who responded said that they take into account and use professional materials produced and published by theoretical and practical experts in the field when preparing their teaching materials (Fig. 3).

Students and teachers also have the opportunity to meet people from the profession during the thematic study visits. Sixty percent of the teachers who responded had this opportunity (Fig. 4).

According to the teachers who responded, the initiation of discourse and the establishment of cooperation between the professional actors of the sector and teachers working in agricultural education are crucial for the positioning and attractiveness of the aquaculture sector for young people. Links should be found through joint projects and various vocational and school programmes. In these forums, companies could share real practical experience with teachers and students. Trainers could be given the opportunity for practical

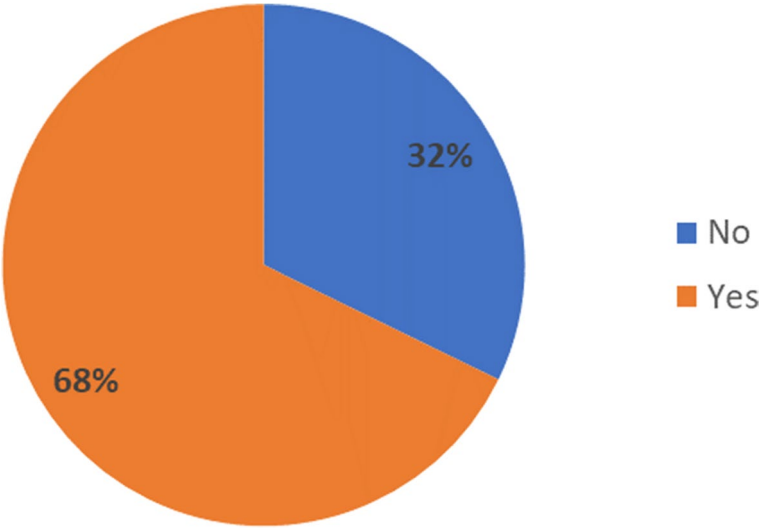

Fig. 3 Do you make use of materials produced by the profession when preparing your teaching materials? Source: own research, 2023 ($n=94$)

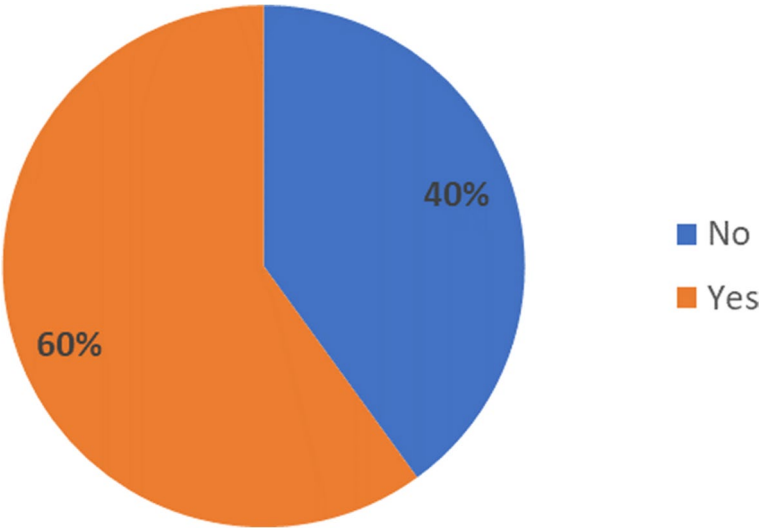

Fig. 4 Do you have the opportunity to go on thematic field trips outside school? Source: own research, 2023 ($n=94$)

demonstrations, training and field demonstrations and practical sessions. Companies should also put more emphasis on creativity and marketing, by producing online content and organising technical presentations and factory visits.

Conclusions and future work

The first and most important step is to raise the profile of aquaculture as a profession and/or a vocation among young people:

- Introducing the basics of aquaculture in public education courses: e.g. in a biology or science subject (nature studies, environment).
- Organising summer camps for primary and secondary school pupils, where young people can learn about the industry through a variety of practical activities.
- Teacher training: to familiarise teachers with the aquaculture sector through study trips for teachers with a biology or science degree.
- Summer student placements in aquaculture companies, where young people can gain knowledge and experience of the sector.
- Raising wages in the sector to bring them on a par with other agricultural sectors.
- In order to promote the sector and stimulate interest, it is necessary to renew and update the training offered in the sector.

Main tasks (not exhaustive):

- Identify the labour market expectations of the practical (for-profit) partners for each training level.
- Develop the basis for funding outside the school system and, in some cases, within it (adult training), the system for allocating partner contributions and, where possible, funding from grants in addition to public support.
- Developing the interaction between theoretical and practical curricula, and preparing training places to carry out the tasks required.
- Integrating digital learning opportunities and new teaching methods into traditional training systems.
- Adopting good practices from abroad and adapting them to the national system.
- Developing the marketing of training courses, using uniform campaigning and marketing tools (coordination).
- Development and implementation of a comprehensive training strategy for fisheries (aquaculture) and angling, and wide communication.

Tasks can be identified precisely. The question that arises for all concerned is how to coordinate, step by step, the work and activities that can be assigned to the different levels. Is there the strength, will and willpower in the profession to make this happen? Are we able to divide and distribute tasks, to make a credible case at the various decision-making and regulatory levels?

If and when we have the answers to these questions (our fundamental interest) and start thinking together, we will be able to lay the training foundations for the sector in the foreseeable future (preferably as soon as possible), which we believe is one of the key factors for its survival.

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Data availability The participants of this study did not give written consent for their data to be shared publicly, so due to the sensitive nature of the research, supporting data is not available.

Declarations

Ethical approval The authors declare that the participants in the study filled in our voluntary questionnaire, in which we indicated anonymity and voluntary participation in advance. Consequently, each person decided of their own free will whether or not to complete the questionnaire. Due to this fact, we did not ask for a separate written consent from the respondents. By completing the questionnaire, they also agreed to the aggregated evaluation and publication of the results.

Competing interests The authors declare no competing interests.

References

Almerich G, Orellana N, Suarez-Rodríguez J, Díaz I (2016) Teachers' information and communication technology competences: a structural approach. Comput Educ 100:110–125. https://doi.org/10.1016/j.compedu.2016.05.002

Arboleya-García E, Miralles L (2022) 'The Game of the Sea': an interdisciplinary educational board game on the marine environment and ocean awareness for primary and secondary students. Educ Sci 12(1):57. https://doi.org/10.3390/educsci12010057

Barab S, Dede C (2007) Games and immersive participatory simulations for science education: an emerging type of curricula. J Sci Educ Technol 16:1–3. https://doi.org/10.1007/s10956-007-9043-9

Belaya V (2018) The use of e-learning in vocational education and training (VET): systematization of existing theoretical approaches. J Educ Learn 7(5):92–101

Bencéné Fekete A (2021) A digitalis oktatással szemben támasztott elvárások a pedagógusok szemszögéből. Fenntartható Örökség, A Magyar Tannyelvű Tanítóképző Kar tudományos konferenciáinak tanulmánygyűjteménye. Subotica, Srbija: University of Novi Sad Hungarian Language Teacher Training Faculty Subotica, pp 294–301. https://ojs.elte.hu/gyermekneveles/article/view/2566

Beyer L, Chan C, LaPorte P, Cheng-Sheng L (2023) Assessing high school students' perceptions and preferences for aquaculture versus wild-caught seafood: the case of O'ahu, Hawai'i. World Aquacult Soc 54(4):801–814

Brandt JO, Bürgener L, Barth M, Redman A (2019) Becoming a competent teacher in education for sustainable development – learning outcomes and processes in teacher education. Int J Sustain High Educ 20(4):630–653. https://doi.org/10.1108/IJSHE-10-2018-0183

Cabero-Almenara J, Gutiérrez-Castillo JJ, Palacios-Rodríguez A, Barroso-Osuna J (2020) Development of the teacher digital competence validation of DigCompEdu check-in questionnaire in the university context of Andalusia (Spain). Sustainability 12(15):6094. https://doi.org/10.3390/su12156094

Cattaneo A, Gurtner JL, Felder J (2021) Digital tools as boundary objects to support connectivity in dual vocational education: towards a definition of design principles. In: Zitter I, Kyndt E, Beausaert S (Eds.) At the intersection of (continuous) education and work: practices and underlying principles. London, pp 137–157. https://doi.org/10.4324/9781003091219-11

Duisenbekova A, Kulisz M, Danilowska A, Gola A, Ryspekova M (2024) Predicting food consumption to reduce the risk of food insecurity in Kazakhstan. Economies 12(11). https://doi.org/10.3390/economies12010011

FAO (2022) The state of world fisheries and aquaculture 2022. Towards blue transformation. Rome, FAO. https://doi.org/10.4060/cc0461en

Fauville G, Payne DL, Marrero ME, Lantz-Andersson A, Crouch F (Eds) (2019) Exemplary practices in marine science education. A resource for practitioners and researchers; Springer: Cham, Switzerland

Fernández-Polanco J, Mueller S, Young JA, Llorente I (2010) Preferences about seafood safety and sustainability among very young children. IIFET 2010 Montpellier Proc 1–11. https://www.researchgate.net/publication/264859786_Preferences_about_seafood_safety_and_sustainability_among_very_young_children

Fox J, McKnight J, Sun Y, Maung D, Crawfis R (2020) Using a serious game to communicate risk and minimize psychological distance regarding environmental pollution. Telemat Inform 46:101320. https://doi.org/10.1016/j.tele.2019.101320

Gardner MK, Strayer DL (2017) What cognitive psychology can tell us about educational computer games. In: Gardner MK (ed) Handbook of research on serious games for educational applications; Zheng R. IGI Global, Hershey PA, USA, pp 1–18

Ghilardi-Lopes NP, Pimentel DS, Kremer LP, Almeida R, Meireles CP (2019) Didactic materials as resources for the promotion of coastal and marine Environmental Education. In: Berchez FAS (ed) Coastal and Marine Environmental Education; Ghilardi-Lopes NP. Springer Nature, Cham, Switzerland. https://doi.org/10.1007/978-3-030-05138-9_8

Ghomi M, Redecker C (2019) Digital competence of educators (DigCompEdu): development and evaluation of a self-assessment instrument for teachers' digital competence. 11th International Conference on Computer Supported Education. https://doi.org/10.5220/0007679005410548

Gil-Quintana J, Prieto Jurado E (2020) La realidad de la gamificación en educación primaria. Estudio multicaso de centros educativos españoles. Perfiles Educ 42:107–123

Guzman A, Nussbaum M (2009) Teaching competencies for technology integration in the classroom. J Comput Assist Learn 25:453–469. https://doi.org/10.1111/j.1365-2729.2009.00322.x

Hajiyeva NA, Huseynov RF, Huseynova MR, Mammadova AV, Mammadov SY (2023) Digitalization of education in Azerbaijan. Agora Int J Econ Sci 17(2):130–136. https://doi.org/10.15837/aijes.v17i2

Hamza H (2023) Marine- and freshwater aquaculture in Europe. Eurofish workshop, Bucharest/Romania, 23.-24 May, oral presentation. https://eurofish.dk/salt-and-freshwater-aquaculture-in-europe-sustainable-seafood-for-the-future/

Herrero M, Torralba-Burrial A, de Moral Pérez ME (2020) Revisión de investigaciones sobre el uso de juegos digitales en la enseñanza de las ciencias de la vida en primaria y secundaria. Enseñanza De Las Cienc 38:103–119. https://doi.org/10.5565/rev/ensciencias.2806

Huang SY, Kuo YH, Chen HC (2020) Applying digital escape rooms infused with science teaching in elementary school: learning performance, learning motivation, and problem-solving ability. Think Skills Creat 37:100681. https://doi.org/10.1016/j.tsc.2020.100681

Imbeah N, Khademi-Vidra A, Bujdosó Z (2020) Assessment of tourists' perceptions on safety at the cape coast tourist destination in ghana. Geojournal Tour Geosites 28(1):217–231

Kelly R, Evans K, Alexander K, Bettiol S, Corney S, Cullen-Knox C, Cvitanovic C, de Salas K, Emad GR, Fullbrook L et al (2022) Connecting to the oceans: supporting ocean literacy and public engagement. Rev Fish Biol Fisheries 32:123–143

Khademi-Vidra A (2014) Identity spaces. Acta Univ Sapientiae Soc Anal 4(1–2):109–120

Khademi-Vidra A (2017) Curriculum planning of the environmental education. J Central Eur Green Innov 1:65–80

Khademi-Vidra A, Bakos IM (2023) The impact of sustainable education practices on food consumption behaviours – an experimental study of agrarian school's students in Hungary. Eur J Contemp Educ 12(2):462–479

Koehler MJ, Mishra P (2009) What is technological pedagogical content knowledge? Contemp Issues Technol Teacher Educ 9:60–70

Koenigstein S, Hentschel LH, Heel LC, Drinkorn C (2020) A game-based education approach for sustainable ocean development. ICES J Mar Sci 77:1629–1638. https://doi.org/10.1093/icesjms/fsaa035

Kontio J, Lundmark S (2021) Didactical dilemmas with mobile phones in vocational educational classrooms. In: INTED2021 Proceedings: 15th International Technology, Education and Development Conference, 8–9 March 2021, The International Academy of Technology, Education and Development. https://doi.org/10.21125/inted.2021.1737

Lindsay L (2016) Transformation of teacher practice using mobile technology with one-to-one classes: M-learning pedagogical approaches. Br J Edu Technol 47(5):883–892. https://doi.org/10.1111/bjet.12265

MA-HAL (2022) Report on the results of the organisation's activities in 2021. Hungarian Aquaculture and Fisheries Interbranch Organisation Budapest (in Hungarian). https://new.magyarhal.hu/English

Manzano-León A, Camacho-Lazarraga P, Guerrero MA, Guerrero-Puerta L, Aguilar-Parra JM, Trigueros R, Alias A (2021) Between level up and game over: a systematic literature review of gamification in education. Sustainability 13:2247. https://doi.org/10.3390/su13042247

McGarr O, McDonagh A (2019) Digital competence in teacher education, Output 1 of the Erasmus+ funded Developing Student Teachers' Digital Competence (DICTE) project. https://dicte.oslomet.no/

Padros F, Constenla M, Gustinelli A, Bonaldo A, Fioravanti M (2023) Better education for better professionals for European aquaculture. Aquacult Eur 48(1):42–44

Paredes-Rodríguez AC, Torralba-Burrial A, Dopico E (2023) Teachers' perceptions on fisheries ecolabels and game-based learning activities in the framework of Education for Sustainable Consumption. In: García-Llamas P, Taboada A, Estévez-Mauriz L, Baelo R (eds) Global challenges for a sustainable society; Benítez-Andrades JA. Springer, Cham, Switzerland, pp 468–475. https://doi.org/10.1007/978-3-031-25840-4_54

Parrondo M, Rayon-Viña F, Borrell YJ, Miralles L (2021) Sustainable sea: a board game for engaging students in sustainable fisheries management. Appl Environ Educ Commun 20:406–421. https://doi.org/10.1080/1533015X.2021.1930608

Plass JL, Homer BD, Mayer RE, Kinzer CK (2020) Theoretical foundations of game-based and playful learning. In Handbook of game-based learning; Plass JL, Mayer RE, Homer BD (Eds.) The MIT Press: Cambridge, MA, USA, 3–24

Rieckmann M (2018) Chapter 2 - learning to transform the world: key competencies in ESD. In Leicht A, Heiss J, Byun WJ (Eds.) Education on the move. Issues and trends in education for sustainable development, 39–59, United Nations Educational, Scientific and Cultural Organization

Roll M, Ifenthaler D (2020) Competence development across different learning contexts in industry 4.0. In: Aprea C, Sappa V, Tenberg R (eds) Connectivity and integrative competence development in vocational and professional education and training. Franz Steiner Verlag, Stuttgart, pp 185–209

Rosenberg JM, Koehler MJ (2015) Context and technological pedagogical content knowledge (TPACK): a systematic review. J Res Technol Educ 47(3):186–210. https://doi.org/10.1080/15391523.2015.1052663

Rudnák I (2023) The impact of the training method on student satisfaction: theory versus practice - one of the most controversial issues in higher education. Educația Plus J 33(SI):365–382

Sanders CE, Byrd AR, Gibson KE, Golson A, Lamm KW, Lamm AJ (2023) Teaching Systems-Thinking Concepts with Hypothetical Case Scenarios: An Exploration in Food-Systems Science Education. Foods 12(14):2663. https://doi.org/10.3390/foods12142663

Schmäing T, Grotjohann N (2023) Out-of-school learning in the Wadden Sea: the influence of a mudflat hiking tour on the environmental attitudes and environmental knowledge of secondary school students. Int J Environ Res Public Health 20:403. https://doi.org/10.3390/ijerph20010403

Seixas S, Eleftheriou M (2020) AQUA-TNET lifelong learning strategy changes E & T attitudes towards ECVET implementation and the EQF. Aquacult Int 28:1825–1836

Stanitsas M, Kirytopoulos K, Vareilles E (2019) Facilitating sustainability transition through serious games: a systematic literature review. J Clean Prod 208:924–936. https://doi.org/10.1016/j.jclepro.2018.10.157

Tarasova S (2021) Planning and piloting of an online course on aquatic sciences, fisheries, and aquaculture. Book.Kyrgizistan

Teo T, Unwin S, Scherer R, Gardiner V (2021) Initial teacher training for twenty-first century skills in the Fourth Industrial Revolution (IR 4.0): a scoping review. Comput Educ 170. https://doi.org/10.1016/j.compedu.2021.104223

Torralba-Burrial A, Dopico E (2023) Promoting the sustainability of artisanal fishing through environmental education with game-based learning. Sustainability 15(17). https://doi.org/10.3390/su151712905

Urbányi B, Lengyel Sz, Bozánné Békefi E, Bokor Z, Fekete R, Kobolák J (2023) The current situation, prospects and expectations of aquaculture education from a domestic point of view. Manuscript (in Hungarian), Halászat, 116/1., pp 27–32

Vare P, Arro G, de Del HA, Gobbo G, Vries G, de Farioli F, Kadji-Beltran C, Kangur M, Mayer M, Millican R, Nijdam C, Réti M, Zachariou A (2019) Devising a competence-based training program for educators of sustainable development: lessons learned. Sustainability 11(7):1890. https://doi.org/10.3390/su11071890

Wilson CD, Reichsman F, Mutch-Jones K, Gardner A, Marchi L, Kowalski S, Lord T, Dorsey C (2018) Teacher implementation and the impact of game-based science curriculum materials. J Sci Educ Technol 27:285–305. https://doi.org/10.1007/s10956-017-9724-y

Young MF, Slota S, Cutter AB, Jalette G, Mullin G, Lai B, Simeoni Z, Tran M, Yukhymenko M (2012) Our princess is in another castle: a review of trends in serious gaming for education. Rev Educ Res 82:61–89. https://doi.org/10.3102/0034654312436980

(1) https://noe.lko.at/mitarbeiterinnen-und-mitarbeiter+2400+++1237

(2) https://www.bridges.eu/partners/guri-kunna-upper-secondary-school-vet-school

(3) https://www.europarl.europa.eu/factsheets/hu/sheet/120/akvakulturas-termeles-az-europai-unioban

(4) https://www.ssrv.cz/a-621-about-the-school.html