Didactics in the age of robot technologies

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Abstract

In Denmark, intensive digitalization has come very far. The "new world of work" has fostered a need for exploring and applying new digital technologies in vocational education (VET), and together with educational institutions across levels and vocational fields.

This paper outlines, why and how teachers in this ecosystem have responded to the emerging technologies in business and social life with diverse courses as the field of action. 79 unique courses, in many different forms, have been realized with, so far, approx. 8,050 students, using programming technologies, robotics and mixed reality. To qualify and evaluate these courses, the tech-didactic model ROBOdidactics was developed and applied during a community action research process in Southern Denmark. The courses and the model were evaluated on the basis of large-scale results, and the conclusions are presented in this paper.

1 Context, research field and research question

Digitalization and automation affect our lives in, roughly speaking, all fields. The new world of work with robot technologies, automatization and industry 4.0, welfare 4.0 and commerce 4.0 has prompted the application of new technologies in education.

1.1 Digitalization in Denmark and new technologies in education

Denmark, as one of the most digitalized countries in Europe (DESI 2020), acts strategically and practically on all levels. National policies and digitalization strategies are also in operation, including the educational sector (Danish Ministry of Education 2017). Curricula have already been extended on primary school level with the subject "Technology Understanding", and young students now enter secondary education with programming skills. "Digital Literacy" has become a mandatory theme in, roughly said, all youth education programmes. Trade-specific technologies can be found in the entire vocational education sector: industrial robots, welfare technologies, artificial intelligence, mixed reality for business models and technical instructions, educational platforms, and many more.

This intensive digitalization has also brought the need for a mutual understanding and greater coherence regarding technological skills across educational levels; more specifically, coherent pathways from lower to upper secondary education with VET and different types of high schools and further on to different types of higher education. These different sections of young persons' educational pathways include also a close interaction with companies and other players in the schools' environments. These sections are intended to be experienced as a well-connected "education chain" with smooth and meaning-making transitions for the students.

Other challenges have been found. In spite of more than 80 accredited public ICT further education opportunities, there is a dramatic lack of advanced ICT specialists in Denmark (IT-Branchen 2021), including robot experts. Global Cybersecurity Index has identified Denmark as one of the countries with the lowest awareness of cybersecurity (2020). Great accessibility to the internet goes also hand in hand with abuse of social media and digital violation. Active involvement of the population in digital development is far from widespread. Thus, Majgaard (2018) and numerous other researchers state that "Digital Literacy" is required much more of all of us, with a fundamental understanding and handling of technologies, with critical and ethical attitudes to technological development, and emphasizing democratic values and human rights. On the European level, there is a call for more comprehensive "computing", pointing at personal, societal, economic and pedagogical benefits (European Commission 2020). While the goals seem evident, their operationalization in local practice is rather vague. The Danish regulations require applying new digital technologies broadly. But operational didactic models are rare, not only when it comes to digital production, but also to student-centered learning, the adaptability to emerging technologies, digital literacy and interaction with society and business; all of this also regarding sector-crossing courses.

1.2 Three tech-didactic projects in the "education chain"

This article relates to a portfolio of three mutually independent projects, with the Southern Danish Region as their main funder:

- crossingIT (2017–2019), implementing programming in teaching and learning processes
- ROBOlearning (2018–2021), implementing robot technologies in and across subjects
- ARducation (2019–2022), exploring and implementing Augmented Reality in commercial and technical vocational programs (note: not yet finished)

The projects ran/are running in youth education and across the "education chain" to achieve coherence regarding learning objectives, didactics and pedagogical methods. Each project had/has a wide outreach regarding geography, the number of participants and produced courses.

1.3 Research questions

In this paper, results from the three above-mentioned projects with their comprehensive data are seen as a combined whole in reflecting on the following research questions:

- Why and how to respond to the emerging technologies in business and social life, in the action field of VET and its ecosystem; representing schools before VET and educational institutions for further education and training after VET?
- When considering courses in a wider sense, as the concrete realization of the field of action: How can teachers apply new digital technologies to practice?

2 ROBOdidactics – a tech-didactic model and its development

2.1 A project portfolio as a framework for development

To bridge the gap between didactic needs and teaching practice, developmental work was initiated, focusing on new technologies such as robotics, programming etc. None of the most common recent didactic models in Denmark addressed all favoured aspects sufficiently. Neither the "Relational model" (Hiim et al. 2005), nor "Didactics 2.0" (Gynther et al. 2010), "Flipped learning" (Hachmann et al. 2014) or "Stepwise improvement" (Caspersen et al. 2013) were comprehensive enough. However, principles, aspects and terminology from these models were identified as helpful elements, supplemented with approaches to Digital Literacy (Majgaard 2018), Career Learning (Law 2010) and playground methods (Gad Christiansen 2020). A new didactic model was needed and was drafted in the framework of one of the projects, while validation, further development and implementation took place in all of them.

2.2 Community Action Research

An action research process was designed to develop the model. "Action research is about working towards practical outcomes, and also about creating new forms of understanding, since action without reflection and understanding is blind, just as theory without action is meaningless" (Reason et al. 2006, p. 2). Action phases alternate with reflection phases and support each other, where at the same time, a balance between action and reflection must be created and maintained (Heron et al. 2001, p. 151).

During the *reflection phases* ROBOdidactics was created and adjusted via input and reviews from 15 "practitioners of expertise" from different schools. These experts were experienced and innovative teachers and educational managers with advanced pedagogical insight. Six didactic workshops and three user tests of the ROBOdidactics app were conducted. During five network meetings in two of the projects, feedback from approx. 75 teachers was collected.

During the *action phases*, the teachers locally developed and implemented new unique courses (79 courses, August 2021) and documented their experiences, which were evaluated and processed during the reflection phases. These processes took place iteratively, where the next activities were designed based on the learnings that had emerged.

The outputs from the three projects represent an extensive empirical knowledge for the promotion of student-centered teaching with digital production. Together the projects encompassed "large-scale group processes", which provide "the opportunity for a large number of organizational members to understand the need for and develop ideas for change as well as to support and take part in the implementation of change" (Martin 2001). At the same time, the process was dynamic and challenged, when new members or organizations joined, or when dedicated users left for different reasons. Knowledge was lost, new attitudes and expertise emerged and had to be taken into consideration.

This process represents a "community action research" design (Senge et al. 2001 in Reason et al. 2006, pp. 195–206). The design focuses especially on a) "fostering relationships and collaboration among diverse organizations, and among the consultants and researchers working with them", b) "creating settings for collective reflection that enable people from different organizations to see themselves in one another" and c) "leveraging progress in individual organizations through cross-organizational links [...]" (ibid).

The researcher from the University of Southern Denmark, the project manager, the local managers and teachers formed together a "knowledge-creating system" (stock-flow diagram, Scharmer 2001 in Reason et al. 2006, p. 198). In this system, ROBOdidactics was developed by cumulating and adding "new practical knowledge" [= insight from new courses] and "practical know-how" [= teachers' experiences], recovering from "knowledge losses" and including "theory and method development" [= research-based literature, model, guideline].

2.3 The tech-didactic model ROBOdidactics and its characteristics

ROBOdidactics addresses teaching with different digital technologies. The model is applicable anywhere in the "education chain", supplementing local didactic approaches.

As a crucial characteristic, ROBOdidactics is non-normative. There is no logical or mandatory order to follow. The users can freely choose and prioritize which elements they will emphasize. Student-centered learning is promoted explicitly by taking in consideration the students' individual needs, skills and goals.

The model comes with a user-generated guideline that contains supportive questions, course examples, video explanations from teachers and playful elements with Augmented Reality. ROBOdidactics is freely available at arducation.dk/robodidaktik/, and since January 2021 also as the app: ROBOdidaktik.

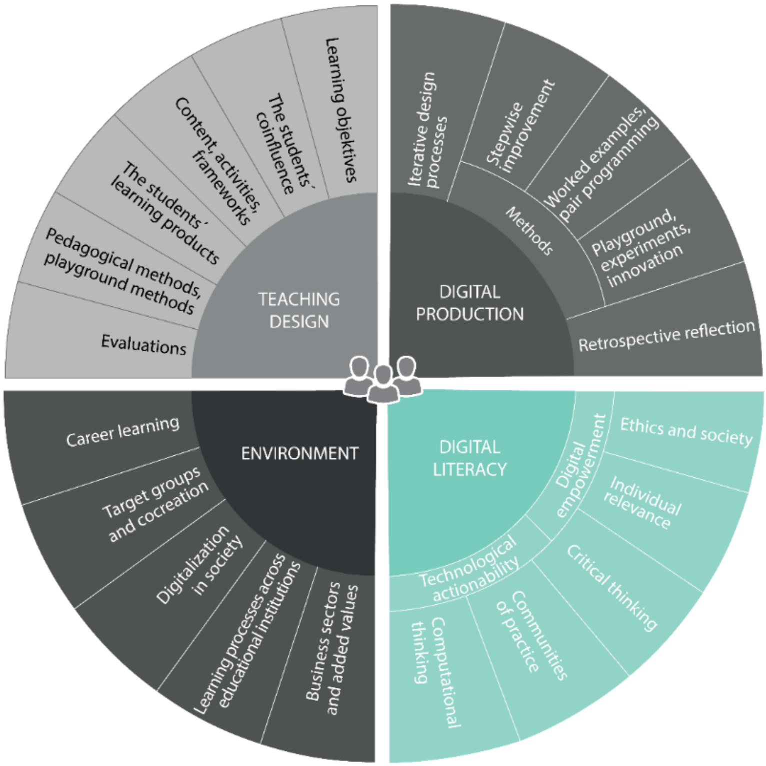

Figure 1: ROBOdidactics (language translation of ROBOdidaktik, Denmark, 2020)

2.4 The four dimensions of ROBOdidactics

The quadrants of the model reflect four dimensions with a total of 21 elements (Majgaard et al. 2019b). The elements each refer to methods or approaches that are rooted in research or in acknowledged policies such as ordinances, the UN Sustainability Goals etc.

Teaching Design, as a classical discipline for teachers, addresses issues such as learning objectives, pedagogical methods and evaluations. In ROBOdidactics, the students' learning products are mainly digital products, such as robots, websites, games or virtual reality elements, which often are supplemented with posters, reports or presentations. The students' co-influence on their own learning processes is strongly promoted, such as when they organize work teams themselves, choose themes or decide on timing.

Digital Production is about the technological part of the learning processes, offering methodological approaches to iterative development and innovation processes. The different methods can exclude each other but they do not need to. The students' production processes and their learning products are in focus, as well as their reflections on all of this.

Digital Literacy covers the technological empowerment of the students, their critical thinking and ethical considerations. In this context, the learners' ability to relate technologies and themselves to others and to different contexts in a well-reflected way is promoted.

The *Environment* is included in teaching and learning processes as a society-oriented perspective for the students, by collaborating with companies, public institutions or non-governmental organizations. In this context, the students' career learning is stimulated.

3 Courses in practice

The courses took place mainly in initial VET and in upper secondary education on the technical, commercial or common high school level (year 10–12), but also in the transition from lower secondary education, typically year 8–10, up to initial VET and high schools. The following summarizes the many variations of the courses:

- Learning units integrated into ICT-subjects, typically 10–20 hours over a couple of weeks.
- Weekly lessons, integrated into longer lasting courses over ½ year or 1 year.
- Extensive project work blocks of a total of 20–30 hours plus homework, typically with content and learning outcomes from several subjects.
- Modules typically of 1.5–4 hours duration in length, as an introduction to pupils from lower secondary school (mostly year 8–10).
- Learning units across levels, joined by students and teachers from different educational programs or types; as short modules, blocks of 10–20 hours or events.
- Courses with mandatory exams or voluntary subjects or leisure time courses.

Until August 2021 79 unique courses have been conducted locally, with improved iterations and numerous repetitions. Each course is described in detail according to the ROBOdidactics framework, including teaching material or examples of learning products. The great diversity of the courses in mind, a few snapshots may illustrate teaching according to ROBOdidactics.

Firstly, in *crossingIT*, a total of 35 unique courses on programming as digital production were implemented on the vocational high school level and in the "education chain".

The course "Influencers – a new business" was a two-day course at Business College Tondern for year 10 students from lower secondary school (2018). Simple coding skills and knowledge about data from website traffic were among the learning objectives. The course resulted in the students' design of business models for influencers, as well as critical case-based reflections on their own use of social media. Qualitative evaluations found an increase of the students' Digital Literacy, as well as their career learning about educational pathways at a VET college.

Secondly, in *ROBOlearning*, robot technologies were explored in 21 unique courses on youth education level and 14 courses in the education chain.

A broad cooperation across education levels and types of VET colleges led to annual learning events, “RoboMotion”. The vocational high schools Svendborg initiated and host the events, now driven by a cross-organizational group of teachers. RoboMotion takes place over 24 hours with robot races and skills competitions as core activities. The students prepare their robots during lessons in their local educational programmes before the event. Companies contribute with robot expertise and assess the students’ robots and their pitches. The playground approach plays a major role, with exploration, creativity and fun as learning drivers. Evaluations show that the students’ technological skill level has risen and that the events have become motivating annual highlights in the schools. The local figures of young people choosing an educational pathway with digital technologies are steadily increasing.

Thirdly, in *ARducation*, ten unique courses with Augmented Reality have thus far been implemented at three vocational colleges. Five unique courses have taken place at year 8–10.

The course “Augmented SWOT Analysis” (2021) at Business College Vestfyn was a module of three hours, integrated into a longer-lasting vocational subject. After an introduction to the commercial use of AR, the students worked in pairs to explore the augmented version of a business model, SWOT Analysis, and related it to their training placements. As learning products, they made practicable suggestions for implementing AR in their training companies. In addition, the students designed mock-ups of AR-elements for PR purposes in business. The high quality of the learning products, as well as a survey and dialogues for evaluation purposes, confirmed the students’ understanding, creativity and motivation for applying innovative technologies in a practical and meaningful way in vocational practice.

4 Evaluations and results

In the following, data are summarized across different evaluations regarding the impact on the learners, the quality of the courses and the usefulness of ROBOdidactics. Reference is made to conclusions for crossingIT (evaluation report; Majgaard/Lamscheck-Nielsen 2019a), to pre-published findings for ROBOlearning (independent evaluator March 2021; Majgaard 2021) and to interim findings in ARducation (independent evaluator; Majgaard 2021).

4.1 Summative evaluations by independent evaluators

The summative evaluations were undertaken by several independent evaluators. The evaluators assessed the projects according to the students’ motivation for learning with digital technologies and their interest in technological career pathways with the following methods:

1. Quantitative surveys of students from several randomly chosen courses in each project.
2. Focus group interviews with a) learners representing the typical student groups, b) different teachers and c) local project managers and school managers.

The methods were applied halfway through the projects and at the end of the projects. The conclusions from these unpublished evaluations for the Region of Southern Denmark have been communicated to the managers of the projects (ARducation is halfway evaluated).

4.2 Formative evaluations and quality assurance

The University of Southern Denmark (SDU) led the development process of ROBOdidactics as well as the quality assurance of the courses. The latter comprised assessment of the courses during and after the projects, feedback to the teachers and support of the teachers' peer reviews. For this purpose, ROBOdidactics was applied, and local evaluations were added. The teachers processed the feedback to improve their courses and to develop new courses.

Systematic evaluations of the developing versions of ROBOdidactics were part of an iterative process in six didactic workshops. In addition, uninvolved teachers' feedback on the model was collected and processed. Among other methods, the "Starfish Diagram" (inspired from Agile Software Development) was used in cross-organizational workshops. The teachers identified principles and features to initiate, to stop, to change, to extend or to keep as they were.

Figure 2: Teachers' feedback on ROBOdidactics during a network meeting, according to the Starfish Diagram (method used in Agile Software Development)

4.3 Results

Results from different evaluations are summarized across the projects. Extracts from non-published independent evaluation reports (Region of Southern Denmark 2019 and 2021) are included, and a published evaluation report (Majgaard et al. 2019a) is referred to.

Courses with digital production

Courses with digital production have been conducted with approx. 8,050 students up until August 2021, at year 8–12 and across years or levels.

Approx. 1/3 of the courses were transferred and applied in different school settings after having added new aspects, changed technologies, and upscaled or downscaled the course.

41 of the 79 unique courses were assessed in depth, with reference to ROBOdidactics:

- In *Teaching Design*, the focus was on adding new technologies as requirements to the students' learning products or as topics to be investigated. The technologies were applied consistently according to the learning outcomes in the different subjects, also in multi-disciplinary courses. The students' co-influence on the design of their learning processes became explicit and innovative, especially regarding the allocation of responsibilities. A new pedagogical method, the "playground approach" for teenagers (Gad Christiansen 2020), was investigated and found particularly useful when creating prototypes. Finally, the teachers considered evaluations more thoroughly than before.
- During the *Digital Production* of the three projects, a wide range of new technologies (Augmented Reality, drones, micro:bits, and many more) and programming languages (templates, block programming, text-based programming) were tested and included. Teachers as well as students seemed to have attained new and more realistic perspectives in applying the technologies. They practiced open and experimenting approaches as well as systematic and stepwise methods for iterative design. This fostered awareness about when and how to use which methods. According to the teachers and to assessors from the trades, a surprisingly high number of students, and on all levels, came up with well-reflected, remarkable digital products.
- The focus on *Digital Literacy* resulted in cases about ethical dilemmas, the use of social media, ICT-security and the role of technologies in society. Local evaluation results indicated a generally increased awareness among the youth about their own behaviour and responsibilities. The students learned to process creativity to digital solutions via logical and abstract thinking ("Computational Thinking", Caspersen et al. 2013). Using new technologies for vocational purposes increased their practical "technological understanding" and career learning (evaluation ROBOlearning 2021).
- The *Environment* was incorporated into approx. 1/3 of the courses; with company cases and societal aspects about digitalization, involving commercial experts in events, juries etc. By applying new technologies to vocational processes, the students came up with innovative proposals to companies in the new "world-of-work" (video recording 2021). The learning processes in the education chain were extended and systemized, which led to an increased understanding among the teachers for each other's methods. The researcher accentuated a new coherence between learning outcomes on different levels and between the humanistic, tech-

nical and mercantile educational fields (Majgaard 2021). According to the school heads (interviews 2019 and 2021), the extrovert concept has strengthened the schools' local ecosystems and their networks. Concurrently with great effects, collaboration with the environment was experienced as time-consuming and often difficult to initiate. And although the focus on the environment motivated the students and supported them in imagining technological career pathways, the career aspect must still be improved (independent evaluator 2021).

ROBOdidactics

ROBOdidactics is now broadly implemented in the projects' educational settings in Southern Denmark, where it was the joint framework for courses in widely different settings. In some cases, ROBOdidactics even had an impact on general didactic development at schools (managers May 2021). The dissemination continues, having extended presentations in research settings and at seminars/webinars with the freely available app.

ROBOdidactics was assessed as "a well-structured model for the long-term further development of teaching with digital technologies and with an impact on young persons' choices of technological career pathways" (independent evaluator May 2021). The high degree of reuse and further development of courses (projects websites 2018–2021) indicates that the didactic framework supports the transfer to other subjects, other school types and other cities. All in all, the concept reflects "authenticity, transferability and scalability" (Majgaard 2021). The non-normative and flexible approach seems to fit educational settings that require fast adaptation to rapidly changing technologies and to unpredictable contexts, such as during the COVID-19 pandemic (ibid.).

However, new users and especially new teachers found it difficult to access "a complex didactic model". Even professionals with many years of educational experience do not necessarily look for new didactic models when in need of improvement – unless they are pushed or nudged with specific impulses. The findings call for personal introduction to ROBOdidactics, preferably in a teacher-to-teacher communication style (user tests April 2021). Videos and easily applicable course examples were also recommended, as "teachers mostly are very busy and need solutions that can be used next day" (ibid.).

Majgaard emphasized: "Tech-didactic further development obviously requires a setting. This can be a project, a teacher network or a dedicated group, specific tasks with reflection on own practice, teacher training or other settings, but in all cases to be promoted by the pedagogical school management. In this light, the projects have fostered an obviously suitable didactic framework for practice-based empowerment, where the exchange among the teachers was facilitated in a targeted way as a community action research" (ROBOlearning report 2021).

5 Conclusions and perspectives

The research questions refer to the exponential growth of digital technologies in business and social life, their impact on societal changes and thus, a more or less direct influence on vocational education (VET) and its ecosystem. The paper has outlined the educational response from VET and in the transition to VET from lower secondary education as the field of action and research.

A total of 79 unique courses, in many different forms, have thus far involved approx. 8,050 students and proven the adaptability of new programming technologies, robotics and emerging technologies such as Augmented Reality in the above-outlined field. The evaluations of these courses, undertaken by different evaluators with different roles and methods, have witnessed the students' high motivation and a surprisingly high quality of their digital learning products with innovative value. An increased interest in career pathways with technologies was also measured, though this can still be intensified.

The courses were designed, implemented and documented according to a didactic framework created from a new tech-didactic model: "ROBOdidactics" has emerged from an iterative process, conducted as theory development in a Community Action Research. The research encompassed three mutually independent but related projects (2017–2022).

The model addresses approaches and methods for student-centered teaching with digital production, emphasizing Digital Literacy and including the environment. Course descriptions with the ROBOdidactics framework eased course transfer to other educational settings, and across levels. The high transferability and scalability were supported by the participatory concept of the projects that stimulated knowledge sharing and co-creation among the teachers. There are still challenges to overcome, first and foremost efficient and practice-directed introductions to new users. But to a certain degree, the effort has contributed to tech-didactic discourses in Denmark in general, and recently, international interest has arisen.

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