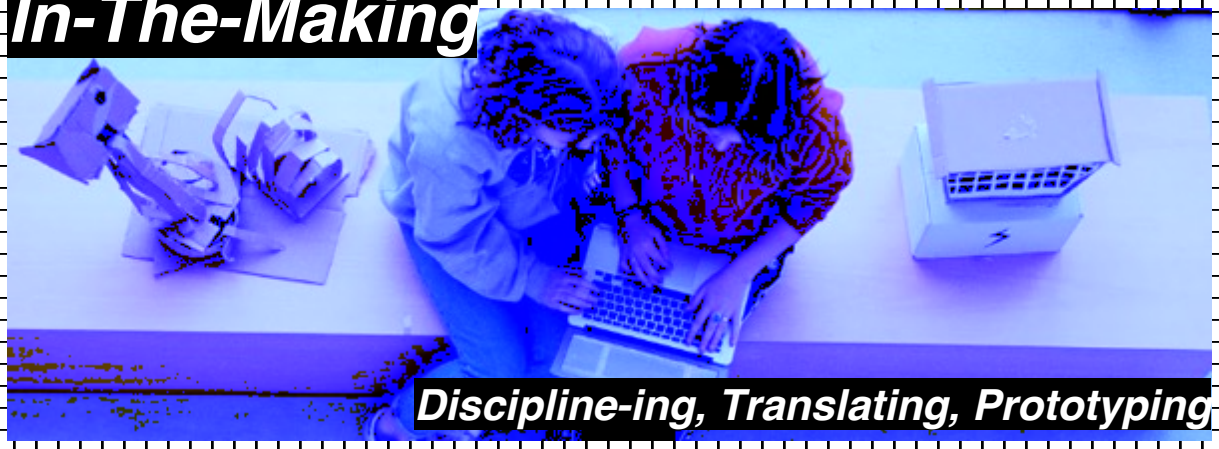
Technology Comprehension In-The-Making



Discipline-ing, Translating, Prototyping

Simy Kaur Gahoonia
IT University of Copenhagen

Technology Comprehension In-The-Making: Discipline-ing, Translating, Prototyping

A dissertation submitted in compliance with the requirements
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Simy Kaur Gahoonia
sgah@itu.dk
Technologies in Practice, Department of Business IT
IT University of Copenhagen
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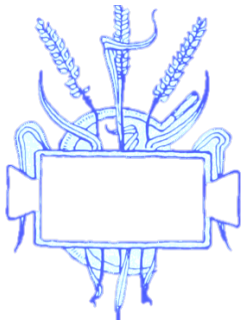
Supervisors
Christopher Gad, IT University of Copenhagen
Marisa Leavitt Cohn, IT University of Copenhagen



Committee
Irina Papazu, IT University of Copenhagen
Cathrine Hasse, Danish School of Education/Aarhus University
Nelli Piattoeva, Tampere University

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Abstract

This dissertation in Science and Technology Studies (STS) examines technology education and knowledge production in public schooling and the postdigital society. It centres on the Danish Ministry of (Children and) Education's trial of technology comprehension (2018-2021): In the pursuit of making young people makers, not only users, of technology, and cultivating active participants in a digital democracy, the trial programme was launched to define, develop, trial, and evaluate a new, potentially mandatory, subject called 'technology comprehension' (*teknologiforståelse*) for the public school. This effort was both historical and politically consequential, as it offered scale to particular understandings of what constituted technologically educated civic subjects and digital citizens.

Driven by a concern for the politics of how technology education is assembled ('critical Tech-Ed'), STS, ethnographic methods, and critical reading strategies are used to examine the relations of heterogenous actors in the experiment with technology comprehension. In particular by engaging the work of researchers, experts, teachers, and consultants. As well as the effects of these relations on lived worlds. In doing so, the thesis aims to understand what comes to be understood as affording technology comprehension and how; as well as what forms of knowing are negotiated and handled in the making of technology comprehension. The dissertation's three papers conceptualise knowledge-making in the trial of technology comprehension as work of 'discipline-ing', translating, and prototyping.

Discipline-ing is explored as an effect of the contents of the subject proposal for technology comprehension. The proposal renders the world as digital building blocks that can be handled by the technologically educated person that technology comprehension subject matter cultivates. A technologically deterministic view dominates and limits how change and agency can be imagined. Translating is explored as the work of integrating design practice into technology comprehension learning, teaching, and subject matter development, due to the promise it is said to hold for ensuring the

democratic and creative-constructive ideals of the public school. Translations of actors generates epistemic cultures, disciplinary canons, and perspectives on what constitutes good formative education. In particular those that are enacted as a boundary between 'theory' and 'practice'. Prototyping is explored through the proliferation of a prototyping culture, as pupils as well as teachers and subject matter developers are engaging in prototyping and with prototypes. The capacity of prototyping is the handling of disparate social worlds, e.g. of epistemic uncertainty and of a 'theory-practice divide'.

The empirical-analytical work in this thesis brings into view the relationality of knowledge-making of the trial programme. The thesis also argues that it is necessary and possible to imagine alternative relations with digital technology than those that reproduce a digital reality; It argues for engaging, with STS, the affordances of a theory-practice divide in the public school to develop technology comprehension; And it argues that the trial programme puts not only technology comprehension to the test in terms of its future as a school subject, but also tests the social fabric of postdigital Denmark, as it makes actors articulate their alliances to certain knowledges and methods. Relations that STS and critical Tech-Ed studies should engage and intervene in to make just, sustainable, and accountable educational and civic futures. These findings on technology comprehension in-the-making may be used to further understand the public school in the postdigital society.

Dansk resumé

Denne afhandling i Science and Technology Studies (STS) undersøger teknologiuddannelse og vidensproduktion i folkeskolen og det postdigitale samfund. Omdrejningspunktet er Børne- og Undervisningsministeriets forsøg med teknologiforståelse (2018-2021). Forsøget blev igangsat for at gøre børn til skabere og ikke blot brugere af teknologi, samt for at danne deltagere i et digitalt demokrati, ved at beskrive, udvikle, afprøve og evaluere et nyt muligt obligatorisk fag kaldet teknologiforståelse til folkeskolen. Denne indsats var både historisk og politisk betydningsfuld, eftersom den muliggjorde skaleringen af bestemte opfattelser af hvem der er teknologisk dannede politiske subjekter og digitale borgere.

Afhandlingen er drevet af en interesse for de politiske aspekter af teknologiuddannelse (kritisk 'Tech-Ed'), og benytter sig af STS, etnografiske metoder og kritiske læsestrategier i en undersøgelse af heterogene aktørers relationer i forsøget med teknologiforståelse, med udgangspunkt i forskere, fageksperter, lærere og konsulenters arbejde. Samt implikationerne af disse relationer for de verdener vi begiver os i. Således sætter afhandlingen sig for at opnå en forståelse af hvad der bliver set som værende teknologiforstående, og hvordan, samt hvilke former for vidanspraksis der forhandles og håndteres i udviklingen af teknologiforståelse. Afhandlingens tre artikler konceptualiserer vidensproduktion som arbejde med 'disciplin-ering', translation og prototyping.

Disciplin-ering undersøges som en effekt af teknologiforståelses fagbeskrivelse. Beskrivelsen gengiver verden som digitale byggeklodser der kan håndteres af det teknologisk uddannede subjekt-individ som teknologiforståelse danner. Her dominerer et teknologisk deterministisk perspektiv dominerer, som afgrænser hvorledes forandring og agens kan forestilles. Translation undersøges som arbejdet med at integrere designpraksis i teknologiforståelsesundervisning og -fagudvikling, grundet det potentiale den siges at have i forbindelse med folkeskolens demokratiske og kreativ-konstruktive idealer. Aktørers translationer genererer epistemiske kulturer, disciplinære kanon og perspektiver på hvad der opfattes som god dannende

uddannelse. Særligt de perspektiver der gengives som en grænse mellem 'teori' og 'praksis'. Prototyping undersøges som udbredelsen af en prototyping-kultur, idet elever såvel som lærere og fagudviklere tog del i prototyping og håndterede prototyper. Prototypingpraksissens kapacitet består i dens håndtering af forskelligartede sociale verdener, fx epistemisk uvished eller en 'teori-praksis'-grænse.

Det empirisk-analytiske arbejde i denne afhandling fremlægger relationaliteten i forsøgsprogrammets vidensproduktion. Afhandlingen argumenterer for nødvendigheden af og muligheden for alternative forestillinger om relationen til digitale teknologier, end de der reproducerer en digital realitet. Endvidere argumenterer afhandlingen for at imødegå 'teori-praksis'-grænsens affordances med STS i den fortsatte udvikling teknologiforståelse. Og afhandlingen fremsætter det argument at forsøgsprogrammet ikke blot afprøvede teknologiforståelse i forhold til fagets fremtid i folkeskolen, men at forsøgsprogrammet afprøvede selve den sociale opbygning af det postdigitale Danmark, idet forsøgsprogrammet tilskyndede aktører at artikulere deres alliancer med bestemte videnstyper og metoder. Disse relationer bør STS-studier og kritisk Tech-Ed-studier involvere sig i med det formål at skabe retfærdige, bæredygtige og ansvarlige uddannelses- og samfundsfremtider.

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theirs. A very special thanks to Pedro Ferreira for his enduring wisdom, guidance, and company; and to Stefania Santagati for her intellect and sisterhood; two of the smartest and silliest people I know, and who I am lucky to call my friends. To my loving parents and brother for always being a safe harbour. To my *'film'å'medie'* besties, who unironically—slightly obnoxiously—but always lovingly call ourselves CHICKZ: Amanda, Anne, Camilla, Karen Kristianna, Louise, Malene, Silja, Stine, and Thea. All of whom I appreciate and admire greatly.

Finally, I dedicate this thesis to the memory of my—our—friend Karen Munk Ebbesen (19 August 1991 – 11 July 2023); gone too soon, but also never gone.

Overview of research papers

This dissertation contains three research papers.

Gahoonia, S. K. (**forthcoming**). Matters of Subjects: The Digital Citizen in Technology Comprehension. In Kjær, K. M. & J. Perriam (Eds.), *Digital States in Practice*. DeGruyter.

Gahoonia, S. K. (**2023**). Makers, Not Users: Inscriptions of Design in the Development of Postdigital Technology Education. *Postdigital Science and Education*. https://doi.org/10.1007/s42438-023-00431-7

Gahoonia, S. K., & Gad, C. (**accepted with revisions**). Prototypes all the way down: Prototyping in the teaching and development of Technology Comprehension. *STS Encounters*.

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Part 1: ‘Kappa’

1. Introduction

This is a dissertation about technology education and knowledge production in public schooling. In the following pages, I critically and empirically explore knowledge production in the context of the Danish Ministry of Education's[1] (the Ministry) 4-year experimental programme to develop 'technology comprehension' (*teknologiforståelse*) as a new school subject for the public primary and lower secondary school, *folkeskolen* (hereafter 'the public school').

I adopt an analytical and methodological approach inspired by Science and Technology Studies (STS), an interdisciplinary field that critically examines the relationship between science, technology, and society (Sismondo, 2010; Danholt & Gad, 2021). STS is especially suited to study the situated practices of knowledge production. Scholars interested in researching education are championing the use of STS to research and intervene in educational phenomena in their societal contexts (Gorur et al., 2019; Fenwick & Edwards, 2010; 2012; 2019), stating that STS is "above all a sociology of knowledge processes," thereby "touching the very core of education" (Gorur et al., 2019, p. 7). Using approaches from the diverse field of STS, I attend to how people, things, and ideas came together—in this case—to establish a potentially mandatory school subject about technology that was congruent with the public school's role in preparing society's youngest for a civic and digital future.

My motivation to analyse the development of technology comprehension in terms of knowledge production is best articulated by one of STS' most famed scholars, Donna Haraway. In her signature coiling style, Haraway remarks that: "It matters what thoughts think thoughts. It matters what knowledges know knowledges. It matters what relations relate relations. It matters what worlds world worlds. It matters what stories tell stories." (2016, p. 35). In my understanding, it matters which things make relations, and which relations make things. This concern with knowledge is usually referred to as a concern

[1] The Ministry's name was changed to Ministry of Children and Education in 2019.

with politics—politics understood as "matters of encounter, ordering and distribution" (Suchman, 2016 in Gorur et al., 2019, p. 7). As I will argue and demonstrate in this dissertation, such matters and politics were very much at stake in the trial of technology comprehension.

1.1. Putting technology comprehension on the school schedule

From 2018 through 2021, policymakers, subject matter experts, educators, consultants, and researchers convened in what was called *The Trial Programme for Strengthened Technology Comprehension in Mandatory Public-School Teaching* (hereafter 'the trial programme' or 'the trial of technology comprehension) to conceptualise, test, and evaluate a proposed technology comprehension subject as a possible addition to statutory schooling.

Early in the process, technology comprehension was conceived and presented as a "generally formative, creative, and constructive"[2] subject (UVM, 2018a)[3]. In the words of the then Minister of Education, Merete Riisager, through "an understanding of technology's building blocks", children should "become creators of technology—instead of just users of it" (UVM & STIL, 2018, p. 2)[4]. This was a sentiment echoed by many actors with a stake in the public school, who often referenced both international developments and national civic concerns: A number of school systems in countries that Denmark compares itself to had already realised various forms of statutory technology education that treated 'digital competence' as more than just digital skills (see Bocconi et al., 2016; Bocconi et al., 2018; Bocconi et al., 2022). By introducing technology comprehension, the Danish public school was to cultivate creative,

[2] A vast majority of the empirical material I have collected is in Danish. All translations into English are done by me, unless otherwise stated.
[3] I have made the choice to cite the Ministry's documents as authored by 'UVM' both in-text and in the reference list. This is both to save space, but also due to the fact that the Ministry was renamed during the period of the trial programme, but their website URL remains 'UVM.dk'.
[4] This echoes Alvin Toffler's conept of 'prosumers' (1980), which combines the word consumer and producer to signal the blurring of the lines between these roles.

critical, and constructive relationships between schoolchildren and new technologies, instead of just supporting consumptive and instrumental uses of technology (UVM & STIL, 2018; UVM & STIL, 2019). Many actors in the Danish school landscape had come to share the belief that to realise the goal of young people becoming creators of and participants in the digital society, rather than just consumers in it, the public school needed technology comprehension as a new mandatory school subject, which in turn also required new teaching, learning, and organisational arrangements.

IMAGE 1: Featured image for the news item about technology comprehension on the Ministry's website. Source: UVM.dk.

The trial of technology comprehension launched with the stated goal of gathering up knowledge about and experience with technology comprehension from previous research efforts and practices; testing different models for how it could become integrated into the public school; and generally, to inform political decision-making about whether and how technology comprehension could become a part of the public school. Over the course of the programme's four years, extensive teaching, research, and consulting took place, including a 'live' trial of the subject in 46 schools from February of 2019 until summer of 2021. During this time, there was experimentation with organisational forms, learning materials, teaching styles, educational technologies, and new pedagogies.

The school trials were evaluated, and the insights were reported in October of 2021. The evaluation report noted that pupils and teachers responded positively to teaching and learning technology comprehension, while at the same time, teachers found it very challenging to teach (UVM, 2021). Despite a positive outlook on technology comprehension's potential, the report remained largely inconclusive and open-ended. As for a political verdict, in April 2022, decision-makers stated that there were 'no plans' to pursue development of technology comprehension under the auspices of the Ministry (Marthinsen, 2022; Wittorf, 2022). As of writing this, it therefore remains an open question whether technology comprehension will become a fixture of the public school as school subject or not[5]. However, as astonishing as this 'non-decision' on technology comprehension was to school actors who had propelled, participated in and/or observed the trial programme, it was arguably just as remarkable that the trial took place at all: Introducing a new school subject to the public school is not a common occurrence. In fact, it has been more than 20 years since a new school subject was introduced[6].

At the time of the trial programme's launch, digital technologies were not new to the public school's practices, but they had played a largely supportive role. Practically, technically, and pedagogically. When the trial started many Danish classrooms were already equipped with smartboards and wi-fi routers. Teachers used digital learning portals, pupils had access to Chromebooks, and school staff organised, partly, on platforms and in 'the cloud'. This infrastructure had been built throughout the 2010s. However, 'on the back' of these 'procurement years' (Caeli & Bundsgaard, 2019), pedagogical concerns about digital technologies in schools and schooling grew: practitioners and researchers problematised the state of affairs in the technology-saturated school, noting that technologies were not by default educational (Balslev, 2018; Bundsgaard et al., 2018), and often classrooms were 'experimentariums' for

[5] On 11 October 2023, Ministry announced plans to integrate technology comprehension subject matter into other subjects, and to introduce the subject as an elective for older pupils in the public school.
[6] *Natur/teknik*, a subject mixing natural science and engineering topics, methods, and experiments.

new technology (Riis, 2012), to the detriment of the educational and formative purpose of the public school.

As educational content in the curriculum, technology had certainly been an important topic. But only across the subjects and thematically, and simply never at the scale and importance of a technology comprehension subject in its own right. What was new with technology comprehension and the trial programme was the elevation technology education and such content to be mandatory and elementary. The proposition about technology education in the trial programme was that technology comprehension should and could be a matter of formative education and thus deserving of being a major subject on par with e.g., Danish and Mathematics. Meaning it could be a subject with its own disciplinary practice, governing principles, learning objectives, and social function—a school subject grounded in the storied institution, intellectual traditions, and *menneskesyn*[7] of the Danish public school.

For proponents of a technology comprehension school subject, it was simply high time the public school led the way of Danish technology education, formalising it and making it the purview of the public school. By the end of the 2010s, these concerns coalesced to become state responsibility and ministerial priorities with the trial of technology comprehension. The launch of the trial programme was decisive political action to put technology comprehension on the school schedule to prepare young minds and hands for the future.

1.2. Critical 'TechEd': Studies in the development of postdigital technology education

What I have described here is a political intervention into schooling that is driven by an increased awareness, among people and social groups of all kinds, that digitalisation impacts lives and society in ways that are changing and highly complex. In research, digital technologies in schools and schooling are the

[7] A rough translation: View of humanity and human nature.

interest of a rapidly growing critical research agenda that is committed to examining the complexities and politics of technology and education (Selwyn, 2010; 2011; 2013; Selwyn & Facer, 2013). A number of these studies use STS and related approaches such as praxeology, political economy, and poststructural analysis. In a time when educational futures seem to be inextricable from digital futures, these studies examine e.g., the orthodoxies of 'good' 21st century school education in government policies (Facer, 2011; Macgilchrist, 2019; Macgilchrist et al., 2020), the changing landscape of actors that participate in school digitalisation, and the 'policy mobilities' that assemble the digital transformation of schools and schooling (Williamson, 2016; Williamson et al., 2019).

Critical 'Ed-Tech'

Critical 'Ed-Tech' (Selwyn et al., 2020; Macgilchrist et al., 2021; Williamson, 2021) is a strand of research that is characterised by making the 'educational technology' or digital education infrastructure the object of analysis, problematising its social and material agencies to open it up to normative critique. This is an important research agenda because of how, time and time again, educational decision-makers take or encourage action to redeem a transitory, yet persistent promise of 'educational value' that these new technologies and systems are said to deliver; a view which, at best, exhibits a technologically deterministic view (Oliver, 2011) that lacks concern for the fact that educational technology is not in itself educational. At worst, it exacerbates existing inequalities and marginalisation of vulnerable persons or communities that the school ought to empower.

Critical Ed-Tech studies, then, has looked at how new technologies and technological practices reconfigure schools and schooling, its responsibilities and roles, histories, and visions. Examples of sociotechnical issues of interest for critical EdTech include data and algorithms in national and transnational education governance schemes (Williamson, 2015; Landri, 2018; Høvsgaard-Maguire, 2019), which engender new accountabilities—peoplings (Ratner, 2020a) that carve populations by the logics of large-scale assessment schemes and commensuration. A related issue is the platformisation and marketisation

of teaching and learning, a development that changes the conditions of knowledge exchange in the teaching profession (Cone, 2022). E.g., when analysing data visualisations reconfigures 'the teacher as data user' (Ratner et al., 2019). Other studies tackle how the idea of the teacher is reimagined through neologisms like 'edupreneurs' (Ideland, 2021; Ideland et al., 2021), and their agency ordered by the policy assemblages of education trade fairs (Player-Koro et al., 2018). The increased visibility and participation of private actors in schooling also shapes the understandings, expectations, and possibilities of learners—the pupils (Cone, 2021).

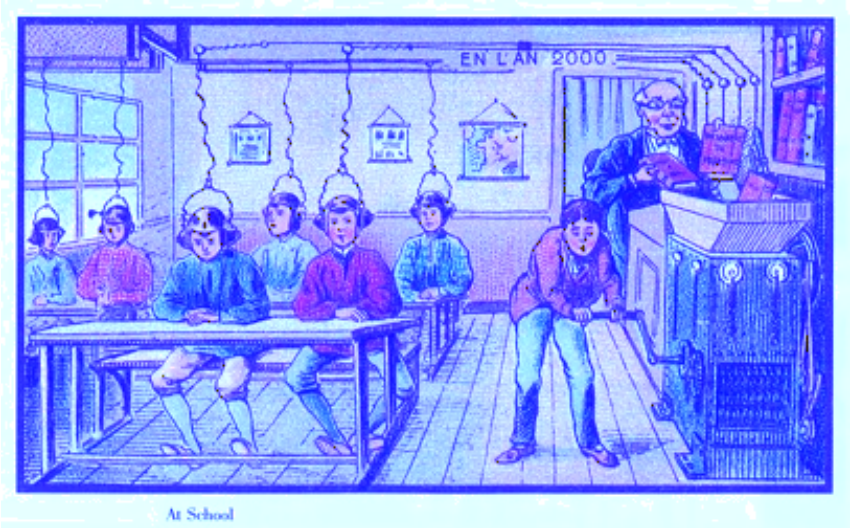


IMAGE 2: The school in the year 2000, as imagined by Jean Marc Cote, 1901. It shows the operation of an apparatus that feeds books—educational content—to pupils. Source: WikiMedia Commons.

Such studies (which are, of course, only a fraction critical Ed-Tech's output) do important work by probing the black boxes of 'shiny' new educational technology and digital education infrastructure. This literature is an essential conversation partner of my thesis, because, on the one hand, I join them in staying with the trouble of digitalisation of schools and schooling. However, in this thesis I do so by following an interest in what is, in turn, casually called 'Tech-Ed' (see Hansbøl, 2019; Erstad et al., 2021; Sehested, 2021).

Schooling in the postdigital condition

School subjects, curricula, and schooling overall function as a 'technology' of government conduct (Rose & Miller, 2010) and nation-state-building (Englund, 2012, 2018). Curricula problematise the future to organise the present

(Popkewitz, 2015). The existence of particular school subjects, arguably, indicate what is deemed to be important by influential actors in their societal context. E.g., Danish and *samfundsfag* (social science) are important to the Danish democratic nation state that 'sees' and governs citizens (Scott, 1998), and also as lifelong learners. As it is no small matter what is on the school schedule, a critical tech-ed study is interested in examining how education in technology is assembled.

The notion of change also plays a significant role in the social formation of schooling (Popkewitz, 1988). In schooling discourse, pressing exogenous societal change is seemingly always around the corner and futures perpetually at stake. As such, "discourse about reform directs attention to schools as responding to people's most cherished beliefs about developing a good society" (p. 77). When talking about schooling's societal role, ideological critique points to the normativities and 'hidden curriculum' of school subjects and their pedagogies (see Giroux, 1991; Freire, 1970/2017**;** hooks, 1994). In a study of Swedish 'school digitalization curriculum reforms', Rensfeldt and Player-Koro (2020) adopt sociotechnical imaginaries (Jasanoff & Kim, 2015) and demonstrate exactly the discursive and material 'reach' school education has into the past and the future. They argue that "digitalization curricula, covering both discourse and materiality, is one of the most powerful arenas for translations and uptakes of socio-technical imaginaries, and as such, they need to be critically examined" (p. 4). A statement I agree with, based on my research in this thesis.

Throughout the past two decades, it has become an expectation that the school's educational content is shaped by "the problems technology poses, with the potential it promises, and with the models of social and political order it seems to make available" (Barry, 2001, p. 2). This approach, however, is increasingly confronted with a growing, though still measured, scepticism of the capacity of technology to fix society's social, economic, and ecological problems—a state of affairs Macgilchrist et al. (2023) term the 'postdigital'. The trial of technology comprehension was imagined as an intervention into some of the sociotechnical complexities emerging from digital transformation. Put a bit polemically: as a technology education for the 'after of digitalisation',

technology comprehension was ostensibly imagined as an educational fix to seemingly technological predicaments.

Though it does not usually involve the suggestion of new school subjects, the public school is routinely a site of government intervention to attend to societal issues, including contemporary challenges of digitalisation (see e.g., Bundsgaard et al., 2018). Additionally, it is the explicit concern of the public school and its key governing actors (the Parliament, Government, Ministry, and sub-ministerial agencies) to conduct an educative process for children to become civic subjects by cultivating their capacity (skills, knowledge, and disposition) to navigate, act, and participate actively in wider society. Other actors and interest groups who are parties to the public school include, but are not limited to, the Danish Union of Teachers, *Skole og Forældre*[8], and Local Government Denmark. In the case of technology comprehension such active citizenship was imagined as the capacity to 'produce' and not just 'consume' a digital reality. This lends credibility to—and anticipation of—the decidedly political act of launching school change to cultivate the citizen-subject as technologically educated beyond being a technology user.

Towards a critical 'Tech-Ed'

Before the actual trial programme, technology comprehension had already been emerging as a subject area. But during the time it was trialled as a school subject, the debate about technology comprehension naturally expanded and intensified, both 'within' the trial programme's planned pedagogical research and development work, but also in school and teacher education research.

However, by and by far, the sociocultural practice of making curriculum and school subject knowledge in digital societies is still understudied (Williamson, 2013; Erstad et al, 2021; see also Hansbøl, 2019). Empirical studies are needed alongside ideological critique of policies and curricula, alongside critical Ed-Tech, and alongside conceptual innovation on new literacies (see

[8] *Skole og Forældre* (Schools and Parents) is a national organisation school boards and parents of children in the public school.

Pangrazio, 2016; Pangrazio & Sefton-Green, 2020, 2021; Potter, 2017). Catrine Hasse and Jesper Balslev articulate the risks of uncritical Tech-Ed introduction, cautioning against technology education—technology comprehension—becoming a 'trojan horse' for problematic educational technologies (Hasse & Balslev, 2021), citing many of the issues critical Ed-Tech has explored.

Ben Williamson's *The future of the curriculum: school knowledge in the digital age* (2013) is based on a study of curricula in-the-making, of what he terms 'curriculum prototypes'. Christo Sims' (2017) *Disruptive fixation: school reform and the pitfalls of techno-idealism* is based on a large empirical praxeological look into school development in a digital age. These studies address the sociomaterial assemblage that curricular texts emerge in. They are exemplary in their subject matter. However, they are also rooted in an Anglo-American context and way of problematising curriculum, learners, and narratives about school education of the digital age. Sims' study is on a public school being located in New York, the U.S. Because school subjects and curricula emerge as democratic and nation-state resources, studies that are more sensitive to the local or regional context of postdigital school interventions are needed.

Specifically, the ways in which schooling traditions and practices are more-than universal and how globalisation-dependent digital and postdigital development create different kinds of universalisms unfolding within school environments. The research in this thesis is about the trial of technology comprehension. But it is also about nation-building, Danish and Scandinavian computing and design traditions, German-Scandinavian education philosophies, and positioning in a global education landscape that increasingly governs through transnational commensuration. The stakes of this critical study of how knowledge is assembled in the Danish trial of technology comprehension are multiple.

1.3. Statement of purpose: How it matters what knowledges make knowledge

In discussions about technology comprehension's potential as a mandatory school subject, decision-makers, proponents, and critical observers gestured at the importance and power of formal school knowledge to nourish young minds and future democratic society. One of the central issues the trial programme was supposed to help was *what knowledge, then*, would be appropriate to make obligatory, incl. the constitution of its component parts, what the outcome of such education should be, and how to go about forming it as school subject.

A particular sense of urgency was at play when the programme launched—'hurrying slowly'—which implied exercising an experimental, explorative, and evidence-based approach to developing a technology comprehension school subject. Because while introducing technology education was pressing, it also required time, resources, and commitment from a variety of the public school's stakeholders. E.g., according to pronouncements by political decision-makers and subject matter experts, doing this pedagogical development work 'close to practice' (*praksisnært*) was crucial. Teachers and their everyday contexts of practice had to be involved and activated in the trial programme. Certainly, stakeholders acknowledged the fact that political mandate alone could not settle this particular matter of school development. Politicians could only set its terms of reference and base criteria—and then mobilise research consortia, subject matter experts, school practitioners, municipal authorities, ministerial agencies, special consultants, and project directors to organise and carry out this large-scale collaborative effort in knowledge-making. So was the ethos of the trial programme throughout its runtime and in all its complexity: to hurry slowly.

As I have mentioned, phenomena of the kind I have described in the preceding paragraphs are one of the core interests of the interdisciplinary field of STS, from which I write this dissertation, and to which I make my academic contribution. STS attends to the relations between science, technology, and society (Sismondo, 2010; Danholt & Gad, 2021), and notably, STS takes a keen interest in the 'how' of knowledge production of all kinds and beings. That is: in STS it is just as (if not more) interesting and politically salient *how* science, technology, and society is done, rather than *whether* it is successful or not. STS also cogently addresses the crux of educational phenomena by bringing into

view what Gorur et al. call “an understanding of knowledge as socially constructed, as a matter of not only creating the knowledge itself, but also constructing and ordering the world in which that knowledge can hold as valid and true” (2019, p. 7). An understanding where the social consists of heterogenous actors and actions.

In this dissertation, then, I follow recent calls to mobilise STS and its ontological, analytical, and empirical commitments (see Gorur et al., 2019; Fenwick & Edwards, 2010; 2012; 2019) to “address big questions in educational research, and offer forms of ethical and political interventions that do not appear in familiar registers” (Fenwick & Edwards, 2019, p. 15). I will address public education about technology through investigation of *the world-making agencies of the very methods and knowledges underpinning and engendered in the trial of technology comprehension as a political and pedagogical research and development effort*.

The public school is a technology of government as it is positioned to cultivate technologically educated citizen through its subjects, pedagogies, and sociocultural exchange with Danish society. The trial programme amplifies and gives scale to select comprehensions of technology, epistemic practices, and forms of citizenhood—to selective realities. Those legitimised orderings make inclusions and exclusions of certain forms of thinking about digital technology, delimiting the potential for individuals, collectives, the empowered and the marginalised, to imagine the societal order otherwise. Therefore, technology comprehension ‘in-the-making’ was and remains a public, normative, and political concern.

The trial programme was a motley of experience-gathering and knowledge-making, driven by a vast and diverse landscape of practitioners and professionals, subject matter experts, opinion-havers, and observers, who were assuredly *knowledgeable* and competent arbiters of ‘school knowledge’ and practice. Their task in the trial programme was in part to bring together, try out, and settle *forms of knowledges*—theoretical, practical, conceptual, experiential, embodied—to make *a* knowledge (a school subject). All, seemingly, with the future of democratic society at stake. These forms of knowledge provide an interesting array for research on digitalised and postdigital education—the

methods, concepts, and tools that assemble (or do not) to become seen as affording *technology comprehension*—for learners and teachers alike. What becomes sanctioned, protected, problematic, or discarded? In this thesis, I offer an examination of what it means to be technology-comprehending, and how this is performed and stabilised.

IMAGE 3: My name on the whiteboard, written by a teacher, who introduced me to the 4th grade she was teaching technology comprehension to. Photo by the author, 2020.

In the following pages I will contextualise, conceptualise, and analyse the trial of technology comprehension as processes of knowledge-making. Of assembling forms of knowledge and modes of knowing. I engage material, social, discursive, and technical practices of subject matter experts, educational researchers, schoolteachers, and learning consultants, and policy advisors. The work of assembling human and non-human actors and their relations in the trial of technology comprehension constitute the object of study. The research object is engaged ethnographically, incl. field observations of school practice and research environments, trade fairs, and inspirational and informational events. With accounts of knowledge-making, I set out to account for the complexities of the trial of technology comprehension as they pertain to knowledge formation.

1.4. Contribution, contents, and formalities

One way to present the contributions of my thesis are the conversations and calls that my research papers respond to: The papers are published, accepted to, or forthcoming in venues that seek to 1) intervene in public sector digitalisation governance; 2) intervene interdisciplinarily in making educational futures of technology education in postdigital society; 3) grow the understanding of science, technology, and society. The dissertation as a whole straddles the aims and scopes of these themes, fields, and publications.

With STS as the conceptual, empirical, and analytical framework to contribute knowledge about, in particular: 1) The 'comprehensions of technology' that won favour in the trial programme, and their implications; and 2) the relations of forms of knowledge in the development of technology comprehension. I also aim to contribute to the ongoing development of technology education for the Danish public school with accounts of knowledge-making practice, offering a critical eye to the philosophies of technology that are inscribed into technology comprehension. Finally, I aim to develop the research agenda that treats the formatting of education and technology into assemblages, Critical Tech-Ed, with STS and a material-semiotic vocabulary. I argue that research and policy in the digitalisation and education space should not only interrogate the affordances and politics of machines and educational technologies, but also the politics of the methods and the human deliberation and expert discretion at use in the knowledge practices and development infrastructures we trust to make good educational futures. This is needed to better understand the public school as a resource of the postdigital society.

This is an article-based thesis. You are currently reading part one of the dissertation, which is the synopsis (*kappa*) of my research. Part two consists of manuscripts of the thesis' three papers. The pages that follow this introductory section are structured like so: Chapter 2 provides background about Denmark and the public school. In chapter 3, I describe the trial programme's contents and I scope and define it as the dissertation's research object. I then introduce my theoretical orientation of STS in chapter 4, and my methodology in chapter 5. Chapter 6 is dedicated to summarising findings and themes that emerged through my empirical-analytical work; the chapter is structured in terms of processes related to knowledge-making in the trial and are signposted in the

subtitles of the dissertation: ‘Discipline-ing’, ‘Translating’, ‘Prototyping’. These rubrics also correspond to the dissertation’s three research papers. In Chapter 7 I discuss the themes and develop them as insights of the thesis overall. In chapter 8 I conclude the thesis and elaborate on steps for future research.

2. Digital Denmark and the public school

The context in which the trial of technology comprehension was launched was a highly digitized Denmark. A country whose public-school efforts are centred around cultivating the citizen-subjects of a Danish democracy. A national context where the public school system is deeply rooted in social democratic ideals and German-Scandinavian education philosophies and intellectual traditions.

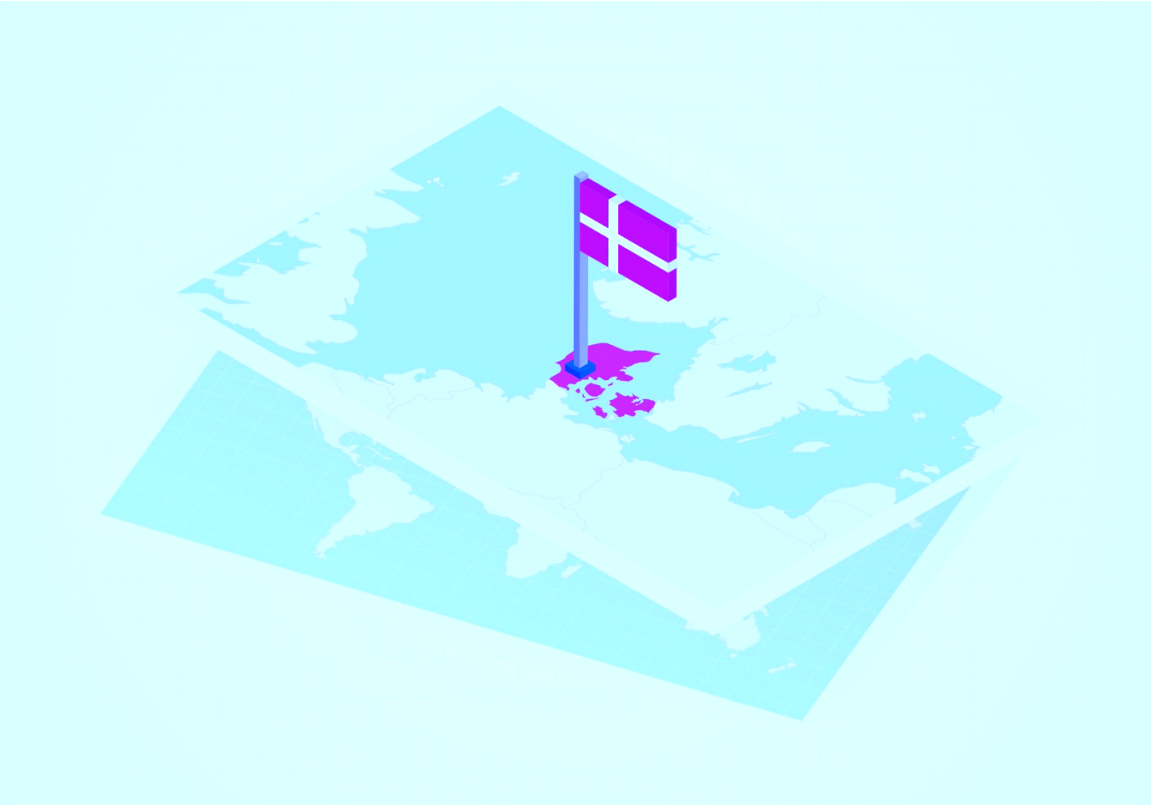


IMAGE 4: Vector graphic of Denmark on a map. Source: Colourbox.

3.1. (Post)Digital Denmark: Welfare after digitalisation

Denmark is located north of Germany and south of the Scandinavian peninsula and populated by about. 5.9 million people. Like its Nordic neighbours, Denmark is largely defined as a social democratic state (Navarro et al., 2004

Christiansen & Petersen, 2001) with a parliamentary democratic form of government (often made up of coalitions between political parties). A major concept in Danish society, civic relations, and self-image is that of 'the welfare state', making it a kind of 'meta-ideology' (p. 26) in parliamentary politics and among Danes. The welfare state, understood as "a social, culturally specific and long-term process of transformation" (Langer & Højlund, 2011, p. 1), is "a self-evident frame of everyday life", the overall legitimacy not many citizens nor politicians would dispute (Bruun et al., 2015). As such, welfare and the welfare state are thoroughly caught up in contemporary efforts to make digital democratic futures. Denmark is a member of the European Union (EU) and participant in global economic and development schemes like the OECD and the SDG. Regarding education, Denmark partakes in a slew of international assessments like The Programme for International Student Assessment (PISA), International Computer and Information Literacy Study (ICILS), Trends in International Mathematics and Science Study (TIMSS), and Progress in International Reading Literacy Study (PIRLS). As such, Denmark has a global outlook and also routinely compares itself to international communities and partakes in international collaborations. No less in matters of digitalisation.

Denmark frequently scores high in assessments of digital excellence. Denmark was number one in the European Commission's Digital and Economic Survey Index (DESI) study of 2021 and second behind Finland in 2022. Though this offers only a partial picture of what it means to co-exist with digital technology in Danish life, the label of being a digital frontrunner and top scorer in digitalisation is of great political importance to a majority of political actors. Behind the numbers and bar charts is the reality that throughout the past two decades, digitalisation has grown to become a near unquestionable circumstance of social life in Denmark. The Agency for Digital Government was established in 2011 as part of the Ministry of Finance, but there have been concerted state efforts to digitalise the public sector since 2001 (KL et al., 2016), not least through 25 years of comprehensive state-led digital transformation of the public sector and its services. It now counts some of the very core functions of the public sector, but increasingly also enrols industries and other spheres of society. It is now mandatory to use many digital solutions, e.g., eID (*MitIT*),

Digital Post. Another marker of how thoroughly digitalisation has become everyday life is the addition of 'digitalisation' to ministry posting, specifically the Minister of Digitalisation and Equality, a seat made in 2022 occupied by Marie Bjerre, and in 2023 Mia Wagner.

IMAGE 5: "Because everyday life is digital", featured image on the walls and website of The Agency for Digital Government. Source: DIGST.dk

Of course, if everyday life in Denmark is digital, that is certainly because year-long authorial intervention to make it so. One of the things that happen when this everyday life is made digital and engaging with it mandatory, is those who are not fully accepting or easily handling digitalisation are problematised as 'non-digital citizens', as is expressed in the 'inclusion agenda' (Papazu et al., forthcoming). Digitalisation implies several forms of marginalisation and struggles among citizens in Denmark (Carerras & Finken, 2022; Carreras & Winthereik, 2023). Promoting the digitalisation of everyday is not unproblematic. From the disempowerment of those categorised as non-digital citizens to spectacularly failed public IT projects that have plagued public perceptions of state digitalisation.

2.2. Folkeskolen: The Danish public school

The public school, *folkeskolen*, is the public and free offer of ten years of statutory education. This consists of kindergarten class (*børnehaveklasse*) (form level 0) followed by nine grades of schooling, similar to primary and lower secondary school in many other national contexts. This corresponds to International Standard Classification of Education (ISCED) 0+1 and European Qualifications Framework (EQF) 1. About 86 % of children aged ca. 6-16 attend the public school. The rest attend either private schools (*privatskoler*), or independent schools (*friskoler*) (best thought of as an alternative to the public school which is the 'the state's' school).

The Danish Parliament authorises the Ministry to regulate public school education. The Ministry has two main agencies: The Agency for Teaching and Quality (*Styrelsen for Undervisning og Kvalitet (STUK)*) and The Agency for IT and Learning (*Styrelsen for IT og Læring (STIL)*). A primary instrument of governance is the learning goals for each of the school's subject areas. These are known as Common Objectives (*Fælles Mål*) and they are settled by the Ministry. Municipalities, on the one hand, are tasked with administering education. Schools are managed by the municipalities in which they are located in, and each school has a local leadership and a school principal. A single school is typically divided into departments that cluster the pedagogical staff and pupils according to the pupils' progression through the grades of schooling, from early schooling to finishing schooling. Grades 1-3 is 'in-schooling' (*indskolingen*), 4-6 is 'middle schooling' (*mellemtrinnet*), and grades 7-9 is 'out-schooling' (*udskolingen*). The only formal examination take place at the end of grade 9, where pupils are subjected to a mandatory 'school-leaving exam' to qualify for further youth education. Since 2007, there has been obligatory testing in the National Testing scheme, testing Danish (literacy performance) in 2nd, 3rd, 4th, 6th, and 8th grade; and Mathematics in form levels 2nd, 4th, 6th and 8th grade. Other ongoing assessment of the pupils takes place in the form of dialogue between pupil, parents, and teachers, and through screenings (for e.g., dyslexia).

The purpose of the public school is outlined in the Act on the Folkeskole, which states that the public school:

> (…) is, in collaboration with the parents, to provide pupils with knowledge and skills that: prepares them for further education and instil in them the desire to learn more, familiarises them with Danish culture and history, gives them an understanding of other countries and cultures, contributes to their understanding of the inter-relationship between human beings and the environment, and promotes the well-rounded development of the individual pupil. (…) is to develop the working methods and create a setting that provides opportunity for experience, in-depth study, and enthusiasm so the pupils develop awareness and imagination, as well as confidence in their own capabilities and backgrounds such that they can make decisions and act (…) is to prepare pupils for participation, co-responsibility, rights, and duties in a free and democratic society. The activities of the school shall therefore be conducted in a manner characterised by intellectual freedom, equality, and democracy.
>
> (Folkeskoleloven, 2020)

The educational practices of the public school are rooted in a German-Scandinavian intellectual tradition and approach to schooling. Bildung and Didaktik are central. These are the German terms for what in Danish is called *dannelse* and *didaktik*. They are crucial terms to understand the Danish public school (and its Nordic neighbours), but notoriously difficult to translate to especially Anglo-American contexts (Krogh et al., 2022; Retz, 2021), as no direct English translation adequately capture their meaning. The German Bildung, Krogh et al., argue, is a term recognised and established enough in the international literature on education, that the lowercase and un-italicised 'bildung' suffices (2022, p. xiv). Thus, bildung will be my international term for *dannelse* in this thesis, and I apply the same rule to *didaktik*—which I will refer to simply as didaktik.

Broadly, bildung signifies a conflated pedagogical and social norm. What these norms are has been subject to change as the society in which the norms are made significant undergoes change, too. In general terms, today bildung signifies the priority of "personal development guided by reason" (Retz 2021, p. 415), and to be guided in relation to others by being party to co-existence with others. In the public school, then, bildung is first and foremost about 'who should children become'. What they should know comes second. An Anglo-American approach to schooling might conversely concern itself primarily with what children should know e.g., curriculum. The term didaktik, too, needs clarification. In the Danish and neighbouring national contexts, didaktik (which

sounds like ‘being didactic’) does not, as is understood in Anglo-American contexts, refer to a person who lectures or moralises. Rather, it is

> language in which a common framework and set of referents govern discussion of educational theory, the practice of teaching, schooling, curriculum-making and lesson design, teacher associations and in-service professional development, as well as issues concerning individual school subjects, academic disciplines, and forms of knowledge
>
> (Retz, 2021, p. 415)

Everyday teaching practice is organised around didaktik. Didaktik practice is then also what profession research, pedagogical development, and teacher training is directed at. As such, the matter of making technology comprehension into a school subject was directly related to bildung and didaktik.

My point in clarifying these terms is that bildung and didaktik belong to a different intellectual tradition of schooling than e.g., curriculum thinking and instruction (Krogh et al., 2022), constituting quite divergent conditions of possibility in matters of public-school education tradition as compared to the Anglo-American tradition. This, of course, does not mean that the two traditions are completely separate, nor that other national school systems completely disregard the social development of the child in favour of rote learning and vice-versa for the Danish school system. The stated aim of the Danish public school is to conduct a secondary socialisation of children, prepare them for life-long education, and cultivate citizens. Job market preparedness is an explicit goal towards the end of statutory education, as it continues to be through youth and higher education. Schooling based in all-round development and didaktik increasingly mesh with skills and competency-based schooling.

In Denmark, the teaching profession is developed and taught in the programme for teacher education, which is housed at six university colleges in Denmark. The university colleges are understood as the core knowledge and practice infrastructure of the welfare professions in Denmark. Learning theories and teaching philosophies are always the subject of debate and development, but project and problem-oriented work is widely adopted for the pupils, as well as teaching in teams, pupil-driven learning. The network of knowledge institutions also includes research centres like Læremiddel.dk,

which researches and develops learning materials, and the Centre for Teaching Materials (*Center for Undervisningsmidler (CFU)*), the latter of which is a part of the coalition of Danish University Colleges (*Danske Professionshøjskoler*). All of these research and education institutions have projects or programmes dedicated to developing digital learning and teaching materials for the public school.

Developing the public school commonly involves many of these institutions. Under the purview of the Ministry, experimental teaching in the public school has been a mainstay of the Act on the Folkeskole since 1950. In a school-historical article former research director at Aarhus University's Danish School of Education (DPU) Poul Skov details the work of governing 'school experiments' in the public school, many of which he has advised on (2006). These efforts are now formally termed pedagogical development work instead of school experiments, because the latter term invokes the image of the pupils being guinea pigs. An image that is neither desirable nor fitting. In fact, Skov references Professor of experimental pedagogy Kaj Spelling who proclaimed that: "The ideal systematic school experiment has not yet been carried out – and probably never will be; for that, our material, the pupils are too lively, varied, and immeasurable – fortunately!" (p. 48). Overall, Skov recounts the many configurations of governance, purpose, and participation in experimentally developing the public school. He offers the impression of a solid tradition of experimental conduct in improving the public school, involving practitioners, researchers, and political delegates in a kind of participatory development work.

However, Skov also notes how the priorities and politics have changed throughout the decades, becoming more top-driven, as opposed to having been more 'grassroots' and anchored in the local practitioner communities, peer-to-peer, and not necessarily towards reformulating Common Objectives or broader political goals. Despite these tensions, experimental pedagogical development work is taken seriously as a way to develop the public school, seen e.g., in the Ministry's strategies for experimental conduct (see UVM, 2014). The continuing tradition of such development work has also legitimised the practice of consultancy in different forms since the 90s, a thread that has continued ever

since then. On the issue of digitalisation, during the years 2013 – 2015, a large-scale research effort took place under the auspices of the Ministry, focused on growing the pedagogical and didactical use of IT and digital learning materials in the public school. These so-called 'demo school trials' (*demonstrationsskoleforsøg*) drew on a corps of consultants (Bundsgaard et al., 2018).

3.3. New technologies and digitalisation in and around the public school

The public school's developmental focus on digitisation and new technologies has grown rapidly over the past 20 years, enrolling many, if not the vast majority, of the institutional actors mentioned above in problematising digitalisation of schools and schooling. I want to stress that digitalisation of schools and schooling is not a fixed phenomenon in the Danish public school, but an issue that has been problematised in many ways. I will account for some of these to illustrate the enduring struggle to reconcile educational, political, professional, and organisational public-school concerns with societal transformation, new technologies, and digitalisation.

IMAGE 6: A Piccoline keyboard. Source: Skolehistorisk billedsamling, Skolehistorie.aau.dk

The pendulum swing between procurement and pedagogy

Danish public schools have been 'on-line' since the turn of the millennium. They have been experimental grounds for encountering new technologies (Riis, 2012), raising pedagogical concerns about bildung and didaktik. 2011-2012 were especially big 'procurement years', where municipalities equipped their schools with interactive boards, tablets, and 'Chromebooks'. However, among education researchers and practitioners, concerns about an overwhelmingly instrumental focus grew, and related, concerns about the lack of attention to the didactic consequences of flooding classrooms with technologies grew. As education experts argued, learning among, with, and about technology had to be considered in terms of didaktik.

A massive research and development effort was launched to study and pedagogically qualify the increased use of digital learning materials and IT in the public school This effort grew a research and knowledge field called IT didaktik (*It-didaktik*), now a mature field of inquiry and practice for the public school's practitioners, researchers, subject matter experts, teacher educators, and consultants. As educational content, the cross-subject theme *IT and Media* has perhaps been the most consistent and substantive area dedicated to teaching digitalisation and new technologies in society prior to technology comprehension. IT and Media was codified in 2014, when all the public school's subjects were to address specific learning goals related to this topic.

Roots and growth of computing and design in the public school

Elisa Nadire Caeli chronicles how computer science was suggested as a school topic as early as 1970, though never making it past the trial and experimental stages (2021). Computer science, or *datalogisk tænkning*, is, however, a perspective that is gaining currency again. In technology comprehension, computational thinking was defined as a competency, and therefore also a matter of great pedagogical and didactic concern (see Caeli & Bundsgaard, 2020; Caeli & Dybdal, 2020; Caeli & Yadav, 2020). Jeanette Wing repopularised computational thinking (2006), and the European Commission developed an interest in it as a proxy for understanding how national school systems were constructing or transforming their technology education towards being "more than just digital skills" (Bocconi et al., 2022). Meanwhile, in Denmark industry

associations were asking for programming and coding to be added to the school schedule (IT-Branchen, 2015, 2016, 2018).

There has also been growing education-scientific and pedagogical interest in incorporating design and emphasising its civic aspect (Iivari 2020) e.g., Participatory design, which has roots in Scandinavian labour unions, and which became prominent in academia in the 1990s. Iversen et al., 2018 suggest "computational empowerment as an approach and a Participatory Design response to challenges related to digitalization of society and the emerging need for digital literacy in K12 education" (p. 1). Digital fabrication was also explored in a pedagogical research project FabLab@School, with the FabLab@School.DK (Hjorth et al., 2015) node producing some key resources and insights for what would eventually become technology comprehension. Finally, such computing and design knowledges also formed the basis of a Ministry-led trial of an *elective* technology comprehension, which ran in 2017/2018 in 13 schools (see Wagner, 2021).

Technology comprehension in the professions and teacher education

Already in the early 2010s, through empirical studies, the Technucation project demonstrated and conceptualised 'teknologiforståelse' in the welfare professions (Søndergaard & Hasse, 2012). In the years leading up to the trial programme, technology comprehension became a moniker for a kind technological literacy and disposition to technology as more than a tool, and more of a change agent and cultural force (Hasse, 2016). Hansbøl remarks, how "seemingly from one day to another [technology comprehension] went from being a complex theoretical and philosophical concept to being synonymous with a school subject in the public school" (2019, p. 16).

Over the course of the trial programme 'technology comprehension' seems to have become the formal English translation of the Danish *teknologiforståelse*., which is why I use it. In Danish, teknologiforståelse is a compound of 'teknologi' and 'forståelse', meaning 'technology' and 'understanding' respectively. Furthermore, teknologiforståelse is both the *name* of the school subject, subject matter, and research field—and a word that can be used as a general or 'pseudo-specific' *term* for the attribute to be

‘understanding of technology’ or to be ‘technology-understanding’. This is also why the trial programme was about “strengthened” technology comprehension: because it already makes sense on its own in Danish.

3. The trial of technology comprehension

The Trial Programme for Strengthened Technology Comprehension in the Public School (the trial programme) was the overall 4-year political project on technology comprehension (Erhvervsministeriet, 2018). The initiation of this project was part of an agreement between the government and other parties about "initiatives for Denmark's Digital Growth" (Erhvervsministeriet, 2018, p. 7). In addition to being a political project, the trial programme is, arguably, also a research project—a pedagogical development project actively involving the public school's supporting knowledge infrastructure and polities, both formally and informally. In this dissertation, I call the political initiative 'the trial programme' or, interchangeably, 'the trial of technology comprehension'.

The trial programme had a number of component parts or sub-projects. The ministerial terms of reference (*kommissorium*) for the trial programme, which was made available on the Ministry's website, specified that the programme had three of these. These were:

> 1. *Development of technology comprehension as [subject matter]*: Development of common objectives for technology comprehension as a new [subject matter] in the public school. This is overseen by an external expert writing group, which is expected to conclude its work in the fall of 2018.
>
> 2. *Experiment with technology comprehension in the public school's mandatory teaching*: Trial of technology comprehension as [subject matter] at 46 schools. The experiment runs three years in the period 2018-2021.
>
> 3. *Technology comprehension in education of teachers and other pedagogical staff*: Project to ensure capacity-building and competency enhancement in the subject matter technology comprehension in the teacher education and pedagogue education at all six university colleges.
>
> (UVM, 2018b, p. 1, italics in original)

Track 1 was to be completed first. Next, track 2 would commence, and then track 3 would launch, while track 2 was ongoing. As shorthand, I will refer to these three tracks as: 1) 'subject matter', 2) 'school trials', and 3) 'capacity-building'. For clarity, here is a visualisation of the Ministry's plan for the programme and its tracks in my shorthand terms:

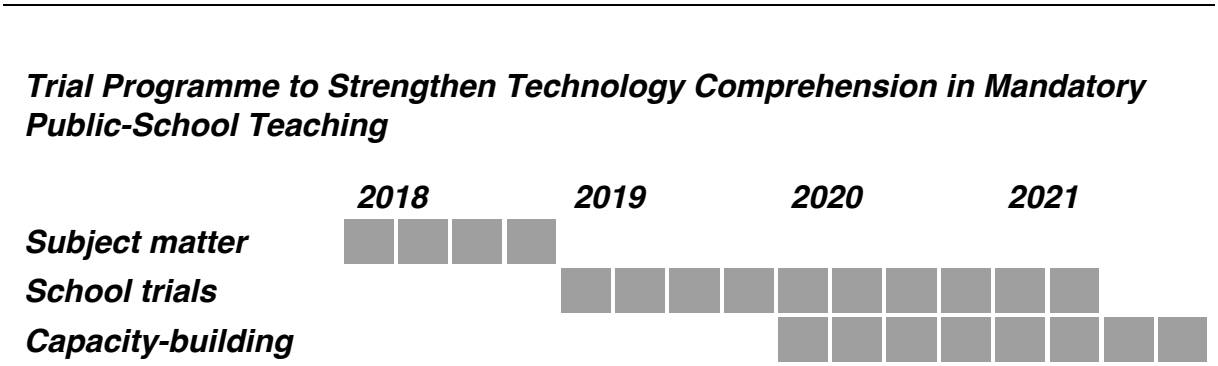


Figure 1: Visualisation of the trial programme's three tracks over the period of 2018 through 2021.

As shown in this figure, describing the technology comprehension *subject matter*; preparing and conducting *school trials* with experimental teaching of technology comprehension*;* and *building capacity* to teach technology comprehension were the cornerstones of the trial programme. In the following paragraphs, I am going to elaborate on these tracks with basis in mostly publicly available material and my observations of the public debate about the trial programme. I am going to 'bookend' my description of the tracks with sections about the 'pretext' and 'afterlife' of the programme. After I have accounted for the trial programme and its context, I will devote the rest of the chapter to defining it as my object of empirical study and explaining important scoping and 'cuts' I made to the trial programme as my case.

4.1. Pretext: 'Digital growth', and active citizenship

As evident from the former chapter, technology comprehension as a school subject did not spawn spontaneously, and the trial programme's launch was the confluence of existing practical and academic knowledge, political trends, cultural awareness, and much more.

In January 2018 the Danish government and the Ministry of Business, Industry, and Financial Affairs launched a glossy publication titled *Strategy for Denmark's Digital Growth* (Regeringen & Erhvervsministeriet, 2018). The

strategy was developed in advisement with the government's Digital Growth Panel, a group consisting of high-profile Danish industry representatives. The Digital Growth Panel had made recommendations about how industry and entrepreneurship could take advantage of digitalisation and new technologies to ensure Denmark's international position as a "digital frontrunner" (Digitalt Vækstpanel, 2017). The *Strategy for Denmark's Digital Growth* thus relayed recent industry recommendations and the cross-party political agreements about initiatives for 'digital growth' and 'frontrunner' status in Denmark (Erhvervsministeriet, 2018).

One of the strategy's six action areas described in the strategy was presented under the rubric "digital competencies for all" (Regeringen & Erhvervsministeriet, 2018, p. 3). Here, the Trial Programme to Strengthen Technology Comprehension in the Public School was introduced with the statement that the growth of Denmark, "largely depends on coming generations becoming skilled users of IT and also knowing how to develop and analyse IT so that they not only participate in the digital society of the future, but also help to create it" (Regeringen & Erhvervsministeriet, 2018, p. 35). Among other initiatives towards 'digital competences for all' was The Technology Pact, a project that was to foster "digital excitement" and encourage more people, of all ages, to take undertake STEM education (p. 38).

Through the Danish education system, children and future citizen-labourers were thus enrolled in the social and economic project of maintaining a 'the digital everyday life'. In other terms, it was launched to cultivate technologically educated citizens, starting from early school age, by preparing children to have more 'active' encounters with technology instead of just swiping on iPads and conversing about screentime, cyberbullying, and 'fake news'. The trial of technology comprehension was financed with 68 million DKK. These funds were to cover evaluation efforts, competency-building and guidance and supervision, and costs incurred by schools' participating in the programme.

Prior to the launch, the Ministry conferred with the Danish Union of Teachers and Local Government Denmark (*Kommunernes Landsforening*) and enrolled subject matter experts in collating research and experience with the

possible subject matter, and qualifying the practical, pedagogical, and educational content of the trial programme as a whole. An expert advisory group oversaw the trial programme, and it consisted of a diverse group of academics, industry spokespersons, educators, and subject matter experts[9].

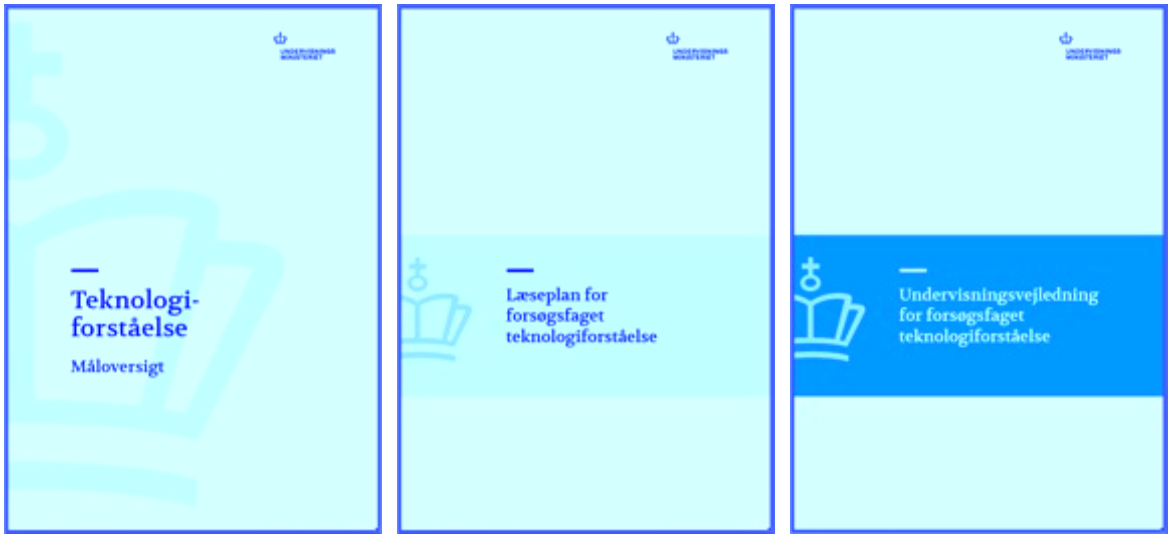
4.2. Subject matter (track 1): The subject proposal

The Minister appointed an expert writing group to define the subject based on their expertise and experience. Their appointment stated that: "Determining the academic content for the trial requires a greater amount of work in the advisory expert writing group". Based on advisement from the Minister's Advisory Group for Technology in Teaching, the terms of reference for the group's work posited that: it is worth considering whether and how technology comprehension subject matter and teaching might include: how technology and automation impact society, computational thinking (informatics); iterative design processes and the interrelationship between the social for which something is and can be designed, and the materials and computing technologies (e.g., code, sensors, pocket-sized computers, or 3D printers) with which something is and can be designed; and complex problem-solving, where children put their comprehension of technology to use in creating new technologies through learned design processed and arguing for the relevance of their technological creations (UVM, 2018a).

The group was led by two chairpersons: Michael E. Caspersen, known among peers as "Mr. Informatics" (It-vest, 2020), director of It-vest, a collaboration between universities on IT education; And Ole Sejer Iversen, an Interaction Design scholar and Professor at Aarhus University. Both Caspersen and Iversen had championed the introduction of a new technology subject for schools for years, and they continued throughout and after the trial programme. This strongly influenced that computing/informatics and participatory design-

[9] The names of these were available to me upon request to STUK.

inspired approach to technology comprehension became dominant. The rest of the expert writing group were academic researchers, educators with subject matter knowledge, and consultants (UVMd, 2018). The expert writing group drafted a proposal, consisting of three documents: Common Objectives, a curriculum, and a teaching guide.



IMAGES 7, 8, 9: Thumbnails of the front pages of the three .pdf documents that comprise *faghæftet*, or what I term the subject proposal. From left: Common Objectives in the format of a 'goals overview' (*måloversigt*), curriculum, and teaching guide. Source: UVM.dk.

The Ministry announced the finalisation of the proposal on their website. The documents were, and remain as of writing this, available for all to download on the website. The Common Objectives were that "pupils should develop academic competencies and acquire skills and knowledge so that they can participate, constructively and critically, in the development of digital artefacts and understand their significance" (UVM, 2018e, p. 3). The composition of the subject was also described in detail. They were described around the concept of 'competency areas', a rubric that all subjects and subject matters in the public school are described through. Here is how they conceptualised and modelled the experimental subject technology comprehension:

IMAGE 10: From the top polygon and clockwise: "Digital Empowerment", "Computational Thinking", Technological Skills and Knowledge", and "Digital Design and Design Processes" (UVM, 2018c).

Computational Thinking (*computationel tankegang*): unfolds the pupil's ability to translate a complex problem into something a computer can understand, making it possible to suggest a digital solution or automate a task. The pupils are familiarised with abstracting worldly phenomena as a way to that makes them appear as processes and objects that can be manipulated computationally. Technological Knowledge and Skills (*teknologisk handleevne*): is about knowing and handling digital technologies, such as computer systems, their languages, and their programming. The key concern is to develop an understanding, and use, of digital technology as a material for developing digital artefacts. Digital Design and Design Processes (*digital design og -designprocesser*): aims to develop the pupil's ability to plan and execute a design process consisting of the elements framing, idea generation, construction, argumentation, and introspection. Digital Empowerment (*digital myndiggørelse*) has the pupils explore digital artefacts: their possibilities, consequences, and impact.

The writers stressed that all the competency fields were equally important. In informational and inspirational material, the composition was presented as 'a symphony' or 'harmony' (EMU, 2021). Additionally, building on

the Common Objectives and the curriculum, the teaching guide (UVM, 2018f) introduced novel terminology and workflows associated with technology comprehension. These included prototyping, iteration, getting 'hands on' with technology, and working with analogue and digital materials, to name a few. The initial subject proposal pertained to technology comprehension as an independent subject, but subject matter descriptions specific to other subjects that would form the basis of an integrated technology comprehension were made later: for Danish, Social Studies, Mathematics, Visual Arts, and Science/Chemistry. To the extent that I analyse the subject proposal in this thesis, I do so exclusive based on the proposal for the independent version of technology comprehension.

3.3. School trials (track 2): Live trials in teaching

Chiefly, the subject was to be taught experimentally in a number of schools during a 2.5-year trial period. The imperative to conduct a 'live' trial in schools was to establish and advance an educative practice specific to technology comprehension in collaboration with teaching staff in their specific school context. I.e., to establish the foundations of a subject-specific didaktik. This was 'track 2' of the programme, focused on trying out technology comprehension teaching and building teacher competency close-to-practice.

On behalf of the Ministry, STUK put the task of executing and conducting track 2 and the school trials up for tender. The bid-winner's task was to make materials and manage schools engaged in teaching technology comprehension. The contract was awarded to a consortium: University College Copenhagen led the effort in a consortium that also included University College of Northern Denmark, VIA University College, and The National Research Centre for Learning Materials (*Læremiddel.dk*). Aarhus University, University of Southern Denmark, and Aalborg University consulted throughout. Rambøll Management Consulting (Rambøll) subcontracted to carry out evaluations. These were many different types of institutions and environments. The consortium had the

responsibility to gather existing knowledge from subject matter experts, practitioners, and consultants.

MAGE 11: Featured image of a post on the Ministry's website, announcing the call for participation in the school trials. The text reads "sign up now for the experiment with technology comprehension in the public school". Source: UVM.dk.

In May of 2018, the Ministry announced a call for participation in the school trials. 142 schools applied, and 46 were chosen to take part, spanning over 32 Danish municipalities. The schools that took part received funding to do so. The funds were dedicated to expenditures related to staffing, not equipment. In a start-up pamphlet circulated by the consortium, the rationale, aim, subject matter, and organisation of the school trials were introduced. It also described the different roles, expectations, and supporting actors in the school trial, both at the schools and in the consortium. The pamphlet addressed participation and responsibility of school leadership, administration, pedagogical staff (teachers), and among these one or more persons were designated 'resource persons' (*ressourcepersoner*). As such, schools in the trials designated a key actor to be the practical 'link' between the other actors in their local trial context. The earliest sparring and consortium efforts were directed at the resource person, who shared and disseminated to peers and collaborators in the school environment.

The school trials kicked off with a conference in early 2019. The conference set the stage for the collaborative effort of the school trials as the

‘practice-centred’ site of technology comprehension; key experts gave presentations and introduced the subject matter; and the conference facilitated the first of many networking, inspiration, and knowledge-sharing events.

While the school trials were taking place at the 46 schools, spreading experimental technology comprehension all over the nation, the consortium also had a public-facing presentation of themselves and the trials on the web at www.tekforsøget.dk, which featured information and news about the trial. Perhaps most importantly, the website was home to all the new technology comprehension materials that had been prepared for the school trials: examples of courses called ‘didactic prototypes’—because they were prototypical of the substance of a technology comprehension lesson or series of lessons.

These materials were ‘stored’ in a what was occasionally referred to as the ‘prototype bank’, a subpage with links to download didactic prototypes in the form of .pdf files and PowerPoint slide decks. To support the use of didactic prototypes and experimental teaching of technology comprehension, the website also featured videos about ‘instructional’ principles, introduction to terminology, and supplementary resources. The school trials were also constituted by a slew of seminars and events about technology comprehension, focused on everything from didaktik to organisational matters, ‘development laboratories’ to ‘learning circles’.

The activities and outcomes of the school trials were evaluated. Of note, a midway evaluation took place and was released in May of 2020, and a final evaluation was made at the end and reported in October of 2021. These were conducted by Rambøll, a subcontractor in the consortium. Arguably, the ‘outside’ factor that had the most impact on the programme’s progress was that of the global SARS-CoV2 outbreak of 2020, which, in varying ways, dashed and mitigated the trial programme quite a bit, mainly due to mandated lockdowns, precautions, and other restrictions on the public school, in-person teaching, and concerns for pedagogical quality. But the programme was never outright cancelled, and it rolled on through this *force majeure*.

3.4. Capacity-building (track 3): Teacher education research

Track 3 was about developing a 'teacher-technology comprehension', i.e., the knowledge that teachers and student-teachers should be educated in at the university colleges[10]. The track was to develop the practical, educational, and pedagogical link between the school subject technology comprehension, and teacher educational technology comprehension. Prior to the trial programme and this track, teacher-technology comprehension was not well-developed as of yet. The track on capacity-building was "based on a triple-didactic interaction between knowledge networks as representatives of the professional's scientific disciplines, profession educators and the teachers and student teachers" who will potentially be teaching technology comprehension to pupils" (Andersen et al., 2022, p. 5).

Capacity-building for technology comprehension centred on developing courses and teaching materials, and other resources for organising teaching, and testing them with teachers. A full report on the activities of and recommendations from the capacity-building effort is detailed the final report (Andersen et al., 2022) and additional information and outcomes of were made available on the website www.lutek.dk.

3.5. Afterlife: 'No plans', new alliances

The trial programme concluded with a positive, yet largely inconclusive evaluation of the school trials (UVM, 2021). The terms of reference for the trial programme had stated that a political decision on technology comprehension's future would follow after the programme had ended, possibly in the spring of 2022. In April of 2022 news outlets relayed a broad statement from the Ministry that there were no plans to develop technology comprehension as of yet. This

[10] The Danish word for this is *lærerfaglig teknologiforståelse*, and I have only the poor translation of 'teacher-technology comprehension' to offer.

was disappointing to many who had been involved in the trial programme. Representatives made public statements in media about their confusion and disappointment at the perceived apathy of the government with regards to technology comprehension. In both research and practitioner communities, the teacher education has routinely been referred to as the likely bottleneck for any pedagogical intervention into the public school (see Caeli & Bundsgaard, 2019). In other terms, a chicken-or-egg problem. If plans for intervention exclude serious consideration and resources and development efforts for capacity-building and competency-development in teacher education, targeting both student-teachers, and active teachers. The recurring conundrum of the bottleneck has roots in the fact that, as a rule of thumb, the teacher education does not get to do specific teacher education for school subjects unless the subject already exist in the school. In that sense, although though technology comprehension had grown relatively mature as a field of interest in the teacher education and adjacent research environments (e.g., around IT didaktik, design and digital fabrication research for schooling, computational thinking, or Coding Classes) as a school subject, technology comprehension was entirely new, with no one truly trained to teach it.

In 2022, key actors in this track responded to the tepid political follow-up on the trial programme in a news opinion piece. They stated that teacher education benchmarks the competences of the future. Building this capacity was to take place more or less parallel to the teachers and pedagogical personnel being exposed to it through their participation in the school trials, thus relying on a few especially motivated '*ildsjæle*'—individuals who embodied a trailblazing spirit and were likely the appointed resource persons, motivated by interest and experience to take part in developing technology comprehension 'live'. When the new digitalisation strategy came out a month later, it did not mention technology comprehension (only 'technology in teaching'), another disappointment to vocal proponents and figureheads of technology comprehension. Of course, the digitalisation strategy was, as now usual, released under the auspices of the government and the Ministry of Industry, Business and Financial Affairs. It was therefore not a strategy targeting the education sector specifically. However, given the political furore around

technology comprehension a few years past, it was perhaps understandable to expect a mention of technology comprehension in the digitalisation strategy.

The ambiguity and uncertainty that has characterised the afterlife of the trial programme has also further galvanised alliances between public authorities, research and education institutions, and unions in promoting further development of technology comprehension for the public school. If not for the entire education system at large. The latter has been the priority of the National Capacity Group for Technology Comprehension since the height of the trial programme. In October of 2023, it was announced that technology comprehension would become an elective with the practical-musical focus that was mentioned in the digitalisation strategy of 2022. The dream of technology comprehension is kept alive by such alliances who stress the democratic significance of a technology comprehension by the education and profession research environments, which now have more ground to develop technology comprehension from. In November of 2023, a consortium consisting of Aarhus University, University of Copenhagen, University College Copenhagen, VIA University College and Læremiddel.dk announced the launch of Centre for Digital Technology Comprehension, having received 50 mil. DKK in funding from The Lundbeck Foundation, Novo Nordisk Foundation, and Villum Fonden for the period of 2023 through 2028.

4.6. Object of research, scoped

That is the case of the trial programme and its national and institutional context of the digitised public school of a ‘digital Denmark’. I have chosen the trial programme as my research object—but I have therefore also had to scope it and make cuts to my ‘case’. I scoped out track 3 about capacity-building in the teacher education, because I would be spreading myself too much. I have tried to illustrate this in fig. 2 below, by transposing my interpretation of the Ministry’s commission (shown earlier in fig. 1) and greyed out track 3 about capacity-building

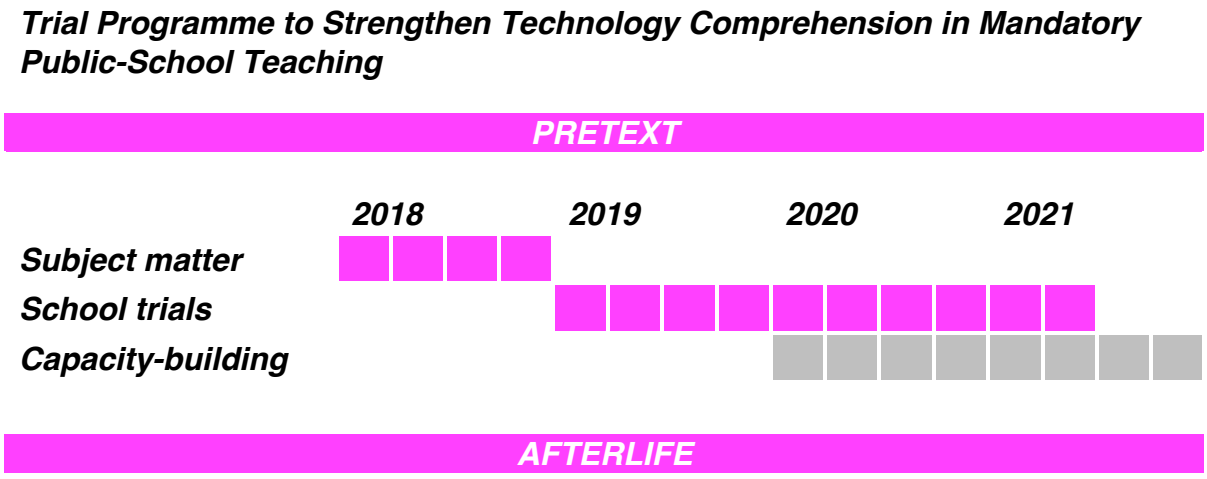


FIGURE 2: Visualisation of my research object with capacity-building scoped out.

As shown here, I pay empirical and analytical attention to namely the subject proposal and the school trials. But I also consider the context of the trial programme: the pre-text and afterlife.

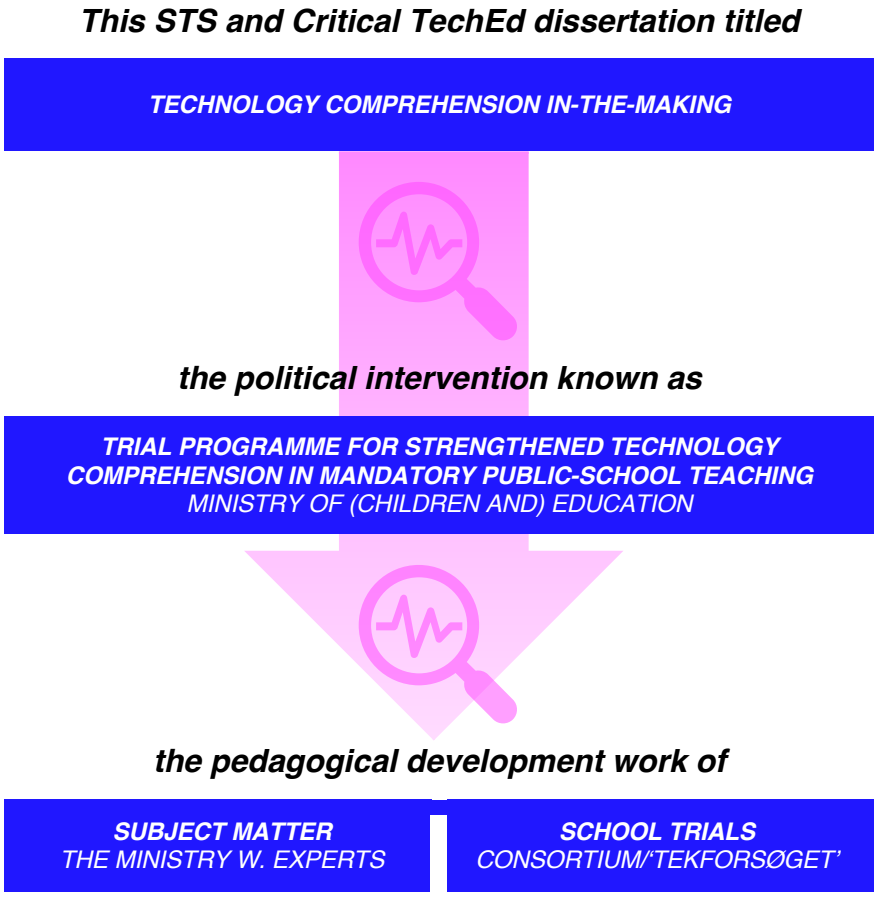


FIGURE 3: Visualisation of the various knowledge-making efforts treated in this thesis. My research and research object in relation to the research objects of those objects.

4. STS: A framework for studies in knowledge production

STS—science and technology studies—is about critically examining the complex relations of science, technology, and society[11]. The utility of STS' diverse approaches and analytics arguably grows each day, as 'science', 'technology', and 'society' become more and more unimaginable without each other. In STS, the practices of knowledge production are often themselves the object of study and reflection (Law, 2004b; 2015). Not least experimental settings of knowledge production (Latour & Woolgar, 1987; Shapin & Schaffer, 1985). It is a well-established approach to study knowledge production, which I apply to the trial of technology comprehension.

In the following paragraphs I am first going to introduce STS as briefly as possible. STS addresses a dizzying range of research topics and fields. Throughout their brief history of STS, Gorur et al. characterise STS as "a broad church from the start", "a loose coalition", using Law's (2009) moniker of the "STS diaspora", and as "a suite" (Gorur et al., 2019, p. 8) of conceptual vocabularies and tools to study the practices through which sociotechnical phenomena, facts, and shared realities emerge. I will therefore aim to clarify ontological and conceptual points that are particularly relevant for my study, and I will discuss the critical substance of STS for studying scientific conduct and knowledge production. I will not offer a comprehensive history of STS or a mapping of all canonical topics in the field. Among the many salient analytic positions associated with STS, I draw out a *material-semiotic* approach and the epistemological and ontological interventions this proposes. I argue that this approach lends itself well to critically examining educational phenomena. Finally, I conceptualise my framework as 'ideas to think other ideas with'—as the ideas I use to analytically think about the ideational work and

[11] Before it became an acronym for 'science and technology studies', the letters in STS referred to 'science, technology, and society' (Sismondo, 2010). The subject matter and concerns remain the same.

'ethnomethods' (Garfinkel, 1967; Maynard & Heritage, 2022) at play in the trial of technology comprehension. I also discuss my position as a social researcher who studies other researchers, and what scientific contribution I expect to make in light of this.

4.1. Science, technology, and society

Introductions and histories of STS commonly trace the field's origins to the Kuhnian Revolution of the 1970s. This is in reference to Thomas Kuhn's *The Structure of Scientific Revolutions* (1962/1970/2012) and the profound impact this work had on how science was understood. By attending to the historicity of science, Kuhn and his contemporaries argued against the widely held belief that science was an "ahistorical accumulation of knowledge" (Nielsen & Andersen, 2021, p. 21). His work showed how science was not 'outside' of society but implicated in shaping it. Furthermore, science had everchanging conditions of possibility that were contingent on social factors of the society that scientific conduct was taking place in. Historicising its conduct, Kuhn's work disrupted science's claim to neutrality.

This made the sociality of science and how scientific facts were made a big topic of interest for social scientists. A number of influential studies have treated the social and material practice of science, e.g., of the laboratory (Latour & Woolgar, 1987), science 'in action' (Latour, 1987), and as 'epistemic cultures' Knorr-Cetina (1999). The social constructivist view that those studies introduced were central in research programmes like the Sociology of Scientific knowledge (SSK) (Merton), and the 'strong programme' (Bloor). STS has also studied the public understanding of science, science communication, and citizen science.

IMAGE 12: A painting titled An Experiment on a Bird in an Air Pump by Joseph Wright, 1768, Derby. The depicted experiment in Steven Shapin and Simon Schaffer's *Leviathan and the Air-Pump: Hobbes, Boyle, and the Experimental Life* (1985), which examines Robert Boyle and Thomas Hobbes' debate about scientific conduct and the experimental method. Source: National Gallery, London.

By the time information technologies were becoming more and more widespread, researchers associated with the programme Social Construction of Technology (SCOT), in particular, made historical analyses and developed arguments that showed how humans and their communities and societies shape technology, as opposed to technology determining human activity. (Bijker & Law, 1994). Technology is thus scarcely the unidirectional application *of* science *to* society. Rather, researchers in the growing STS field developed concepts that capture a more relational and dynamic view of the interrelationship between science, technology, and society.

A concept like 'sociotechnical imaginaries', for example, is defined as "collectively held, institutionally stabilized, and publicly performed visions of desirable futures, animated by shared understandings of forms of social life and social order attainable through, and supportive of, advances in science and technology" (Jasanoff & Kim, 2015, p. 4). The concept of sociotechnical imaginaries problematises, too, the technological determinism that orders many mechanisms of society, like policy, governance, and regulation. E.g., techno-optimism in school development (Sims, 2017) or nation-building through investments in technology-driven entrepreneurship (Lindtner, 2020).

STS studies both problematise and/or dissolve the boundaries, dichotomies, and categories that both materially and discursively structure dominant understandings of the world and how change can be imagined. STS therefore also lends itself well to ideological critique of some of the most persistent socioeconomical 'truths' like (neo)liberalism, growth, capitalism, and scaling (Stengers, 2020). And of how, by whom, and for what, knowledge is produced, used, qualified, or discarded. Feminist and postcolonial STS (Haraway, 1988; Subramaniam et al., 2017; Tallbear, 2013) direct sociomaterial critique at the enduring Westernised knowledges that 'know' and order the world. One of the foundational contributions of STS is that it has rendered science, technology, and society thoroughly contingent, emergent, and relational phenomena. This ontology is the basis of much of the critical work STS can do. But also, the basis for making change on the basis of that critique. The implications of STS complicating scientific facts, the formation of societies, and technological innovation is that it brings into view *that* things could be otherwise. *That* it is possible to intervene in phenomena which seem enshrined.

New concepts have been deployed to capture the complexity of sociotechnical phenomena, while maintaining that they are real and not simply make-believe, nor the outcome of Machiavellian 'scheming'. As early STS studies showed: "Robustness and validity are enacted through various forms of assemblage of the human and nonhuman in research practices. They are ontological achievements rather than epistemological discoveries" (Fenwick & Edwards, 2019, p. 10; see also Latour & Woolgar, 1987; Latour, 1987). They become 'black boxes', by "the way scientific and technical work is made invisible by its own success (…) paradoxically, the more science and technology succeed, the more opaque and obscure they become" (Latour, 1999, p. 304). Matters of fact, being another staple STS concept attributed to Bruno Latour (2004, 2008b), refer to stable phenomenon, the boundaries and veracity of which appear fixed e.g., as a statistic, a piece of furniture, a task, or a school subject. Latour adds that 'matters of fact are not all that is given in experience. Matters of fact are only very partial and, I would argue, very polemical, very political renderings of matters of concern' (2004, p. 232). The kin concept of 'matters of concern', on the other hand, signal contested phenomena, aptly

understood as constructed and unsettled, with fuzzy boundaries, and, for better or for worse, not easy to agree on. This latter concept, Latour proposed, exactly because STS' critique and deconstruction of scientific seemed to have gone rogue, e.g., for haphazardly (or in bad faith) disputing or outright discarding science. Another concept is a controversy. Controversies are interesting sites of research as they are often:

> seething with a variety of points of view and a heterogeneity of practices, the outcomes of which are unknown. They offer a rich mix of facts, objects, people, rhetoric, institutions, protocols and a number of actors all bidding to translate each other, impose their view on the scene, become spokespersons and so on.
>
> (Gorur, 2015, p. 96)

Controversies, I argue, is a suitable way to conceptualise the trial of technology comprehension. As such, I the researcher am urged to locate the practices that engender the phenomenon, the practices through which what I observe as 'the trial programme' is done. How to study matters of fact, black boxes, or controversies? To STS, worlds, 'the social', and realities are constructed through a variety of material, social, discursive, and technical practices. And through the relations of different actors. Practices are performative and constitute reality. Therefore, STS overwhelmingly studies practices, and STS research, with relevant empirical and analytical approaches, can perform various forms of critique.

4.2. Deploying a material-semiotic approach

In addition to the general position of STS, I use an analytic called *material-semiotics*. In the plethora of STS approaches, material-semiotics is at times also referred to as Actor-Network Theory (ANT): STS abounds with material-semiotic approaches, and ANT is a staple material-semiotic approach. I will be using the term material-semiotic[12], but the literature I reference might self-identify as

[12] Because I do not have space to deal with the baggage of ANT and its name.

being about ANT. This is because ANT is one of the more enduring STS approaches, credited with the growth of the STS field. ANT started to take shape in the late eighties to early nineties (Law, 2009) with the now infamous empirical studies of scallops at Brieuc Bay, (Callon, 1986), the work of scientists and engineers (Latour, 1987) and scientific laboratories (Latour & Woolgar, 1987). Although it has the word 'theory' in the name, the originators of ANT have spent at least half of its lifetime softening the idea that it is a theory, because ANT wanted to render theories themselves contingent and relational.

As a consequence, over the years, an ANT reflexive of itself has emerged, turning its critical view on itself (see Law & Hassard, 1999). ANT has become 'post-ANT', the 'consequences' of which are also reflected upon by its users (see Gad & Jensen, 2010). Roughly speaking, the 'goal' of ANT was about showing contingency, and in a post-ANT view, it is more about how, if contingent, to manage this contingency, and how worlds cohere, despite everything being 'in flux'. The latter, 'post-ANT', is exemplified by Annemarie Mol's studies of the enactment of arteriosclerosis as multiple 'things' (2002). However, while reckoning with its naming (Latour, 1999), ANT remains "a toolkit for telling interesting stories about, and interfering in, (…) relations" (p. 142). Add to this another obstinate caveat: ANT is not a ready to use package or template for doing STS or ANT research itself (Law, 2009). Rather it is:

> tools, sensibilities and methods of analysis that treat everything in the social and natural worlds as a continuously generated effect of the webs of relations within which they are located. It assumes that nothing has reality or form outside the enactment of those relations.
>
> (Law, 2009, p. 141)

Empirically, "ANT may be viewed as a vessel of intellectual resources that can only bear fruit with empirical matters" (Gad & Jensen, 2010, p. 75). As much as this can seem abstract, to walk away with that impression would be to miss the point of ANT: that it is grounded in cases. It means that doing inquiry is about locating, encountering, and studying practices. Practices are the relations of interest for a material-semiotic approach, which is

> a set of tools and sensibilities for exploring how practices in the social world are woven out of threads to form weaves that are simultaneously semiotic (because they are relational, and/or they carry meanings) and material (because they are about the physical stuff caught up and shaped in those relations.)
>
> (Law, 2019, p. 1)

What I operate with in this thesis is tools and sensibilities particular to the empirical case, the field of practice. They are "analytic methods that honour mess, disorder and ambivalences that order phenomena, including education" (Fenwick & Edwards, 2010, p. 1). What I do is tell stories of knowledge-making in the trial of technology comprehension. I do this to better understand and intervene in the technological worlds and technologically educated civic subjects that emerge when educational programmes problematise digitalisation and digital technologies, which offer solutions in the form of school subjects, methodologies, learning goals, and 'comprehensions of technology'.

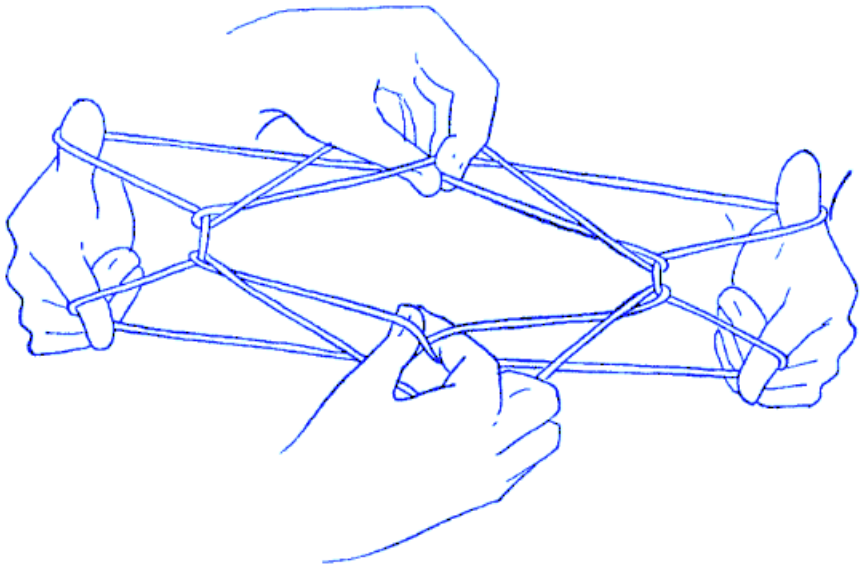


IMAGE 13: A line drawing of hands doing 'the cat's cradle' with strings. The cat's cradle game is a concept signifying the entanglement of actors in constituting being and reality, associated with Donna Haraway (1994).

The analytical edge and epistemic value of telling such stories is afforded by the core ontological propositions of the material-semiotic approach: 1) that all entities that "modify a state of affairs by making a difference" (Latour, 2005 p. 71) can be considered an actor. 2) That actors are at once "semiotic (because they are relational, and/or they carry meanings) and material (because they are

about the physical stuff caught up and shaped in those relations.)" (Law, 2019, p. 1). Such 'stuff' can also be intangible (ideas, dreams, statements), i.e., 'simply' *non*-human.

For an actor, to be caught up, and be shaped is to be in relation and to be translating. Translation, as addressed by Michel Serres (1982/1995). ANT progenitors like Michel Callon developed this into a sociology of translations (1986). Studying how actors relate, translation, and the effects thereof—the phenomena, worlds, and realities they are caught up in and shape—has since, been an important analytical concept, and ontological proposition, out of STS and its material-semiotic vocabulary.

To be is to be related
(Mol, 2002, p. 53)

In *After Method,* Law argues that methods do not just describe realities; they are also implicated in producing realities (2009). He articulates with the impish phrase, "making facts is making values is making arrangements that are in one way or another political" (2004a, p. 2). Law's statement echoes Haraway's argument that it matters what knowledges make knowledge. Their arguments stress that it is important to study "how theories, methods, and material pieces of equipment are used in practice in specific social, organisational, cultural and national contexts – and (…) look at the effects of those practices" (Law, 2015, p. 1). As I will elaborate on later in Chapter 5, this proposition is as much a way for me to conceptualise the emic relations of knowledge-making I study in the trial of technology comprehension, as they are for the relations of knowledge-making I am caught up in and shape when I conduct and account for my research in this thesis. If I argue that knowledge-making in the trial programme is political (because methods make realities): a matter of encounter, ordering, and distribution; Of making worlds at the expense of other worlds; And of doing so already situated in worlds. Then the same applies to me. More on these implications for reflexivity in my thesis later.

In the latest iteration [13] of their argument for an 'ANTiE' ('ANT in education') Fenwick and Edwards stress that "Education remains almost inherently humancentric by definition, yet socio-material studies suggest the need for us to at least problematise such a focus, if we want to do worthwhile educational work" (2019, p. 15). My understanding of this point in relation to the trial of technology comprehension is that there is both more at play than the researcher, but also less than the researcher as a human actor. Moreover, Law states that is "not only what is present in the form of texts and their production, but also their hinterlands and hidden supports" (2004a, p. 144). Hinterlands is another way of thinking about the worlds a researcher (doing e.g., pedagogical development work or STS) is situated in, and which comes to bear on the translations. The hinterland is constituted by matters of fact and "disciplinary practices of social and natural sciences already in production" (Law, 2004, p. 31). Hinterlands, in the socioscientific controversy of the trial of technology comprehension, are implicated in how "Disciplinary canons then are not simply received; their reception requires certain practices, discourses, inscriptions and rituals" (Fenwick & Edwards, 2014, p. 39).

With a material-semiotics, my aim is firstly to introduce the *relationality* of actors—not just what these actors *represent* as analytically salient and politically consequential. My description of methods and material-semiotic relations in the trial programme is an attempt to crystalise the epistemic tensions and ambiguities that co-exist with institutional stability, disciplinary canon, education-scientific facts, government regulation, and formal knowledge in the form school subjects. Second is to decentre the role usually afforded to human deliberation in the constitution of social worlds and material realities. Not least the ubiquitous realities and worlds of school reform, subject matter development and educational research practices undertaken in the trial programme, where instruments, concepts, and methods, are used explicitly and implicitly to make knowledge. This is challenging proposition to some, but it is an approach that is, to again quote Fenwick and Edwards "deeply empirical and

[13] Developing ANT in education (research) since 2010 and 2012.

material in ways that evoke less-explored opportunities for doing critique and making a difference" (2019, p. 15). As a hopeful theory, it offers a way to participate in the productive struggle over good, transgressive education. To stand alongside critique of ideology and norm in the school space. To get involved in the making of technology comprehension.

4.3. Epistemological implications for scientific knowledge about knowledge-making

> Scientists have a culture. They have beliefs. They have practices. They work, they gossip, and they worry about the future. And, somehow or other, out of their work, their practices and their beliefs, they produce knowledge, scientific knowledge, accounts of reality. So how do they do this? How do they make knowledge?
>
> (Law, 2004a, p. 19)

This thesis is driven by an observation, curiosity, and concern for how education practitioners, pedagogical researchers, subject matter experts, and learning consultants make knowledge and enact the realities where this knowledge can hold true. My research participants are also engaged in scientific conduct, acting reflexively, and using sociological theory. This complicates any stark division between the research and the researched (Ratner, 2021). The division between that necessarily reads from this thesis is an enactment itself. STS' proposition is that I do not stand outside of discourse—no one and nothing does, there is no god's eye view to be taken (Haraway, 1988). In my encounter, analysis, and description of how actors translate each other and with what effects, I am necessarily also transforming the actors, and transformed. If the knowledge-making work I do in my research is an enactment of me as a researcher, then this has implications for the scientific contribution and production of reality imminent to my research.

The concept of hinterlands, which I deploy in my empirical-analytical work, can also be used as a key to understand the epistemological implications of making scientific knowledge about knowledge-making. Specific to education research with STS and material-semiotics, Rimpiläinen (2015) shows how the hinterlands of researchers who research educational practices come to bear on

the realities, and possible educational development trajectories that are made possible. Sriprakash & Mukhopadhyay (2015) suggest that “social researchers, through the methods and disciplinary discourses they deploy, are ‘brokers’ and ‘translators’ of knowledge” (p. 231).

The trial programme was a highly anticipated, widely publicised, and politically supported pedagogical research and development project that set its sights on qualifying the introduction of technology comprehension subject matter to the public-school curriculum. Contingent in this pursuit of formalising technology education for an increasingly digitalised societal context, school actors related, contested, and assessed existing expertise, concepts, ‘social worlds’, and methods to build the epistemic practices of novel technology comprehension for the public school. To broker knowledge about this as a social researcher is to be caught up in, shaped by, translating, and producing particular understandings of the world that emerge. Being a translator “in the sense that the salience of their mediations is contingent on the role and agency of other actors connected to the research network and on the negotiations of these interconnections” (Sriprakash & Mukhopadhyay, 2015, p. 231).

The fact that some worlds are performed ‘at the expense of’ others, is my engaging in an ontological politics (Mol, 2002). My thesis is the critical, reflexive, and politically consequential forging and foregrounding of education-developmental and societal realities imminent to the trial of technology comprehension. The tension here is that it, while the knowledge I produce comes with the enactment of reality where that knowledge can hold true, it could also be otherwise. The latter is a necessary condition of doing STS and using a material-semiotic approach.

5. An empirical-analytical strategy

This chapter details my empirical and analytical encounters with the trial of technology comprehension. Of note, the Covid-19 pandemic both constrained and enabled how I constructed the trial programme as the research object: it shaped how and where I located practices of experimental technology comprehension and, as a result, how I generated and collected empirical material. In this chapter I also recount how I analysed the empirical material.

5.1. Locating the technology comprehension experiment

Before I recount how I approached locating the technology comprehension experiment, and the time-spaces I traversed throughout my project, I will have to call an interlude to discuss some matters of the pandemic.

Pandemic reflections

The official start date of my PhD project was April 1st, 2020. This was during the first lockdown in Denmark, during which schools (as well as everything else) were closed. The trial programme was never cancelled during the many months of intermittent lockdowns and gradual reopening. Covid played an active part in shaping, to me, emic understandings of the trial programme, too. The encounter between the trial of technology comprehension and the pandemic appeared in different modalities, many of which I did not observe through rigorous method, but rather in a strange mix of pragmatic and affective state. Things I observed were: The view became that a technology comprehension school subject was even more urgent because of how new technologies and platforms, like Zoom, MentiMeter, and Kahoot, were enabling and constraining teaching and learning in various ways during lockdowns and the pandemic at large. The information critical literacy that was supposedly associated with technology comprehension (e.g., the competency area of Digital Empowerment) was highlighted because of how social media amplified or drive dis- and

misinformation. Pandemic preparedness was linked to digitisation and digitalisation. Everyday life was already largely understood as digital (see Chapter 2). For better or for worse, corona just rocket-fuelled the digitalisation of 'the everyday' in Denmark and made the notion of digitalisation being "the grammar of participation"[14] more poignant. And prior to the pandemic, the trial of technology comprehension was, after all, grounded in a broader public digitalisation effort to make citizens of a digital democratic society (read more about digital citizenship in technology comprehension in Chapter 6).

On the one hand, in sociotechnical imaginary, technology comprehension became even more important for desirable futures. On the other hand, schools in the trial were still, and perhaps even more, expected to conduct schooling in a manner that suited their local context. When another lockdown started in Denmark, the school I had been observing technology comprehension teaching in also closed. I did not move my observations online, because I was told that teaching experimental technology comprehension in a trial programme context was not a priority in the competing context of 'emergency teaching', where the focus of pedagogy was more so about pedagogy for camaraderie and well-being of the pupils, and teaching that was sensitive to the impact on daily lives—and learning—that the pandemic had.

All that is to say that as society changed during the pandemic, so did the expectations about technology comprehension. But never in any uniform way. Throughout this project, I, like everyone else, including my research participants, were finding new openings when things closed. Covid did not once and for all cancel things, delay them, move them online, make them virtual, make them smaller of bigger. The field of practice as an organisational space was in "constant deformation (…) contingent upon dis/continuities between (non)human agencies" (Ratner, 2020b, p. 1). For the purpose of locating the technology comprehension experiment in my research, the spatial matter of scale, size, and location is best understood as an ongoing situational achievement.

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[14] See the research project *Deltagelsens grammatik* at https://deltagelsensgrammatik.itu.dk/

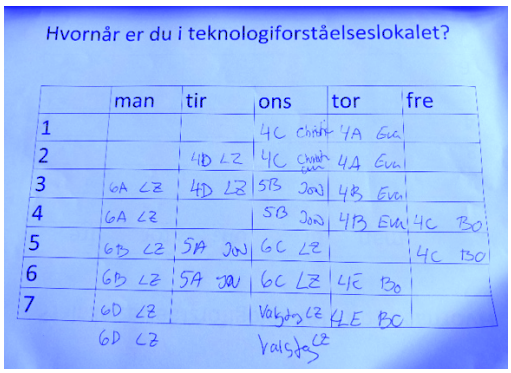
School's in session!: Technology comprehension at the Metro School

The school trials were slated to take place in 46 schools across Denmark. For the most part, it did indeed seem feasible to observe technology comprehension at a trial school, because the schools were set to re-open (after a lockdown in the Spring of 2020) in the 2020 summer term. An exciting prospect, because observing in one of these schools seemed an obvious and attractive venue for ethnographically generating data about experimental technology comprehension. It was an opportunity to see how pedagogical staff and schoolchildren 'animated' technology comprehension. A list of the 46 schools was available on the Ministry's website. I was scanning that list in late spring of 2020. A time of massive uncertainty about when, where, and how *any person* could move—not just an STS researcher like me; Due to the SARS-CoV2 pandemic, at this time, I was working against both temporal and spatial constraints for any empirical work, but especially for an on-site school ethnography in the public school. To make things as feasible as possible at that time, I opted to contact schools in the Greater Copenhagen Area close (but not too close) to where I reside to be as much in control of the logistics of potential visits to the school locale I eventually ended up in. My pseudonym for this school is the Metro School.

My contact in the Metro School was the resource person (see Chapter 3 on roles in the school trial) on the technology comprehension teaching team, and as such she was thoroughly excited about having me visit. My past volunteer work in the children's' after-school club Coding Pirates also ingratiated me with the teachers, as did my insistence that I was not there to evaluate or pass judgement on how they were teaching. They were also not surprised to have been contacted about possible visits regarding technology comprehension, because participating in the school trials meant a certain degree of being 'opened up' for outsiders. And not only those that were conducting 'official' school trial business and inquiry in the school. In fact, during one of the lessons I observed, I was one of four people observing technology comprehension teaching, the other three being a group of university students collecting data for their course work about IT didaktik. Negotiating,

gaining, and maintaining access is one of the more persistent issues in ethnographic research (Neyland, 2008), but I had many things working in my favour, both in terms of the 'public' nature the school trials and topicality of technology comprehension in the Danish society, but also in terms of my network and the overlap of the Coding Pirates community and technology comprehension actors.

My research participants at the school were pedagogical staff, teachers. I was never directly studying or assessing the children or the outcome of teaching and learning for the children. There were five technology comprehension teachers, including the resource person. In the late summer of 2020, I was invited to a meeting they were having in preparation for the upcoming school year. At the time of that meeting, the school had been teaching experimental technology comprehension for approximately one school year, from Spring of 2019 to Summer of 2020. They were keen to know what my interest in them and technology comprehension at their school was. I stressed that I was not part of the school trials, and not representing the consortium or any other official trial programme actors. I was conducting my own study of the trial programme. I was not there to evaluate teaching, learning, nor organisational matters. I was there to understand, in an exploratory way, the social and material life of technology comprehension in the local school context.



IMAGES 14 and 15: The technology comprehension classroom at the Metro School and the schedule for using it: "When are you in the technology comprehension room?". Photos by author, 2020.

At the Metro School, experimental technology comprehension was taught as an independent subject to pupils in middle-schooling, i.e., form levels 4, 5, and 6 and the ages approximately 9-13. Each class of pupils received 30 lessons of 45 minutes each throughout the school year. By the 2nd year of the school trials, the teachers had turned one 'data room' ('*datalokale*') into a designated space for technology comprehension lessons, though lessons sometimes also took place in the home rooms (*klasseværelset*).

School's out for Covid!: Technology comprehension wherever

The experimental subject technology comprehension was described in the subject proposal. The trial programme and technology comprehension generally were discussed on the web e.g., on social media such as X[15] and LinkedIn, and on Folkeskolen.dk. www.tekforsøget.dk was the website about the school trials, hosting a lot of the trial's output and information about its background. The website was not updated as frequently as the debate was happening elsewhere—like in newsletters, news reporting, and opinion pieces. The trial programme, and namely the Tekforsøget during the School Trials, hosted many technology comprehension events for a variety of school actors. I characterize these events as either, or a combination of, informational (like the kick-off event), inspirational (exhibitions at trade fairs), and instructional (workshops and seminars focusing on building competencies).

The big trade fair to speak of was that of Danmarks Læringsfestival (Learning Festival Denmark), where technology comprehension featured, among other topics, technologies, communities, debates. Learning Festival is usually co-located and on-site in one of the larger Danish cities, but in 2021 it took place virtually due the SARS-CoV2 pandemic. The auditoriums of University College Copenhagen were also a site of knowledge exchange and debate about technology comprehension, as two inaugural lectures took place, which both treated aspects of technology comprehension promise and practice. Læremiddel.dk hosted a conference to celebrate the publication of a special

[15] The social media platform formerly known as Twitter.

issue of *Learning Tech* titled Technology Comprehension's Subject-Specific Didaktik. Additionally, I attended political events, like public consultations (*høringer*).

IMAGE 16, 17: On the left, a sign outside of University College Absalon on the day of Læremiddel.dk's conference on research on technology comprehension's subject-specific didaktik. Photo by the author, 2022. On the right, Ole Sejer Iversen presenting technology comprehension. Screenshot by the author, 2021.

5.2. Generating and collecting empirical data

Methods science, social or natural, are generally considered to be "a more or less successful set of procedures for reporting on a given reality" (Law, 2004a, p. 143). In this and the next subsection, I will describe and discuss my procedures: how I generated empirical material (and the kinds I generated), how I collected empirical material (and the kinds I collected). And, finally, how I analysed the mess I made with it.

Encounter through ethnographic methods

Because they are usually interested in studying practices and relations of actors it is common for STS studies to use qualitative methodologies. STS researchers have, however, been using and developing quantitative methods throughout the years. They are, after all, often interested in methods, experimentation, and knowledge production. In the recent decade, e.g., 'digital' methods (Rogers, 2013; Marres, 2015) have been conceptualised, materialised in software (Jacomy, 2021), and grown into research infrastructure.

My methodology is thoroughly qualitative. Usually, the purpose of a qualitative study is to examine a phenomenon as it is, in rich detail. The research design is expected to be flexible and evolve throughout the study. Either an inductive or abductive approach is used and may lead to theorising. It is often said that the researcher is the primary instrument of data generation. This also means that the researcher has to reflect on their role as an instrument of data generation, e.g., how they have relied on their senses in observing, perhaps being able-bodied. This issue is sometimes discussed in terms of positionality. The sample size in a qualitative study can be quite small, or at least does not have to be large. The analysis of data generated through qualitative methods are analysed using e.g., coding (Saldaña, 2013), resulting in narrative description and interpretation drawing on hermeneutics. A rather broad classification, qualitative, quantitative, or mixed methodologies are often further theorised in the research fields they are put to use in.

Being interested in what actors are doing, how they achieve organisation, and with what tools is something that drives many STS studies. It is fitting, then, that there is a kinship between STS, material-semiotics, and ethnographic methods and the like (Czarniawska, 2007). To be sure, my study is not an ethnography. It is a qualitative STS study that draws on ethnographic methods. Ethnography is both a practice (Hammersley & Atkinson, 2007) and the outcome, e.g., an ethnography of X. The trial of technology comprehension as a field of practice is an assemblage of social, material, discursive, and technical work. Actors are doing things—they relate and translate each other, and they assemble the phenomena, e.g., of the trial of technology comprehension and the various ideas, things, and people that are, also, actors, insofar as they are generated as effects of all these agencies.

Generating and collecting empirical data

I generated data through *observations* of technology comprehension classes, teacher meetings, meetings with between teachers and the subject matter developers, the teacher lounge, the playground, and the hallways of the Metro School. I was also observing when I attended research, development, and pedagogical events hosted by the consortium or that were off-shoots from the official consortium-hosted events.

In a similar vein, I generated data through *shadowing* (Czsarniawska, 2007; Northcott, 2010). E.g., I followed (with consent) one or more teachers for a period of time at the Metro School before, during, and after a lesson. Shadowing being a method of observation that is cognisant of the spaces to be in constant formation (see also Ratner, 2020b). Addey and Piattoeva emphasise that "Scholars are seeking, following and meeting their research participants in formal and informal settings and networks, physically and virtually, blurring the identities and practices of scholars and research participants" (2021, p. 6). In this light, shadowing as a form of ethnographic encounter and method becomes useful. I took notes during or as soon after observations and periods of shadowing. This produced fieldnotes. I subjected these notes, these data, to many kinds of processing and transformation, some which arguably count as analytical treatments as well. I (cloned and) rewrote some for clarity; made fragments of some into more granular notes; and wrote about aspects of some notes in new notes.

I conducted semi-structured *interviews*, audio-recording these with the knowledge and consent of the interviewees. I interviewed teachers at the Metro School. I had many informal chats with various staff at the school, and others involved in the trial programme throughout my research project. These encounters are harder to categorise, but nevertheless crucial. Despite this tension, neither the audio-recordings nor my notes from informal chats are expected to be objective records of reality, situations, or phenomena. Transcription software has come a long way in the past few years. However, I did not use any transcription software, instead transcribing them manually. The interviews were conducted with the intent of having the research participants

narrate and make sense of their worlds and practices (Kvale & Brinkmann, 2009), and the same purpose applied to the informal encounters. I conducted the interviews in person and audio-recorded them. Even before I subjected the transcripts to various forms of analysis, like coding, or annotation they were, no matter how accurately I turned audio is into text, is never objective (Green et al., 1997).

Glued to my phone and laptop for most of 2020 and 2021, I *browsed* the web for content about technology comprehension. Much of the documentation about the trial of technology comprehension was available online on the Ministry's website (e.g., list of expert writing group members and list of participating schools), EMU.dk, or the dedicated website for the school trials at www.tekforsøget.dk. The list of advisory members was available to me upon request to STUK, and the members were informed of my request. The trial programme and technology comprehension's content and emerging practices were discussed on social media, in practitioner venues like blogs and commentary on www.folkeskolen.dk.

		METHOD	***DATA***
1	**GENERATED**	Interviews of 45 – 60 min. in length: 1 x subject matter developer, 1 x substitute teacher; 4 x technology comprehension teacher; observations at Metro School: During September, October, and November, totalling ca. 72 hours. Observations of other events in connection with the school trial is N/A, as these took place throughout the course of the entire project.	Pictures from observations of school life, teaching, teacher lounge; screenshots from online events; videos from observations (only of stuff); fieldnotes, and transcripts of interviews.
2	**COLLECTED**	Browsing the web and collecting artefacts of ministerial governance in the trial programme.	Subject proposal (Common Objectives, curriculum, and teaching guide), political agreements, policy documents, news reporting, opinion pieces, strategies, commissions, tenders, requirements.
3		Browsing the web and collecting artefacts of the school trials.	Documents, books, podcast, visualisations, 'didactic prototypes', PowerPoint slides, scientific journal special issues, reports, academic-scientific and pedagogical literature.

FIGURE 4: Overview of empirical data.

These methods of 'field' and 'desk' research, which I used to encounter the experiment with technology comprehension (in and beyond the Metro School) generated an abundance of materials. I have tried to give an overview over

what the outcome of observing, shadowing, interviewing, browsing was below, sorted in three main clusters: 1) Things I generated. 2) Governance and publicity materials. 3) Artefacts of namely the school trials as a pedagogical research and development project, all public, in particular on www.tekforsøget.dk. This overview is scarcely organised. It is a list of things I produced or collected through my empirical work. As I show below in image 18, it is a mess loosely ordered in clusters and in relation to X and Y axes. STS and material-semiotic approaches encourage making a mess in research, for the simple reason that the world that methods are expected to help report on is itself messy (Law, 2004a). It is relational, emergent, and complex. I elaborate on how I analyse a mess to making academic knowledge and a scientific contribution in the next few pages.

IMAGE 18: The state of my whiteboard in the Spring of 2022. Photo by Barbara Nino Carreras, 2022.

5.3. Analysing experimental technology comprehension

Here I share some of my thoughts about the analytical work I did. The analytical toolbox I use is informed by ethnographic anthropology, STS, poststructuralism, policy research, and organisational studies. It spans well-established procedures and new experiments with analytical practice.

Reading strategies: Adding more agency to texts

Government proposals and strategies often embody a tension between being prescriptive in some sense, but also deliberately vague. Documents play an important role in scientific and organisational work, and this is a reality that STS can help articulate. Jensen and Lauritsen discuss "two ways of relating to" documents, reports, and other such governance texts, which they call 'reading against' and 'reading with' the text (2005, p. 353). These have different "interpretive effects" (p. 353). Reading-against the text treats it to e.g., ideological critique characterised by a scepticism of the visions and worldviews in the text, or a problematisation of the subjectivities and normativities it embeds. Indeed, it is a strategy that characterises many post structural and critical theory studies of curricula. The alternative STS-inspired strategy of reading-with is about treating reports as material-semiotic actors and following them in their evolving relations to other actors in the assemblage. The STS-inspired reading-with strategy does not disregard the content of the text, "but it does allow the suspension of narrow concerns with textuality and meaning, and it adds more agency to the text as it moves in practices" (Jensen & Lauritsen, 2005, p. 353). While readings-with the text presents a great analytical opportunity for making sense of governance, it is also necessary to dive into the texts in addition to following them around in the network. This is needed to identify their effects and for readings-with as well (Gad (2010).

In Paper 1 I analyse the subject proposal as a governance document. A governance document in that it is both a curriculum, and as such visionary, descriptive, and prescriptive. But also, a governance document because it is supposed to form the basis of preparation and conduct in the more open-ended exploratory work of pedagogical development in the school trials. With attention to different strategies and their interpretive effects, I do a critical and 'sceptical' reading of the subject proposal, complicating its conceptual premises and logical underpinnings. Paper 1 is informed by poststructural work, which shares many of the concerns of STS, and material-semiotics can be understood as "a particular empirical translation of poststructuralism" (Law, 2009, p. 146). Locating technology comprehension in the three texts of the subject proposal, I analyse it in terms of subjectification (Foucault, 1982), i.e. the types of conduct

that pupils are disposed to in technology comprehension. Critical studies that solely read against might overstate the determining effects of curricula and schooling. Solely reading with backgrounds a necessary understanding of the contents of technology comprehension that are translated, negotiated, struggled with, celebrated, or critiqued by actors in the trial programme.

Experimenting with ethnography: Making time-space for analysis

Some of the central tensions I explore are those between past, present, and future, and the dividing practices that occur when creative-constructive and design engagements are favoured at the expense of other types of relationships with digital technology. I generated an abundance of curricular, inspirational, policy, and organisational artefacts from the field. I consider these inscription devices that forged interesting tensions in the field, and, which, kept the dream of technology comprehension alive during the trial programme. I am someone who is situated in an interdisciplinary research environment populated by ethnographers, anthropologists, STS researchers, and researchers of organisation. We routinely problematise sociotechnical phenomena, study heterogenous practices, and discuss the performativity of methods. A part of scientific knowledge-production I have found more diffuse, difficult to conceptualise, and almost impossible to locate in this very environment is that of analysis. I also know that I am not alone in this experience. I have shared office with colleagues, and even more thoughts about navigating the social and professional life of academic research particular to our field. Yet somehow analytical practice remained hard to grasp, bar that of coding and writing memos in multiple cycles (Saldaña, 2013)—a well-established and well-theorised practice.

In a recent contribution to anthropological ethnography titled *Experimenting with Ethnography: A Companion to Analysis* **(**2021) Ballestero and Winthereik engage this exact issue, stating: “If analysis is a concrete process of opening our insights, we should see it happening in particular times and places and through concrete means (e.g., writing, conducting fieldwork, following protocols, reorganizing materials)” (p. 4). The edited volume collects so-called protocols to follow, which are intended to make empirical material salient,

"bringing it into existence in a different manner than how it previously was" (p. 4). In her protocol called 'multimodal sorting', Karen Waltorp (2021) directs attention to "the images that informants make and share, and images that anthropologists make and collect" (p. 133). Waltorp argues, that following the protocol—appropriating and adapting it to the research context at hand, "ethnographic insights may emerge through multimodal sorting of these (digital) materials alongside other fieldwork materials" (p. 133). Because the protocol is exactly that—a set of steps to be followed to make material salient, I am able to share a snippet of here.

> Select the images your informants have shared and that you have made/collected and want to work with (…) Sort them in several forms or framings: as collage, as montage, or according to themes and categories that you have chosen on the basis of previous knowledge. Be aware of—and play with—the automatic function of a particular software you are using (e.g., iPhoto, Adobe Premier Pro, Adobe InDesign), and pay attention to how it inevitably sorts and frames the material. (…) Query your groupings and framings and ask, What are the apparent and unapparent patterns and logics that undergird the groups and/or (temporal) sequences? How is the software part of the analysis and "logic," with what implications?
>
> Waltorp, 2021, p. 149

In its concreteness, multimodal sorting, as well as the other protocols in the volume, push the analysts to physically make time and space for analysis. Experimenting with ethnography, I have used "resources that focused on analysis as a practice that does not fall into cognitivist or mechanical territories but can, nevertheless, be engaged as an organized and methodical process" (Ballestero & Winthereik, 2021, p. 9). Multimodal sorting made the design process models I analyse the relations of in Paper 2 salient as inscriptions (Latour, 1986) of the 'design approach' that is prominent in technology comprehension, educationally, and in the pedagogical development work organisationally.

Studying relations and interactions with artefacts

The pandemic and ensuing lockdowns and uncertainty in my field of research limited my in-person access to human actors and social groups working on technology comprehension. The strain of the uncertainty even limited my ability to generate virtual encounters with the work of teaching and developing

technology comprehension. It has therefore been crucial for my empirical-analytical work in this thesis to draw on STS and material-semiotics to treat the abundance of artefacts (documents, pictures,) I collected from virtual spaces like the web and from the in-person observations I was able to do the fall of 2020 (see fig. 4). Thus, studying the heterogenous practices of knowledge-making, I examine actors describing their actions and settings, their making sense of phenomena, and their encounters with material artefacts. E.g., in Paper 3, Gad and I draw on Alberto Corsín Jiménez' writing about 'prototyping cultures' (2014) and STS literature to develop an STS perspective on my multiple ethnographic encounters with different prototypes. We develop this perspective to study and discuss inflictions of prototyping in the trial programme.

6. Knowledge-making in the trial of technology comprehension

The source material for this chapter are the dissertation's three research papers, which I organise as Discipline-ing, Translating, and Prototyping. In the following pages, I give an overview of the findings of each paper, and I remark on their context, i.e., the calls they respond to and the fields they contribute to. Two of the papers are single-authored, and the third paper is first-authored. The research papers are the following:

Discipline-ing

Gahoonia, S. K. (**forthcoming**). Matters of Subjects: The Digital Citizen in Technology Comprehension. In Kjær, K. M. & J. Perriam (Eds.), *Digital States in Practice*. DeGruyter.

Translating

Gahoonia, S. K. (**2023**). Makers, Not Users: Inscriptions of Design in the Development of Postdigital Technology Education. *Postdigital Science and Education*. https://doi.org/10.1007/s42438-023-00431-7

Prototyping

Gahoonia, S. K., & Gad, C. (**accepted with revisions**). Prototypes all the way down: Prototyping in the teaching and development of Technology Comprehension. *STS Encounters*.

6.1. Discipline-ing

Gahoonia, S. K. (**forthcoming**). Matters of Subjects: The Digital Citizen in Technology Comprehension. In Kjær, K. M. & J. Perriam (Eds.), *Digital States in Practice*. DeGruyter.

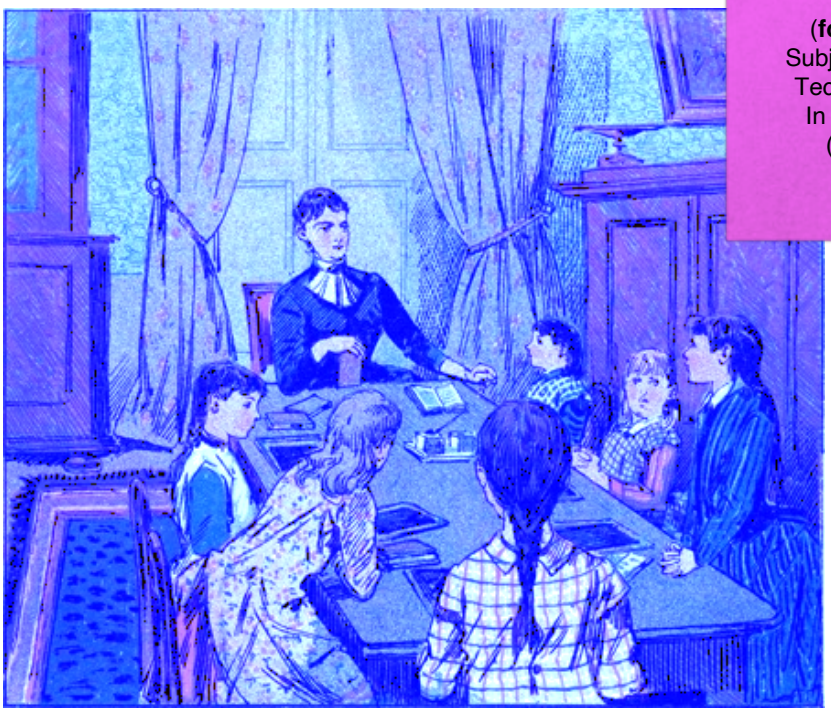


IMAGE 19: An illustration (titled *Representation*) of home-schooling, brought in PUNCH magazine, April 1889. Source: WikiMedia Commons.

The rubric of this section is an attempt at playing on the double meaning of the word 'discipline'. On the one hand, I want to invoke discipline (verb) as in the motif of subjectification associated with Michel Foucault's governmental rationalities (1982). On the other hand, I want to invoke discipline (noun): A discipline can be a field of study and/or subject matter, i.e., a school subject. Discipline-ing is, thus, a reference to the process of mattering (Law, 2004b) digital citizenship and schooling in the trial programme, as it is located in the subject proposal, i.e. the contents of technology comprehension.

On 21 December 2018, the Ministry announced on their website that the expert writing group's subject proposal for technology comprehension had been finalised (UVM, 2018). As such, the first track ('subject matter') of the trial programme was complete. The subject proposal consisted of Common Objectives, a curriculum, and a teaching guide. This content that was going to be prepared (by the consortium) and trialled in the following three years in the schools.

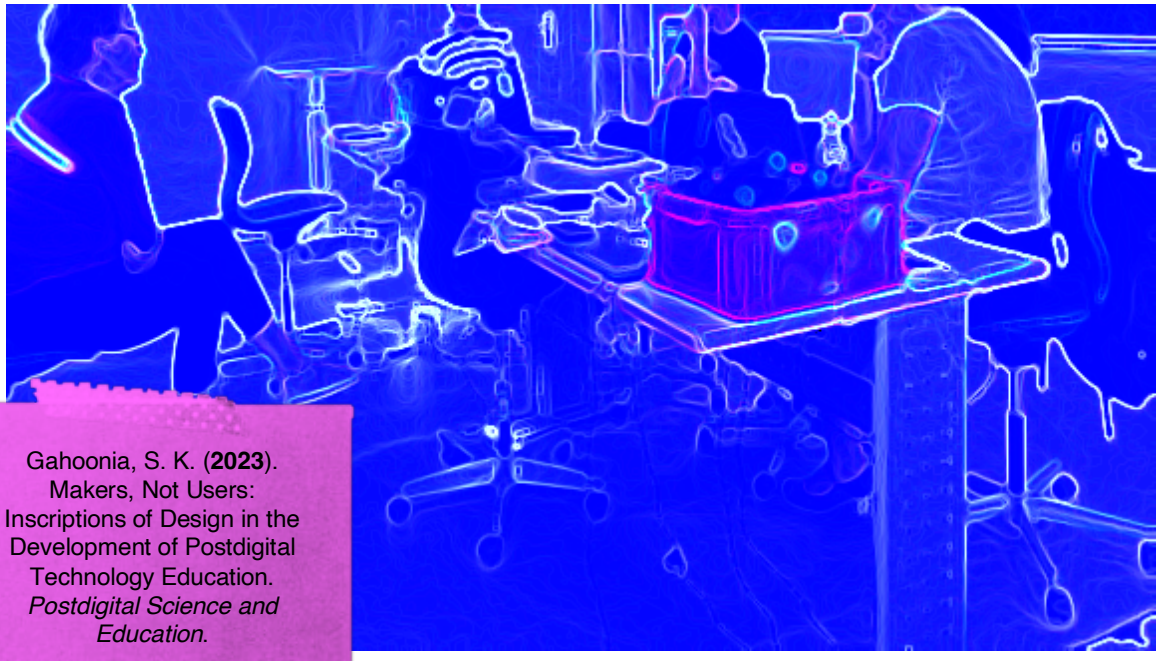
In Paper 1 I analyse the subject proposal to understand how the digital citizen is imagined. It is a book chapter in an edited volume titled *Digital States in Practice*, edited by Katrine Meldgaard Kjær and Jessamy Perriam (forthcoming). The trial of technology comprehension is the digital state of Denmark in practice, as it deploys technology comprehension as a technology of government (Rose & Miller, 2010). Examining the subject proposal is a way to get an understanding of the public school as a democratic resource for the state. Technology comprehension imagines the technologically educated civic subject, a digital citizen. It disposes pupils, and future citizens, to particular forms of conduct (Foucault, 1982), to particular relationships and encounters with technology, digitalisation, and digital society.

Technology comprehension problematises technology use and introduces the making and analysis of technology as desirable. To aid in this, 'technology' is given subject-specific terminology that frames technology in two distinct ways: a 'digital artefact' is a human construction built with intention and affordances for use, and it thereby becomes a thing that is possible to analyse. On the other hand, 'digital technology' is a conceptualisation of technology that draws attention to the material (code, 3D printing filament, algorithms, physical computing). Technology comprehension renders the world and field of civic participation digital, to then put agency in the hands (literally) of the pupils—i.e., humans, who when they want to act, act on the digital material. Technology comprehension has four competency areas, combining human, machine, technical, and social topics subject matters. The writers of technology comprehension stress that these competency areas are equally important. A symphony even, and this composition signals a holistic approach to technology education. The implication is that the intended outcome of technology comprehension is a diverse comprehension of technology. A Swiss army knife of skills and competencies. In the future of digital Denmark, the digital citizen should be a maker, not (only) a user.

It is an interesting notion, considering the relatively recent public sector digitalisation initiative of 'digital inclusion', which renders non-users of mandatory digital solutions problematic (Carreras & Finken, 2022; Papazu et al., forthcoming). Though presented as a response to the sociotechnical

complexities of society, the presentation of such an understanding of technology also performs that complexity. Overall, a stark human-technology binary is performed, which limits how change can be imagined, e.g., by overwhelmingly presenting social problems as design problems, and encouraging technological fixes to the problems individuals or society faces. Thus, it might overstate the capacity of 'designerly' attitudes and conduct to deliver on ideals of participation, and it implicates the citizen in reproducing a digital hegemonic order.

6.2. Translating



Gahoonia, S. K. (**2023**). Makers, Not Users: Inscriptions of Design in the Development of Postdigital Technology Education. *Postdigital Science and Education*.

IMAGE 20: Subject matter developer and learning consultant visits the Metro School for a meeting with members of the technology comprehension teaching team. Photo by Author, 2020.

This section is about the enactment of 'a design approach' in the trial programme, which I address in Paper 2. My concern is how a design approach was translated, what it inscribed, and what it generated.

Although technology comprehension was not a design subject, design methodologies and the epistemic practices and organisational forms associated with design were especially significant to the technology comprehension

subject matter and its development, no less so in the school trials. Here, conductors, contributors, and knowledge persons mobilised 'making', co-creation, experimentation, participation, prototyping and collaboration as key methodologies for learning, teaching, and developing technology comprehension for the public school. That is: Not only did such approaches become inscribed in the subject's contents as something the schoolchildren should learn; A design approach was also posed as foundational to teaching technology comprehension (Iversen et al., 2019), as well as being a motor in the very development work of the school trials.

Paper 2 is published to a special issue on the topic of 'designing postdigital futures' (Macgilchrist et al., 2023) in the journal *Postdigital Science and Education*. In the international scope of this journal, I frame Paper 2 about how, in Danish technology education, design figured prominently, which is interesting with regards to how a majority of technology education initiatives (about 'more than just digital skills') centre computing (see Bocconi et al., 2016; Bocconi et al., 2018; Bocconi et al., 2022). In Denmark, design took on an important role, not least by explicit comparison to this international context, because design was given equal footing to computing (see Wagner et al., 2020). In Paper 2 I direct attention to how this 'meta-ideology' of a design approach is enacted in the development of technology comprehension, specifically through an exploration of how subject matter experts, researchers, and teachers related to process models in this work. What I find is that the models enact the production and handling of boundaries between types of social knowledge.

'The Design Process Model, which visualises the cycle of steps in a design process, is presented as central to learning in technology comprehension, and something which pupils should undertake. In the pedagogic literature on technology comprehension, proponents of a design approach and the model, stress that it is not because pupils should become designers. What this shows is the translation of 'real world' or academic knowledge into a school subject. Translation and inscription that Popkewitz (1988) also calls the alchemy of school subjects. This alchemy, then, draws on pedagogic and education-scientific disciplinary hinterlands, the matter of fact of bildung. 'The Prototype Model' enacts the boundary between 'theoretical-conceptual' and 'policy'

knowledge by seeking to align expectations and worlds of these with the model. And they perform the ritual of negotiating the balance between and managing the boundary.

6.3. Prototyping

Gahoonia, S. K., & C. Gad. (**accepted with revisions**). "Prototypes all the way down: Prototyping in the teaching and development of Technology Comprehension." *STS Encounters*.

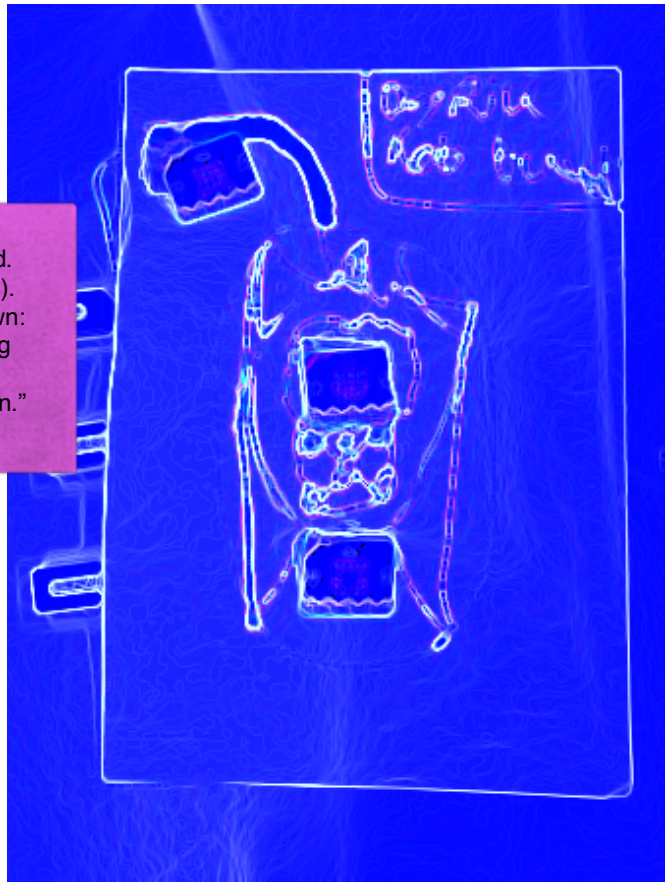


IMAGE 21: A picture of what is ostensibly a prototype, crafted by a 6th grade pupil in a technology comprehension lesson. Photo by author, 2020.

This section is borne out of my many encounters with prototypes in the trial programme. Prototyping being one of the techniques of a design approach, described in the subject proposal as something pupils should be undertaking in technology comprehension. Something which is also indicative of the subject drawing inspiration from participatory design (Wagner et al., 2020). In particular, this section is about prototyping as epistemic practice. Prototyping was done and made significant as a classroom activity for the pupils by which they could construct and reflect on technology, but also for the organisation and

conduct of the pedagogical development work on a designated technology comprehension teaching practice.

Prototyping in technology comprehension is indicative of how the concept and practice of prototyping is no longer solely associated with systems engineering and design. STS researchers have theorised about the social and material agencies of prototypes, e.g., the capacity of the prototype as "a performative artefact that works to align multiple, discontinuous social worlds" (Suchman et al., 2002, p. 176). Corsín Jiménez discusses the proliferation of 'prototyping cultures', calling prototyping "an important currency of explanation and description in art-technology contexts, where the emphasis is on the productive and processual aspects of experimentation" (2014, p. 381), and prototyping functions as both a form of "knowledge-production and cultural and sociological styles of exchange and interaction" (p. 381). In Paper 3 (which is accepted with revisions to the STS journal *STS Encounters*), Christopher Gad and I draw on these discussions to examine enactments and inflictions of prototyping by looking at the relations of two outcomes—prototypes—of prototyping in the school trials: 1) an object that a pupil had made and demo'ed for the teacher; and 2) a didactic prototype for app design, made by subject matter developers from the consortium, and put to use by a teacher, who fed back his experience of 'testing it' it.

When demoing his creation, the pupil's prototype had a minor technical malfunction, but otherwise functioned well. The teacher remarked on both: great work, but iterations could be made. The pupil remarked, tongue-in-cheek, that he believed his creation to be perfect as it was. We argue that "this rehearses chaotic conditions and epistemic uncertainty in the teacher-pupil relation, and in the pupil-world relation, an outsized part of which cannot be taught 'in theory', as the teacher remarked to [me], the latter would be like 'dry swimming'" (Paper 3, p. 15). In the other situation, the teacher was motivated to teach the didactic prototype, not least because app design had similarities in subject matter to his Visual Arts teaching. But it was also challenging to teach in daily practice, requiring many adjustments due to its complexity and various local technical limitations. The prototype here performs "tension and a difference between 'theoretical' and 'practical', inscribing pedagogical theory,

research, and knowledge into a theoretical artefact that prefigures and models [technology comprehension] teaching" (Paper 3, p. 19). The teacher experienced that taking part in the trial and trying out didactic prototypes was like 'building the boat while sailing it'.

This expression, like that of 'dry swimming', underscores how prototyping absorbs and reconfigures social and material agencies. Thus, we argue that "prototyping not only appears as a response via [participatory design] to digitalization but performs a digital world through prototyping by enrolling pupils, teachers, and subject matter experts in making, demoing, testing, and iterating on tangible and material artefacts—prototypes" (Paper 3, p. 5). This amounts to "an epistemic culture built on collaboration, provisionality, recycling, experimentation and creativity, which seems as much oriented to the production of technological artefacts as it is to the social engineering of hope." (Corsín Jimenez, 2014, p. 382). Finally, we argue that, based on the enrolment of participatory design imaginaries and these inflictions of prototyping in the school trials, technology comprehension is itself a prototype: It was prototyping *all the way down*[16], and the trial programme, too, can be understood as an instance of prototyping. The proliferation of prototypical things, experimental attitudes, democratic imaginaries, and open-ended processes of trial points to a recent call for a sociology of testing that draw attention to experiments as a form of governance that tests the very fabric of the social (Marres & Stark, 2020).

[16] We riff on the phrase "turtles all the way down", which, in myth, refers to the problem of infinite regress: the idea that every explanation requires another explanation, and so on, and so forth…

7. Technology comprehension in-the-making

From the empirical-analytical work done by the thesis' three research papers, three themes about knowledge-making in the trial of technology comprehension emerge (see also fig. 5). In the following, the themes 'digital building blocks', 'design imaginaries', and 'testing societies' are the passkeys with which I interpret the results of my work. I elaborate on the themes to develop the contributions of my thesis about how, in the postdigital technology education, it matters what knowledges make knowledge and what comprehensions of technology assemble (or do not).

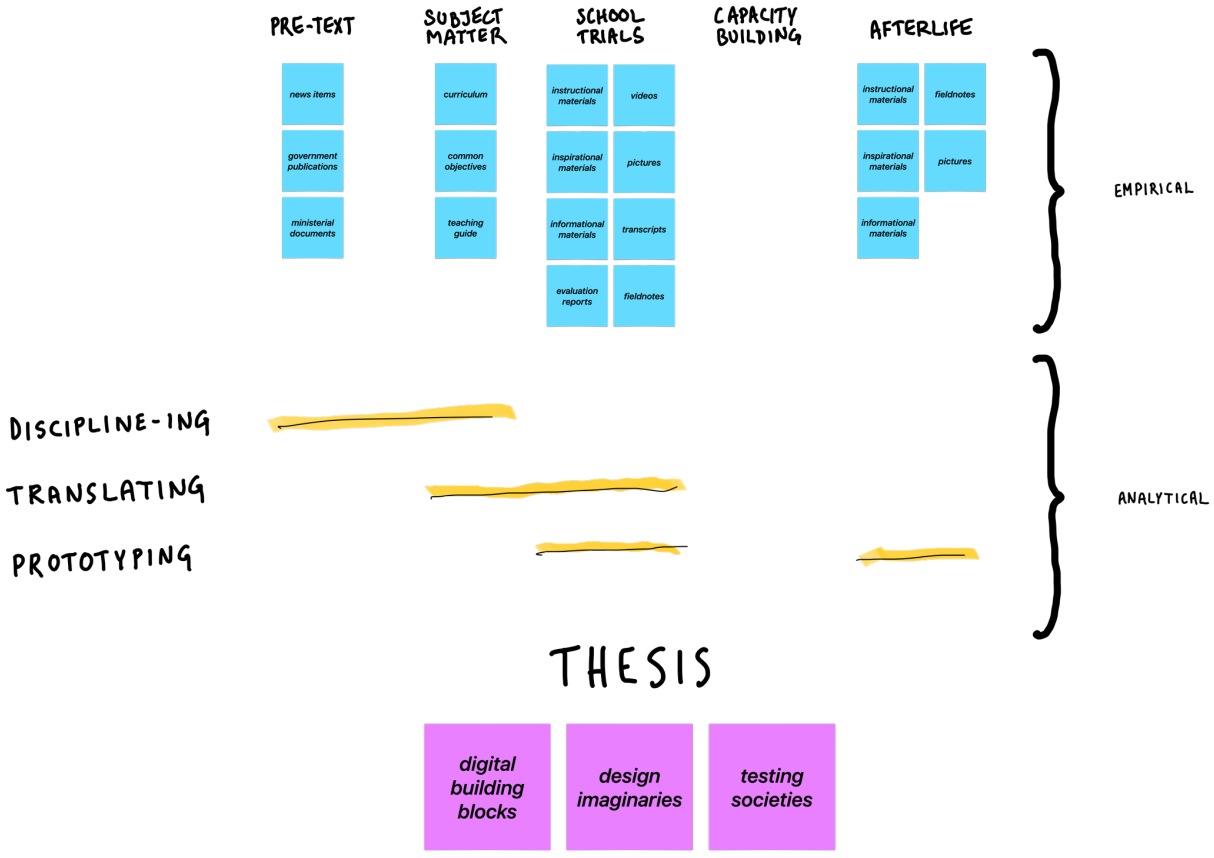


FIGURE 5: Illustration of the relation between empirical-analytical work done in select sites of the trial programme (**see also fig. 2**), and the themes that emerged from that work as found in the research papers.

7.1. Digital building blocks

The epistemic object generated by the trial programme, technology comprehension is not only a socially, discursively, materially constructed knowledge. Its making is also a matter and process of constructing and ordering the world where that knowledge can be seen and hold as valid, true, and desired—or not.

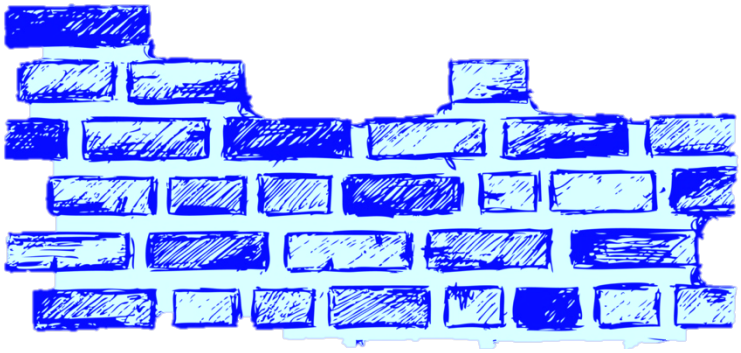


IMAGE 22: Ballpoint pen sketch of laid bricks by Oleksandr Melnyk. Source: Colourbox.

Technology comprehension prescribes skills and competencies for human intervention in a society where digital technologies are pervasive, seeing civic participation as a matter of engaging with what is perceived as the digital fabric of all things social. The subjectivity that emerges is that of the technologically educated digital citizen who, through 'designerly' conduct, is afforded agency to mould the digital fabric of social life. The world where that knowledge is legitimated is one where 'everyday life is digital'—made up of digital building blocks.

In terms of world-making, ontological politics, the conceptual premises of technology comprehension renders the world digital and prescribes a human-centric view of how, and for whom, change in this world can come about. As I interpret this, it seems like technology comprehension concedes to a technologically determined view but professes to recoup human agency by making humans skillful at manipulating digital fabric, as opposed to 'being overrun' by it or being *programmed by* the technology rather than *programming it*.

What is crucial and desired knowledge in the public school (and thus world-making) is ritually narrated in policy texts and pronouncements by political actors. To the extent that government policies propose solutions to problems, the solutions are usually presented as responses to conditions 'out there' or in the future. The subject proposal invokes the future to legitimise particular forms of organisation of social life in the present (Popkewitz, 2015; Rensfeldt & Player-Koro, 2020). A contingency of this problematisation is that some individuals, social groups, or ways of being are empowered, while others are disempowered; some are celebrated, while others are rendered problematic.

Poststructural approaches to policy study complicate that relationship and offers another view into the world-making in technology comprehension. E.g., Carol Bacchi's 'what's the problem represented to be? (WPR) approach (2009; 2012). The premise of that approach is best explained in the basic vernacular that when someone presents a solution, this tells you what they think the problem is. Thus, the WPR approach is interested in how problems are made (in e.g., policy text and pronouncements). Asking what the problem is represented to be is to interrogate problems and solutions as constitutive. Such analyses disrupt the view that the problems governments, expert decision-makers, politicians, or other empowered actors suggest interventions to are exogenous. And not only is it endogenous—it also becomes possible to imagine how to intervene and develop for more e.g., more just, sustainable, and accountable problematisations that empower.

It is worth pointing out that the digital reality and digital building blocks are endogenous, performed into being by exactly the conduct of proposing a technology school subject. This enacts the sociotechnical complexities it is said to intervene in. In the proposal, digitalisation and sociotechnical complexity is posed as the reason—the problem—which makes it urgent and elementary for young people to become not only users, but analysts and creators of technology. That reality, however, is performed in the same action that the subject proposal problematises it. This is not to say that digitalisation is made up or that digital technologies are unproblematic, but to highlight that this has implications.

The digital citizen is enacted in the situated practices of other domains of public governance as well. The 'digital inclusion' agenda makes public sector digitalisation focusing on 'including' individuals who are deemed non-digital and problematic; the digital society is not the problem but implicates citizens in reproducing the digital order of society.

This is a relation to be aware of. It limits how change can be imagined when technological solutions are posed to society's problems. This problematisation formats how mechanisms of social change and civic agency are ordered in ways that limit the conditions of possibility for worlds conceived in terms other than digital. However, rather than doing away with technology comprehension because of its philosophy of technology, what this thesis shows is that what is enacted as matter of fact is exactly an enactment and it can thus be otherwise. E.g. other relationships and views than that of a strict human-technology binary can be imagined (Danholt, 2021). What is at stake in putting technology comprehension on the school schedule is, exactly, understanding how to co-exist with digitalisation and digital technologies; whether problems are always design problems; or whether one can legitimately be averse to creating more technology. These latter worlds are not necessarily the better alternative, but they are invisible when society is rendered as a box of digital building blocks. It is worth asking what other things can be put into that box, or whether to find a different box entirely.

7.2. Design imaginaries

Subject matter experts enrolled in defining technology comprehension recommended a design approach to technology comprehension (see Iversen et al., 2019). Such an approach was said to deliver on both the creative-constructive and critical aspects of formative education, and the civic ideals of democratic participation in a digital society. The intent, however, was not that all children should become designers, developers, or systems engineers when they grow up (a point I will return to). Related to the latter, computing and design, the two main disciplinary domains inspiring technology

comprehension, were even worked into a new concept 'computational empowerment'[17] (see Wagner et al., 2020) by the main architects of the subject.

IMAGE 23: Ballpoint pen sketch of a pair of glasses by Oleksandr Melnyk. Source: Colourbox.

The proliferation of design into domains and conduct not traditionally associated with design is not a new phenomenon. Thinking and doing in terms of design, whether it is defined as design thinking (Cross, 2011) or seen as a broader concept, has, arguably, become a more general heuristic. Latour remarks that "design has been extended from the details of daily objects to cities, landscapes, nations, cultures, bodies, genes" (2008a, p. 2). In that sense it is not at all surprising that design figured so prominently in technology comprehension's subject matter and in questions of bildung and didaktik. Pedagogic and education-scientific research has sought to develop design for the public school, e.g. design competences in curriculum (Rusmann & Ejsing-Duun, 2021), participatory design's philosophies for realising democratic goals (Iversen et al., 2018), and as 'design for learning' (Paaskesen & Nørgård, 2016). What I highlight here, is how a design approach was translated in the trial programme.

Leading experts wholeheartedly promoted the promise of a design approach. They referenced pedagogic and education-scientific research and literature, and to the point of 'making, instead of only using technology. But the design approach was also critiqued in what I see as a ritual of struggle over the

[17] Not to be confused with the digital empowerment competency area.

matters of fact of public-school education. Subject matter researchers problematise emerging or existing educational content. I.e., the capacity of different disciplines, methods, and academic-scientific knowledges to deliver on bildung.

The competency model prescribes what I called a Swiss army knife of skills and competencies. Though the four areas of the competency model are said to be equal, and the overall composition of the subject is said to be holistic and combining a mixture of social, human, machine, and technical elements, how well-developed those areas remains up for debate. STS, among other hinterlands, is used to complicate the epistemic object of technology comprehension. E.g., Andersen and Tafdrup (2021), argue for "what could tentatively be termed an STS-based Technology-Comprehension" (p. 221) to inform, further, the 'digital empowerment' competency area using ANT terminology and adopting a historical focus, too. Their starting point is that most of the competency areas have an academic-scientific basis in the form of concepts and tools, "methods and theoretical resources" (p. 221), and they discuss how STS concepts could be useful in conceptualising this the Digital Empowerment competency area.

In the trial programme, the design approach is translated into 'school knowledge' to deliver on bildung and didaktik, enacting and handling different boundaries between 'theory' and 'practice', of the mind reflecting on technology vs. getting 'hands on' with technology; of academic-scientific and subject matter consultancy knowledge and local teaching practitioner knowledge in the everyday locale of school. Thus, imaginaries of design, thus, perform as fixes, but also crystalise established tensions and struggles of knowledge production in the public school. E.g. the sociocultural issue of academisation (*akademisering*) and the political economy of knowledges theoretical, practical, experiential, and so forth. This is a topical concern in Danish society and the debate about the public school and its hinterlands. Critically examining technology comprehension sheds light on the reproduction of the digital society, and who belongs in and can shape it. To follow the thread of design imaginaries in school development for the postdigital society is, I argue, a passkey to

understand unfamiliar registers of knowledge politics (Fenwick & Edwards, 2019) other than those explicitly pronounced in the subject proposal.

7.3. Testing societies

Imaginaries from Participatory design and design approaches to social life also introduce prototyping to the public school. They introduce, and elaborate on, experimentation as a form of epistemic practice, organisation, and governance. The trial programme itself can be understood as a prototyping process where the 'under-realised' technology comprehension subject is itself a prototype.

IMAGE 24: Ballpoint pen sketch of test tubes by Oleksandr Melnyk. Source: Colourbox.

The fact that technology comprehension remains in development and has only been trialled is not a novel insight. Anyone can go to the Ministry's website and download the subject proposal. If browsing the subject proposal's documents, the reader will notice that the pages are watermarked with the word "*forsøg*" (experiment) in large font. This serves as another reminder that the trial of technology comprehension was exploratory and probationary. Yet it was still highly consequential. The trial programme was launched to conceptualise, trial, develop, and evaluate technology comprehension as a potentially mandatory school subject. For actors involved with the trial programme, its afterlife was a time of, first, waiting for; next, disappointment; and since, efforts to keep the

dream alive as the future of technology comprehension for the public school remains uncertain. As I have argued earlier, it was astonishing that, in broad terms, 'nothing' came of the trial programme, but just as astonishing that it took place at all. For me, the trial was a way to engage with the tension between the real and the imagined, and to question why the trial programme is of material public concern. It was an experiment, and it is over. Experimentation takes place in diverse practices, and the expectations of their outcomes vary greatly. Goalposts move. In what analytical terms can we treat—both seriously and critically—an experiment?

Marres and Stark (2020) take an interest in testing, in particular 'the ubiquity' of testing. They point out that it has become commonplace to use experiments as a form of governance or to frame political interventions. In this way, this is similar to the emergence of the trial of technology comprehension. However, rather than testing having 'moved' from the confines of scientific conduct of not only natural science laboratories, but also social-scientific field experiments, to societal settings, something else is at stake. Something that requires a new sociology of testing, one that moves beyond studying 'testing in the social', and 'the social in testing'. Similar to testing, prototypes figure something, and they have material-semiotic agency and are performative artefacts. Studying inflictions of prototyping in Paper 3, Gad and I argue with the phrase 'prototypes all the way down', how the trial programme propagates a prototyping culture. Indeed, I would claim that technology comprehension is, in the words of Corsín Jiménez "more than many, less than one" (2014, p. 381)[18]. The implication of this view is an opening for new experiments, e.g., STS or a critical Tech-Ed, to interfere with the attachments and relations in this context.

[18] With this phrase, Corsín Jiménez plays on Marilyn Strathern's concept of partial connections being more than one, less than many (1991/2004)

8. Conclusion

I learned early that the imaginary and the real figure each other in concrete fact, and so I take the actual and the figural seriously as constitutive of lived material-semiotic worlds.
(Haraway, 1997, p. 2)

This dissertation has been about technology education and knowledge production in public schooling and the postdigital society. Putting technology comprehension on the school schedule, potentially in the form of a mandatory school subject, was a political intervention aimed at formalising technology education; at making young people makers, not only users of technology; at cultivating active participants in a digital democracy and grow the digital democratic Danish nation-state. The trial of technology comprehension mobilised the public school's parties to conceptualise, test, develop, and evaluate technology comprehension; to experiment with and experience new forms of learning, teaching, and organisation that necessarily come with a new subject matter, and which enter into relations with the matters of fact, rituals, and canons of the public school. E.g. bildung, didaktik, experimental pedagogical development work, and school governance.

The trial programme offers scale to understandings of what constitute technologically educated civic subjects, digital citizens, and schoolchildren. It gives scale to particular epistemic practices for critique and intervention in a reality that is thoroughly represented as digital. In that sense it is political. Because it matters what knowledges make knowledges; what relations make things, and what things make relations. Using STS and a material-semiotic approach, I have conceptualised the trial programme as a phenomenon where those possible relations got tested, celebrated, critiqued, codified, handled, and so forth, by heterogenous human and non-human actors. I have examined the social, material, technical, and discursive work of, in particular, subject matter experts, teachers, researchers, learning consultants, and policy-makers. I have examined knowledge production in the trial programme as a relational

phenomenon to understand what comes to be understood as affording technology comprehension and what knowledges, methods, and instruments, i.e. what lived worlds and realities they enact. I have engaged this work through ethnographic methods, critical reading strategies, and experimental ethnographic analysis.

Ontologically intervening in the making of technology comprehension with STS and material-semiotics is to become "ready to transgress the more limiting categories and constructs of current educational practice to embark on genuine transformation" (Fenwick & Edwards, 2019, p. 13). It is to critique and interfere with the relations of knowledge production and technology education in the public school. And, as I do with this thesis, contribute to the ongoing development of technology education and to critical research that examines how such education is assembled, i.e. a critical Tech-Ed. As such, I find that:

The work and knowledge-making of discipline-ing matters profoundly to schooling and citizenship. Making civic subjects that encounter digital technologies and digital society as merely digital building blocks to be made sense of and reworked with a design approach, is not enough. Intervening with STS in this is getting to make room for other understandings of the relationship between humans and technology, or the more-than human and technology. It is to stay with the trouble of the Danish state and other decision-makers' problematisation of digital citizens, not only in the public school, but in other spheres of the Danish society as well.

The trial of technology comprehension was an effort to settle forms of knowledge by putting them to work. A design approach, in particular, was deployed as a heuristic, epistemic practice, and overall motor in learning, developing, teaching technology comprehension. Actors entered into relations accepting the design approach, performing its capacity be an answer to the sociotechnical complexity of a postdigital society, but also bringing into view an enduring division between what is so-called theoretical knowledge and conduct, and practice knowledge and conduct. Imaginaries of design are complex, but useful to critically engage with to better understand how these patterns enact the conditions of future postdigital society and the comprehensions of technology that proliferate.

The vocabulary of testing societies makes it possible to understand piloting actions and technology education development as possible to intervene in, not just because as experiments they are ephemeral, but rather because the trial did generate worlds at the expense of other worlds, which we can speculate on. The trial programme as an experiment puts not only technology comprehension to the test, but also tests the social fabric of postdigital Denmark. Thus, interfering in the political, epistemic, and cultural affordances of the test itself is to intervene in the knowledges that make knowledge, and the trajectory of society.

Future research should collate the above to explore how research-based knowledge about technology comprehension in-the-making may be used to further understand the public school in the postdigital society. This is a question that the further development of technology education in Denmark is tangled up in, and as such it is likely to remain a matter of both civic and academic concern for the foreseeable future.

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Part 2: Research papers

Matters of Subjects: The Digital Citizen in Technology Comprehension

Simy Kaur Gahoonia

Forthcoming, *Digital States in Practice* (Eds. Katrine Meldgaard Kjær & Jessamy Perriam)

Introduction

As Felicitas Macgilchrist remarks, "much discussion – euphoric and dystopian – about the kind of education necessary in the "twenty-first century" revolves around digital technologies" (2019, p. 239, emphasis in original). There is now an increased awareness among scholars, educators, researchers, politicians, parents, children, activists, industrialists, and the public at large that the ongoing digital transformation of society brings with it a need to transform basic schooling and curriculum in order to equip young people for not only the complexities of this present reality of childhood, but also their supposed future as citizens, labourers, change agents, developers, and community members in a digital society. This awareness and the educational initiatives it has borne in national school systems around the world have been of interest in both local and transnational policy sites. The European Commission, which governs a commensurate space of education across many nation states, has been following the implementation of namely 'computational thinking' (Wing, 2006) in school systems (e.g., Bocconi et al., 2016; Bocconi et al., 2018; Bocconi et al., 2022).

Denmark, a small country with a population of approx. 5.9 million, is often touted as a frontrunner in digitalisation. The Danish state has been committed to rolling out a comprehensive, now decades-long, national digitalisation strategy that has made close to all interaction with the state and society at large contingent on digital platforms and processes. And it applies to virtually everyone: companies, individuals, public institutions, and non-profit organisations. Denmark is at first glance a highly digital society with a seemingly digitally competent business sector and a well-faring 'early-adopter' digital public. But research shows a much more nuanced, complicated, and even

problematic picture. At worst, this surface-level diagnosis of 'Denmark = digital' obfuscates the daily struggles and marginalisation of those individuals deemed 'non-digital' by the state (Carreras & Finken, 2022), and who have become the objects of concern in the state's 'digital inclusion' agenda (Papazu et al., forthcoming). At best, presenting as a 'digital Denmark' is something that takes a notable amount of statecraft, government initiative, and knowledge infrastructure to establish and maintain.

The Danish public school, *folkeskolen*, (the public school) plays an important role in this. The public school is attended by 86 % of all Danish schoolchildren aged 6-16, and it is widely considered the extended arm of the welfare state (Coninck-Smith et al., 2015, p. 383). The public school is also no stranger to the political, practical, and cultural problematique of educating young people for life in a digital societal context. Most recently, it has tested a technology subject matter and curriculum that draws significantly on design narratives and traditions to equip the future citizen for life in a society where digital technologies are seen as catalysts for change, including changes to Denmark's educational and democratic values of inclusion, competency, empowerment, and participation.

In the years 2018 through 2021, the public school was the site of a much-anticipated experimental effort to develop, trial, and potentially introduce a new mandatory school subject on 'technology understanding'. The school subject, called Technology Comprehension (DA: *teknologiforståelse*) (TC), combines elements of computing, design, and societal reflection (Wagner et al., 2020). In early 2018, the Ministry of Education[1] (the Ministry), which launched, funded, and led the programme, appointed a group of education experts to write a *course proposal* for the novel subject matter and formulate its learning goals. The course proposal would then form the basis of a 3-year pilot of TC in 46 schools across Denmark. The course proposal outlined and contextualised the skills and competencies considered to be elemental for Danish school children in order for them to comprehend technology appropriately. It also included a teaching guide, in which novel terminology and teaching approaches relevant to TC were introduced to teachers and other participants and stakeholders in the experimental programme.

[1] It is currently named the Ministry of Children and Education.

The Ministry wanted the subject matter to be 'creative' and 'critical'. With reference to the purpose of Danish schooling, charted in the act on the public school (Folkeskoleloven, 2020), it should also be, 'formative'. That is, it should support the pupil's process of personal development to become a self-determining individual, who can participate actively and constructively in a democratic society marked by increasing digitalisation i.e., as a kind of digital citizen. The public announcements about the trial programme, many made by the then Minister of Education, Merethe Riisager, made it clear that the initiative with TC was grounded in a conviction that digital technologies were now ubiquitous, constituting a digital reality for which the public school had to adapt in order to live up to its purpose. Therefore, according to Riisager and many polities and interest groups, who shared her views, the central proposition was that "children should not just be users of technology"; They should learn to be "creators of technology– rather than just users". They should understand and be creative with "the building blocks of technology" (Undervisningsministeriet & Styrelsen for IT og Læring, 2018, p. 2). At the time of the trial, then, children-cum-citizens undergoing TC education were imagined as not only digital citizens, but a particular kind of digital citizen, the capacities of which were negotiated across public policy, curriculum initiatives, digitalisation strategies, professional practice communities, and industry associations.

The trial programme to strengthen technology-understanding was launched and funded as part of a government-led coalition's initiatives for Denmark's 'digital growth' (Regeringen & Erhvervsministeriet, 2018, p. 37). It was not conceived as an implementation project, but rather a limited period of development and trial, concluded with an evaluation of the insights, knowledge, and experience gathered about how to possibly introduce such a subject in the public school. After this, there would be a political assessment as to the future of TC. This assessment came in April 2022, when the Ministry, now led by a new government coalition, stated that they had no plans to develop TC further. As of writing this, the mandatory school subject TC remains shelved. Despite this, the cultural-historical significance of the Danish government even attempting to put a new subject on the school schedule should not be lost. The last time a new subject became a fixture in Danish schooling was in 1992[2]. It is not something that happens every day.

[2] In 1992 a subject on social and civic studies (*samfundsfag*), and a natural science and material tinkering subject (*natur/teknik*, now *natur/teknologi*) were added as mandatory subjects.

Additionally, the trial of TC and its focus on establishing a substantive subject matter and knowledge area for technology education marked a significant shift from the previous decade's instrumental and infrastructural approach to technology in schools and schooling (Caeli & Bundsgaard, 2019). These were the years where classrooms were equipped with smartboards, pupils were handed iPads to read on, teacher-parent communication moved to the intranet, and digital learning platforms and teaching materials became the norm. Finally, the steps towards a mandatory TC subject matter were a change from treating technology as a topic in or across the subjects to now conceptualising and addressing it as a distinct discipline. The trial programme also followed close on the heels of several glossy strategy documents released by the then Ministry, which problematised the aforementioned 'procurement years', and made the school child the object of a particular, and relatively new, civic human-technology relation: That of the pupil as critic and creator of technology, rather than just user of technology.

Complicating Technology Comprehension

While the Minister's statements about technology users and creators are as explicit and polemic as they come, the policies, framing documents, and educational initiatives they are put in relation to by decision-makers also have conceptual premises that reproduce and/or introduce certain orders of relations between young people, technology, and society by dialectically demarcating and constructing problems and proposing their solutions, e.g. educational ones (Bacchi, 2009). Although such prescriptions and normative statements do not determine the experiential effects and lives lived of those who undergo schooling, they do arguably put forth strong ideas about what ways of being a person in the world are good, possible, and desired, and those that are less desirable, lacking, and/or problematic. In other words, education is politics by other means (Gorur et al., 2019), decidedly implicated in shaping the material circumstances of experiential effects and lives lived. Furthermore, education is not just politics at the scale of decision-making in government, but also in the local practices of everyday schooling, e.g., classrooms, teacher lounges, pedagogical training seminars, playgrounds, municipalities, research institutions, and school boards.

A central device in the conduct of schooling is the national school curriculum. In critical analyses of government, power, and policy, the school curriculum can be understood as a 'technology of government', an apparatus the state can use to exercise

power 'at a distance' (Rose & Miller, 2010) from that everyday life and localities of schooling. One of the discursive features of the school curriculum is that it relies on describing an idea of the future in order to legitimise planning and governing the immediate present (Popkewitz, 2008). The school curriculum is therefore of highly political, practical, and organisational concern. To this end, the curriculum also concerns itself with enacting an idea of 'the pupil'. This idea often also maps on to ideas of 'the future citizen' and/or 'the child' (Popkewitz, 2004). The child, for example, is supposed to enter the role of the pupil, undergo schooling, and become a person that can be 'seen' and 'known' by the state (Scott, 1998) as a citizen, and simultaneously also see and know itself as an individual civic subject that is party to co-existence with others. Bluntly, but aptly put, society is made by making the child (Popkewitz, 2008).

This echoes John Dewey's diagnosis of the relationship between the child and the curriculum (1966). Dewey, whose pragmatic and pupil-centred philosophies also undergird the contemporary institutional affordances and pedagogical practices in Danish schooling, stated many years ago that: "The fundamental factors in the educative process are an immature, underdeveloped being; and certain social aims, meanings, values incarnate in the matured experience of the adult. The educative process is the due interaction of these forces." (Dewey, 1966, p. 4). This relation is the focus of this chapter, which examines how digital society is made by making the digital citizen through the school curriculum, the curriculum being a "regulated enactment of the competency of the future citizen" (Popkewitz, 2004, p. 22). Just as policies on education in the 21st century imagine a variety of 'digital human subjects' (Macgilchrist, 2019), so, too, do school curricula, telling stories that are rehearsed at the scale of the classroom and society (Gudmundsdottir, 1991), a majority of which now cast humans as protagonists in a cosmopolitan world (Popkewitz, 2008). This matters because the school policy will be "stigmatising some, exonerating others, and keeping change within limits" (Bacchi, 2009, p. 65).

A key concern of this chapter is to both encounter and complicate the TC course proposal by asking of the TC course proposal: What do its writers and decision-makers want children to learn, and who or what do they want children to become? How is this expressed with regards to a future citizen, and what form does it take, e.g., what are its emergent capacities, responsibilities, and penalties? And also, what are the logical

underpinnings and conceptual premises of the subject matter, and what social orders of hegemony or subordination does it bring to the fore?

To aid in complicating the course proposal, I draw on philosopher and historian of ideas Michel Foucault's work, much of which inspires the critical thinking about curriculum and curriculum-making expressed by the scholars referenced above. Foucault was broadly engaged in a diagnostic of the contemporary modern era, attending to the material and discursive relations of power, forms and formations of knowledge, state and government conduct, and (groups of) people and their becoming. The outcome of his varied studies and innovative thinking is not only the argument that the former is intricately related and can be investigated through study of archives of texts and situated practices. In particular, the post-structural studies that draw on Foucault often conceptualise his contribution to critical inquiry as a theoretical 'toolbox' of concepts and analytical approaches (see Hermann, 2006; Hope, 2015). As scholarly readings of Foucault's vast opus show, this toolbox is well suited for critical engagement with educational matters (Deacon, 2006). Not least what Deacon terms "the everyday mechanisms of schooling as a disciplinary technology" (p. 177), herein the ways in which the curriculum disposes the pupil to certain types of self-understanding and conduct in society. That is, how the curriculum is imbricated in the performance of subjectification, which for Foucault is "the modes by which our, in our culture, human beings are made subjects" (Foucault, in Rabinow, 2020, p. 7; see also Foucault, 1982). The subject figures of this always emergent and distributed subjectification refer to "the specific cultural form that individuals adopt in a given socio-political-historic configuration in order to become a legitimate, desirable and competent being" (Macgilchrist, 2019, p. 242).

It is this analytic I apply to the TC course proposal when I analyse its three distinct documents: 1) the Common Objectives (DA: *Fælles Mål*) (hereafter referred to as Objectives) 2) the curriculum (DA: *læseplan*) (hereafter referred to as Curriculum), and 3) the teaching guide for the experimental subject TC (DA: *undervisningsvejledning*) (hereafter referred to as Guide). The course proposal was made public on the Ministry's website (Undervisningsministeriet, 2018) on December 21st, 2018. As of writing this, it remains available for download as .pdf files in Danish. Due to the scope of this chapter, I do not offer an exhaustive analysis and discussion of the course proposal. Rather, I present my encounters with TC, organised in three analytical sections, respective to the three texts in the curriculum proposal. My aim is to start unpacking the basic question of Dewey's

proposition above: given that the premise of education is to equip the child to take on the life of a citizen, what educational content should the child get, and what are the implications of this?

The Common Objectives: Human Agency and Technological Determinacy

Every subject in the Danish primary and lower secondary school has a set of learning goals called Common Objectives. These are defined and authorised by the Ministry, and it is not uncommon for this to be done in advisory processes with relevant experts and stakeholders, such as educators, academic researchers, subject matter specialists, consultants, and industry representatives. The Common Objectives are an essential governing instrument for an otherwise relatively autonomous locale of schools and classrooms. That is, while the municipalities manage their schools akin to organisations, and each school has a local leadership, the pedagogical staff at each school is free to organise, select materials for, and conduct their teaching as they see fit, as long as it echoes the goals. Thus, the Common Objectives set an important practical framework for schooling and are also the primary indicators of the epistemic priorities and philosophies of technology inscribed in TC. The Common Objectives state that, in TC:

> The pupils develop academic competencies and acquire skills and knowledge so that they can participate constructively and critically in the development of digital artefacts and understand their impact. Pt. 2. The pupils' mastery of the subject necessitates a comprehension of digital design processes and the language and principles of digital technologies, for the purpose of, iteratively and in collaboration, being able to analyse, design, construct, modify, and evaluate digital artefacts for the purpose of learning, and solving complex problems. Pt. 3. In the subject TC, the pupils acquire academic competences to understand the opportunities of digital technologies and the consequences of digital artefacts, for the purpose of strengthening the pupils' preconditions for understanding, creating, and acting meaningfully in a society where digital technologies and digital artefacts, increasingly, are catalysts for change.
>
> (Objectives, p. 3).

These Common Objectives suggest that creating technology has educational and formative value. It also emphasises an imperative to materialise technology as part of the learning activities in TC. The formative good is to embody creative and 'designerly' capacities and attitudes. Importantly, the Objectives understands creativity as creative-constructive practice, which means that pupils should be learning by making and crafting technological things, not by only talking about them. Critical engagement is premised on getting 'hands on' with the technology and must not be limited to critiquing technology viva voce through discussion-based activities. The pupils' inquiry should be directed at

the many technological objects that are a part of their daily lives and the society around them.

These virtues of material engagement with 'the digital fabric of life' or 'building blocks of technology' are underscored by the terminology of the subject matter, specifically in how TC distinguishes between 'digital technologies' and 'digital artefacts'. This seems puzzling at first, but a footnote in the beginning of the companion Curriculum text states that the distinction is used systematically: a 'digital artefact' means something like an app or a device, "brought into being in order to fulfil a specific purpose and therefore [it] contains an intentionality regarding its use and function". 'Digital technology', on the other hand, is "the potential that exists in a digital technology as material, which is used in the construction of a digital artefact" (Curriculum, p. 5).

Recall that, in political pronouncements about TC, the ubiquity of digital technologies in society constitutes a de facto digital reality. In the course proposal, this digital reality is rendered as a material that can be moulded by an individual with the capacity to think and do in terms and techniques of design. The material can be (human)made–its affordances partially fixed by a designer or developer–but it can also always be remade by creative-constructive practice, rearranging the supposed digital building blocks of society. This means, in theory, that in a learning situation where the pupils are being creative, they would be manipulating digital technology, or digital matter, in order to produce an artefact. Equally important, making artefacts is about turning digital technologies into objects of reflection and analysis so that pupils understand all technologies as designed; as something made by someone, be it a company or a classmate, with particular intentions and as something emerging from a design process and therefore something which could always be designed otherwise.

This exposition, however exciting and novel, has important implications for, and implicitly proposes limits to, how people's relationship to technology can reasonably be imagined. Emergent is a citizen that understands their relationship with technology as one that puts control squarely in the hands of 'the human' for human purposes. Furthermore, it implies that problems experienced by the human individual, communities and/or society can be remedied by design or redesign of digital technology–such problems simply constitute design challenges, which can themselves be complex or downright 'wicked'. Here, the capacity to recognise digital technology as a material is presented as vital for social conduct itself, because doing so allows a person to, then,

engage with that material and be an agent of change. It conditions the citizen to not only be, and have the capacity to be, reactive to technology (i.e. use it), but to be active (i.e. productive) in their meeting with it, thereby implicating citizens in reproducing the order of digital civic life that TC is said to prepare them for.

Users, creators, critics. These are a variety of subject positions pupils can take in their relation to technology, and as mentioned earlier, some of these are certainly favoured in TC and the present debate about the future of technology education. Of concern is that, regardless of the claims to human empowerment, the premise of TC remains technologically determined. That is, societal problems can take many forms, but their fixes are heavily implied or urged to be technological. Inscribing this technological view in learning goals arguably does much work to foreclose the potential for social change not bound up in the development of new or more digital apps, processes, or infrastructures.

Granted, TC can be understood as an effort to recoup some of 'the human' supposedly lost to decades of dehumanising automation, digitalisation and technological transformation, a valid concern and viewpoint in debates about digital transformation and its impact on almost all spheres of life. Not least those of children, epitomised in phenomena like fake news, cyber bullying, platformisation, and data commodification. One can speculate about whether and how TC is an effort to restore 'the human' and soothe anxieties about these sociotechnical issues. What can be an issue is that this prism of the human reinforces a stark human-technology binary, becoming, as Peter Danholt (2021) argues, narrowly humanistic and anthropocentric to the point of significantly limiting more-than-human technology-understanding. As expressed by the Common Objectives, TC keeps change within limits of that which can be achieved with more technology, reducing the capacity to imagine lives and living otherwise as well the techniques of intervention to enact that change.

The Curriculum: Of Competence, Empowerment, and Inclusion

The Curriculum is the document that describes in depth the contents and identity of the TC subject matter. One of the key and most debated artefacts in the Curriculum is the so-called 'competency model' (see fig. 1) which presents and organises the four domains of knowledge and practices that the TC subject matter is conceptualised through. Although the formative development, not employability, of the pupil is the main concern of Danish

schooling, education has become much more goal-driven over the past 25 years. Skills and competencies, the outcomes of teaching, are central in contemporary thinking about and development of curriculum. Similar to the Common Objectives, the Curriculum is highly politicised in addition to being of practical pedagogical concern, and it is also often the result of compromise rather than consensus about its composition and priorities. TC's four competency areas are defined as follows:

'Computational Thinking' unfolds the pupil's ability to translate a complex problem into something a computer can understand, making it possible to suggest a digital solution or automate a task. The pupils are familiarised with abstracting worldly phenomena. 'Technological Knowledge and Skills' is about knowing and handling digital technologies, such as computer systems, their languages, and their programming. The key concern is to develop an understanding, and use, of digital technology as a material for developing digital artefacts (as described earlier). 'Digital Design and Design Processes' aims to develop the pupil's ability to plan and execute a design process consisting of the elements framing, idea generation, construction, argumentation, and introspection. In 'Digital Empowerment', the pupils explore digital artefacts: their possibilities, consequences, and impact.

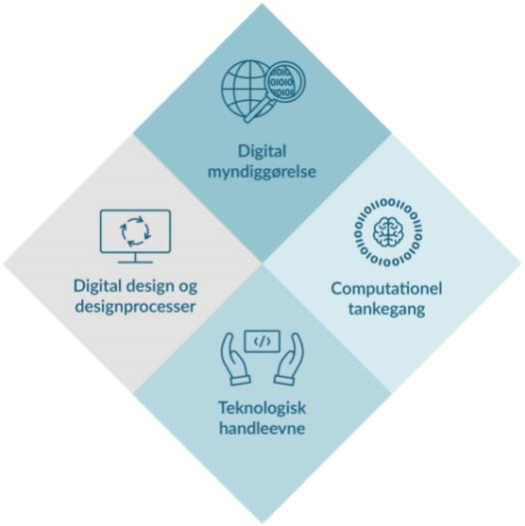

FIGURE 1. The competency model. Clockwise: Digital Empowerment (*Digital myndiggørelse*), Computational Thinking (*Computationel tankegang*), Technological Knowledge and Skills (*Teknologisk handleevne*), and Digital Design and Design Processes (*Digital design og designprocesser*) (Curriculum, p. 8).

The competency model shows that TC is composed of a combination of computing and design, 'the human' and 'the machine', 'the social' and 'the material'. This modelling

further indicates the supposed need for a variety of interrelated approaches to understand technology. The plurality is gestured at and celebrated by its writers and proponents, for whom it is demonstrative of a comprehensive, interdisciplinary, human-focused technology education, rather than an instrumental and narrow one. This is also apparent in how the course proposal and model was publicised during the trial programme, where subject matter experts affiliated with TC and the trial programme emphasised that each area should be considered components of a 'symphony', creating a harmonious (emu, n.d., para. 2) approach to understanding and relating to technology in society.

Through this mode of representation, the model and composition of TC's content prescribes a dexterity in the citizen akin to a Swiss army knife of knowledge, methods, and dispositions that equips them to be "active co-creators" of digital society (Curriculum, p. 5). The model is an inscription of TC as the educational answer to the complex condition of 21st century living, for which there is no single disciplinary approach, but a need for a holistic set of skills. However, as Bacchi's Foucault-inspired policy studies pedagogically put it, what someone suggests as the solution to a problem, also indicates what they think is problematic. The problem is as much a matter of proposition as proposing solutions is: The problem of complexity is not exogenous ('outside' of), the educational solution (e.g., TC), but co-constituted with the policy solution (Bacchi, 2012). That is not to say that complexity is unreal or entirely a rhetorical construction. Rather, it emphasises curriculum-making as an inherently discursive and material 'problem-representing' activity, one which also necessarily renders certain individuals or groups of people that populate the society 'problematic', whether explicitly or implicitly (Bacchi, 2009). By suggesting these varied skills and competencies, the model also performs into reality this very problem space of complexity that TC is made to intervene in.

A school subject in the Danish public school necessarily inscribes Danish society's ideals of e.g., empowerment in ways that empower some, while disenfranchising others. The citizenship education that is sutured into the public school and its subject matters is a process of normalisation and classification that intersects with other domains where the state 'sees' (Scott, 1998), shapes and overall concerns itself with citizens. While TC sets out to format the competencies of the future citizen, the citizen is never a finished subject, not even in the future. It is, according to Foucault, always becoming through subjectification, through being disposed to certain types of conduct, adopting a cultural

form to become a legitimate being, with the state as a significantly powerful arbitrator of those conducts and forms.

A good example of this is found in the ongoing public digitalisation effort of 'digital inclusion', where citizens, who for various reasons are excluded from the ecology of digital systems that the state operates within, are rendered as problematic and in need of intervention. Here, 'digital competencies', a notoriously nebulous term (see Ilomäki et al., 2016), which nonetheless, in situated practices of public digitalisation like digital inclusion signifies the capacity of a citizen to use the digital infrastructure through which much interaction with the state, its services, and civic democratic participation is mediated. The digital inclusion project, in particular, is one for which the active and participating digital citizen is 'the user' of technological solutions. The problem, on the other hand, is those classified as 'non-users' or 'non-digital' and become objects of state interventions.

It is reasonable that these different sites of practice (public schooling and public digitalisation) have differences in how they problematise the digital citizen. But even this partial comparison of state interventions crystallises how the goalposts of democratic participation in the Danish digital society are always moving. The digital citizen is subjected in and across many, sometimes similar, sometimes different, temporal, and spatial scales. What is desirable, legitimate, and unproblematic, e.g. the digital citizen is not a matter of fact, but one of concern (Latour, 2004; 2008): The digital citizen might be best understood as a figure that is always unsettled, but nonetheless legible in the state's conduct, whether these be the educative process of a TC curriculum or that of being enrolled in the digital infrastructure of the digital state of Denmark. Thus, the contours of a digital citizen, its form and its capacities and responsibilities, is certainly perceptible in TC, but it is also imbued with an ephemeral quality, because it is contingent on the problematisation and construction of a particular future.

The Teaching Guide: Participation by the Name of Design

The teaching guide familiarised teachers with the novel terms, methods, and workflows of TC As such, the Guide gives a glimpse into the nascent subject-specific didactic of TC. It is hard to overstate the importance of didactic (noun) in Danish education. To understand its importance also requires disentangling it from what the word plausibly evokes in Anglo-American audiences: that of "an overbearing person prone to moralizing and

lecturing others" (Retz, 2020, p. 415). In Denmark, didactic (or *didaktik* in Danish) stems from a German-Scandinavian intellectual tradition, where it is, theoretically but certainly also practically, a "language in which a common framework and set of referents [govern] discussion of educational theory, the practice of teaching, schooling, curriculum making and lesson design, teacher education, school administration, textbook production, the sites of exchange between teachers, teacher associations and in-service professional development, as well as issues concerning individual school subjects, academic disciplines, and forms of knowledge" (p. 415).

A subject-specific didactic, then, is specific to the subject matter at hand, and the issue of "individual school subjects, academic disciplines, and forms of knowledge" (p. 415), including how to plan, conduct, and evaluate teaching, and the concrete work methods the pupils will be engaged in. TC's subject-specific didactic could not reasonably be decreed by the Ministry. It had to be studiously established and developed by persons close to and knowledgeable about the daily educational practices, i.e., pedagogical staff, school personnel, and consulting subject matter experts. The language of TC–its subject-specific didactic, too, divulges the contours of the technology-comprehending digital citizen.

While TC was not explicitly conceptualised as a school subject about design, the course proposal consistently makes a case for the educational and formative value of rehearsing design practice with pupils, suggesting "design process-understanding as a didactic foundation" for not only TC, but also other subjects in the school (Curriculum, p. 49). The Guide also states that "it is central that the pupils learn to construct with digital technology (program, develop prototypes or use fabrication technologies) and thereby get the opportunity to create new and rethink already existing digital artefacts" (Guide, p. 10). This iterative, open-ended, and experimental approach is the identity of TC as a whole, not just the competency area of Digital Design and Design processes. In fact, "digital construction (including programming and prototype development) is central for this subject, and there will be thorough and focused work with this element - beginning from early schooling" (Guide, p. 15).

This is in part where TC supposedly has a unique take on how to do technology education, something that the architects of experimental TC are not shy about emphasising. They state: "In a Danish educational context, the philosophy in participatory design can be viewed as a driving force for ensuring that the students don't just learn

programming skills in school, but also become involved to such a degree that they can begin to cognise and create with the technology" (Wagner et al., 2020, p. 10). TC represents a particularly Danish approach to technology education, "inspired by descriptions of similar subjects internationally, but with a Danish angle with special emphasis on digital design and digital empowerment" (Curriculum, p. 3).

The design approach to technology-understanding expresses TC's historical roots in Scandinavian and Danish design and computing traditions. One that receives international attention because of how design theory has equal footing to computing, the latter being a leading concept and knowledge domain in many other nation's recent efforts to introduce technology education. The claim is that an interdisciplinary approach that embraces participatory design (i.e., a methodology that involves the users of future designed objects or systems into the design process) approximates better conditions for the pupil and future citizen to comprehend technology; That these engagements with technology are empowering. The making of TC as a school subject knots together Danish democratic virtues of empowerment and participation, and the material and epistemic practices of participatory design to make participation and empowerment into a regulated enactment of competency. As Bruno Latour has meditated on, design lends TC a theory of action (see Latour, 2008a) in the democratic project of Denmark as a digital society. It suggests the blueprints for a design-democracy-education complex as a way to handle the ongoing digital transformation of society, its strength lying in design's capacity to be both a matter of fact and a matter of concern (Latour, 2008b). A matter of concern (e.g., inherently open and unsettled, and possibly even wicked); but also performing as a matter of fact (e.g. as a bounded school knowledge, manageable as lessons on a timetable, over the course of 10 years of mandatory schooling).

But TC's emphasis on design in all its many forms risks overstating how much agency an individual is afforded by being able to do and think in terms of design. How far can such a claim to empowerment and participation in so-imagined civic design processes extend, given that, without systemic change, these are still formatted and gate-kept by political decision-makers, who choose which parts of society can be a matter of civic participation and design, and who is invited and included in the processes of iterating on a digital Danish democratic state?

Conclusion

Public education is routinely mobilised to make and remake society, shaping citizens and making them legible to the state and its conduct (Rose & Miller, 2010; Scott, 1998), but also to enact change. Change is part and parcel of education, and its institutions are a fitting place to intervene if you want to move society in a particular direction. If you want to do politics (Gorur et al., 2019). TC has this role in performing the next iteration of the digital Denmark. For a moment in time, during the trial and its immediate afterlife, TC almost took a nation-building role, by way of the subject's architects leading and substantiating it with historical Scandinavian and Danish participatory design and computing traditions.

The premise of the TC trial was, according to the then Minister, that children should not only be users of technology, but creators of it. It was due time that they learned the inner workings of technology, in order to both be able to critique it and develop more of it, for the purpose of both individual learning and making collective change with technology itself being the prism of that learning and change. As a school subject, TC's regulated enactment of competency is one that underscores a disposition to technology that is creative-constructive, rather than only reactive or reflective on it. This supposedly empowers the pupils and future citizens to take charge of the ways technology impacts their daily lives and society. However, this perpetuates a human-technology relation, or binary, that simplifies understandings of 'human', 'technology', and their relation. As Danholt (2021) points out, TC might be better suited to keep this relation unsettled and educate people to live with this uncertainty and learn to act under conditions of such uncertainty.

The premise of 'creators' and 'just users' is a binary construction that constitutes what in terms of subjectification is understood as a dividing practice. It does the work of "stigmatising some, exonerating others" (Bacchi, 2009, p. 65). Although it does not determine who end up as the celebrated creators and the marginalised users of future digital society, its effects are the carving up of the population into those who are problematic, cause for concern, and likely the objects of future inclusion or education efforts; and those who can be celebrated as proliferating technology and reproducing the digital hegemonic order.

Currently, the public, politicians, and practitioners have an awareness of TC. TC has a nascent identity and practice as a subject matter and a potential school subject. To the frustration of its proponents, TC remains deprioritised by those in charge of its future as

a mandatory school subject in the public school, something which has galvanised many to promote TC even more, and promote technology-understanding in general in the education system at large. This limbo that TC finds itself in presents an opportunity for TC to grow and become otherwise, specifically in terms of the beings it celebrates and the conditions of, limits to, and techniques of change it inscribes and teaches to pupils and future citizens in a digital society.

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ORIGINAL ARTICLES

Makers, Not Users: Inscriptions of Design in the Development of Postdigital Technology Education

Simy Kaur Gahoonia[1]

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Abstract

This paper directs attention to a recent government-led school development initiative in Denmark, where a broad concept and practice of *design* became central to imagining and reworking technology education for the postdigital condition, in which schoolchildren were imagined to become makers, not users of technological society. Using an analytical apparatus inspired by Science and Technology Studies (STS), the paper examines how and what understandings of design were propagated in the trial of technology comprehension in the public school. The paper examines two design models as didactic-pedagogical translation of design into the epistemic practices of the public school, articulated in the intellectual traditions of *Bildung* and *Didaktik*. Examining the knowledges that make knowledges, the paper contributes an elucidation of the features, capacities, and limitations of the concept and practice of design, as it is mobilised to make knowledge and subjectivities about agency and change for schooling in the postdigital educational future.

Keywords Technology comprehension · Design · Postdigital · Education · Inscriptions · Mattering

Introduction

Many recent efforts to introduce, develop, and expand technology education in national compulsory school systems are grounded in computing (see Bocconi et al. 2016, 2018, 2022). In this paper I direct the reader's attention to a recent government-led school development initiative in Denmark, where a broad concept and practice of *design* in particular became central to imagining and reworking technology education for the postdigital condition (see Macgilchrist et al. 2023).

During 2018–2021, the Danish Ministry of Education (The Ministry) ran an experimental programme centred on developing a new potential mandatory

✉ Simy Kaur Gahoonia
sgah@itu.dk

[1] Department of Business IT, IT University of Copenhagen, Copenhagen, Denmark

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school subject about technology in the public primary and lower secondary school, the *folkeskole* (the public school). The school subject was called technology comprehension (TC), congruent with an also emerging academic knowledge field of 'technology-understanding'. TC combined elements of computer science, design, and the humanities (Wagner et al. 2020) to make understanding of technology a multidisciplinary school subject that could equip children to become critical and creative in their encounters with technology. The dominant political vision for TC was that young people ought to become not just consumers of technology, but creators of the digital technological society they live in, both at present but also further along the trajectories of life-long learning and citizenship that the public school is tasked with preparing Danish schoolchildren for through the ten years of statutory education.

As the trial programme launched, first, a new subject matter was described by a group of subject matter experts appointed by the Minister of Education. Next, over the course of 2.5 years, the newly described subject matter was tried out in 46 schools, namely to facilitate the pedagogical development work on how to teach this new subject, and to see how it fared as a subject in everyday schooling. In both of these tracks of the experimental programme, *the broad concept of design was mobilised* by education researchers, school practitioners, pedagogical consultants, and subject matter experts to frame and drive knowledge-production. That is, as an approach to schoolchildrens' critical and creative-constructive learning about technology, and to organising large-scale pedagogical development work on a novel school subject and subject matter. When the trial programme concluded political decision-makers, now in a new government configuration, decided not to pursue further development of TC. Regardless, the trial programme was an engine for knowledge-production attending to postdigital technology education where design was made to have a significant though ambiguous and opaque role.

The confidence in design expressed by the trial programme's actors and stakeholders is not surprising. Design and its auxiliaries have become ubiquitous and familiar, no longer confined to the tasks of systems development or the trade of crafting functional and/or aesthetic objects. Nor is it solely associated with the professions of designer or developer. In a keynote on design, delivered on invitation to an academic society for design philosophy, sociologist, and science and technology studies (STS) scholar, Bruno Latour remarked that 'design has been extended from the details of daily objects to cities, landscapes, nations, cultures, bodies, genes' (2008: 2). According to Latour, in the contemporary 'design is applicable to ever larger assemblages of production' (2). Not least, then, to the (re)production of society that is the purview of public statutory education. In that regard *thinking and doing in terms of design* has in studies of education and schooling been everything from a curricular issue of design competences (Rusmann and Ejsing-Duun 2021) to a techno-optimistic culture of metropolitan public school reform (Sims 2017). The utility of 'design thinking' (Cross 2011) has been unfolded by education researchers for its potential in developing pedagogy and design for learning (Paaskesen and Nørgård 2016), as well as how participatory design's practices and philosophies can help realise the democratic goals of public schooling (Iversen et al. 2018).

In this paper I explore relations of design in the development of postdigital technology education, attending to the trial of TC as an assemblage of material, discursive,

social, and technical agencies. For one, despite the varied disciplinary make-up of computing, design, and humanities, TC's subject matter had a significant and deliberate critical, explorative, and maker-oriented 'design approach' to comprehension of technology (Iversen et al. 2019; see also Wagner et al. 2020), routinely espoused by the main architects of the school subject, who were prominent scholars in the fields of interaction design, informatics, and child-computer interaction. Second, the above was in part also the rationale for organising the local school trials of this newly conceptualised subject matter as a design project (rather than an implementation), in which subject matter experts and teachers at volunteering schools worked to 'co-create' (Tekforsøget 2018: 3) TC by collaborating on prototypical lesson plans called *didactic prototypes*. The Ministry and the consortium of institutions it contracted to conduct these school trials expressed that this conceptualisation and testing was an effort in gathering and joining theoretical and practical knowledge, becoming familiar with the new subject matter, and sharing experiences of teaching. To this end, *a variety of visualisations of a design approach for knowledge-making* proliferated in the trial programme to illustrate, scaffold, and pedagogically address taking a design approach to learning and development of technological pedagogy.

As design is looking more and more like a broad theory of action (Latour 2008), and a style of problematisation in the postdigital condition, it also formats the very concepts and practice of social change and human agency in various, but often technologically determined ways. As such, design becomes potent to everything from large-scale social innovations to curricular content. The sheer ubiquity of design as a concept and tool to navigate what is commonly understood as an increasing socio-technical complexity in the educational landscape is remarkable and warrants investigation. Particularly into how design is translated into the many layers of epistemic practice in compulsory schooling, where it intersects with the shaping of human individuals, communities, and societies. In this paper I ask: How is the concept of design translated into TC? What comprehensions of technology and society follow from the emerging design approach to TC and are thus set to be amplified and sanctioned by the public school? What are the implications of this in the context of a school system that seeks to produce citizen subjects?

While education does not determine lives, it does shape them. Schooling routinely meditates on the future, e.g. in the style of a national curriculum, which, according to curriculum scholar Thomas S. Popkewitz, mobilises ideas of the future to legitimise organising the present (2008). As technologies of government and power 'at a distance' (Rose and Miller 2010), national school curricula (of Western countries) and their development are acts of making society by making the child into 'the cosmopolitan citizen' (Popkewitz 2008). Or, as seen in recent policies about education technology, by imagining a variety of desired as well as marginalised twenty-first century 'digital' subject figures, e.g. 'The Social Designer' (Macgilchrist 2019). In the EU-centric commensurate space of education, there is 'growing understanding that digital competence goes beyond basic digital skills' (Bocconi et al. 2022: 5). The trial programme as a development project and the herein emerging experimental school knowledge of TC are problematisations of this, understood as efforts to make and remake educational content with complex digital transformation in mind. One EU survey of such initiatives remarks that Denmark has been 'extensively

piloting actions of this kind' (Bocconi et al. 2022: 5). As I explore in this paper, through such piloting actions, design's politics and social philosophies were actively leveraged by knowledge persons and educational actors to legitimise it as a foundational disciplinary undertaking in schooling due to its seeming capacity to traffic the purpose and ideals of the public school and Danish democracy while also holding digital technologies at arm's length. However, there is a need to elucidate the features, capacities, and limitations of design when it is translated into educational and pedagogical concerns.

Using STS approaches, I aim to contribute an understanding of these, by examining two distinct but interrelated translations of design into school subject matter to understand what knowledges make knowledge, and how. The study in this paper is based on a combination of desk materials (reports, promotional and inspirational material, and the subject matter description) and ethnographic data collected through fieldwork. I observed three months (September, October, and November, 2020) of in-person teaching of TC for pupils aged 9–13 at a school in the Greater Copenhagen Region of Denmark (which I will refer to as The School). During this time, I also shadowed and interviewed teaching staff, and saw how these actors approached design through visualisations and models.

STS and the Study of Knowledge-Production: Matters and Translations

In the trial programme, modes of knowing from distinct yet seemingly complementary fields of design and schooling coalesce to reconcile struggles and hopes for human society's continued existence with digital technology in a condition where problems are wicked, democracy is in crisis, and the planetary future is under threat. This is an immense scale of societal concerns, but they can be examined by looking at situated performances of knowledge and with attention to the material and social agencies that enact such phenomena. The field of STS has a long-standing interest in examining knowledge-production and its methods, and in particular the heterogenous arrangements of it in, e.g. experimental sites like the laboratory setting (see Latour and Woolgar 1987) as well as more public kinds of experimentation (see Shapin and Schaffer 1985). STS research has thus contributed conceptualisations of science 'in action' (Latour 1987), and as 'epistemic cultures' (Knorr-Cetina 1999).

STS offers a vocabulary and analytic suited to examining the contemporary mobility of design in educational matters and schooling. One analytic is Latour's proposition about how to think of and with phenomena as 'matters of concern' and 'matters of fact' (2004). The phenomenon of design can on one hand be conceptualised as a matter of fact, that is, as a stable phenomenon, the boundaries and veracity of which appear fixed, e.g. as a vocation, a piece of furniture, or an epistemic practice. Matters of concern, on the other hand, are contested phenomena, aptly understood as socially constructed and unsettled, with fuzzy boundaries, and, for better or for worse, not easy to agree on. Latour adds that 'matters of fact are not all that is given in experience. Matters of fact are only very partial and, I would argue, very polemical, very political renderings of matters of concern' (2004: 232). In this paper, the utility of the concepts

of matters of fact and matters of concern is, indeed, less as a binary, and more so as a heuristic to empirically explore the enactment of knowledge(s) and knowing(s) in relations where design is put to work to knot together imaginaries of the future, young people's education, pedagogy, and technology.

One of the central tensions in the trial programme echoes Tara Fenwick and Richard Edwards' remark that 'disciplinary canons (…) are not simply received; their reception requires certain practices, discourses, inscriptions and rituals' (2014: 39). I conceptualise the trial programme as an 'enactment of knowledge as matter-ing' (43; see also Law 2004). My attention is on translations of design into models as instances of epistemological scientific fact, and the social and material agencies that arise in the relations of these models. The models give an entry point into the matter-ing of design. In this paper, two such design models are entries to following actors', human and non-human as they problematise technology education, draw together existing practices, and translate and inscribe knowledges in the course of experimentally making TC. The models are performative and they perform knowledges and knowing persons: they perform, e.g. the technologically educated child, TC subject matter developers, or the pedagogically informed TC teacher—as much as they are made to represent knowledge and matters of fact, i.e. core educational aims, intellectual traditions, organisational frameworks, and practical realities of the Danish public school.

The Danish Public School: Who Should Children Become, and How?

Denmark, population 5.9 million, is regarded as a highly digitalised country, having undergone more than two decades of comprehensive digitalisation of the public sector, including schools and schooling. A total of 86% of all children aged 6–16 attend the public school, which is the public offer of the ten years of statutory education. While technology has been on the school agenda in a variety of ways, as content, in infrastructure, with pedagogy, and for organisational communication (Caeli and Bundsgaard 2019), the trial programme for strengthened understanding of technology was a historic event not because it dealt with digital technologies, but because it could potentially add a new school subject to mandatory schooling. It is extremely rare that the public school gets a new school subject at all. More than 25 years have passed since it last did so. The public school has a stated concern for conceptualising and practising education grounded first and foremost in the question: 'who should children become?', rather than 'what should children learn?'. To this end, the German-Scandinavian intellectual traditions of *Bildung* and *Didaktik* are important.

Danish law states that schooling should support the pupil's process of personal development to become a self-determining individual that can participate actively and constructively in a democratic society. The public school is responsible for the early period of school education, and through this also much of the formative development of the school-aged child. This is expressed in the term Bildung and denotes 'personal development guided by reason' (Retz 2021: 145). In education theory, Bildung is increasingly put in contrast to, e.g. curriculum instruction (Krogh et al. 2022). The purpose of learning and undergoing compulsory schooling in the public primary and lower secondary school is not the employability of

the child but preparing them for the socially and culturally desired trajectories of life-long learning and coexistence in a democratic civil society. To this end, The Ministry defines the learning goals of all school subjects. These are known as the Common Objectives, and often formulated advised by experts in the subject matter at hand. The public schools are managed by the municipalities in which they reside, and each school has a local leadership that handles daily affairs. Notably, the teachers have 'freedom of method': they are free to plan and conduct their teaching as they see fit using their professional pedagogical knowledge and discretion, as long as they aim for the general goals formulated for the subject area.

Thus, teaching is a relatively autonomous affair in the everyday of schooling, substantially articulated as Didaktik, a prism through which schooling is conceptualised in Denmark, in contrast to, e.g. curriculum. Didaktik is a 'language in which a common framework and set of referents [govern] discussion of educational theory, the practice of teaching, schooling, curriculum making and lesson design, teacher education, school administration, textbook production, the sites of exchange between teachers, teacher associations and in-service professional development, as well as issues concerning individual school subjects, academic disciplines, and forms of knowledge' (Retz 2021: 415). To Anglo-American audiences, the adjective to be didactic may conjure up the image of 'an overbearing person prone to moralizing and lecturing others' (2022: 415). This definition has little to no bearing in the Danish educational context, where the word primarily operates to denote the intellectual field and practice of Didaktik. Following this, a *subject-specific Didactik* is specific to the subject matter at hand, and the issue of 'individual school subjects, academic disciplines, and forms of knowledge' (415), including how to plan, conduct, and evaluate teaching, and the concrete work methods the pupils will be engaged in. In addition to defining TC 'on paper', a major challenge in the TC trial programme, then, was to establish a subject-specific Didaktik by actually trialling TC and putting it to work in a 'school reality'; to familiarise teachers with the pedagogies required to realise TC's educational goals and embed teachers' practical knowledge into the subject, and feed these experiences back into the further conceptualisation of TC as a school subject and subject matter.

The following analysis of the translation of design in the public school's encounter with TC falls in two parts, attending to two distinct but interrelated concerns and practices in developing TC for the public school: 1) the composition of the subject matter; 2) the organisation of the large-scale trial phase, in which the subject matter was subsequently tried out. I attempt to articulate the translation of design in the trial of TC in terms of matters of fact and matters of concern; and of practices, discourses, inscriptions, and rituals that are matter-ed. I then discuss and conclude on the results with the aim of expanding the understanding of design's mobility and morphology in postdigital educational presents and futures.

The Design Process Model and the Formative Potential of Design Processes

Let us first turn to the subject matter of TC as it was articulated in the subject matter proposal. This was a collection of documents that conceptualised and defined TC as a subject matter and potential school subject for the public school. It contained a description of learning outcomes (Common Objectives), a teaching guide, and a curriculum. The proposal was drafted by the Minister of Education's experts in 2018. The group was given the task of defining the subject matter as a formative, educational, creative, critical, and constructive subject. The expert writing group came up with a description modelled on four interconnected 'competency areas'. According to the description in 1) 'Computational Thinking', the pupils learn to translate a complex problem or phenomenon into something a computer can understand. In 2) 'Technological Knowledge and Skills', they learn about and to handle digital technologies, like computer systems and programming languages. In 3) 'Digital Design and Design Processes', the pupils learn to plan and execute a design process. In 4) 'Digital Empowerment', the pupils explore the possibilities, consequences, and impacts of digital artefacts (Undervisningsministeriet 2018). Notably, the proposal stressed that all competency areas should receive equal attention in the teaching, but that *the methodology that cuts across is a design approach*, driven by design processes. To this end, the design process model, shown hanging on a classroom wall in Fig. 1, was an important device in making design matter to pupils' learning and workflows in TC.

The design process model illustrates the categories of activities involved in a design process in TC. It shows a circle, an iterative process, of exploration, creation, and framing from the design task, doing field studies, generating ideas, fabricating and materialising, argumentation, and reflection. The gradient colouration of green through red, yellow, and back to green indicates the flow between what can be conceptualised, and visualised, as discrete activities, but in practice would be more of a fluid process of moving from divergent to convergent thinking (and doing). On field visits to The School, I encountered the model printed, laminated, and hung on the wall of the designated TC room, among other posters, e.g. about 'Corona hygiene rules' and the popular nationwide after-school coding club initiative Coding Pirates, which has been doing so-called 'IT creativity' since 2014. The design model resembles many such process models, and also pre-dates the TC trial programme. It was made by researchers in the 2014 FabLab@School.dk project at Aarhus University, which explored digital fabrication's educational potential (Hjorth et al. 2015). The model has since 'lived' on the project's website as one of many outcomes of FabLab@School.dk. As stated on the website, the model is now a resource that conveys what a design process is (or can be). Relevant to the trial programme, then, the model has been reproduced in textbooks, pedagogic literature, and inspirational material about TC.

Key subject matter experts (among them one of TC's main architects who is an interaction design scholar) explain the significance of design processes for TC, expanding on the official subject matter proposal. They discuss and introduce

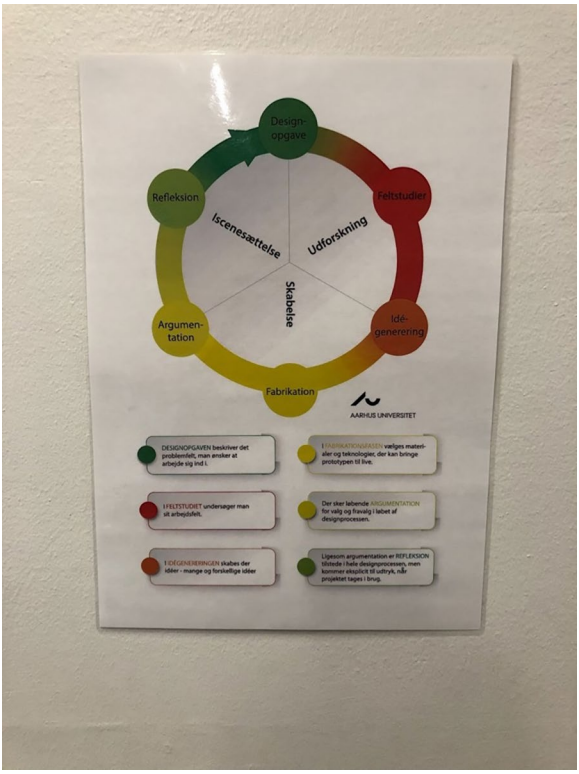

Fig. 1 A laminated poster of a Danish-language version of The Design Process Model, attributed to Aarhus University (see Hjorth et al. 2015). The poster has a legend with small plain-language blurbs about what each activity entails. The poster hangs on a wall in The School's TC classroom. Author's fieldnotes September, 2020

both TC and the design approach. Importantly, they reflect on the design process model and note how it has made its way into the emerging disciplinary canon of TC by adapting design knowledge and techniques for school knowledge: 'The process model is in many ways similar to other design models, as it describes how we get from a challenge, through studies, to the construction of a digital artefact. However, it stands out by not being a model directed at professional designers, but rather at people who want to engage in Technology Comprehension' (Iversen et al. 2019: 44). This is an example of actors visibly doing and reflecting on the translation work involved in making a school knowledge from more general phenomena, vocations, practices, and knowledges.

Popkewitz describes such translation work as the 'alchemy of school subjects' (2004), 'an analogy for thinking about the translation "tools" of pedagogy as disciplinary knowledge (e.g., physics, biology, literature, sociology), which are made into problems of teaching and learning. Schools require translation and transportation models, as children are not scientists or historians' (Popkewitz 2008: 95). That is, learning to design is not intended to make children into designers, nor is learning to design a mirror of what happens outside of the school where design is undertaken. It is a unique inscription of design, which, however, necessarily translates, among other things, a set of social principles, civic values, and political desires that become translated into the school subject.

But even such a concern for who children become, rather than *what* they should become (what skills and competences they should acquire), routinely constitutes a discursive marker of 'struggle' over rather than reconciliation in debates about schooling in Denmark. The question of experts, observers, politicians, leaders, and practitioners becomes: Is *this* proposal, model, or approach formative? Indeed, it is often the question of whether a course of education or its content is formative that becomes the centre of debate, and where proponents and critics leverage subject matter knowledge and research to struggle over and debate the emphasis of, in this case, a design approach in realising the formative educational goals of TC.

Part of the translation of design into TC is this struggle, done, e.g. in the waves of pedagogical literature that emerged alongside the trial programme and TC's introduction to the Danish educational landscape, and which aimed to explore how to actively *work with* and develop the proposed form of TC. In what could be characterised as more critical and reactive literature, some of which leverage STS perspectives, critique is directed at the working methods and pedagogies of TC, what disciplines are 'invited' to compose TC, or for raising concerns about the 'technology-comprehensions' of TC. Peter Danholt has critically examined the proposed 'comprehension of technology' that is enacted in the subject matter proposal (2021), discussing the limitations of the anthropocentric view of technology it performs, and suggesting a 'more-than-human' technology comprehension that allows for a more complex understanding of co-existing with digital technology that is not a 'human-technology' binary. Bjarke Lindsø Andersen and Oliver Tafdrup remark on the lack, and potential, of history to balance the design and computing content (2021). Johannes Fibiger asks of a design approach: 'But is it [formative] to design a gadget?' (2020). Such probes show resistance to the underlying logics and, as Fibiger puts it, understanding(s) of technology that TC itself has. Proposals and critiques are as much a part of the translation of design, performing design as a knowledge that can make knowledge, but with disagreement about what it includes and excludes.

Among the experts who drafted TC for the trial programme, some have expressed profound frustration with what the discontinuation of TC's development means for Denmark, but also about what it projects about Denmark as a leader in digitalisation and an exemplar of technology education. Throughout the introduction of TC to the Danish school system, academic pedagogical research and commentary have made design matter by inscribing participatory design, stating: 'In a Danish educational context, the philosophy in participatory design can be viewed as a driving force for ensuring that the students don't just learn programming skills in school, but also become involved to such a degree that they can begin to cognise and create with the technology' (Wagner et al. 2020: 10). Design is made to matter as a mirror of the values of Danish public school education. TC is consistently touted as a Danish brand of technology education, even explicitly so in the subject matter description, which states that TC is 'inspired by descriptions of similar subjects internationally, but with a Danish angle with special emphasis on digital design and digital empowerment' (Undervisningsministeriet 2018). Design was made to matter for postdigital technology education by many pedagogically informed public gestures about design providing a balance to the computing fixation that other nations' technology education seemed to be developing from.

However, design in TC can be understood as reproducing a technological determinism, regardless of 'all the humanity' that is put into the equation. It thus keeps change within the limits of technological fixes because it encourages framing social problems as design problems. This is a potential limitation of design being put to work in technology education, and it appears in the same gesture that attempts to recoup human agency over technology by prescribing 'hands-on' critical and creative-constructive design processes as a central activity in learning TC and in young people being makers, not users, of digital technological society. The design process model is put to use by its proponents as a suggestion, a proposal, but still as a matter of fact. However, it is also received as a matter of concern for the Bildung question that the public school must contend with.

The Prototype Model and Co-Creating Didactic-Pedagogical Knowledge

The trial of TC was an ambitious large-scale experiment responding to the ongoing technological transformation by intervening in one of the most established institutions of the Danish state: the public school. It was an effort of great political value in a highly digitalised democratic society that was galvanised to compete on a global economic and labour market, and in an increasingly commensurate transnational educational landscape. The TC experiment was not the first of its kind in Denmark. The public school has a long history of conducting so-called 'school experiments', now more formally referred to as pedagogical development work to avoid invoking the idea of the schoolchildren being lab rats or guinea pigs. Experiments in pedagogical development work have throughout the years been organised and mandated by different configurations of practitioners, councils, ministerial bodies, funding mechanisms, exemptions from regulation, and political mandates (see Skov 2006). Relative to earlier in the school's history, today the programmes are often responses to political goals that come to bear in, e.g. the Common Objectives, which thereby function as a key instrument of governance and power in Danish schools and schooling.

The Ministry contracted a consortium of research and teaching institutions to organise and conduct the development work in the school trial portion of the trial programme. The consortium adopted the shorthand Tekforsøget. The purpose of Tekforsøget's efforts was 'primarily to qualify and revise teaching materials and exercises in an iterative process with involvement of the participating teachers and other pedagogical staff from the participating schools' (Undervisningsministeriet and Styrelsen for IT og Læring 2018: 20). As stated in their start-up material for participating schools, Tekforsøget saw the school trial as 'fundamentally […] a co-creation project, where the participating schools and [Tekforsøget] collaborate closely' (Tekforsøget 2018: 4). To this end, Tekforsøget performed the task of turning the Ministry's steering documents and the expert-written subject matter proposal into materials that could be the focal point of a subsequent co-creative process of building the didactic-pedagogic foundation of TC with schools and teachers. The bulk of the materials that Tekforsøget's consultants, called subject matter developers, made were templates of lesson plans and courses of teaching, inscribed into.

pdf documents and PowerPoint slide decks that they uploaded to their website and made available for download to any and all. The materials were dubbed didactic prototypes, indicating that these were drafts, if not explicitly prototypes, of the subject-specific Didaktik of TC. Teachers (and others interested) could navigate to Tekforsøget's website and find the materials in 'the prototype bank'. These didactic prototypes were central in designing TC itself, a notion explained by Tekforsøget on their website (see Fig. 2), where the prototype model features.

This prototype model is a model about design because it illustrates the school trial's purpose of trying out the subject matter in relation to the subject matter description, Common Objectives, and the teaching guide. At the centre of this were the didactic prototypes: a suggestion for a subject-specific Didaktik that subject matter developers invited teachers to elaborate and modify. As such, in the trial the teachers and subject matter developers were also co-existing in an iterative design process, exploratively attempting to solve a problem of conceptual-theoretical knowledge being put to work in the field of everyday practical knowledge and conduct by working on prototypes that might bridge what was understood as a gap between the aforementioned. The statements and inscriptions by Tekforsøget perform the trial as a whole as a design project, if not a participatory design process, with Tekforsøget as the designers who invite teachers-cum-users into a co-creative process, to develop and iteratively design TC in an experimental frame constructed by Tekforsøget and dictated earlier by The Ministry. The prototype model and its use to illustrate the

Fig. 2 A screenshot of the subpage at www.tekforsoget.dk/forlob/didaktiske-principper (accessed 29 September 2023) about didactic prototypes where the term and format were explained with a graphic that shows the role of the didactic prototypes ('prototype') and their relation to other steering documents, which were, from the top and clockwise: 'Goal descriptions', 'Formats', 'Teaching Guide', and 'Curriculum'. Author's fieldnotes, January, 2021

organisation of the trial phase around conceptual and theoretical artefacts perform teachers as makers of technological knowledge.

As I observed at The School, teachers did not always adopt the language of design and prototyping used by the subject matter developers, e.g. calling lesson plans didactic prototypes. Subject matter developers, too, would switch back and forth between calling them prototypes and lesson plans. This initially confused me, as I believed myself to be missing a crucial distinction. One teacher explained that the terms were interchangeable in the day to day; that didactic prototypes were for all intents and purposes courses of teaching, lesson plans, and examples of the progression of instruction, to use the known didactic-pedagogic 'field' terms for materials of this kind. When I enquired with Tekforsøget about why the materials were called didactic prototypes and not simply lesson plans or another term immediately known to teachers, a consultant affiliated with Tekforsøget explained that it was to give teachers 'some of their own medicine'. That is, the school trials and the experimental resources that circulated were deliberately conceptualised in the same design terminology that they aimed to teach the schoolchildren in TC. The consultant did also remark that giving the same medicine caused some 'conceptual confusion', because, indeed, in addition to prototyping with Tekforsøget, practically the teachers were also supposed to be helping the pupils make prototypes in the design processes embedded in TC lessons (which I discussed earlier).

In addition to being modelled into the prototype model, teachers and Tekforsøget also related through face-to-face meetings. In such a meeting, a subject matter developer from Tekforsøget, who was assigned to the school, would visit and spar with the teachers about their experience with teaching TC, the didactic prototypes, or things more general to the trial programme. The subject matter developer would introduce the latest relevant research and development in TC and contribute helpful tools to conduct the experimental teaching, e.g. co-teaching. As illustrated by these practices of design, conceived broadly, yet visualised 'simply' in the prototype model, the trial programme as a design project was about filling a perceived practical gap by building on prototypes of that practice. This is what, in the prototype model, the dotted lines around the space of the word prototype openly suggest. That the didactic prototype is a deliberately ill-structured object (Star 1989; Star and Griesemer 1989), but is a materialisation of an emerging, not finished, TC practice that teachers could meaningfully contribute to as makers, not users.

Conclusive Discussion: Approaching a Comprehension of Design in TC and Beyond

As much as the trial of TC caused commotion because subject matter development of such consequence and scale rarely occurs in the public school, and new school subjects seldom become mandatory, the political outcome at the programme's natural end was just as controversial. Politically, the public school (as well as the corresponding national teacher education and training programme) was *not* made available to scale and develop TC from an experimental to a mandatory school subject. Yet TC and design as a foundation in its didactic-pedagogic conduct live beyond

the spatiotemporal configuration of the Ministry's four-year trial programme in the material artefacts, e.g. models and didactic prototypes that circulated in the trial. What is harder to inscribe and make material is the embodied tacit knowledge in those educators and subject matter developers who took part in the school trials and the months of immersion in TC. As much as TC and a design approach to engaging with digital technologies has become, if not a school subject, then a different kind of obligatory passage point, the lack of translation for embodied experience with learning, teaching, and developing TC renders its future as a school subject in the Danish public school uncertain.

In the preceding sections, I have attempted to show the role of pedagogical research, theories, conceptualisations, discourses, rituals, and visualisations in inscribing design into TC's epistemic practices. When introducing a new subject matter to the public school, it must contend with, e.g. Bildung and Didaktik, Common Objectives and 'freedom of method' and the friction and reconciliations of these discourses that are ritual in the public school and schooling. One point of tension, which critical studies of postdigital education should intervene in is exactly the Bildung question of who children should become through various schooling activities. With TC, children are to become more 'active' in their encounters with technology, and while that previously meant learning to be proficient in using technology, 'use' is now problematised as 'inactive' or 'passive'. This binary drives the imaginaries about desired and less-desired subjectivities and what 'the educated subject' looks like, favouring makers, not users. The rigorously researched, pedagogically conceptualised, and well-intentioned design process model shows that TC is modelled on participatory design, which highlight many of the same values and subjectivities as the very institution of the Danish public school. However, as remarked by Macgilchrist (2019), if the present and future world is consistently performed as 'digital' and scarcely imaginable as anything but digital, then there is an argument to be made that 'active' is 'reactive' to the digital building blocks of society. This is not an inconsequential limitation to design in postdigital education.

What can be seen in these inscriptions, performances of knowledge, and emerging subjectivities is a proposition that citizen subjects can (with design approaches) and should (because it is set to become part of statutory education) be makers of a technologically determined democratic society. This crystallises a particular form of agency and change, but keeps these within limits of the technologically determined. Such an imaginary raises questions of those forms of agency and change. Are all problems design problems? Can you say no to designing? Who can demarcate the terms of participation, and who has to be invited to participate?

On another but related note the participatory ideal of design is performed in the inscriptions of the trial programme itself when subject matter experts invite teachers to create and be makers, not users. The implication is that TC can be designed, but should be designed by merging 'theoretical knowledge' and 'practical knowledge' from the 'field' of everyday schooling. The prototype model, e.g. is a research-based, didactic-pedagogically sound 'fact' that the field relates to, because it promises to reconcile the tension between exactly both types of knowledge, 'theoretical' and 'practical'.

It is just as critical to examine the performances of knowledge and subjectivities in schooling's subject matters as it is to examine those of platforms, data analytics, and proctoring software. As the scope of both critical studies of EdTech is growing (Selwyn et al. 2020; Williamson 2021), scholars have also directed a critical eye to what could be termed 'TechEd' (see Hansbøl 2019), where it is the social, discursive, and material configuration of educational content about technology that is empirically examined and/or theorised as new curricula, literacies, or competencies, e.g. 'data literacy' (Pangrazio and Selwyn 2021), 'critical data education' (Pangrazio and Sefton-Green 2020).

Subject matters and school subjects have the appearance of matters of fact, but as Latour remarks, all matters of fact are unruly bundles of concerns, and there is merit to engaging with the unruliness, e.g. such as it is enacted in a trial programme for a new school subject about technology in a public school system. An institution like the Danish public school is positioned to amplify and 'give scale' to the knowledges, facts, and concerns it puts on the school schedule, and which its practitioners and experts perform in the day to day, thus implicating educational futures in its very present design engagements.

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Prototypes all the way down: Prototyping in the teaching and development of Technology Comprehension

Simy Kaur Gahoonia
Christopher Gad

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Introduction

This paper examines enactments and inflictions of *prototyping* in a recent experiment to introduce 'technology comprehension' (hereafter TC) as a mandatory subject in the Danish public primary and lower secondary school, known as 'Folkeskolen', (hereafter the public school). We begin by discussing some important aspects of the context in which the trial emerged, and the ways in which prototyping mattered overall to the trial. We then introduce and discuss our STS approach to prototyping, after which we examine some of the social, technical, discursive, and material elements at stake in two interrelated prototyping enactments within the trial.

As we shall see, prototyping in the trial amounted to something more and other than originally intended: a teaching form and technique aimed at enabling school children to become actively engaged in tackling complexities of social life brought about by digitalization. Indeed, it remains unclear how prototyping really mattered to those students subjected to learning activities designated as such. Instead, our argument is about how prototyping was able to bind diverse activities together and how it can be posed as descriptive of the trial as a whole. The trial became prototyping *all the way down*, we argue, as it catered to the view (broadly adopted today) that all kinds of activities – from dealing with technology, subject matter development or teaching practices can --- and maybe even should be -- framed as being about probing and tinkering with stuff in an open-ended and increasingly complex digitalized world.

Finally, we discuss how prototyping inflictions appear in the evaluation of the trial and how this is connected to the trial's ultimate failure to convince politicians to decide on introducing TC as a mandatory topic.

For the last decade, Danish politicians, industry spokespersons, and experts have increasingly aligned in claiming, that future citizen-subjects urgently need to develop their IT-proficiencies to keep up with the digitalisation of society. In the Minister of Educations' words (UVM 2018a), the common claim today is that this must involve educating young people to become *not only users, but makers and analysts of the digital technological society* that they are already part of. How to accomplish this feat is however a more contested topic as was also the case when the Ministry of Education (hereafter 'the Ministry') launched the Trial Programme for Strengthened TC in the public school (hereafter 'the Trial Programme') to inform political decision-making about future compulsory education in the area (Erhvervsministeriet 2018; UVM and STIL 2018a). From 2018-2021, the public school following became the site of an ambitious large-scale experiment in developing TC as a completely new subject matter, combining computing, design, and humanities knowledge and skills and as a subject which would familiarise schoolchildren with creative-constructive practices, i.e., digital design processes, 'making' and tinkering, problem-solving with digital technology, and analysing digital artefacts in the context of everyday life. TC was posed in the foundation of the trial as integral to the formative schooling and personal development of children which the public school is already tasked with providing via several other subjects and regards.

The Trial Programme had three main components. In this paper we focus mostly on 'the School Trials': the period when experimental teaching of TC occured in volunteer[1] schools. The School Trials took place parallel to capacity-building efforts in the national teacher education programme, and happened after an initial conceptualization of the subject matter proposal (UVM 2018b; UVM 2018d)

A consortium of experts from research institutions, and subject matter developers (Danish: *fagudviklere*) aided the Ministry in the process. This consortium refers to itself as 'Tekforsøget'[2]), and organised the school trials around pedagogic-didactic teaching resources called 'didactic prototypes'. The idea was that teachers would use these

[1] Though volunteering, the selected schools that took part in these trials received financial support from the Ministry to do so.
[2] https://tekforsøget.dk

prototypes to plan and carry out their teaching. The school trials concluded in 2021 after three years of extensive subject matter development and teaching activities at 46 schools and was evaluated in 2023 by Rambøll as being largely inconclusive.

In the following we draw on empirical material collected through ethnographic methods and desk research. This includes Gahoonia's three months (September-November, 2020) of observations of TC classes and teacher preparation at a school located in the Capital Region of Denmark. Additionally, we draw on observations from meetings attended (involving teachers and subject matter developers); participation in school research conferences about TC; and informational and inspirational material about the Trial Programme, the School Trials, and TC generally, distributed by Tekforsøget and the Ministry. Interviews, ethnographic notes, and relevant documents have been subjected to thorough reading and interpretive scrutiny in relation to where and how prototyping mattered.

From prototyping in Participatory Design in the trial to an STS approach to prototyping cultures

Prototyping was regarded in the trial as a motor in pupil-facing teaching and pedagogical development of TC. This was especially, albeit not exclusively, inspired by Participatory Design (PD).[3], which we will first characterize and then expand upon to developour own STS-perspective on prototyping and prototyping worlds and cultures.

In PD prototyping was originally a response to a lack of user involvement in software development and to the prevalent volatility of such processes. In the early 1980ies, Floyd (1984) observed that prototyping already denoted such a large variety of practices that any attempt at a strict definition would be pointless. Floyd argued that prototyping had multiplied like this because it is always embedded in broader systems development processes, because the functions and purposes of software are often ill-known in advance of development, and because software always remains 'unfinished' - 'in beta.' The relation between the 'prototype' and the 'product' is thus much more complex when making software, than when prototyping designates "the first of a type" in the manufacture of a

[3] Arguably prototyping as well as the set-up and many concrete technologies used in teaching (like Scratch, and Micro bits, as well as the curriculum frame for TC also has roots in the Silicon Valley ideology and in an Anglo-Saxon 'literacy' tradition which in many ways conflict with the Danish 'dannelses'-tradition and PD In our interpretation 'Tekforsøget' was however grounded at least rhetorically more in the PD approach which furthered it's legitimacy as a genuinely Danish and democracticizing practice, rather than an American import good. This our choice of focus and an equally valid argument can certainly be made that prototyping in TC has at least as many roots in the American teaching tradition and digital ideology.

simple product. Instead of defining prototyping Floyd then instead categorized it according to different purposes and the degree of openness in the development process: as either explorative, experimental, or evolutionary. The common thread to these different 'modes of prototyping' is that they all substitute "the [rational planning mode of] anticipation of a future system by a process of learning and practical experience." (15)

This understanding of prototyping was core to the trial of TC. The trial adopted the critique, imminent to the PD prototype concept that taming the future through rational planning methods, like requirements specifications, is futile. Instead, the prototyping concept was adopted in arguments about learning to cope with the uncontrollable nature of both technology and the future, the necessity to rely on continuous learning in practice, and of offering more future citizens the capacity to contribute continuously to the making of those digital technologies which fundamentally shape their lives.[4]

This understanding of the prototyping has been partially accepted but also expanded within STS. In 2002, Lucy Suchman, Randall Trigg, and Jeanette Blomberg argued for adopting a more complex view of prototyping than PD offers. They report from a case study of a prototype deployed as "an exploratory technology designed to effect alignment between the multiple interests and working practices of technology research and development." (167). The prototype's capacity in their case was to remix past and future assumptions, visions, and different social and material agencies, producing new socio-technical configurations. Suchman, Trigg, and Blomberg (2002: 176) state that "the prototype offers a perspicuous case of a performative artefact that works to align multiple, discontinuous social worlds. Like any technology, the prototype does not work on its own, but as part of a dynamic assemblage of interests, fantasies, and practical actions, out of which new socio-material arrangements arise." Prototyping in this view affords making connections between existing worlds but is also about building future 'open' ones (see also Maguire 2018). Prototyping is then not only a response to the 'openness' and volatility of technology development and the future, but also performs technology, the world and the future in exactly that way.

[4] Central to the early discussion of prototyping in PD was also the conundrum of whether prototyping was mostly about enabling creative imagination and co-design or mostly amounted to the excavation of peoples pre-existing assumptions, habits, or tacit knowledge (e.g. Mogensen 1992). Another central tenet in PD in the scandinavian form has always been a democratic politics. In early developments PD researchers was developed in cooperation with trade unions and was about involving workers in improving their work process, rather than them becoming subjects to automatization surveillance and control, which IT also affords (see e.g. Bjerkness et.al 1987).

Alberto Corsín Jiménez remarks in this sense on the emergence of a 'prototyping culture', where prototyping visions, ideas and practices has moved well beyond design, and has become part of a broader cultural repertoire for describing and engaging the world. To him "prototyping has become an important currency of explanation and description in art-technology contexts, where the emphasis is on the productive and processual aspects of experimentation." (2014: 1) As such, "prototyping and experimentation have taken hold as both modes of knowledge-production and cultural and sociological styles of exchange and interaction." (1) In this view prototyping even becomes generally descriptive of 'the social' as always perpetual and in the making.

Taking these perspectives to the School Trials, prototyping not only appears as a response via PD to digitalization but performs a digital world through prototyping by enrolling pupils, teachers, and subject matter experts in making, demoing, testing, and iterating on tangible and material artefacts–prototypes - amounting to "an epistemic culture built on collaboration, provisionality, recycling, experimentation and creativity, which seems as much oriented to the production of technological artefacts as it is to the social engineering of hope." (ibid. , 382)

The Trial Programme - going beyond consumption via prototyping didactics

As mentioned, one important hope of The Trial Programme promoted by political actors, educators, expert observers, technologists etc., was that future citizens would evolve from 'passive consumers' to being 'actively' engaged with technology. Being active was articulated as being creative, critical, and taking part in the construction of technologies. This problematisation of technology education is not unique to Denmark. A series of EU-sponsored mappings and reports (Bocconi et al. 2016; Bocconi et al. 2018; Bocconi et al. 2022) show national school systems across the EU have lately been concerned with implementing subjects and curriculums, which teaches *more than* the use of technology. This is occasioned by a "growing understanding that digital competence goes beyond basic digital skills," (Bocconi et al. 2022: 5).

This is suggestive of what Macgilchrist et al. (2023) refer to as the postdigital condition, which is characterised by an increased, though still modest, scepticism about the capacity of technology to solve social and economic problems. The emergence of phenomena like 'fake news', cyberbullying, 'digital exclusion' and commercial data-driven operations has produced a general awareness of the negative impact and complications

to national democracy, well-being, and resource distribution that technology poses (Schou and Hjelholt 2018; Maguire and Winthereik 2019; Carreras and Finken 2022) and inadequacies in how technology development is dealt with and who is involved. As 'the extended arm of the Danish welfare state' (Coninck-Smith et al. 2015: 383), the public school was positioned to contribute to making the future both more democratic while remaining a key ingredient of the concurrent government's strategy for Denmark's "digital growth" (Regeringen and Erhvervsministeriet 2018), via formal education.

Throughout the Trial, a central focus of the debate on formal education attained to Bildung (*dannelse*) and Didactics (*didaktik*). Stemming from a German-Scandinavian intellectual tradition, Bildung signifies the priority of "personal development guided by reason" (Retz 2022: 145) and which might also be understood as education that is formative of the individual as a social being. Regarding the key Bildung question of what students should become via TC (and second, what, then, they should know), experts appointed by the Minister of Education in early 2018, drafted a subject matter proposal consisting of Common Objectives (learning outcomes), a subject matter description, and a teaching guide for TC. Their proposal was made public in December 2018. The overarching goal of TC in the Common Objectives was that: "The pupils should develop academic competencies and acquire skills and knowledge so that they can participate, constructively and critically, in the development of digital artefacts and understand their significance." (UVM 2018f: 3).

The expert writing group described TC's four equally significant 'competency areas' in the proposal, stating that: 1) "Computational Thinking" unfolds the pupil's ability to translate a complex problem into something a computer can understand; 2) "Technological Knowledge and Skills" includes learning about the computer's systems and (programming) languages; 3) "Digital Design and Design Processes" aims to develop the pupil's ability to plan and execute a design process; in 4) "Digital Empowerment", the pupils explore digital artefacts: their possibilities, consequences, and impact (UVM 2018e). While TC was not conceptualised as exclusively a design discipline, the proposal consistently makes a case for the educational and formative value of creative-constructive design practice and rehearsing prototyping with pupils, stating: "(...) it is central that the pupils learn to construct with digital technology (program, develop prototypes or use fabrication technologies) and thereby get the opportunity to create new and rethink already existing digital artefacts." (UVM 2018g: 10) Furthermore, "digital construction

(including programming and prototype development) is central for this subject, and there will be thorough and focused work with this element - beginning from early schooling." (15)

Didactics is a "language in which a common framework and set of referents [govern] discussion of educational theory, the practice of teaching, schooling, curriculum making and lesson design, teacher education, school administration, textbook production, the sites of exchange between teachers, teacher associations and in-service professional development, as well as issues concerning individual school subjects, academic disciplines, and forms of knowledge." (Retz 2022: 415). Didactics in the trial became strongly influenced by PD (Iversen, Dindler, and Smith 2019; Wagner, Iversen, and Caspersen 2020), suturing it with the civic and empowerment ideals of Danish schooling. The main architects of TC explain that "[in] a Danish educational context, the philosophy in participatory design can be viewed as a driving force for ensuring that the students don't just learn programming skills in school, but also become involved to such a degree that they can begin to cognise and create with the technology." (Wagner, Iversen, and Caspersen 2020: 10) Along with this, PD and empowerment is reworked into "Computational Empowerment", a kind of companion concept to the technology-understanding suggested by TC, with Computational Empowerment being defined as childrens' ability to co-create the future that emerges through the construction of technologies (Iversen, Smith, and Dindler 2018).

Thus, sampled from continental European educational philosophies, research and theory on Scandinavian PD and a Danish canon of informatics, prototyping became a central normative concept and visibly practised in the trial programme, and for the wider concern for cultivating a postdigital citizenship. In particular, prototyping was done and made significant as a classroom activity for the pupils by which they could construct technology, but also for the organisation and conduct of the pedagogical development work on a designated TC didactics, where "the experimental and open-ended qualities of prototyping have become a surrogate for new cultural experiences and processes of democratisation." (Corsín Jiménez 2014: 382)

Prototype 1: A Super Animal

The first prototyping enactment we explore in detail is a 6th grade TC lesson that took place in the school's designated TC classroom. Our focus is one pupil's digital artefact and

the conditions under which it was constructed and presented to the teacher during the lesson.

This lesson was based on educational material provided by the project ultra:bit, a collaboration between the public media institution, the Danish Broadcasting Company, and several partners in the education landscape, inspired by BBC's micro:bit project. Supplemented by a vast array of children's audiovisual content and educational material, it introduced rudimentary, imaginative, and playful coding exercises targeted towards children ages 9-13, and centered around a small kit of open source, simple architecture hardware: the 'micro bit'. Today, the class was 'working with' Super Animals. Most of the instruction for the exercise was available online and the ultra:bit kits were plentiful, having been generously distributed to all interested schools in Denmark.

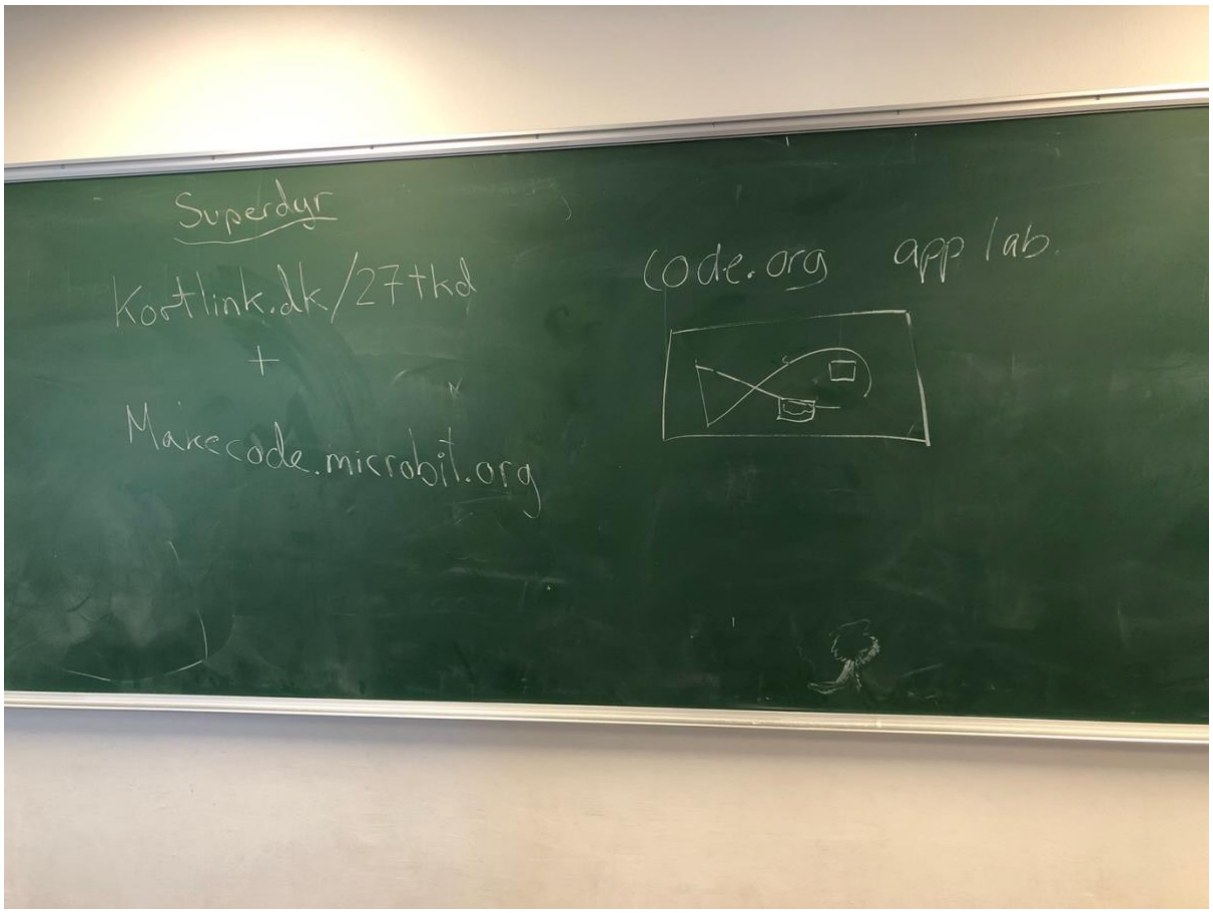

***FIGURE 1*:** The blackboard with hyperlinks and writing in chalk. Photo by Author 1.

Despite not being a Didactic Prototype, like a majority of the classroom activities in TC, the Super Animals exercise was modelled on a design process model for TC developed at Aarhus University (see Hjorth et al. 2015). The design process model resembles and is

indeed an adaptation of many such process models found in professional engineering, design, and project management. The Design Process Model for TC addressed various phases of a design process. As for Super Animals, its creative-constructive phases of design both correspond to and depart significantly from practices of problem-based learning and project work congruent with e.g. the 21st Century Skills paradigm and various new media literacies that map onto digital competence (see Ilomäki et al. 2016). Key in TC, drawing on design approaches, was to make it a practical subject of not only the mind, cognition, and 'talking about it', but of craft, making, and getting hands-on with the very stuff of digital technologies, here represented by chip-like processors that compute and transform human input in the form of code. Thus, the Super Animal exercise was about materialising, with a mixture of analog, digital, and computational supplies, an animal with fantastical abilities. Under the banner of 'coding a better world', the exercise problematised environmental change, namely how animals might adapt to changes in their ecology. Within that framing, pupils ideated and constructed partially digital artefacts in an iterative fashion.

The lesson in question is a glimpse into the construction phase of the design process, conducted by the pupil and supported by the teacher. The role of the teacher was to facilitate the iterative processes and *being in* these with the pupils. At the beginning of the lesson, the teacher gave a brief introduction, recapping previous lessons and key topics and aims for the day's lesson. The teacher also wrote out shortened URLs on the blackboard, directing the pupils to the online ultra:bit material where the rest of the instructions, hyperlinks, and audiovisual resources were located.

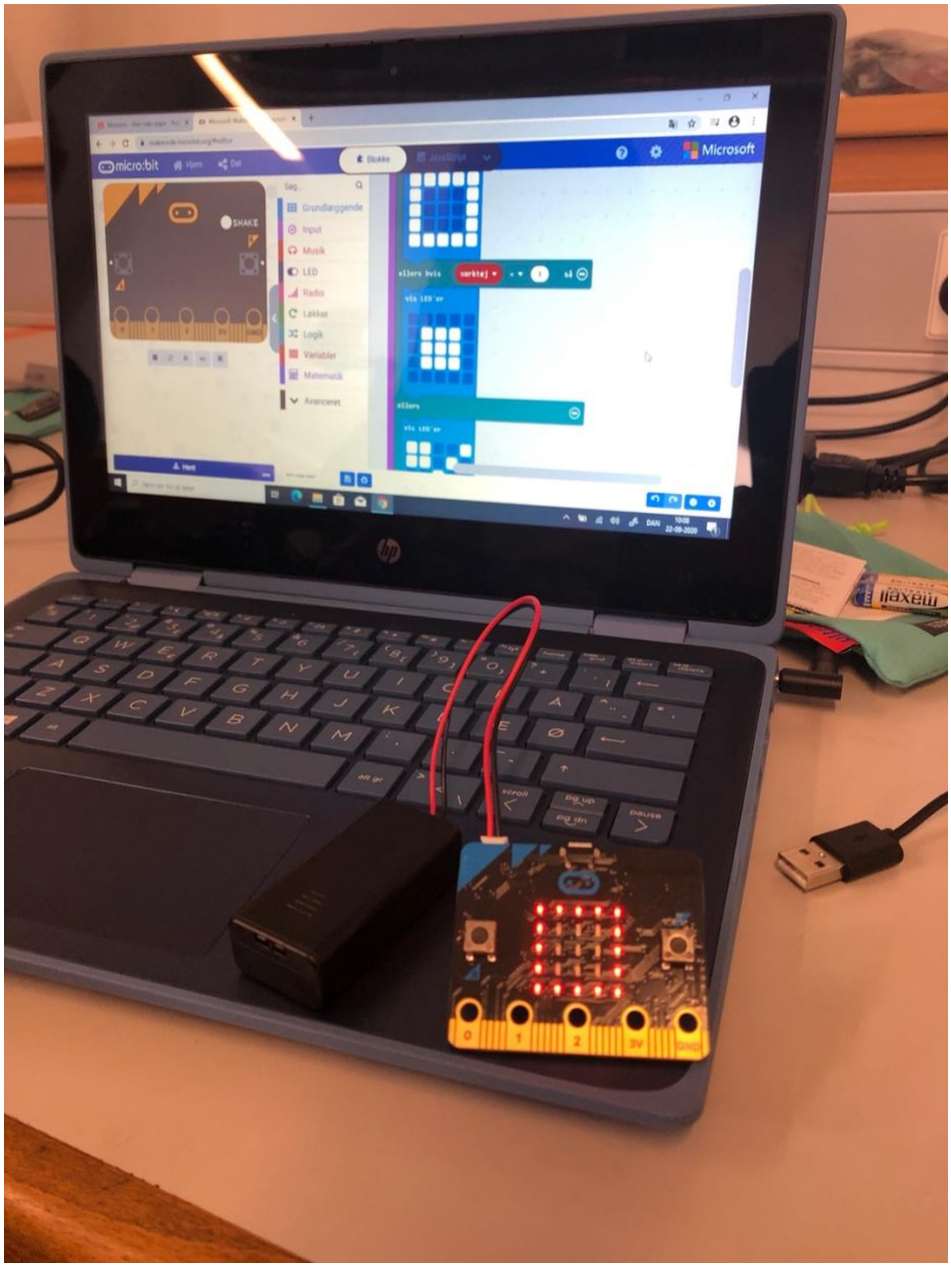

***FIGURE 2**. A micro:bit rests on a Chromebook. Photo by Author 1.*

The pupils then got to work with both analog and digital materials. The analog involved using cardboard or copier paper as the base structure of the Super Animal. Next came the 'fusing' of this with the small micro:bit computers, which they first had to program. Programming involved the pupils translating the imagined visual effect of an animals 'change' or 'adaptation' into language the computer could understand. The tool here was Scratch, a visual programming language and environment, where code is presented as blocks of different colours and shapes that can be dragged and dropped to create syntax on the screen.

The pupils scattered into groups or worked individually, occupying the desks, floor, and spilling out into the hallway. Meanwhile, the teacher facilitated the ongoing process, supporting the pupils' creativity and experimentation. For example, when the pupils' noticed that there were not enough scissors and markers to go around, they notified the teacher, who then enthusiastically leapt out of the classroom to fetch more supplies. The other teacher walked and sat among the pupils, supervising from afar and engaging them in conversation about their process.

One pupil constructed a working prototype of his Super Animal, composed of a sheet of white A4 paper, on which he had traced the contour of a dragon-like figure with green marker (see fig. 3). 'Showing his work' he did an informal 'demo' of the prototype for one of the teachers. He presented a paper-based dragon with fantastical abilities suggested by its computational micro:bit hardware elements: Three micro:bit diode boards peeked out from cut-outs in the paper and lit up when he shook them. The dragon, thus, had dynamic scales, as demonstrated when the micro:bit in its body is shaken. Shaking the 'tail micro:bit' shot its missiles. The eye was also a micro:bit, blinking when he shook it.

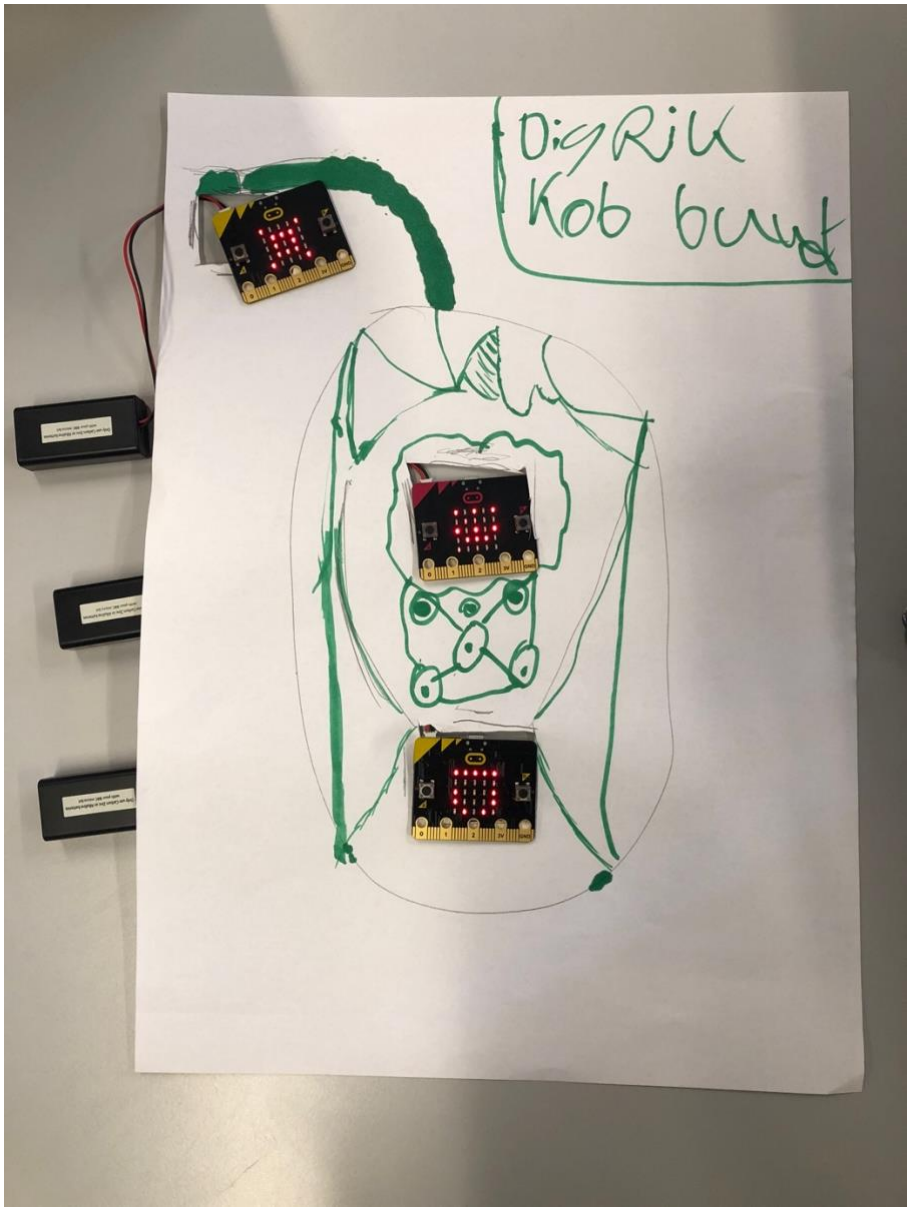

FIGURE 3. The pupil's prototype of a Super Animal. Photo by Author 1.

However, while demoing the prototype, one of the micro:bits malfunctioned, remaining 'stuck' on a static pattern of diodes. Neither the pupil nor the teacher seemed to know why. The teacher waved the failure aside and stressed that it was a fine piece of work regardless. She asked him how he imagined he could improve on his creation. The pupil responded, tongue-in-cheek, that there was nothing to improve, because it was as perfect as could be. The teacher laughed off his remark and began instead to inquire about whether he had fun working independently and making this artefact all on his own, to which he responded 'yes.'

This exemplifies how in TC, the creative-constructive work and learning is focused on the process of construction, more so than on the product. This focus is promoted across the TC pedagogical experience, research, and literature. The Super Animal, upon demo, elicits communication and feedback between the teacher, the pupil, and Gahoonia as participant-observer. The prototype is somewhat faulty; it is an accomplished piece of work; it has room for improvement (according to the teacher); but it could also, in the words of the pupil, decidedly not be improved and left incomplete. All these things can coexist and be held in place within a prototyping culture, and they are congruent with the intended learning outcomes of TC. Mobilising prototyping as a pedagogic-didactic principle allows for the negotiation of epistemic closure and opening. Thus, we see how prototyping can be a currency of explanation and description and a style of social exchange.

The Super Animal prototype as a performative artefact spans and brings into view the social and material agencies in technology construction. Corsín Jiménez suggests "prototyping as something that happens to social relationships when one approaches the craft and agency of objects in particular ways." (2014: 1) The Super Animal in this prototyping activity performs 'the pupil', 'the teacher' and their relation in teaching and learning TC. It performs 'the teacher' as facilitator of an open-ended, experimental, error-prone, creative, and iterative–yet bounded–learning environment, and as someone who is less concerned with demonstrating authority on the subject matter. The prototype performs 'the pupil' as playful and 'daring to fail' (*fejlmodig*). It inscribes and tests one of the central novelties and reconfigurations of TC: that of shaking up the relations of 'pupil' and 'teacher' in order to allow for being in an iterative process that negotiates closure and opening ongoing. This relation is rehearsed, but so too are the complex, and often outright chaotic teaching conditions, which the pedagogical literature asks TC teachers to embrace (see Beksgaard et al. 2021), and which pupil's need guidance through in order to feel safe 'failing' and navigating the supposedly inevitable failures embedded in this learning practice.

The one micro:bit failing during the demo shows that the use of digital technologies that one does not entirely master (and is not expected to master) in the creative-constructive process compounds with the existing pedagogic, didactic, social, and organisational challenges of "the classroom as experimentarium for new technologies" (Riis 2012: 87). Much as it holds in place closure and opening, failing and

succeeding, prototyping absorbs the very conditions of complexity that practitioners concerned with schooling understand as the effects of technology on the social and material process of education. Ie., Prototyping handles a tension between the imperative to materialise technology, at the same time the technology is understood as a disrupter. This apparently rehearses teachers and pupils an embodied experience of living with the complexity digital technologies introduce to the making of epistemic objects and cultures such as learning and 'the educated subject'.

Prototyping can here be understood as the rehearsal of chaotic conditions, in the teacher-pupil relation, and in the pupil-world relation, an outsized part of which cannot be taught 'in theory', as the teacher remarked to Gahoonia, the latter would be like 'dry swimming'.

Prototype 2: A Didactic Prototype

According to a consultant from Tekforsøget, the choice to call the pedagogic-didactic resources "didactic prototypes" was deliberate and suggested that 'the grown-ups were taking some of their own medicine', doing and learning about prototyping while teaching students how to do it. The second prototyping activity we examine is the collaboration between Tekforsøget and a teacher on the school's TC teaching team as it centred around the format of the Didactic Prototype. The prototype we examine is called App Design. The teacher observed used this prototype in teaching and communicated his feedback on it to a subject matter developer over the course of the school term.

Given the novelty of TC and the proposed TC didactics, the teachers had no formal training in how to teach the subject to their pupils. As a rule of thumb, the teacher education programme at university colleges does not offer comprehensive subject-specific training unless the corresponding subject already exists in the school. This created an obvious paradox in the introduction of TC , and it was consistently problematised and sought overcome or remedied with innovative development practice; pedagogically exploring TC was a matter of establishing subject-specific didactics in a manner that addressed this central concern of the bottleneck. Politically, the trial programme at large was framed as a test and knowledge-gathering effort, congruent with the fact that there did not yet exist a cohort of pre- or in-service TC teachers. TC was not an implementation project; it was an experiment in both pedagogy and (inter-) organisational practices.

In August 2018, Tekforsøget was contracted to lead the pedagogical development work on TC (UVM 2018c). Their task was in part to create and prepare teaching materials for and organise this development work and deploy with municipalities, who had applied to be part of the school trial with one or more of their schools (UVM and STIL 2018b). The bulk of the preparatory work on e.g. Didactic Prototypes by subject matter experts was carried out from August to December of 2018. The school parties were then invited to 'co-create' (Tekforsøget 2018) TC through Tekforsøget's in a three year trial period. At a kick-off meeting for the school trials, Tekforsøget had presented the Didactic Prototypes format as "the first didactic and material starting point for the pedagogical personnel's work of trying out the new subject matter". According to Tekforsøget, the purpose of organising the trial around prototypes was to provide direction and 'scaffold' the testing, while also offering flexibility, and to allow for feedback and iteration on them (Tekforsøget n.d.).

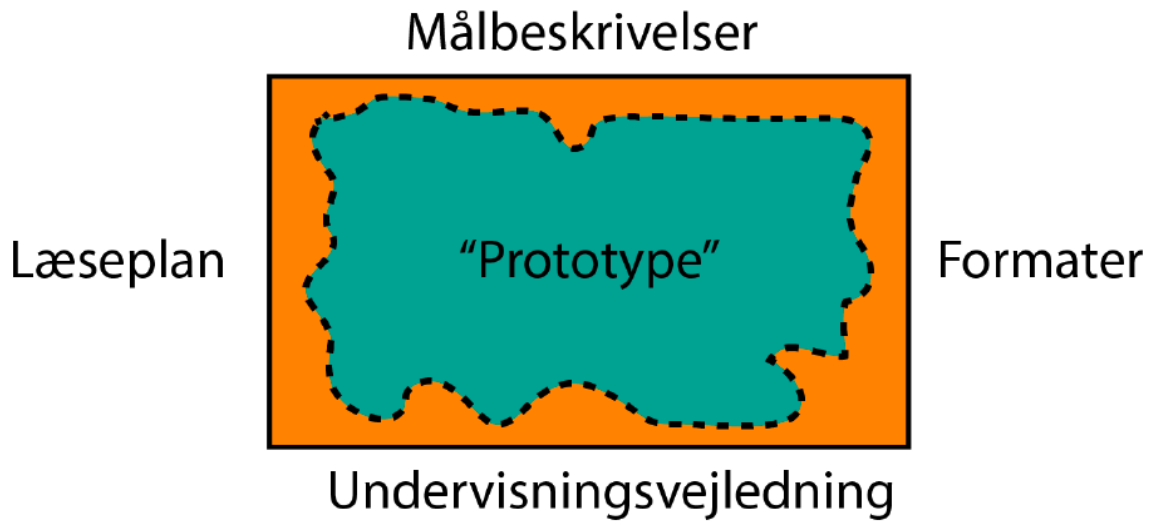

FIGURE 4. *From the top and clockwise: goal description, formats, teaching, and* curriculum. Figure reproduced from Tekforsøget's website, specifically the subpage on 'didactic principles'. (Tekforsøget n.d.)

On their website, Tekforsøget described the Didactic Prototypes as 'inspirational' (sic.), using a graphic (fig. 4) to illustrate their role in relation to other key steering documents such as the subject matter proposal's texts (curriculum, learning goals, and teaching guide). By models like this, it was framed as a design engagement. Furthermore,

Tekforsøget stressed the importance of teachers actually trying out the Didactic Prototypes in TC teaching.

The Didactic Prototype 'App Design' was aimed at teachers and teaching in the 5th grade. The prototype was developed by Subject Matters Developers–a group of teacher education researchers and pedagogical consultants–under the auspices of Tekforsøget. The App Design prototype was a document of 14 pages. It had a similar template to other Didactic Prototypes, e.g. an orange front page with Tekforsøget's logo, consortium attributions, a table of contents, and a course description. The .pdf document was hosted and downloadable on Tekforsøget's website in what was termed 'the Prototype Bank'. The Prototype Bank was a subpage that listed over a hundred such prototypes, audiovisual resources, and hyperlinks to materials on the web that could aid in the teaching of TC.

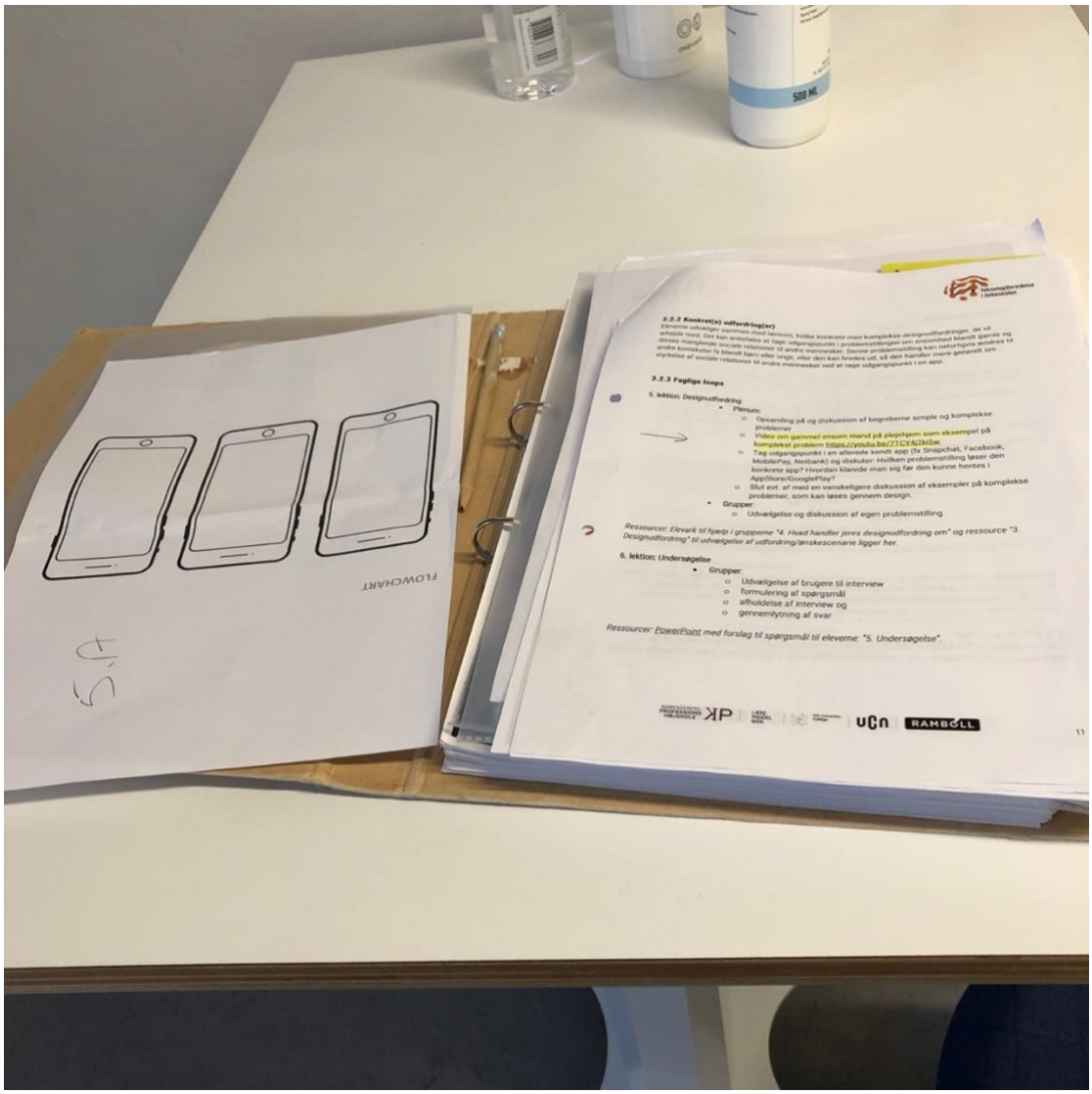

FIGURE 5*. Open binder with a page of the prototype, with highlighted passages and notes. Photo by Author 1.*

For a series of app design lessons in the 5th grade, the teacher had printed the prototype and put the pages into a binder. He carried it with him to the lessons. He had highlighted passages and made notes on the pages, preparing for and reflecting on the teaching of the prototype. He conducted his teaching; Most of the lessons Gahoonia observed focused on the construction phase of the design process model. Most of this time, the pupils were working in groups on paper-based app prototypes, usually after a brief introduction or recap of last week's activities by the teacher. On occasion, the teacher interrupted the group work for a short plenary by the blackboard. For example, to discuss matters of visual aesthetics, typography and iconography in mobile app interfaces in a way that engaged the pupils' understanding of their process and choices during the construction of their apps. According to the Didactic Prototype for App Design, the pupils should make their apps in the programming environment AppLab once they had progressed in the construction of their mockups and done an initial round of demo and feedback on the paper prototypes. This latter part of the course proved too difficult to carry out in the way that the Didactic Prototype suggested. Instead of using AppLab to program the apps, the teacher opted to make the pupils use PowerPoint software to present how the app would work; transitioning to AppLab programming was too complex and demanding. It was challenging to reconcile the practical guidelines for time and space with the complexity of the teaching content and the technological infrastructure and skills available. The teacher made discretionary choices informed by his professional and content knowledge. The teacher shared these observations with Author 1, but he also shared them with other teaching staff, not least during their recurring meetings with Tekforsøget.

FIGURE 6. The teacher has lined up the pupils' poster prototypes to take a picture and share with the Subject Matter Developer. Photo by Author 1.

Tekforsøget had a learning consultant with subject matter expertise linked to the school. The Subject Matter Developer would visit the school on occasion to spar teaching methods, subject-specific didactics, exchange theoretical and practical knowledge, discuss the teachers experiences with trial-based TC and the Didactic Prototypes, and collect general feedback from the teachers. They were familiar with each other either from working with TC or from other education and research contexts. Between meetings, the teacher would continue teaching app design in the 5th grade. At one point, the pupils had finished their paper prototypes (posters) and presented and got feedback on them from their classmates. After this demo and feedback-centered lesson, when the pupils had left the classroom, the teacher said he wanted to take pictures of the posters and share them with the Tekforsøget consultant. He lined the posters up on a table and snapped photos of them, musing that the consultant, who he and the other teachers were first-name acquaintances with, would probably like to see the pupils' splendid work.

Based on these observations, we wish to first bring attention to the role that conceptualisations of 'the theoretical' and 'the practical' play in the experimentation and

deliberation of teachers, Tekforsøget, and subject matter experts. Tekforsøget invited schools and teachers to co-create subject-specific didactics for TC by testing and feeding back their experience of teaching the Didactic Prototypes. There appears to be a shared understanding of these two concepts, their differences, and their mutual constitution in the public school landscape; there is furthermore wisdom to the fact that the lines between 'theoretical' or 'conceptual' and 'practical' can be blurry. For example, reflecting on the TC trial at large, one teacher remarked that the subject matter proposal was very dense, an example of 'deskwork'. On the other hand, those subject matter experts that contribute to such deskwork routinely concede and encourage the incorporation of 'the practical' in developing TC, pronouncing that "we need to have the teachers with us". Naming this division is a productive act, because of the knowledge gap that prototyping seeks to make fertile and overcome.

The Didactic Prototype performs this tension and a difference between 'theoretical' and 'practical', inscribing pedagogical theory, research, and knowledge into a theoretical artefact that prefigures and models TC teaching. As such, TC is stabilised in the Didactic Prototype, affecting alignment between distinct but deeply entangled and mutually constitutive social worlds of knowledge practice: the ongoing quotidian teaching practice, characterised by being localised in schools or classrooms, and temporalities of the lesson, the school term, or the amount of hours the teacher can work and should spend on different tasks; and the abstract deskwork 'theoretical' practice of advising, doing and presenting pedagogical research, and consulting, which is characterised by being much more distributed spatially, and temporally delineated by the e.g. the 3-year school trial phase or the government cycle.

The prototype is an artefact of the pedagogical development work ongoing. It assembles pedagogical-didactic research, practical knowledge, the steering documents, subject matter developers, and the subject matter proposal. It is made significant to the organisational matter of developing and testing the experimental subject TC, for one, by way of the below model. Recall fig. 4, through which Tekforsøget explained the role of the prototype. The dotted lines around the space of the prototype, openly suggest exactly that the Didactic Prototype is a deliberately ill-structured object, and makes it appear akin to a boundary object (Star 1989; Star and Griesemer 1989). It is made to facilitate "the productive and processual aspects of experimentation" (Corsin Jiménez 2014: 1) between the epistemic cultures, and handle the introduction of complexity into disciplinary canon,

fx. new material and social technologies, roles and relationships etc. The didactic prototypes constituted the tangible, material first instances of the emerging and diffuse subject matter, knowledge, and practice field of TC–purposefully and productively unfinished enough to make the teachers' participation seem meaningful and worthwhile. Some of the feedback made it into the development process.

The prototyping that was arranged by Tekforsøget and which the teachers participated in did yield new iterations of the Didactic Prototypes that were, in turn, tested out in schools in later stages of the school trial. Despite this fruitful outcome and a personal interest in the subject matter, the teacher's experience with taking part in the trial and trying out Didactic Prototypes was, as he put it, like building the boat while sailing it. This is yet another image (like the idea of 'dry swimming' mentioned above), that emphasises the seeming impossibility that prototyping can absorb and make new social and material agencies out of.

Concluding discussion: The Afterlife of the trial of TC

The implication of propagating a prototyping culture in the school is inseparable from the general role of public schooling and statutory education. As curriculum scholar Thomas Popkewitz remarks, education routinely mobilises the future to organise the present (2012). Propagating a prototyping culture in the public school takes experimentalism out of systems development and design and suggests that it is vital for civic participation and social conduct in a digital democratic society. the public schoiol as a culture-bearing institution, attended by ca. 86 % of all Danish children ages 6-15, has the potential to 'give scale' and 'give reality' to, and amplify certain 'comprehensions of technology', understood as the desired and sanctioned human-technology relations, and techniques of human intervention in a digital society.

For better or for worse, the trial of TC consistently prioritised process over product. The two prototyping enactments we examined exhibit this. In the first instance, the insistence is that, facilitated by the teachers, the pupils should not be focused on making good and viable technologies, but rather get attuned to the process (iterative and open-ended), human agency (critiquing and making design choices), and materiality (code, micro:bits, batteries) assembled in technology. In that sense, the product has a function, though it was not to be functional, but rather to be an epistemic object that frames and absorbs both 'failure' and epistemic uncertainty and makes it possible to

reflect on the digital construction process. The second is characterized by an insistence that the trial of TC was not an implementation project. The aim was to "test different models for strengthening 'technology-understanding' as a mandatory part Public School teaching." (UVM 2018d: 1) The Didactic Prototype as theoretical-conceptual artefacts with practical use in local schools in and beyond the school trials (available still to this day in the Prototype Bank), exhibit this preoccupation with testing and open-ended exploration as legitimate and desirable markers of knowledge. This is further amplified by the evaluative efforts that followed the conclusion of the trial phase in schools.

In 2021 Rambøll Management Consulting, a partner in the Tekforsøget consortium, subcontracted to carry out evaluations, published their assessment of The School Trials (UVM 2021). The report summarises interviews and questionnaires with teachers who were involved. The report observes, e.g., that some content was too hard for the youngest pupils and that the subject required engaged teachers and supervision. Fundamentally, however, the report remains largely cautious about making any kind of conclusion due to various methodological issues. The SARS-CoV-2 pandemic, the large variability of how the subject was taught at the 46 different schools, and changes to the evaluation process itself, namely a cancellation of the use of "taskforce and comparison groups"are mentioned as reasons for such cautiousness (18).

Jensen and Lauritsen (2005) say that policies and policy reports are most often open-ended because they must align with many interests. As a concept prototyping certainly supported the conduct of the trial in this sense. Most noticeably though, the evaluation report suggests similar to Marres and Stark's (2020) argument, that the concrete reason for the evaluation report being open-ended, is that the trial and its effects is thoroughly mixed up with the broader social life of school children: "Concretely, the quantitative investigation does not make it possible to conclude if the pupils got better at TC because of the trial, as it is not possible to isolate the effects of the trial from the expected natural development of children as they grow older and increasingly get access to and experience technology" (UVM 2021: 18). Followingly, the report suggests that the trial and the evaluation itself could have deployed other, possibly better methods. From the point of view of the evaluation report both the trial and the evaluation itself thus also appear prototypical. Everything is mixed up with something else and everything must thus be seen as unfinished improvable form: from teaching to the evaluation itself. The trial is prototypical all the way down.

Nearly six months after this evaluation, there was still no announcement from the Ministry about TC's future in the public school, and decision-makers had to be prompted by the media to come forward. The political actors who were in charge of the Ministry when the trial ended (its leadership and composition changed with the new government in 2019) gave ambiguous answers as to the further development of TC under the auspices of the Ministry (Marthinsen 2022) and acknowledged that the future of TC was uncertain (Wittorf 2022). Despite this, and wherever the public school ends up going with the prototype as an epistemic culture and object, it is important to reflect on the implications of scaling up a prototyping culture by seeding it in the public school. As much as it is telling of the fact that the trial ended with a non-conclusion and non-decision, it is just as telling that the trial took place in the first place. It has been over 25 years since a new school subject made it into statutory schooling in Denmark. In this context, the demo-ing, failures, scaffolding, and feedback prototyping allows–as shown in the prototyping activities that the Super Animal and the Didactic Prototype are assembled and performed in–seems at once hopeful and disappointing.

As of writing this, TC itself remains prototypical. The subject matter has been defined well enough for a test, however realising it as a new school subject and fixture of Danish schooling has not been achieved yet. TC, thus, lives on as Didactic Prototypes that can travel to other locales of schooling, pedagogic research, education consultancy, or extracurricular coding clubs. But TC is largely also an embodied experience and knowledge, tacit in those teachers, Subject Matter Developers, and pupils that took part in the trial. Like many prototypes of PD, TC is so far shelved. The trial of TC seems in this light as much as an experiment in rendering social relations and knowledge-making, open-ended and experimental as it is an experiment in cultivating that exact attitude towards technology, but also towards societal affairs and knowledge-production in general.

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