**IND's skriftserie**

# Digitalisation in Core Topic Teaching

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# Executive Summary

Rapid technological changes, and particularly recent AI developments, mandate universities to wrestle with new technology, integrate digital methods into teaching, and negotiate the changes it brings to established custom and practice in higher education. In this report, we address the key question this challenge poses in relation to core topic teaching: **How are students, teachers, curriculum, and administrators to respond to this digital transformation**?

The university of Copenhagen developed a conceptualization of digitalization in relation to the strategy work initiated in 2018, which distinguished three strands of digitalisation: 1) broad aspects of students' digital literacy, 2) digitalization of core topics, and 3) digital tools for teaching purposes. This report covers work conducted in the second strand—digitalization of core topic—between 2021 and 2023. Our work focuses on two aims: 1) understanding the strategy and implementation at the university, and 2) conducting experiments and interventions to support various stakeholders' work with strategy at the university. To pursue these aims, we pursued several projects in which we identified underlying challenges and opportunities in preparing the university and its students for the future, as well as insights into the mechanisms behind these opportunities and challenges. We developed these projects by engaging with various actors across the faculties at the university. Through these contacts we developed multiple projects of varying scope and topic, including: a summer course on AI-literacy with non-technical instruction related to a European initiative (4EU+), student projects around artificial intelligence robots in Chemistry, integrating collaboration-principles into a basic computer science course in Communication, collaborative instructional design to identify core-concepts for data literacy in Anthropology, and developing technology-supported assessment in Law. In this report we summarise what we learned from these projects in terms of three research questions related to: 1) students' adoption of the digital practices, 2) teachers' transformation of teaching practices, and 3) institutional barriers and enablers of digitalization.

In addition to project work, we also conducted workshops and dissemination to align stakeholders' visions of the digital future and inform routes forward in the university. Through these efforts, we worked with the existing structures at the university for development of in-service and training. We also responded to new national standards for continuing development of teachers at the university. This work included evaluating a three-year course for digital competence development among

health science professors, coordinating new competence development courses aligned with university and national frameworks, and presenting at pedagogical days (faculty- or department-wide conferences on teaching).

To share these outcomes of our work in this report we discuss key pointers for future efforts which aim to make teaching and learning at the University of Copenhagen more flexible, adaptive, and receptive to the relentless speed of technical change. The report is structured as follows: We begin by describing digitalisation and the context at the University of Copenhagen. Next we outline the research questions guiding the various projects we developed. Proceeding this are descriptions of each project and key insights. Finally, the report concludes with insights for practice, a summary of what we learned about responding to the digital transformation.

In brief, these insights for practice show that core subject digitalisation demands a lot from teachers and students but is also rewarding. This is, in part, because it is difficult to modularize digital expertise in relations to disciplinary topics. We also learned that it is important to centre the students as well as the problems and professional conditions of disciplines. And finally, our work illustrates how the institutional culture, policy, and organisational structure at the University of Copenhagen (and probably many other universities) struggle to follow a phenomenon such as digitization of core subjects, because it is so multifaceted and individual.

# Background

This report describes research and development projects initiated at the University of Copenhagen (UCPH) with the purpose of supporting digitalisation in the core topic teaching at the university. The project was initiated and financed as a part of the 2023 Strategy, under its focus on digitalisation (University of Copenhagen, 2022). This report summarises some the projects which developed digitalisation in core topic teaching and offers practical insights for practice based on these projects as well as our overall survey of the knowledge and activity flow at the university. The focus is on the situation at the University of Copenhagen, but as digitalisation influences many universities, this work can also support reflections and decisions beyond.

## Defining Digitalisation

Digitalisation is a buzzword that evokes an institutional call to action. Digitalisation—defined as the process of digital transformation—is multifaceted and refers to many processes at the same time. It represents a phenomenon which is understood differently by different people. At its root, digitalisation represents a process of increasing change to the environment in which everybody works and lives due to introduction of new digital technologies; that environmental change affects universities, industry, government, and personal life.

To study digitalisation more specifically, we considered its impact at specific levels, by looking at different groups: students, teachers (and the curriculum that organises teaching), and administrators. From an **administrative** perspective, digitalisation refers to the digital systems which support management, quality control, and administration. From the perspective of subject discourse and the **curriculum**, digitalisation refers to the new digital methods and solutions used by researchers and professionals as they probe the frontiers of knowledge and innovate in industry. From **teachers'** perspective, they may see some of these research-driven activities as difficult to teach their students, requiring the specialist skills of data analysts or AI experts. For them, digitalisation could be a threat to established professional practice, a burden of additional labour, or an exciting opportunity to develop curriculum content or skill. From the perspective of individual **students,** digitalisation may be either a term which merely indicates another requirement in their program of study, or it may describe their lived-experience as a negotiation between multiple platforms, interfaces, services, and big-tech corporations. Equally, for some students, digitalisation is an invitation to exercise agency: exploring digital tools beyond the interface and create new innovations.

These different groups are all involved in digital transformation at the university in different ways. As a collective, as an educational institution responding to digitalisation, we suggest that universities have:

**an obligation** to support the development of general digital literacy among students

**a need** to educate new generations of professionals and scientists capable of using modern technology-supported methods

**an interest** in adopting efficient technology-enhanced teaching practices

These obligations, needs, and interests were reflected in the three strands of UCPH's digitalisation initiatives (summarized in the section *Digitalisation at the University of Copenhagen*). Clearly, the university intends to address digitalisation, but what how to respond is not as clear.

Rather than adopt a single definition and approach to digitalisation, UCPH adopted a pragmatic, multi-strand characterization of digitalisation. Internal debate within the digitalisation project stakeholders at the university about the conceptualisation of digitalisation mirrors the complexity of defining and delineating this concept that is also present in scholarly discourse. In basic definition, digitalisation refers to the process of "rendering of social and natural worlds in machine-readable digital format" (Williamson et al., 2020). However, this definition *does not* encompass the breadth of what UCPH strategy seeks to accomplish regarding digitalisation. Within UCPH's strategy, the term digitalisation refers to both teaching and student learning outcomes related to the digital transformation as well also the digital transformation of education with digital tools. This double meaning also appears in education research. For example, compare how differently the phrase "digitalisation of schools" was defined in the following papers:

"Digitalisation of schools" by which we mean how to manage a school with a well-functioning Information and Communication Technology (ICT) infrastructure.
(Babaheidari & Svensson, 2014)

"The digitalisation of schools" is used to describe the enabling of digital competence for all.
(Gustafsson, 2021)

The first refers to institutional infrastructure and the second refers to student competence—both using the same term. This two quotes illustrate how digitalisation as a term has been used to refer to

different phenomena related to digitalisation in education. Using terms in such diverse ways blurs what type of intervention or change is indicated in response. The Appendix provides a summary of common definitions digitalisation and illustrates further how the use of this term varies across disciplines.

As it stands, UCPH adopted its own approach to defining digitalisation which corresponded to the response initiatives. It should be note models exist but were not adopted at UCPH. One such framework is the *European Framework for the Digital Competence of Educators*, also known as DigCompEdu (Redecker, 2017). This framework elaborates digital competences that educators can have, these are competences that teachers use need for training students in areas related to digitalisation and teaching in a digital age. In the future, the UCPH may align its definition of digitalisation with this or other standardised frameworks, which would facilitate more alignment across universities and provide connection to external resources. This would not contradict the approach we took in our projects, as our understanding of digitalisation has been informed by reviewing such frameworks.

In our projects, we adopted an ecological and situated stance defining digitalisation as an environmental change to which learners, teachers, administrators must adapt. We approach digital education as embedded in meaningful educational activities and without clear borders. In this way our definition is in opposition to framing digitalisation as stable (specific things/software that you can point to), intrusive (a movement from outside the academic and pedagogical arena) or functional (solving specific isolated problems). The intended focus of our work was on teaching and curriculum: what was termed core topic teaching. In other words, it was on the translation between the work of researchers who use digital techniques to advance knowledge and the curriculum content and teaching which would support students in acquiring these new techniques. This approach was initially seen as an implementation problem, but through our projects we realised that transformation of core topic in response to digitalisation is not straightforward implementation.

Often, implementation is focused on a clear envisioned change and aimed at the adoption of a specific innovation. While this may sometimes be the case in smaller subprojects, it is—in the case of the grand project of digitalisation of core topic teaching at the university—more difficult to pinpoint the adopted innovation and envisioned change for the whole university. There are several reasons for this. Universities are simultaneously developing new disciplinary approaches and educating new scholars into such approaches. There are also generation gaps in relation to digital

technologies whereby students bring approaches and technological solutions into the university. Furthermore, digitalisation of core topic activities is deeply situated in disciplines, contexts, and the purpose of a specific activities. Given this complexity, we conceptualised digitalisation ecologically rather than as an implementation problem.

## Digitalisation at the University of Copenhagen

The university of Copenhagen is one of the oldest universities in the Nordic countries It is organised in with a central administration which has adopted a strategic development plan, referred to as the 2023 Strategy (University of Copenhagen, 2022). Digitalisation was a key element in the 2023 Strategy, which stated, "in line with the overall ambition of enhancing the quality of teaching, we will develop and disseminate the use of digital teaching methods. Such methods must underpin the quality of teaching, increase learning intensity, and help free up time for increased interaction between academic staff and students" (University of Copenhagen, 2022, Strategy Point 2.3). This was the first time that digitalisation was included as a strategic focus at the university.

The 2023 Strategy built on strategic development goals initiated with the 2016 Strategy which was outlined 2012 as well as Destination 2012 which was outlined in 2007 (University of Copenhagen, 2012). The 2023 Strategy focused on a mission for the University of Copenhagen to be a "knowledge and culture-bearing institution, which, based on independent research and research-based education at the highest level, provides a framework for critical thinking, insights and a quest for truth for the benefit of society" and a vision to "be among the world's best universities measured by the quality of research and education and to be recognised for excellence and intellectual creativity" (University of Copenhagen, 2022). More specifically, the 2023 Strategy had four main areas, including (1) attracting, developing, and retaining academic talent; (2) education with closer ties to research and practice; (3) collaboration and societal commitment – nationally and globally; and (4) one unified and focused university. Our work with digitalisation of core topic teaching related to the second of these areas. This strategic area is further specified with a focus on learning environments with inspiring research-based teaching, a closer affiliation to practice and the job market and with improved digital teaching.

More specifically, the focus on digitalisation of core topic teaching come from the implementation plan that followed the strategy. In the implementation of the 2023 Strategy, one of the important

elements was developing a digitalisation programme outlining three different strands of digitalisation that all feeds into the strategy goal. These three strands include:
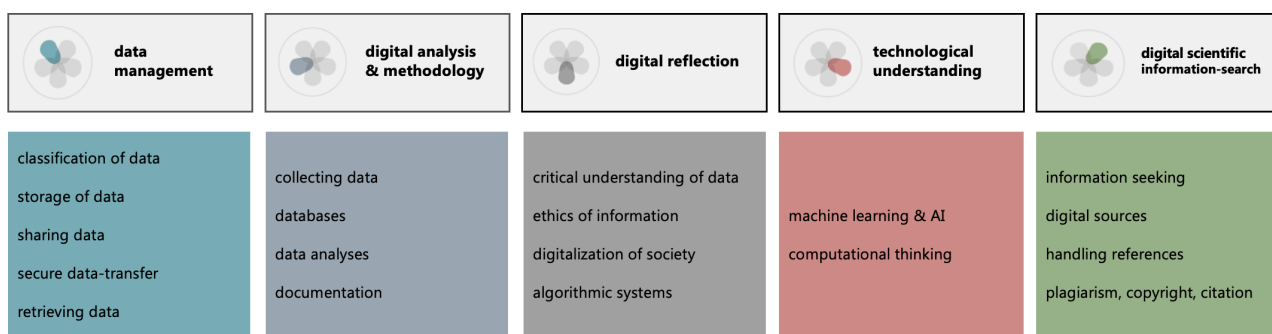
**Strand 1**: Students' digital literacy

**Strand 2:** Digitalisation of degree programmes and of core topic teaching

**Strand 3:** Digital tools for teaching purposes

Our projects all aligned with Strand 2 but intersected the other strands for alignment and greater efficacy. Our ecological understanding and definition of digitalisation means that some projects and tasks must cross these strands to be meaningful.

In relation to **Strand 1**, students' digital literacy, the students at the university are expected to become acquainted with important digital phenomenon's and develop skills and literacy so that they can solve general tasks choose appropriate specialised tools. To this end, the university outlined a model of student digital literacy, illustrated in the figure below. This model is relevant in Strand 2 because it identifies basic topics skills and competencies students will need to develop to in relation to digital literacy. The digitalisation of degree programmes and teaching builds on this model by integrating intended learning outcomes into programmes and core topic instruction that both target these specific areas of digital literacy and build on them to more advanced topics.

**Model of Student Digital Literacy (Strand 1) at the University of Copenhagen**



| data management | digital analysis & methodology | digital reflection | technological understanding | digital scientific information-search |
|---|---|---|---|---|
| classification of data<br>storage of data<br>sharing data<br>secure data-transfer<br>retrieving data | collecting data<br>databases<br>data analyses<br>documentation | critical understanding of data<br>ethics of information<br>digitalization of society<br>algorithmic systems | machine learning & AI<br>computational thinking | information seeking<br>digital sources<br>handling references<br>plagiarism, copyright, citation |

In relation to **Strand 2**, digitalisation of degree programmes and of core topic teaching, students graduating from the university are expected to be able to understand the digital transformation and influences to use their disciplinary knowledge in a modern digital labour market and in research. To address this area, we conducted multiple design-based projects and evaluations across the university. Summarising this process and outcomes of these efforts is the main aim of this report.

Finally, in relation to **Strand 3**, digital tools for teaching purposes, there was a focus on the use of tools and technologies that are used to support the teaching situation. When introducing our work in Strand 2 to stakeholders across the university, we often encountered confusion around the term digitalisation. We observed that people usually think of topics related to Strand 3 in response to the term digitalisation. To clarify this point. We wish to highlight that the work in this report focuses on changing what students learn in core topic education, and to that end we are studying the design of curriculum and how teachers approach teaching core subjects in response to digitalisation.

# Projects

In this project we developed multiple projects to address the aims of digitalisation in core topic teaching in relation to a range of stakeholder groups. Each faculty at the university has been addressing digitalisation independently and so working across faculties required different approaches. In the light of these various projects, our work evolved as understanding of the challenges emerged and our targets adapted. Our methodology was design-driven, beginning by meeting with study boards in each of the faculties to get a sense for their goals for digitalisation of core topics teaching. Based on these meetings we identified specific courses and instructors for further collaboration and developed projects with these individuals organically.

## Research Questions

These various projects address the following research questions in multiple ways. These questions concern the ways in which the implementation of digitalisation can be approached by the three groups of stakeholders involved in our project: students, teachers (and curriculum) and administration. We translate this general question to be relevant to each of these groups:

**Students:** Under what circumstances do students adopt digital practices (for example, data analysis or coding)? Under what circumstances might students resist adopting digital practices?

**Teachers/curriculum:** Which conditions empower teachers transforming their teaching practice and curriculum design to integrate issues of digitalisation? Under what conditions might teachers resist?

**Administration:** What are the barriers to administrative support for digitalisation?

To address these research questions, we developed projects at each of the faculties at the university (excluding Theology). The table below lists these projects, the stakeholders most impacted, and the faculty in which the project took place. This table also shows how the research questions relating to students, teachers, curriculum, and administration, are related across different interventions and different curriculum areas. To address questions about students, we focused on a small number of students in chemistry, observed students in anthropology, and developed and taught a 4EU+ course project C-Camp. For questions about teachers and curriculum, we studied university teachers' competence development in the Digital Health and Data course, worked with professors in law and anthropology, and developed teacher-training workshops (Post-UP workshops) for university teachers after the Universitetspædagogikum (UP). Finally, for questions relating to administration the Post-UP and the Digital Health and Data course projects were salient.

**Projects across the UCPH Faculties and their Target Stakeholders**

| | Students | Teachers | Curriculum | Administration |
|---|---|---|---|---|
| **Health and Medical Sciences** | | | | |
| Multi-disciplinary (Digital Health and Data Course) | | x | x | x |
| **Humanities** | | | | |
| Communication and IT | x | | | |
| **Law** | | | | |
| Instructional technology development | | x | | x |
| **Science** | | | | |
| Multi-disciplinary (Post-UP Workshops) | | x | x | x |
| Chemistry | x | | | |
| **Social Science** | | | | |
| Anthropology | x | x | x | |
| **Interdisciplinary** | | | | |
| C-Camp: 4EU+ Summer Course | x | | | |

Subsequently in this *Projects* section, we introduce each of the projects outlined in the table. We organise these projects based on which stakeholders were most impacted. As the table shows, these initiatives involved multiple stakeholders. But for clarity, we describe each project in the most relevant context, either students, teachers (curriculum), or administration. The following sections relating to student-, teacher-, or administration-centred initiatives are structured the same. First, we describe the projects and our overall approach. Next, we describe each project with a narrative of what happened. Finally, we summarise the key reflections and outputs from the projects in relation to the specific focus stakeholders. Each project added to our understanding of digitalisation, through our work we have developed our understanding of digitalisation and recommendations for practice, which we share in the subsequent section, *Insights for Practice*. We don't link recommendations to specific projects because our overall understanding developed iteratively and don't correspond one-to-one to specific projects.

## Projects with Students

In this section we describe three projects that focused on students in digitalisation of core topic teaching. At the University of Copenhagen, these projects took place primarily in chemistry and Communications and IT, and focused on supervision, teaching, and instructional activity design. Additionally, the 4EU+ course called C-Camp included students from multiple institutions (including UCPH). Our work in the anthropology department also involved observing students but this is discussed in the next section on interventions with teachers. We developed student-focused interventions because understanding student needs and perspectives is an essential first step in developing instruction. This work with students provided this understanding to our work with teachers and administrators.

### Chemistry

Interventions in chemistry were partly prompted by a desire from the teacher to create novel tools for chemistry assessment. This led to a presentation to a full class of students about technology in chemistry, and an invitation for any students to pursue this in more depth. A small number (4) of students expressed an interest in pursuing a deeper engagement with digitalisation. We note that the opportunity we presented was additional to their requirements, which often attract only a small number of participants. Individual meetings were conducted with these students to find out how and why they were interested in looking deeper at the technology. Some recurrent themes arose from

these meetings including: "I'm interested, but I haven't got time with pressure from my studies"; "Is there a pre-requisite to be able to program?"; and "It seems interesting, but I can't see how it is relevant to my degree." It was noticeable that of all the aspects of digitalisation shown to these students (particularly about chemistry and tools for creating questions), AI was the most intriguing for the students. They were not particularly interested in the teacher's idea for novel teaching tools.

Following these discussions, two students agreed to pursue a deeper investigation. With one of these students, we established an elective credit-bearing project module to support a tailored investigation into AI using the recently released OpenAI text API (pre-chatGPT). Both students attended weekly sessions where together students explored simple Python programming and the capabilities of the AI. We developed and facilitated several different student-centred initiatives that were offered directly to students. The purpose of this was to study hand-on what instructional approaches work well for digital topics in core topic teaching. The chemistry students were offered several tinkering days around the topic of AI. This instructional approach combines interested-driven instruction with a playful approach to learning. These informal learning opportunities also resulted in several formalised independent studies, in which students completed a patchwork project and report.

Finally, the two chemistry students created novel web-based solutions with support. These solutions became important as a foundation for later work on the C-Camp project, where a greater use of AI was promoted as a way of stimulating interest.

## C-Camp: 4EU+ Summer Course

C-Camp was summer intensive instructional program funded through a 4EU+ grant. This means it was offered to students at three other universities in addition to the University of Copenhagen. In total, 25 bachelors students travelled to Prague and participated in a three-day seminar on topics including AI, social media, and data ethics. Students were from a variety of humanities, social science, and science fields. The students developed their interdisciplinary collaboration and critical thinking skills through interactive instructional activities. In particular, C-Camp was a way we explored developing instructional activities that build AI literacy in non-technical ways (without becoming programmers).

In preparation for the program, a software "teaser" was created to stimulate curiosity based on the work that the chemistry students had done previously. This was distributed to the participants of C-

Camp as a way of emphasising the transdisciplinary nature of the C-Camp approach. There was no directive to focus on specifically technical matters, although some students were particularly interested in the software we provided and asked for the source code. The idea behind C-Camp was to allow students to find those aspects of digitalisation which they found interesting, and to connect students with similar interests as a way of building new projects from the ground-up.

## Communication and IT

In the Communications and IT program we developed a week of instruction for students in a course about the fundamentals of programming (Grundlæggende Datalogi, 2022). In this work we collaborated with course instructors to redesign a final assessment to be more project-driven. Using a backwards design process, we identified design thinking topics relevant to students conducting a programming related project in the domain of communications. We also helped build connections between technical and the theoretical instruction (Grundlæggende Kommunikationsteori, 2022).

Students received a week of instruction in this design thinking module. In this instructional development, we focused on how technical instruction in programming can be integrated in meaningful ways into traditionally non-technical disciplines, in this case communications. We focused on the importance of theory and design as a bridge to make the technical aspects meaningful and relevant for students. By introducing a self-guided design project, this course invited students care about developing technical skills.

## Reflections on Student-Focused Projects

In response to the research questions that we posed about students in digitalisation—**Under what circumstances do students adopt or resist digital practices?**—we found that interest and meaningfulness were key for students' engagement. Without these dimensions, students couldn't see "what's in it for me?" in terms of learning new skills. And exhortation of the importance of digitalisation on its own are insufficient.

First, that some students did take an interest after sufficient experimenting with different approaches indicates that there are ways in which certain technological affordances fascinate and stimulate an appetite for deeper inquiry. This offers us insights into what instructional strategies work well for developing digital literacy in students across a variety of fields. Specifically, instructional strategies that allow open-ended exploration, problem solving, and cultivate the authentic interests of the students. Secondly, hands-on instructional experiences helped us learn about what additional

competencies beyond core topic students will need to achieve our digitalisation-related learning objectives. Through these instructional design projects, we gained an instructor's perspective on the challenges and joys of digital education in core topic areas. Finally, these projects put us in contact with students' experiences and expectations around digital education.

With a focus on "core topic teaching across the university", there is a question of what aspects of digitalisation are relevant in what fields. Working directly with students and their instructions helps inform this question. For instance, we found that interdisciplinary groups can work on digital competence together in terms of digital literacy, computational thinking, or design thinking through the C-Camp course. This interdisciplinary course showed how deep engagement with digitalisation could happen in a course that was not aligned to a specific discipline. We believe this learning transferred back into students' respective discipline-based learning. Further, we observed that is important to learn about students and the specifics of their programs of study to create tailored instruction for digital literacy, rather than offering a generic module or course for digital competencies.

**Outputs from student-focused interventions**

- Instructional materials and activities in digital core topic teaching for in multiple fields
- Chemistry students received ECTS for work related digitalisation in core topics
- Student-led interest-based networks for collaboration
- Revision of instruction in the multi-disciplinary Communications and IT course
- Students from multiple universities received ECTS at C-Camp and participated in a course to develop AI literacy through non-programming based instruction

## Interventions with Teachers & Curriculum

In this section we describe four projects that focused on teaches in digitalisation of core topic teaching. At the University of Copenhagen, these projects took place primarily in law and anthropology and focused on teaching and instructional design. Further, focusing on competence development among teachers we also developed competence development courses in a post-universitetspædagogikum (post-UP) framework and evaluated the Digital Health and Data course. The initiatives with teachers were at the heart of digitalisation of core topic teaching, as changes in teaching were a key outcome of the university's strategy.

**Anthropology**

The project with undergraduate anthropology began as an instructional design project with an anthropology professor to design digital competency modules into introduction to anthropology course (Antropologi som Samfundsvidenskab, 2022). In this work we collaborated with a professor to adapt a core-topic course to include digitalisation. This instructional design worked wrested with what digitalisation meant in the field of anthropology and how that translated to instruction. However, over this work, the instructional design expanded to include an analysis of the anthropology curriculum for the bachelor program at the Department of Anthropology, which was compared with the other programs in the Faculty of Social Science. This shift happened for two primary reasons. First, the course instructor left the university, so the modules we were working on were never offered. Second, designing modules without considering the students prerequisites and future learning offers a limited scope for developing high-level competencies. As such we broadened our analysis to the program of study to better understand the kinds of changes would be necessary to reach the intended educational goals.

In this project we were able to work directly with instructors to modify their course. In this interdisciplinary collaboration, we provided expertise in digital competence development, and they provided anthropology expertise. From this work we realised that instructors at the university can be interested and excited to include more data science and digital literacy concepts in their field. For some, these digitalisation-related topics are also areas of research expertise. But most instructors are not prepared to teach in these topics without learning new things. This highlighted a broader structural need in the institution to create training opportunities for professors. In effect, if university professors are expected to teach students about what they are experts in, often in terms of research, and they do not conduct research in digital topics or using digital methods, how will they successfully teach students digital issues in their core topics? Based on this insight we supported anthropology with an instructional design and curriculum analysis project. But more broadly, we initiated a project to design competence development for instructors.

As we discovered, at the time, the instructors and study board members did not have a unified approach to digitalisation in anthropology. (Since our project, a more systematic curriculum analysis project has begun in in Social Science, including the Anthropology department.) To understand the implementation practices impacting this project we conducted interviews, observations, and document analyses that helped us better understand the culture and goals at

anthropology. But given our position outside the faculty and department, after our collaborating teacher left, we were not positioned to continue instructional design work. Our experiences highlighted how program-level choices such as reducing the number of employees impact curriculum change and teaching-practice development efforts.

## Law

Working with the Law department took the initial form of a workshop presentation at the faculty teaching day (pedagogical day). We introduced a range of scenarios where technology was going to be of crucial importance to law, including AI and copyright, automatically-generated case-studies, and dialogical approaches to legal training. Two teachers expressed interest in pursuing digitalisation in collaboration with us.

As with chemistry and anthropology, the teachers' approach to digitalisation tended to be framed by existing pedagogical practice, while the perception of opportunities for engagement were seen as a means of creating or exploring new tools that would facilitate their existing practice. One line of investigation concerned ways in which ethical issues around digitalisation could be developed. The other concerned tools for improving assessment and (potentially) provided data analysis opportunities for students. The latter project resulted in a prototype which provided a means of keeping the discussion going with the teacher. Further presentations to students in Law followed, with increasing emphasis on the legal challenges of AI (which by this time was producing remarkable artistic work – "who owns the IP of this?" was the question asked of the students). While there was interest, it was not pursued by the students.

The prototype was tested by the teacher, but they realised the complexity of what they were wanting to achieve would demand more time and development resource than was available and the digitalisation benefits to students were not clear. While this intervention was not a success, it frames an underlying theme repeated in other interventions of the difficulty in encouraging teachers to see the necessity to change their own practices and develop digital skills themselves. It also highlights how teachers often combine their use of digital teaching tools and digitalisation of core topics teaching. While our interactions with law began with a talk on digital core topics changes in law (Strand 2) what the teachers were primarily interested in were technology applications to use in their teaching (Strand 3).

## Post-UP courses

We developed and offered professional development courses and workshops for instructors in the Science and Health Sciences around digital literacy and digitalisation. The impetus for this project was the release of a national framework for advancing pedagogy in Danish universities (Danske Universiteter, 2021). This framework addresses professional development around teaching generally. As described in the framework, it sets out competence benchmarks related to 'dynamic development of the universities' teaching and supervision tasks and ensuring that associate professors and professors have the possibilities to update and maintain necessary competencies within one of the university's most important core tasks, education' (Danske Universiteter, 2021).

After an analysis of existing professional development opportunities, we identified that no course around digitalisation existed for professors in the Faculty of Science. As members the Department of Science Education, we were situated to modify and extend existing teacher training opportunities for the Faculty of Science. In this project we developed a framework for pedagogical development around digitalisation and designed several courses related to digital literacy and instruction. The first step in designing meaningful course offerings involved identifying existing professional development opportunities and identify gaps. In this process we coordinated several working groups and workshops with experts. The results of this project was a framework for developing courses for instructors' competence in digitalisation and instruction. Using this framework we developed, piloted, and offered several workshops and courses.

We experienced the workshops related to digitalisation being cancelled several times due to low registration. We suspect that these workshops are challenging for professors to prioritise for two reasons. First, to participants, it is not clear how these courses relate to the systematic teaching development requirements. If it is optional they must weight attending against all their other demands. Second, learning about the UCPH model for digitalisation may be uninspiring. In contrast, we have seen that since ChatGPT was introduced the workshops relating to ChatGPT have had strong attendance. So, it seems when digitalisation, in general,  is not as interesting.

**Framework for Professional Development in Core Topic Teaching**
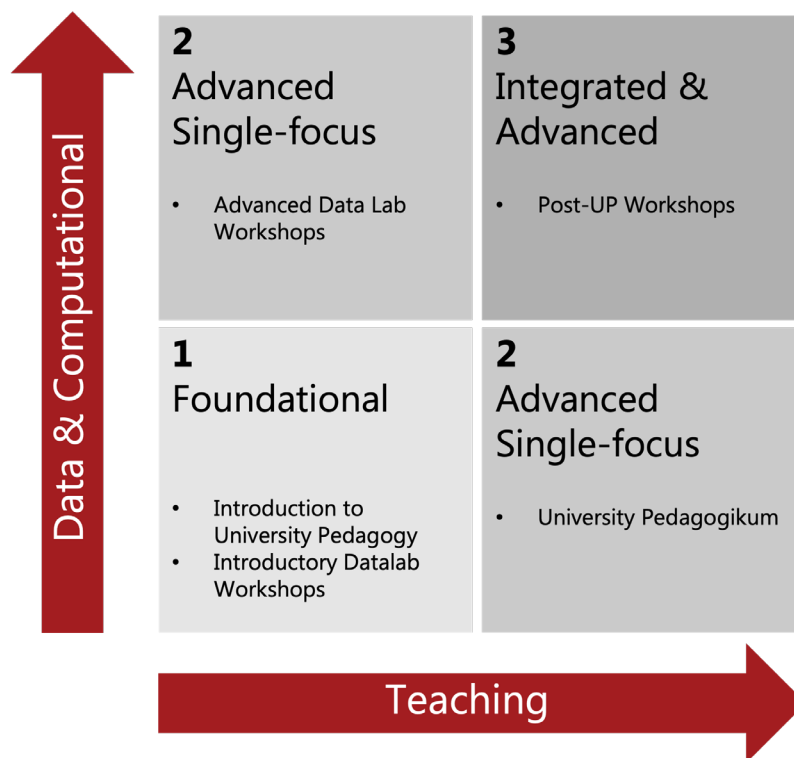


The figure above shows the framework for professional development offerings at UCPH for teachers to build the skills necessary for digitalisation in core topic teaching. This framework includes two types of competence, shown in the red axes: teaching as well as data and computational competencies. These axes represent competence development from basic to advanced. In each of the quadrants, we highlight what competences are being developed. The first quadrant represents foundational skills in both competence areas. The second two quadrants focus on advanced skills in one of the two competence areas, focusing either on data and computational competencies or teaching. The third quadrant is the most complex, developing advanced skills in both competence areas. In each quadrant, there is a non-exhaustive list of the types of courses, workshops, and competence development opportunities exist at Science for teachers. This framework is a guide for spotting areas where more competence development opportunities are needed.

## Digital Health and Data

The Digital Health and Data course provided instructors in the Health and Medical Sciences a three month long professional development course as a 'competence boost that enables them to

incorporate modern data-driven methods and technology in their teaching' (Lillholm, 2020). In short, instructors learned about data science over this course that included a project, nearly a week of talks and hands-on workshops, and completing and instructional group project. This course was offered in 2021 and 2022 to nearly 65 participants. This training initiative was funded by the Danish Agency for Research and Education through their Digitalisation Pool.

Our role in Strand 2 was to observe and evaluate this instructional initiative to provide institutional insight into the efficacy of competence development programs for data science and translation into teaching practice. The evaluation of the Digital Health and Data course includes analysis of surveys, instructional observations, interviews, and focus groups. Course participants were sent a course survey after each day of instruction. In addition to these responses, instructional observations and interviews with course participants provided additional context.

## Reflections on Teacher- and Curriculum-Focused Projects

Turning to the research questions we posed in our work with teachers: **What conditions empower teachers transforming their teaching practice and curriculum design to integrate issues of digitalisation? Under what conditions might teachers resist?** We observed a general tendency in all interventions with teachers where digitalisation was interpreted not as a demand to learn new skills by the teacher, but as a means of enhancing existing teaching practice with new tools. This perspective was informed by the law and anthropology teacher-focused initiatives as well as the chemistry and C-Camp student-focused initiatives.

In our work with Chemistry students (introduced in the *Student-Focused Initiatives section*), we began from the expressed desire of the teacher to create new tools for teaching. This, however, did not excite the students. In the chemistry intervention and in the C-Camp intervention, we avoided this problem by eventually going straight to the students. In the anthropology course we worked directly with instructors to modify their course. In this interdisciplinary collaboration, we provided expertise in digital competence development, and they provided anthropology expertise. From this work we realised that instructors at the university can be interested and excited to include more data science and digital literacy concepts in their field. For some, these digitalisation-related topics are also areas of research expertise. But most instructors are not prepared to teach in these topics without learning new things.

This highlighted a broader structural need in the institution to create training opportunities for professors. In effect, if university professors are expected to teach students about what they are experts in, often in terms of research, and they do not conduct research in digital topics or using digital methods, how will they successfully teach students digital issues in their core topics? Based on this insight we supported anthropology with an instructional design and curriculum analysis project. More broadly, we explored this question in the post-up framework development and digital health and data course.

Exploring the question of what empowers teachers to change their teaching practice assumes teachers wish to adapt their teaching practice. However, what about the conditions when teachers resist change? **What does it take for teachers to see the necessity of transforming their teaching practice and the curriculum?** One way of addressing this problem was to put teachers in a safe environment where they could experience teaching digital skills in their discipline with appropriate support. The digital health and data course aimed to provide this, where teachers were invited to gain knowledge of data science by teaching data science in their respective specialties. As was written in the funding proposal: "Today, technology focus is partly already part of the curriculum in the educations, but there are clear challenges in translating the learning objectives into concrete inclusion of the possibilities of technology in the broad core subject teaching. This is partly due to a competence development need of the teachers. The purpose of the course is of course not to retrain the core subject teachers to become data science specialists, but to develop a broad-based methodological readiness and competencies to consider the ongoing technological development and how it affects and develops professions and disciplines and thus ensure relevant involvement in education. of future graduates" (Lillholm, 2020). While the university seeks to digitalise core topic teaching, instructors often lack knowledge or experience in relation to digitalisation in their field. The Digital Health and Data builds up the knowledge and experience level among instructors. This excerpt from the course description also highlights the need to change curriculum to support instructional change.

The analysis of this course provides several important insights into how to prepare instructors for teaching that includes data science. First this course was a first. It was a large-scale professional development course that was specific to teaching that also focused specifically the necessary skills for data science among their students. Given this, studying this course gave insight into what resonates with the needs of instructors; it also identifies strategies that do not work and can be

avoided in the future. Longer term, the second thing this evaluation accomplishes, is looking at the efficacy of professional development for teaching data science in core topics. Specifically, how instructors do or do not put what they learned during the professional development into practice in real classes. To have impact, training must transfer to actual practice—this evaluation looks at when and how such transfer happens. Through focus groups we are also probing institutional policies and practices that support and hinder practical changes to instruction.

Findings from the development of Post-UP courses focused on the requirement to support change in teaching practice so as to instigate change in digital literacy. Again, as a way of creating a safe-space for teachers to deal with the uncertainties of digitalisation and digital literacy, we approached developing professional development first as a curriculum design task. This presented an opportunity to connect administration-oriented interventions (the provision of teacher training courses) with pedagogical interventions, for example by incorporating these courses into existing courses such as the Universitetspædagikum (UP) and creating new post-UP courses, building on the existing institutional structure for teacher training (Institut for Naturfagenes Didaktik, 2022).

But ultimately stand-alone curriculum development options are not sufficient. The alignment between training options shown in the framework developing from the post-UP project illustrates how a lack of alignment can result in too few advanced training opportunities, courses misaligned to teachers skill levels, or courses that are introductory and never integrate complex competencies. We discuss some of the administrative tasks that can support such alignment in the next section. But in relation to teaching, we want to highlight the connection teaching and curriculum. This strategic project asks for changes in core topic teaching but doesn't specify an mechanism for change. Such change could take place in teaching itself, teacher skills, or curriculum. Our projects often focused on changing teaching directly, but changing curriculum will have longer impact and longevity. Depending on the program, teachers are assigned to teaching in different ways. We also observed how the many practical tasks related to setting up instruction (how courses are assigned, when teachers know, group divisions, room assignments, and the use of co-teachers or teaching assistants) all impact the capacity of teachers to bring change to their teaching. Failing to account for these or find synergy among these processes impacts our capacity for digital transformation in core topic teaching.

**Outputs from teacher and curriculum-focused interventions**

- Course evaluation report the 2021 and 2022 Digital Health and Data course summarising on student engagement and learning outcomes. This report informs future data science related trainings for instructors in Science and Health Science faculties

- Interviews on transfer into practice after the Digital Health and Data course in collaboration with KP researchers

- A framework for designing professional development courses that was validated in a curriculum design study

- Professional development courses for instruction for digital literacy aligned national competence-development frameworks

- Workshops on digital literacy for teachers, course responsibles, and study board members

- Anthropology curriculum analyses of digital competence development of social programs at the university

- Expert-validated instruction modules for data literacy in anthropology

## Interventions with Administration

In this section we revisit three interventions that touch on administrative roles in digitalisation of core topic teaching. These initiatives in law, post-UP courses, and digital health and data have already been introduced. However, though it was not our initial or primary focus, through these initiatives we realised there is an important role for administration to play in digitalisation transformation efforts. Below we highlight how these three initiatives relate to administrations roles and how the structure and practice at the university can hinder or improve digitalisation of core topic teaching.

### Law's Module Boards

Constraints which can prevent safe spaces for creativity and teacher experimentation are noticeable across the university faculties. One of them was analysed in Law, where the system dynamics which reflect the administrative tensions between the different bodies who oversee approval of curriculum changes was loosely mapped out using the cognitive mapping approach of Eden and Ackerman (Eden et al., 1992). This diagram illustrates our analysis of how feedback loops between

those seeking to modernise the law curriculum and those seeking to maintain practices exist among competing agendas both within and outside the university.

**Feedback Loops in Digitalisation Management**
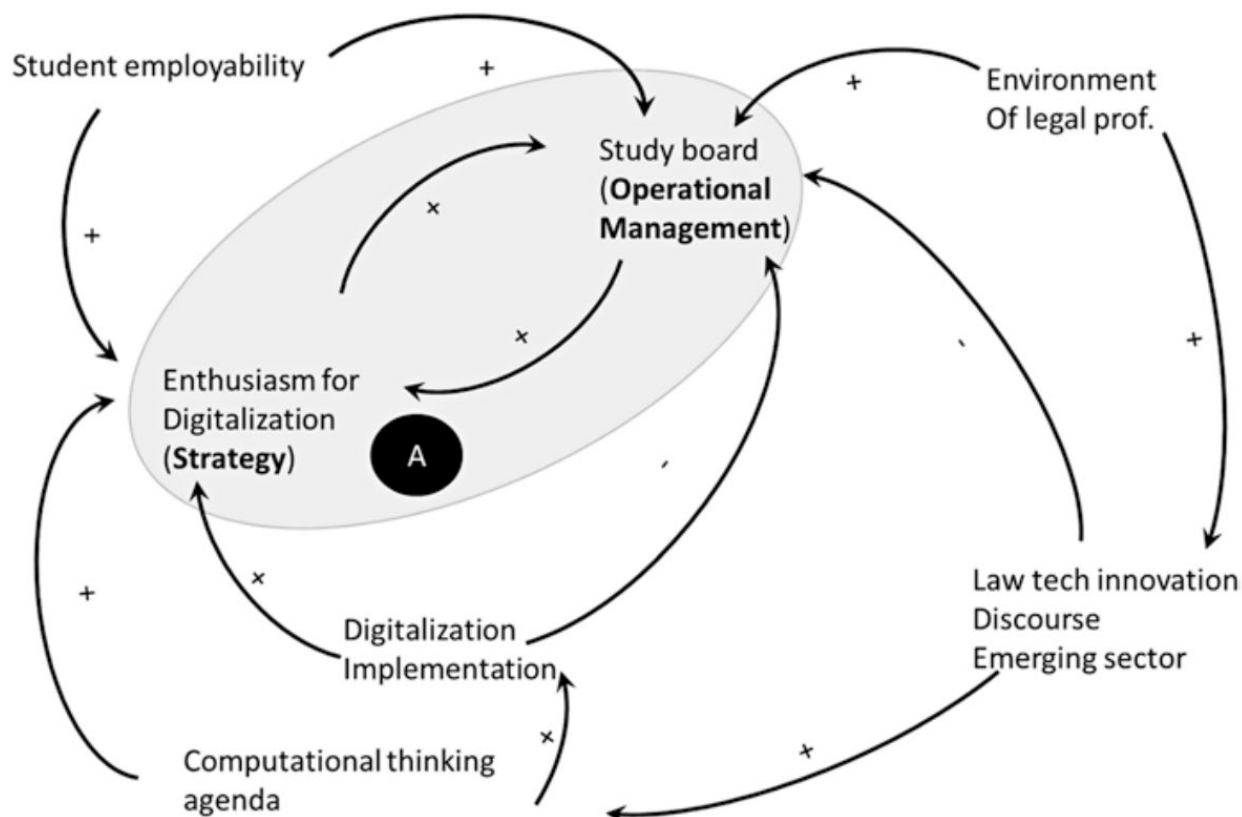


This diagram shows s positive feedback loops where contradictory forces cancel each other out. For example, the Law technology sector outside the university both seeks to connect with issues like computational thinking and digitalisation, while being sponsored by some in the professional legal environment, while others will seek to reinforce traditional practice and uphold conservative values within study boards. Meanwhile, arguments about student employability will drive contradictory forces, one upholding traditional practice, the other driving innovation.

## Post-UP Implementation

The impetus for Post-UP courses comes from national standards, interpreted by university policy. However, this process is still in progress. Currently, the funding, merit, and training criteria standards are still being developed. Without these guidelines was difficult to align training offers with broader institutional policy and goals. While there is a recognised need to support teachers in

developing the skills to teach digitalisation, the path to doing that is still under construction. This can result in a disconnected series of courses related to digitalisation which aren't integrated or compatible with other training opportunities or initiatives.

## Digital Health and Data Transfer

The creation of the digital health and data course reflected a rationale for creating spaces for teachers to explore ways of teaching digitalisation. This course was novel in several ways, including its focus on digital technology and data healthcare in teaching rather than research. Further, it spanned multiple institutions (UCPH and KP). But like other training programs in digitalisation of teaching, this program struggles to have staying power beyond its initial run. There are two administrative challenges here. First, programs like this should be developed for long-term impact, rather than existing and then fading away. Second there must be sufficient follow-up to embed new practices and transfer them into teaching and avoid the temptation to see participation on the course as a kind of "badge collection". This broader transfer requires collaboration among many different administrative roles, which is complex but necessary.

## Reflections on Administrative-Focused Interventions

Here we reflect on the research question we posed regarding administration: **What are the barriers to administrative support for digitalisation?** The University's digitalisation project began with interventions from high-level faculty teams which was intended to cascade down to individual programmes and teachers. It was an approach developed in the expectation that digitalisation of core-topic teaching was a matter of implementation—such as offering professional courses and changing classes topics. This turned out to be challenging for reasons we illustrated in the diagram of the law department. We found that many contradictory forces were pushing an agenda which different actors interpreted quite differently. Teachers tended to see digitalisation from the perspective of their current practice, seeking ways to ensure the continued security of their existing practice. Some students were interested in digitalisation, but most students were more concerned to maintain stability in their existing studies than venture into uncharted territory around technology. We learnt a lot from those few students who were willing to do this.

What can the administration and hierarchy of the institution do about this? The fact that one student found a way to excuse themselves from official study to play with technology and gain certification provides one possible answer: the university could provide space in the curriculum for students to

play with technology. Equally, however, the university could provide space in the working week for teachers to experiment with technology, and for communities of practice around teaching with technology to be grow in organic ways. In the face of the challenges of AI, the provision of this space may become more urgent. The temptation within universities is often to create a "centre" for some aspect of practice which it wants to encourage (for example, data analysis or learning support). But these new centres or projects can be disconnected from existing. One way to avoid this is to reflect on existing structures, as leaders in administration and use these to integrate digitalisation, building on what is already there.

> **Outputs from administration-focused interventions**
> - Meeting and presentations with steering and study board committees in different faculty
> - Developing working relationships with individuals working in digitalisation across faculties and types of roles (administration, technology management, consultants, course leaders)
> - Discussing implementation approaches at curriculum and instruction design workshop in multiple departments

# Insights for Practice

Our projects impacted or studied students, instruction, curriculum, and administration. We argue that digital transformation in core topic teaching must extend beyond instruction itself. To this end we are summarising our insights for practice into three clusters targeted at who the change or recommendation most impacts. These groups are teachers, study board members (or anyone developing curriculum), and administrators. These insights are collectively on two years of work in the projects described above. Importantly, these are not stand-alone recommendations. These recommendations build on one another. We hope this list will promote discussion among individuals in different roles about what and how—instruction, curriculum, and institutional practice—needs to change. We present the following holistic, overall insights based on our work over three years at UCPH. They are not based exclusively on what we learned from the specific projects described in this report, they are also informed by our collaborations, planning meetings, observations, emails, and numerous conversations. After each recommendation, in italics, we list the projects that best illustrated and supported that specific recommendation.

# Instructors and Teaching

Here we summarise insights related to instructional design, teaching, and teacher competence development in terms of two main themes: competence development and didactical demands. The topic of competence development identifies how teachers need to build new skills to effectively reach the goals for the university's digitalisation agenda. The topic of didactical demands present instruction-specific considerations.

## Competence Development

- Teaching novel topics outside of teachers' research expertise requires significant skill development. Gaining these skills can be best supported by giving instructors time, learning resources. Department and faculty should evaluate whether these supports require financial investment to succeed.

  *Anthropology; Digital Health and Data*

- Developing students' digital competencies works best when instructors have both digital literacy and teaching competencies. Initiatives that develop teachers' digital literacy do not necessarily promote successful student learning if the resulting content is taught with ineffective teaching methods.

  *C-Camp; Communication and IT*; *Digital Health and Data;*

- It is challenging for instructors to simultaneously develop skills in digital and instructional literacies. Since one cannot succeed without the other, both are essential. As such, professional development approaches should balance and align learning outcomes across various competence areas. Plans for teacher competence development need a strategic perspective that recognizes developing both digital literacies and other literacies (e.g., instructional design, assessment, activity-based instruction) as a part to the digitalisation agenda.

  *Digital Health and Data; Post-UP*

- Strategies for teacher competence development need an ecology including digital literacy, pedagogy, and research competence development. These three aspects do not need to be reflected in every initiative–but offering need to be connected and complimentary at the macro level (e.g., competence development offerings in a 4–6-year perspective).

  *Anthropology, Digital Health and Data, Post-UP*

- Professional development resources for teachers around digital literacy must be continually developed because it covers fields that develop and change quickly. One way to address this challenge is to empower teachers to follow self-directed learning. Training on specific tools and

methods are not sufficient on their own. A complementary and longer lasting approach to change deals with trainings in which teachers learn conceptual foundations of thinking and working with technology independent of specific platforms and technologies.

*Digital Health and Data; Law*

## Student Needs and Teaching Demands

- Student interest and self-guided learning are critical to students developing long-reaching competence in digital areas. Technical competence alone is insufficient.

  *C-Camp; Chemistry; Communication and IT*

- Instructional quality is essential to developing student digital literacy. As such, supporting pedagogical and didactical development among instructors is essential for ensuring high quality digital literacy training for students.

  *Digital Health and Data; Post-UP*

- Learning about digital topics is best done in hands-on, experimental, and active learning—not through one-direction instruction such in which the teacher only lectures.

  *C-Camp; Chemistry; Communication and IT; Digital Health and Data*

- Learning in digital topics, due to the fields quickly changing nature, is often messy and difficult to structure. For examples, teachers cannot create a lecture on ChatGPT and reuse it for several year, it will be outdated. There are teaching methods well suited to this type of fast changing content. These include problem-based, student centred and constructivist teaching practice which are already best practices in didactics from teaching support centres and university pedagogy courses at KU. Work that supports making these instructional practices dominant instructional practice at the university also supports digitalisation.

  *Chemistry; Post-UP*

- With myriad technologies and a quickly changing landscape, instructors can benefit from an organised curriculum for digital literacies relevant in their field. Without this guidance, course level changes are limited and do not build on prior learning for students.

  *Anthropology; Digital Health and Data*

- Rapid changes in responses to digitalisation means that structured curriculum focused on specific tools will be in constant danger of obsolescence. As such, curriculum aligned with general competence and not only content will support more flexible and responsive instruction.

  *Anthropology; Digital Health and Data; Post-UP*

- The new expectations for developing students' digital literacy shifts teachers' responsibility beyond technical skills into the realm of ethics, policy, law, and governance.

  *C-Camp; Digital Health and Data*

## Study Boards and Curriculum

Here we summarise the insights relevant for study board members or anyone designing curriculum. Curriculum is a structure that supports excellent teaching and sets high-level learning objectives. As such, without changing the broader framework of curriculum changes to instruction are not compressive. These recommendations do not change instruction or student learning directly but provide the scaffold that supports such changes.

- Core topic instruction that includes digital literacy instruction is inherently interdisciplinary.

  *C-Camp; Communication and IT; Digital Health and Data; Post-UP*

- Digital literacies are not equally important in all disciplines. Study boards are responsible for prioritising which aspects digital literacy are essential for their programs based on their discipline-specific expertise and a critical understanding of digital literacy.

  *Anthropology; Law*

- There are different ways to change or redesign curriculum. A modular approach involves adding individual classes or course units to existing curriculum. An integrated approach involves revising the existing course topics and learning activities by analysing the scope, sequence, and topics within the curriculum and making connections to digital topics. Early development can benefit from a modular approach, this results in small-scale impact and changes in student learning outcomes. But systematic change will ultimately depend on an integrated approach.

  *Anthropology; Chemistry; Communication and IT*

- Study boards proposing new topics to the curriculum should assess the capacity of instructors to teach these topics and provide resources and training opportunities as needed.

  *Digital Health and Data; Post-UP*

- Study leaders and study boards should review whether their departments have capacity to train students in digital topics. Solutions to increase capacity may include cross-department courses, hiring interdisciplinary professors, or providing professional development to current professors.

  *Communication and IT; Post-UP*

- Study boards can support teachers' integration of digital literacy into core topic teaching by assessing students' prior knowledge in digital literacy and sharing this knowledge with

teachers. This supports teachers aligning core topic instruction with their students' abilities and existing knowledge.

*Anthropology*

## Administrators

Initiatives for instruction often end by focusing on the two areas identified above: curriculum and instruction. However, through these projects we found that the structure of the university and digitalisation strategy were also critical to understanding the digitalisation of core topic teaching. So, although an institutional analysis was not the focus of this project, we have included some insights related to institutional structure and the administrators not directly involved with student learning.

- The university's technology infrastructure shapes the possibilities or limitations on professors' abilities to advance learning in digital topics.
  *Digital Health and Data; Law*

- Changing instruction requires the support from multiple domains in the university: collaboration between instructors, department leaders, upper administration, and student representatives. Without adequate support for instruction-level interventions that cross these different domains of the university, instructional changes are likely to be short lived.
  *Anthropology; Communication and IT; Post-UP*

- Leadership must provide adequate time and money to support professional development for instructors to develop high level competency in digital topics.
  *Digital Health and Data; Post-UP*

- Digital education for students and developing competencies among instructors involves many stakeholders in the university (learning centres, technology consultants, administrators, academic staff, student groups, libraries, and more). Creating channels sharing information and building collaborations is essential for work in multidisciplinary instructional topic such as digitalisation. Heads of departments, leaders should create such opportunities.
  *Anthropology; Digital Health and Data; Law*

# Concluding Remarks

In summary, we have identified specific recommendations for practice in terms of teaching, curriculum, and institutional structure through multiple design-based projects in various disciplines. Based on these insights, there remains questions for what the next step will be in terms of university priorities and goals. The digitalisation of core topic teaching is in no way done. In the short term, we are continuing dissemination work and training based on several of the projects described above in 2024. But long term, based on what we know about how to promote digital core topic teaching, there is a need for more comprehensive and collaborative projects across the university.

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# Selected Publications

*The following papers were produced in relation to the research conducted in Strand 2.*

Hagood, D. (2022). Deeper data literacy across the curriculum. Workshop at Society for Learning Analytics Annual Conference, LAK22.

Johnson, M. W., Maitland, E., Torday, J., & Fiedler, S. H. (2022). Reconceiving the Digital Network: From Cells to Selves. In *Bioinformational Philosophy and Postdigital Knowledge Ecologies* (pp. 39-58). Cham: Springer International Publishing.

Johnson, M., & Saleh, R. (2022). The guts of assessment: a digital architecture for machine learning and analogue judgement. *Interactive Learning Environments*, 1-15.

Johnson, M. W., Suvorova, E. A., & Karelina, A. A. (2022). Digitalization and Uncertainty in the University: Coherence and Collegiality Through a Metacurriculum. *Postdigital Science and Education*, *4*(3), 772-792.

Hagood, D. (2023). Coordinating a multidisciplinary course development project through design-based collaboration. In A.A. Andersen Arias & F. V. Christensen (Eds.), Improving University Science Teaching and Learning - Pedagogical Projects 2023 - Volume 18 (pp. 283-290). Improving University Science Teaching and Learning. https://www.ind.ku.dk/publikationer/up_projekter/improving-university-science-teaching-and-learning---pedagogical-projects-2023---volume-18/

Johnson, M. W. (2023). Postdigital Practical Axiology. In *Postdigital Research: Genealogies, Challenges, and Future Perspectives* (pp. 129-151). Cham: Springer Nature Switzerland.

Johnson, M. W., Alavi, K., & Holm-Janas, V. (2023). Communicative Musicality, Learning and Energy: A Holographic Analysis of Sound Online and in the Classroom. *Postdigital Science and Education*, *5*(2), 327-346.

Nøhr, L., Stenalt, M. H., & Hagood, D. (2023). University Teachers' Agency in Relation to Technology Use in Teaching: A Quantitative Investigation. *EDUTEC, Revista Electrónica de Tecnología Educativa*.

Stenalt, M. H., Johnson, M. W., & Aagaard, J. (2023). Reclaiming the teacher perspective in digital education–an analysis of university teachers' agency. *Interactive Learning Environments*, 1-13.

# Appendix

| Source | Definition of Digitalisation |
|---|---|
| **Defining and contextualising this phenomena** | |
| Astorp (2021) | In Denmark, the approach to digital technology in schools and teacher education has been driven by a focus on developing ICT **skills**, increasing **internet** and computer access in schools, being **competitive** as a nation and, finally, **integrating ICT into all subjects** |
| Gustafsson (2021) | "The digitalisation of schools" is used to describe both the enabling of digital **competence** for all. |
| Williamson et al. (2020) | The rendering of social and natural worlds in **machine-readable digital format**. |
| De Felice & Petrillo (2020) | Experiencing the ongoing digital revolution means being invested by an increasingly rapid and pervasive flow of induced changes from the adoption of **new tools** and digital **media**. |
| Khoza & Mpungose (2020) | A digitalised curriculum is a plan for and/or a plan of teaching, learning, and research, driven by specific **hardware**, **software**, and theories. |
| Babaheidari (2014) | "Digitalization of schools" by which we mean how to manage a school with a well-functioning Information and Communication Technology **(ICT) infrastructure**. |
| **Existing frameworks for digitalisation in eduation** | |
| Norway's Digitalisation Strategy for the Higher Education Sector 2017–2021 (2016) | Digitalisation refers to the use of technology to innovate, simplify, and improve. It is about offering new and better services that are easy to use, efficient, and reliable. |
| DIGICOMP, Ferrari (2013) | Digital Competence includes information, communication, content-creation, safety, and problem solving. |
| DigCompEdu, Redecker & Punie (2017) | Digital competence encompasses different aspects of educators' professional activities, including: professional engagement, digital resources, teaching and learning, assessment, empowering learners, and faciliting learners' digital competence. The latter is learners' use digital technologies for information, communication, content creation, wellbeing and problem-solving. |
| **Applications and influence from industry** | |
| Sezer et al (2021) | The digitalization index developed in this paper requires an assessment of the degree of digitalization [in construction] through four activities: (1) visualization and 3D modeling on sites, (2) updating drawings, models, and system documents, (3) creating and updating work disposition plans, and (4) updating time and resource plans |

| | |
|---|---|
| Taylor (2017) | The reordering of the world, people and things, is driving the need for more digitally equipped professionals. As a consequence, it is time for digital literacy in social work to move beyond the skills to send an email or update computer based records, to more complex tasks that require an intricate and nuanced understanding of technologies and the connected world. |
| Fathulla (2018) | Digitalisation is the application of digital tools and technologies in all their forms to the value chains of businesses who make things (e.g. automotive and construction) or are operationally asset intensive (e.g. power grids, wind farms etc.). It is the merging between the physical and digital worlds to significantly enhance performance and productivity. |
| Valenduc & Vendramin (2017) | Current changes are rooted in a set of technological, economic and social trends that emerged during the two last decades of the 20th century [this places] the current wave of digitalisation in the perspective of long waves of economic evolution and changes in techno-economic paradigms. |
| Ng et al. (2018) | The digital transformation is a profound transformation of business model, organizational processes, and capabilities enabled by the application of digital technologies, as well as the impacts on all aspects of human society. On the other hand, the scope of "digitalization" is much smaller – it is the use of digital technologies by a company to change its business model and move towards a digital business. |
| **Implications and concerns** | |
| Atenas et al. (2020) | Participation in democracy, in today's digital and datafied society, requires the development of a series of transversal skills, which should be fostered in higher education (HE) through critically oriented pedagogies that interweave technical data skills and practices together with information and media literacies. |
| Holmwood & Servós (2019) | The implications of digitalisation for the internal organisation of universities are more extensive [and are a] real problem facing traditional universities and their modes of traditional autonomy. |
| Bayne & Gallagher (2021) | A problematic future for teaching is in the process of becoming normalised in universities, one driven by the anticipatory logics of technocorporations, the ideologies of marketisation determined by government policy. |