TEACHING MODULES UTILIZING EMERGING TECHNOLOGIES ACROSS EDUCATIONAL LEVELS AND SECTORS

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Abstract

Young learners' educational pathways and career perspectives seem more complex than ever. This is compounded by the advent of yet unknown professions driven by rapidly emerging technologies such as Generative Artificial Intelligence, the Metaverse with Extended Reality, and advanced robotics. While these technologies are having a growing global impact across various fields, educational institutions often face and address related challenges on a local scale.

The paper outlines common characteristics and challenges overcome in a sample of successfully implemented *teaching modules* involving emerging technologies. The diverse courses were conducted within local *education chains* across various educational levels and sectors between 2017 and 2024.

The analysis relates to the tech-didactics applied and how these have been utilized to strengthen resilience within local educational ecosystems for approaching emerging technologies. Thus, *education chains* could evolve into genuine *learning chains*. The results outline the steps for the implementation of scalable teaching modules with emerging technologies sustainably within the education chain.

Keywords: Emerging technologies, teaching module, education chain, digital production, digital literacy.

1 BACKGROUND

1.1 Challenges and Vision

Young learners' educational pathways and career perspectives are more complex than ever. Even traditional vocational programs or academic studies struggle to align with specific job profiles [7]. This is further complicated by the emergence of yet unknown professions driven by rapidly emerging technologies such as Generative Artificial Intelligence (AI), Metaverse with Extended Reality, advanced robotics, and Quantum Computing. While these technologies increasingly dominate various fields of life with global impact, educational institutions often contend with local challenges. These include preventing the misuse of technology while simultaneously striving to harness its potential for students and teachers.

A broader and more effective readiness seems to be necessary to equip schools and teachers locally to meet these technological trends. At the same time, greater coherence across educational levels and sectors is essential to facilitate students' transitions between phases of education and to align educational programs with the needs of new students.

Joint teaching modules across educational levels and sectors have proven valuable in fostering sustainable links and building a more integrated educational framework.

1.2 Teaching modules

The following criteria characterize the highly diverse ´teaching modules´ implemented in a portfolio of projects [13]. Each module incorporated one or more emerging technologies. While the modules varied in selection of target groups, duration, technologies, levels, and content, they all aligned with a shared didactic framework [3]. The modules followed a student-centered and practice-based approach, enabling students to work with the technologies themselves as much as possible.

All teaching modules complied with the respective local ordinances. Simultaneously, they were designed to be scalable and adaptable to different regulations, subjects, and levels. The modules originated from local initiatives, refined through mutual inspiration and reviews across educational institutions, and in some cases, across country borders.

1.3 Emerging technologies

Emerging technologies, in the context of this paper and for the given purpose, are defined as technologies that have not yet been broadly or formally implemented in mainstream education and remain relatively unexplored in terms of their educational value. They may already demonstrate commercial value or be highlighted in research as innovative and influential.

Educators identified global tech trends [16] through sources such as IT-related media, IT-knowledge centers and institutes, trade organizations, and public hearings or political debates [15].

1.4 Data selection

This paper draws on a selection of well-functioning and well-documented teaching modules involving emerging technologies to propose a method for designing scalable modules applicable across the 'education chain.' The impact on students was assessed through quantitative and qualitative data derived from formative and summative evaluations.

In five different projects [13], the teachers explored various emerging technologies for their potential of integrating them into teaching and learning processes. These teaching modules served as frameworks for students´ digital production.

1.5 Education chain

Fig. 1 provides a simplified illustration of a generalized ´education chain´, as applied to the project portfolio. Teachers, managers, and students collaborated across levels and sectors of educational institutions within the ecosystem of young people's educational pathways.

The simplification in fig. 1 overlooks the fact that many personal educational pathways exist, including detours, skips, or alternative progressions.

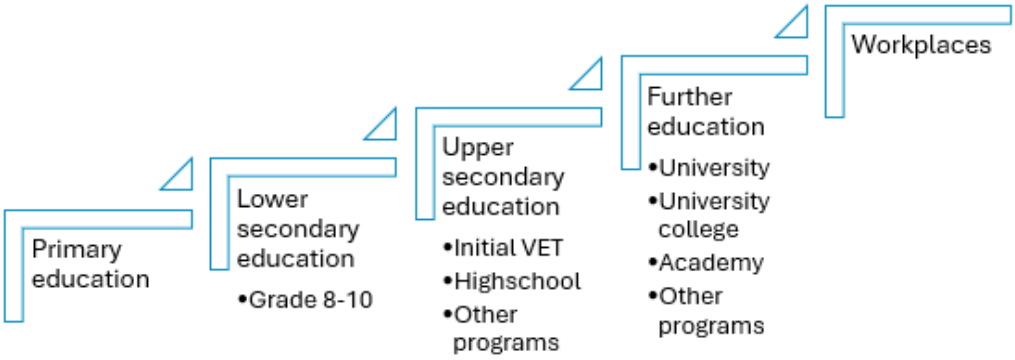

Figure 1. Simplified illustration of ´education chain´ (Lamscheck-Nielsen, 2024)

This paper primarily focuses on a limited section of the education chain, spanning from lower secondary education (grades 8–10) to technical and business high schools, or alternatively initial vocational education (VET), and including university colleges as well as various faculties at universities. Workplaces were occasionally involved.

Locally, education chains may consist of additional or alternative partnering organizations, such as training companies in VET, partner schools across country borders, youth support initiatives, education preparation courses, academies, or others.

In Denmark, the connective principle has been promoted in governmental strategies. The ´education chain´ is intended to strengthen coherence between different educational levels. At an individual level, a strong ´education chain´ is expected to support students´ career learning [2], enabling them to make personally meaningful choices.

Experiments have shown that coherent links within the education chain can ease the often difficult and confusing transitions for students. In the best cases, students experience overlaps between the levels or a sense of continuity from one level to the next, particular in terms of learning objectives, pedagogical methods, or educational relations with older students.

2 METHODOLOGY

The methodology includes a data selection, clustering of success criteria [4], reflecting on common denominators through relevant theories, and simplifying the findings into a practical guide.

2.1 The data selection

The data selection stems from a pool of 105 teaching modules developed, implemented, and documented during five innovation projects [13], conducted between 2017 – 2024 in Southern Denmark and in Northern Germany. In total, 62 educational institutions participated in these projects, involving 108 teachers and approx. 11,500 students across various educational levels, study lines, and subjects.

From this pool, 52 modules were selected that had been scaled and implemented within the education chain. Special focus was on those highlighted as exemplary in the evaluations of the five projects [12].

These modules typically originated at the upper secondary level, with some developed at the further education level (fig. 2, squares). A few modules were initiated at the request of companies (fig. 2, stippled square) to address specific challenges, such as creating effective and affordable language translations of videos. Additionally, experts from companies contributed directly to the teaching modules, serving as assessors of students' digital learning products or delivering field-specific presentations.

The modules spanning multiple educational levels (fig. 2, circles) were designed in diverse formats, including events, optional subjects, student-to-student tutoring within ordinary subjects, co-teaching among students from different programs, or product development by students across country borders.

All modules were aligned with the learning objectives of the educational programs and subjects involved, ensuring their sustainable integration and adaptability for future purposes. Several modules were even scaled down to primary education (fig. 2, stippled circle), further expanding their reach.

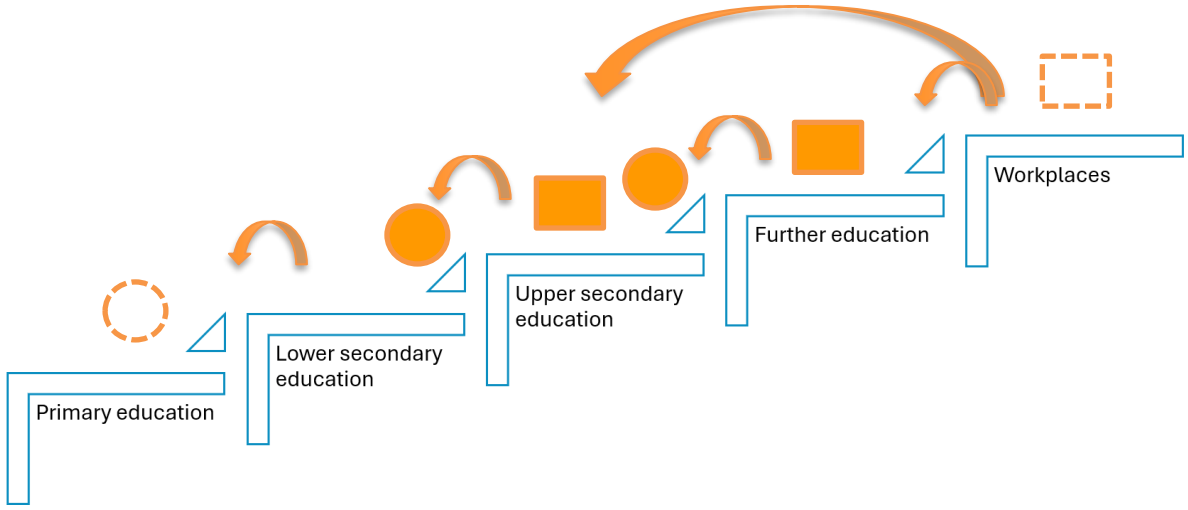

Figure 2. Teaching modules in the ´education chain´ (Lamscheck-Nielsen, 2024)

2.1.1 Three examples of Teaching Modules in the Education Chain - extracts

Example 1) "Supportive AI-tools for Entrepreneurship" (Oct.-Nov. 2024), Svendborg Erhvervsgymnasier (Business High School) & Haahrs (Lower Secondary School), Svendborg, Denmark

This module built on experiences from innovation activities at the upper secondary level (spring 2024). Marketing and economics teachers explored some of the latest AI-tools for optimizing marketing processes. A class of 25 12th grade students applied these tools to develop marketing products. Among the tools were HeyGen for creating avatars to communicate messages in foreign languages, the commercial-producing app Invideo.ai, and the film-translating tool Rask.ai.

The students primarily learnt how to prompt, quality assure outputs and align the AI-generated results with realistic business needs. Another essential focus of the module was critically assessing the tools for reliability, ethics, and data security.

Based on these experiences, a 20-lessons module was developed for 50 10th grade students from lower secondary education. The teachers co-designed the module, and 11 12th grade students acted as mentors, guiding the younger students in selecting and applying AI-tools for entrepreneurship purposes. The tools supported brainstorming business idea, logo design, budgeting, app-development, and more.

The students' learning products included mock-ups of their digital creations, team pitches for their business concepts, stand designs, and marketing materials. Environmental sustainability was a mandatory element of the business concepts.

The evaluation of the module involved assessors from commercial companies, among them a bank, a marketing agency, and an IT enterprise. Feedback from two assessors included these quotations:

“The products are impressive. Many ideas are much more well-developed than expected.” “I have joined [these kind of events, ed.] several years, and the level raises from year to year”. “I have children of the same age, and I can see that there is great enthusiasm around here.” “I have concerns regarding AI, yes. But AI is the future, and it is important that our young people learn to master these technologies.”

Notably, the teachers had established a Padlet, which served as a shared virtual platform. It contained crucial information and instructions, learning resources, and students´ learning products.

Example 2) ”Girls Day with Robotics” (January 2024), Regionales Berufsbildungszentrum Wirtschaft Kiel, Germany (Business High School) & Gesamtschulen (Lower Secondary Schools), Kiel

This module originated at grade 11, high school level, in Informatics and Physics lessons with 18 students, conducted as a block of five days. The module introduced different emerging technologies and let the students explore them hands-on. Thus, complex scientific and ethical topics, relevant to society, were treated in interaction with the technologies.

Students worked in groups to construct Lego Mindstorm robots and programmed them with sensors for sorting tasks. Additionally, they created Augmented Reality (AR) elements, which were used to illustrate posters about renewable energy. One student went further, designing and 3D-printing a fully functional model of a hydroelectric power plant.

Three students from this class volunteered to introduce to their learning products and interact with visitors during an open-door event at the high school. This activity was adapted into a shorter teaching module lasting four hours and promoted as a "Girls' Day" event, aimed at STEM-interested students from lower secondary levels. Approximately 70 students, primarily girls, participated in this module.

The female high school student shared a core message during her presentation:

"It must be emphasized that skills in mathematics are essential for programming and working with new technologies. However, many girls are capable of much more than they think."

The teachers highlighted the importance of fostering an interest in scientific and technical careers among young girls, as these fields are critical for producing the skilled workers and technological experts of the future.

Notably, the enrollment of girls in ´Business Informatics´ increased significantly after this event.

Example 3) “XR in Health Education” [Extended Reality, ed.] (2023-2024), UCL University College & Svendborg Erhvervsgymnasier (Technical High School) & SDU (University of Southern Denmark)

This module span over three educational levels, initiated at Danish University College UCL. 75 students from Physiotherapy and Multimedia programs worked cross-disciplinarily in groups to create XR-solutions with Augmented Reality and Virtual Reality. These solutions were designed to strengthen the prevention of common welfare diseases or address typical challenges in rehabilitation.

The students´ learning products included a VR app for educating diabetes patients and an AR introduction to MRI scanning to help patients overcome fear, among other innovative suggestions. All the solutions added value for both patients and health professionals by providing more flexible access to critical data, individually tailored training plans, and awareness of the importance of regular exercise.

The student groups showcased their solutions during a final plenary session lasting five hours. The session included feedback from lecturers and peers. Additionally, 10 advanced 12th-grade students from Technical High School Svendborg, were invited to contribute with their perspectives.

Following this, the XR-expert from UCL delivered a guest lecture to second-year Software Engineering students at SDU. The lecturer presented examples of the UCL students´ XR productions, highlighting needs in the health sector. Consequently, several university students chose to focus their technological semester projects on healthcare-related issues and were subsequently examined on these projects.

The bachelor students from UCL noted collectively an "increased understanding of the healthcare system's willingness to embrace innovative solutions" and reported gaining "knowledge about the application of XR in healthcare and its potential for problem-solving." Positive anticipation about their future roles as health professionals, stating they saw "great potential for the development and implementation of XR technology in healthcare."

Both the technical high school students and the engineering students expressed surprise at the healthcare sector's innovative use of technology, despite operating under resource constraints. Some even considered pursuing technical career pathways in this field.

The principle of the Vocational High Schools Svendborg (evaluation MYRE Syd, 2023) [12]:

"We have focused on strengthening our students' competencies for the future job market. Through teaching modules with emerging technologies, our students have been given a unique opportunity to prepare for the technological changes that will shape our society. Our students have gained insight into how these technologies can be applied in practice. They have had the opportunity to experiment and explore their potential."

"We look forward to continuing the further collaboration with other stakeholders in the education chain and the business community to ensure that our students are well-equipped for the challenges and opportunities of the future."

2.2 Characteristics and Challenges for the Exemplary Teaching Modules

Data about 25 modules in the education chain were clustered and organized, according to the Kawakita method [4]. A grid captured the sorted data and evolved as additional data were incorporated.

The characteristics were primarily derived from freely available descriptions of the modules, supplemented by extracts from teacher and manager interviews conducted during the evaluation processes of the five projects.

Notable promotive elements came up, observed across the exemplary teaching modules.

Table 1. Characteristics of exemplary Teaching Modules (2017-2024)

<table>
<tr><td colspan="2">25 exemplary teaching modules in the education chain (of 52 modules in the education chain)
DK: Svendborg, Odense, Glamsbjerg, Tønder, Sønderborg, Odense, Vejen, Vejle, Billund, Faaborg, Nyborg, Haderslev. DE: Kiel
Duration: from 3 hours up to 3 weeks
As lessons, blocks, events, co-lecturing, online collaboration on distance, and more</td><td>Technologies

Consciously chosen
Scaled versions
Students hands-on</td><td>Students´ Learning objectives

Overlap between levels (generic objectives for educational programs)
Learning results over average</td><td>Students´ Learning

Innovative learning products
Personal interaction
Co-influenced by students</td></tr>
<tr><td>Students´ motivation</td><td>Digital literacy</td><td>Students´ career learning</td><td>Teachers</td><td>Mind-set</td></tr>
<tr><td>High commitment
Excitement
Personal relevance</td><td>Critical approach, ethics, context-related to society
Focus on students´ actionability
IT-security</td><td>Peer-to-peer
References to business
Practical approach
Collaboration with companies</td><td>Teacher-teacher collaboration across levels
Joint ambitions
Mutual benefits
Mutual respect</td><td>Sustainability
Integration in daily operations
Agility, flexibility</td></tr>
</table>

Complementing this, some general challenges and barriers were identified through the surveys and interviews of the five evaluations. Teachers and managers primarily highlighted the following obstacles, which were addressed with varying degrees of pragmatic solutions.

Table 2. Obstacles for Co-creation within the Education Chain

Obstacles	Well-proven solutions
Different school types operate with varying planning horizons and yearly schedules ("year wheels").	Joint teaching modules should be planned well in advance, with active management support.
There is a lack of shared infrastructure to facilitate direct communication between teachers and students within the education chain.	Teachers established websites, TEAMS rooms, or Padlets as virtual communication channels with accessible to all participants. Personal meetings during leisure time often substituted for formal meeting spaces when needed.
Extraordinary costs may arise, such as those associated with events or transportation.	Incorporation of associated costs into the schools´ annual planning and budgets.
Additional time resources are often required for coordinating efforts among the teachers involved.	Teachers´ negotiations with management regarding work conditions, using evidence of the teaching modules´ impact on both schools and students.
School partners often have differing cultural practices, values, and frameworks for their pedagogical work. Iin cross-national teaching modules, these differences can become even more pronounced.	Adopting a new mind-set is essential, and this shift should be addressed, with mutual respect for differing approaches. Open-minded communication and trust-building are critical to success.

2.3 Analysis

Not all characteristics and challenges were evident in every module, but collectively, they were represented in most of them. As a result, common denominators emerged across the modules. In the following, these common denominators are analyzed through theoretical perspectives, with the aim of identifying a simple guide to communicate the work within the education chain to educators.

2.3.1 Technologies and Digital Literacy

At the time of experimentation, the technologies chosen were not yet implemented broadly or formally in education and still rather unexplored for their educational value. Many had already demonstrated some commercial value. Some were still in technological beta stages, yet all could be categorized as anticipated global significance in the future. According to the Gartner Hype Cycle [16], some could still be considered "Innovation triggers", and others slightly beyond the "Peak of Inflated Expectations".

The technologies were generally adaptable for students at various competence levels. For younger or less experienced students, simpler tools were used, such as creating Augmented Reality (AR) elements with HoloLink or Social Media apps. At high schools, tools like CoSpaces were introduced, while more advanced students at technical high schools or universities worked with the professional platform Unity.

Some teaching modules were conducted across the education chain, maintaining nearly identical teaching designs and content. This was particularly true after the public release of Generative Artificial Intelligence (GenAI) with large language models in late 2022. Across sectors, educational and commercial partners collaborated to explore and discuss the usage and impact of AI technologies.

A strong and urgent interest merged across all educational levels to address Digital Literacy [3]. Both educational and commercial partners emphasized the importance of equipping students – and teachers – with knowledge and training on IT security and a critical approach to these technologies. Ethical considerations included topics such as data storage, bias in GenAI apps, protection of personal data, and other GDPR-related issues [11]. Technology's broad impact on society was explored through analyses of dilemmas, such as the use and misuse of drone inspections, and the promotive or obstructive impact of emerging technologies on environmental and social sustainability.

Altogether, the focus was on enhancing the students´ actionability with emerging technologies.

2.3.2 From ´Education Chain´ to ´Learning Chain´

Teaching modules within the education chain became particularly valuable when sustainable links were established through coherence of learning objectives across educational levels and open communication about differing didactical and pedagogical approaches. This process transformed the organizational ´education chain´ into a genuine 'learning chain' for the students involved.

In the module "*Supportive AI-tools for entrepreneurship"*, one of the involved high school students had previously participated in similar events at his former school. Drawing on these experiences, he chose Business High School Svendborg as the next step of his educational pathway. Now, he became a tutor and role model for the 10th grade students from his former school. For him, the connection between the educational levels provided a sense of continuity and coherence in his learning pathway.

Historically, educational institutions in Denmark have often been competitors, whether in attracting students or applying for permission to offer educational programs. However, the data collection indicates a shift in this competitive approach. As the need has arisen to address technological mega-challenges within a broader cross-organizational framework, the competitive approach appears to have diminished.

Instead, shared high ambitions for the students, the quality of joint teaching modules, and the exchange of competencies have become strong driving forces. The partners made their resources available to one another, such as Makerspaces, VR glasses, tech tutorials, and initial experiences with applying AI. In *Death of Competition* [5], Moore provides an overview of the required mindset shift for leading 'expanding business ecosystems' [ibid, p. 159]. This mindset shift is comparable to that needed in educational ecosystems – the 'education chain.' Educational institutions have become "allies" with a "common set of goals," and "co-evolution" has taken on significant importance.

Anholt et al. (2021) highlight the necessity of "societal resilience" in the face of megatrends and global crises that increasingly challenge our social systems. The education sector is one such system, with digitalization as a megatrend that introduces high levels of uncertainty and a complex web of interdependent social issues. In this context, resilience means more than technological and cultural preparedness, emergency response, and crisis governance. According to the authors, resilience is closely tied to "adaptive and transformative capacities" of a system. Anholt et al. also emphasize interdisciplinarity in addressing major phenomena: "The complexity of our realities calls for integrative understanding of different approaches […] complementary to each other" [8].

McGrath [6] introduces the concept of "ambition loops" as a part of future teacher professionalism. These loops emphasize collaborative connections within a "broader community of expertise" surrounding teachers and students. McGrath envisions partnerships that strengthen teacher leadership, and predicts the "interdisciplinary approach" to become a core element of the teaching profession.

The *´education chain´*, as illustrated in fig. 1 and fig. 2, aligns with these approaches. However, unlike McGrath's ambition loops, the education chain reflects a direction-giving principle. Here, joint ambitions set a collective direction for educational professionals, potentially extending to the local educational ecosystem as a foundational and influential part of society.

2.3.3 Students´ Learning and Didactics

A joint didactic framework, based on the tech-didactic model 'ROBOdidactics' [3], had been employed to facilitate communication across educational levels and sectors. This non-normative model was designed to foster mutual understanding and was used systematically for describing teaching modules, providing peer feedback, conducting evaluations, and identifying areas for further development.

The model evolved into 'DigiDidactics' (fig. 2) following a cross-national review process of ROBOdidactics. Both versions maintain a student-centered approach and emphasize four critical dimensions for teaching with emerging technologies within the education chain:

- *Digital production:* Selecting appropriate technologies and methods for production.
- *Teaching design:* Addressing classic elements such as defining learning objectives, selecting pedagogical methods, and specifying students' learning products.
- *Environment:* Focusing on interactions with the school's ecosystem.
- *Digital literacy:* Encompassing ethics, IT security, and personal relevance of the technologies.

Sustainability, encompassing both environmental and social aspects, was given a new explicit role in the model as a shared responsibility. In recent projects, nearly all teaching modules thematically incorporated at least one of the UN Sustainable Development Goals (SDGs) [14]. Students were able to identify these goals and relate them to the technologies' impacts. However, this broad area of work offers significant potential for further exploration and application.

Teacher-to-teacher planning and evaluations across educational levels fostered mutual understanding of each other's student groups and their needs. As a result, student motivation, the quality of their learning products, and the consistency of the modules´ teaching design were significantly enhanced.

As illustrated in fig. 2, students are at the center of the didactics. Many teaching modules applied this approach both innovatively and convincingly. Notably, student-to-student interaction across levels proved successful, particularly for tutoring, co-creation, and role-modelling. Given the students' strong commitment to these activities, this aspect holds considerable potential for further exploration.

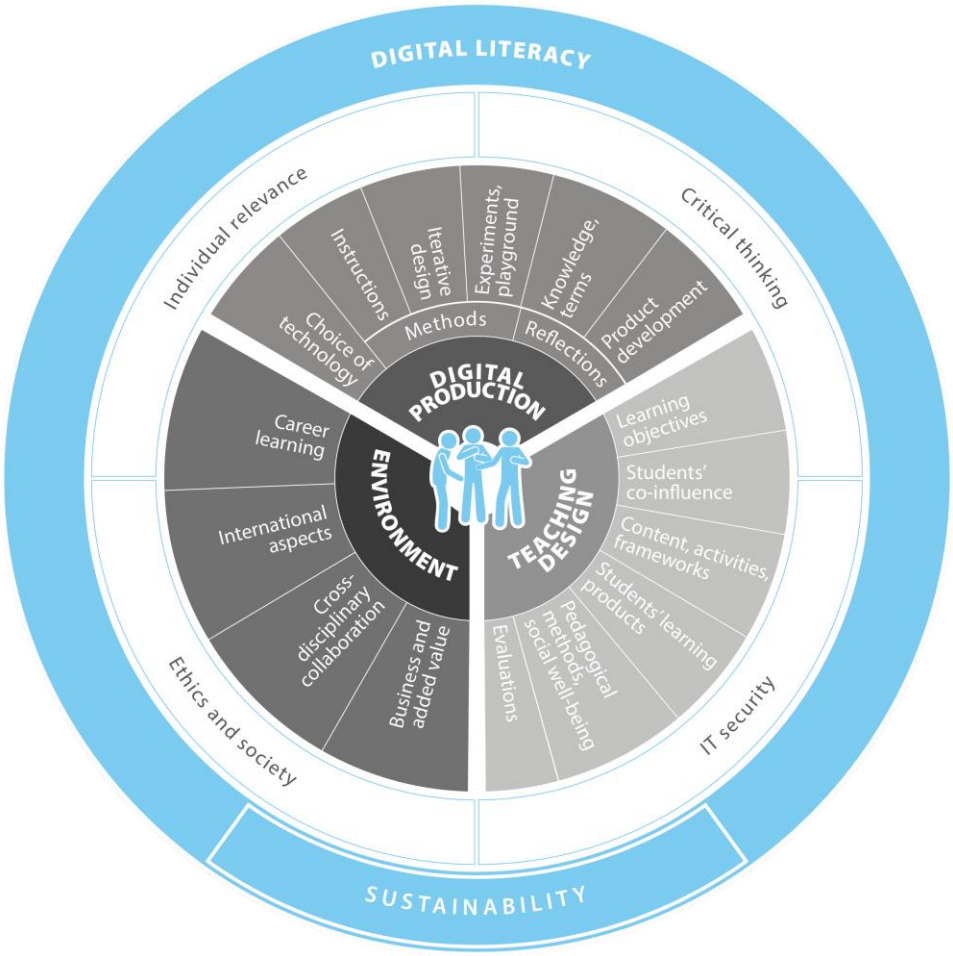

Figure 2. DigiDidactics (2024), further developed from ROBOdidactics [Majgaard, 2020]

3 RESULTS

The analysis has resulted in a concise guide for implementing scalable teaching modules with a focus on digital production within the education chain. Table 2 provides an overview of the steps necessary for sustainably implementing and scaling teaching modules across educational levels.

Step (1) includes exploration and commitment to collaboration within the local education chain.

Step (2) relates to scaling of the teaching design across the educational levels, integrating digital production, focus on digital literacy, and potentially incorporating other aspects of the environment.

Step (3) transfers the decisions made into educational practice, ensuring quality assurance and focusing on the long-term sustainability of the implemented modules.

Table 2. Sustainable Implementation of Scalable Teaching Modules (Lamscheck-Nielsen, 2024)

3 SUSTAINABLE IMPLEMENTATION a) Coordination and practical agreements, cross-organizational communication channels, and shared virtual infrastructure b) Shared didactic framework for communication, joint terminology, quality assurance, and mutual feedback c) Focus on sustainability with integration in ordinary daily operation and budgets 
2 SCALABLE TEACHING MODULES a) Identification of technologies, topics, subjects, and ethical challenges b) Drafting of teaching module as original (or reuse of previous modules) c) Scaling of technologies and content to different target groups and settings 
1 FOUNDATION FOR THE CONNECTIVE PRINCIPLE a) Identification of partners for the local education chain b) Commitment from management: joint vision of a resilient educational ecosystem with mutual respect and meaningful benefits for all educational partners c) Professional dialogues among teachers, exploring each other´s mindsets 

4 CONCLUSIONS

The results of the analysis highlight the need for connectivity between educational institutions that is relatively easy to implement and directly benefits all involved partners. Co-created teaching modules across educational levels, scaled and adapted to each context, have the potential to serve as vital links.

These connective modules appear to empower not only the students and teachers involved but also to strengthen the entire local ecosystem by equipping educational institutions to engage with the technologies of the future. This forms the foundation for ´societal resilience´ [8] which is increasingly necessary in the face of megatrends and global crises that challenge social systems.

The intended connectivity can be sustainably maintained by integrating it into daily operations - *if* teaching modules are created with purpose and meaning for all stakeholders. This approach encourages reuse, promotes resource sharing, strengthens communities, and facilitates the transparent involvement of new partners. Aligning with UN Sustainable Development Goal #17, which emphasizes multi-stakeholder partnerships, this method holds potential for broader applications in various contexts.

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Denmark), as well as from the Regional Vocational Center Business Kiel (Germany), along with their partners in the local education chains.

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