

**This is a self-archived version of an original article. This version may differ from the original in pagination and typographic details.**

**Author(s):** Tuhkala, Ari; Wagner, Marie-Louise; Nielsen, Nich; Iversen, Ole Sejer; Kärkkäinen, Tommi

**Title:** Technology Comprehension : Scaling Making into a National Discipline

**Year:** 2018

**Version:** Accepted version (Final draft)

**Copyright:** © 2018 Copyright held by the authors. Publication rights licensed to ACM

**Rights:** In Copyright; <http://rightsstatements.org/page/InC/1.0/?language=en>

**Rights url:**

**Please cite the original version:**

Tuhkala, A., Wagner, M.-L., Nielsen, N., Iversen, O. S., & Kärkkäinen, T. (2018). Technology Comprehension : Scaling Making into a National Discipline. In M. Giannakos, M. Divitini, L. Jaccheri, & O. S. Iversen (Eds.), *FabLearn Europe'18 : Proceedings of the Conference on Creativity and Making in Education* (pp. 72-80). ACM.  
<https://doi.org/10.1145/3213818.3213828>

# Technology Comprehension - Scaling Making into a National Discipline

**Ari Tuhkala**

University of Jyväskylä  
Faculty of Information Technology  
P.O. Box 35 (Agora)  
Jyväskylä FI-40014, Finland  
ari.tuhkala@ju.fi

**Marie-Louise Wagner**

Aarhus University  
Center for Computational Thinking  
and Design  
Helsingforsgade 14  
Aarhus DK-8200, Denmark

**Nick Nielsen**

Aarhus University  
Center for Computational Thinking  
and Design  
Helsingforsgade 14  
Aarhus DK-8200, Denmark

**Ole Sejer Iversen**

Aarhus University  
Center for Computational Thinking  
and Design  
Helsingforsgade 14  
Aarhus DK-8200, Denmark

**Tommi Kärkkäinen**

University of Jyväskylä  
Faculty of Information Technology  
P.O. Box 35 (Agora)  
Jyväskylä FI-40014, Finland

## ABSTRACT

We account for the first research results from a government-initiated experiment that scales Making to a national discipline. The Ministry of Education, in Denmark, has introduced Technology Comprehension as a new discipline for lower secondary education. Technology Comprehension is first experimented as an elective subject in 13 schools. The discipline combines elements from computing, design, and the societal aspect of technology and, thus, resonates with the existing FabLearn and Making initiatives in Scandinavia. We report the identified opportunities and challenges based on interviews, surveys, and a theme discussion with experienced teachers from the 13 schools. The main takeaways are: First, the teachers did not perceive Technology Comprehension as a distinguished discipline, which calls for more research on how Making is scaled into a national discipline. Second, Technology Comprehension opens up for interdisciplinary and engaging learning activities, but teachers need scaffolding and support to actualise these opportunities. Third, Technology Comprehension challenges teachers' existing competencies in relation to the discipline and students' prerequisites

---

Permission to make digital or hard copies of all or part of this work for personal or classroom use is granted without fee provided that copies are not made or distributed for profit or commercial advantage and that copies bear this notice and the full citation on the first page. Copyrights for components of this work owned by others than the author(s) must be honored. Abstracting with credit is permitted. To copy otherwise, or republish, to post on servers or to redistribute to lists, requires prior specific permission and/or a fee. Request permissions from [permissions@acm.org](mailto:permissions@acm.org).  
*FabLearn'18, June 18th, Trondheim, Norway*

© 2018 Copyright held by the owner/author(s). Publication rights licensed to Association for Computing Machinery.  
ACM ISBN 978-1-4503-5371-7/18/06...\$15.00  
<https://doi.org/10.1145/3213818.3213828>

and needs. Teachers need pedagogical means to take the societal aspect into account within the discipline. Finally, we argue for further research on supporting teachers when scaling Technology Comprehension on a national level.

## KEYWORDS

technology comprehension, computational thinking, design, education, teachers, national, scaling, making, discipline

## ACM Reference format:

Ari Tuhkala, Marie-Louise Wagner, Nick Nielsen, Ole Sejer Iversen, and Tommi Kärkkäinen. 2018. Technology Comprehension - Scaling Making into a National Discipline. In *Proceedings of FabLearn Conference, Trondheim, Norway, June 18th (FabLearn'18)*, 9 pages. <https://doi.org/10.1145/3213818.3213828>

## 1 INTRODUCTION

We present the opportunities and challenges of scaling *Making* into a nationwide discipline, which is called as "*Technology Comprehension*" (translated from "*Teknologi Forståelse*", hereafter referred as TC). The new discipline is initiated by the Danish Ministry of Education and will be incorporated into the national lower secondary education curriculum (13-15 y.o. students). TC comprehends three main learning objectives: Students understand the core concepts in computing, such as programming, algorithms, pattern recognition, and abstraction. Students specify and articulate a problem and utilise an iterative design process to develop a digital solution. Students reflect and evaluate the problem solution, its applicability, impact, and ethical concerns, from the societal perspective. During the implementation of the new discipline, we conducted interviews, surveys, and a theme discussion with teachers from 13 Danish secondary schools to investigate how the discipline is actualising and what opportunities

and challenges the teachers perceive. For this purpose, we address two research questions: **How is Technology Comprehension perceived as a discipline by experienced teachers** and **what opportunities and challenges teachers face when introducing TC in lower secondary education?**

Making considers hands-on activities, collaboration, prototyping, and iterative design to create digital and physical artefacts and to promote self-cultivation and democratisation [Ball et al. 2017; Blikstein 2013; Blikstein and Krannich 2013; Schelhowe 2013; Smith et al. 2016]. Thus, Making is strongly connected with previous research on design of technology and learning activities with children [e.g. Iivari and Kinnula 2016; Rode et al. 2003; Scaife et al. 1997; Soloway et al. 1994]. Much of the research, that is carried out particularly under the concept of Making, examines opportunities and challenges of Making activities in out-of-school context [e.g. Ryoo et al. 2016; Tan et al. 2016]. However, more research in formal education context is emerging [Berman et al. 2016; Chu et al. 2017; Eriksson et al. 2017; Hjorth et al. 2016; Tan and Barton 2017, e.g.]. Hence, our study contributes to research in formal education context by scaling Making into national policy level through TC.

TC is inspired by extracurricular activities in Denmark, such as Fablab at School [Smith et al. 2015], Coding Class [Hansbøl and Ejsing-Duun 2017], and Coding Pirates [Nørgård and Paaskesen 2016]. Consequently, we consider TC as a Scandinavian alternative for CS4all<sup>1</sup>, Code.org<sup>2</sup>, and the curriculum defined by the Computer Science Teacher Association<sup>3</sup>. These are heavily grounded on *computational thinking*, which was made popular by Wing [2006], and later clarified by Aho [2011] as: "*thought processes involved in formulating problems so their solutions can be represented as computational steps and algorithms*". In national educational policies, such as in the United Kingdom, computational thinking is positioned as a necessity for students' future careers [The Royal Society 2012]. In contrast, TC combines computing, design, and a societal aspect as an interdisciplinary discipline, where the learning goals are understood as means, instead of end-goals, to engage creatively in technology development, understand the role of technology in society, and critically reflect the role of technology in one's life.

The paper reads as follows: Section 2 overviews the current research about Making in formal education context. Section 3 presents the goals and learning objectives of TC, as defined by the Danish Ministry of Education. Section 4 describes the research context, research questions, and the

data collection and analysis methods. We present and discuss the findings in sections 5 and 6. Finally, we conclude the findings, present the limitations, and propose further research.

## 2 MAKING IN EDUCATION

Making has gained a lot of attention in recent years [see Blikstein 2013; Katterfeldt et al. 2015; Martin 2015; Papavlasopoulou et al. 2017]. *Making* refers to the process of adopting a "*maker mindset*" through the creation of meaningful, significant, and shareable artefacts [Giannakos et al. 2017; Martin 2015]. *Maker mindset* relates to the definition of *technologically fluent*: developing adaptive skills in technology and computation to empower people to manipulate the medium to their advantage and to handle unexpected problems [National Research Council 1999]. Making manifests Dewey's democratisation, Papert's constructionism, and Freire's critical pedagogy by incorporating democratisation and empowerment into classical learning-by-doing approaches, such as project-based, student-centred, and constructionist learning [Blikstein 2013].

The possibilities of Making are recognised in education context. Katterfeldt et al. [2015] argues that Making provides opportunities to interact with concrete objects-to-think-with, link students' personal interests and learning activities, and develop self-efficacy through affecting the surrounding environment. Blikstein [2013] states that Making provides an environment for working in a design process with an interdisciplinary approach. Martin [2015] proposes that Making provides sophisticated tools for students to build and think and a tolerant environment for experimenting, play, and making errors. Chu et al. [2017] found that students acquired, through scaffolding, sufficient technical skills, mental models related to troubleshooting and problem decomposition, and understanding the possibilities and practices of sharing ideas and responsibilities.

Despite the opportunities, unfolding Making is challenging due to the incompatibility between obscure processes and the formality of educational settings [Smith et al. 2015, 2016]. Hjorth et al. [2016] point out that teachers need to be able to navigate a complex process, manage digital and analogue materials, and balance different modes of teaching. Smith et al. [2016] emphasise understanding Making technologies as reflective tools instead of outcomes, developing language to express the quality in Making, and creating means to handle insecurity, contingency, and possible lack of authority. Consequently, teachers are too often left alone after the first stage of introducing Making for schools [Blikstein and Krannich 2013].

Eriksson et al. [2017] examined a national level distributed Makerspace project as a single case study by using thematic

<sup>1</sup>CS4All, [www.cs4all.io](http://www.cs4all.io), retrieved 14.3.2018

<sup>2</sup>Code.org, [code.org](http://code.org), retrieved 14.3.2018

<sup>3</sup>Computer Science Teacher Association, [www.csteachers.org](http://www.csteachers.org), retrieved 14.3.2018

analysis of a set of heterogeneous material. They summarise five main considerations: Procurement practices to identify tools, materials, and kits in partnership. Teacher and leader perspectives emphasizing professional training and knowledge sharing with mutual understanding between teachers and school leaders. Informing national policy-making to support general management, for example, of joint teaching material and curriculum development. Creating equal opportunities on both Making and computing for both genders, especially for girls. And finally, creating initial interest, later supported by knowledge creation, through challenging and more advanced projects.

Despite the previous findings, research on Making in the formal education setting is still scarce [Berman et al. 2016; Giannakos et al. 2017; Martin 2015]. Furthermore, a great extent of studies considers Making in the STEM, Computer Science, or Natural Sciences [e.g. Ball et al. 2017; Fields et al. 2017; Tan and Barton 2017; Tan et al. 2016]. Only a few studies have examined Making in an up-scaled version, which reaches beyond a municipality or a school district [for examples, see Bødker et al. 2017; Eriksson et al. 2017]. Hence, there is a crucial need for examining Making as a part of an established and nationwide discipline.

### 3 TECHNOLOGY COMPREHENSION

The Danish Ministry of Education initiated TC as a new discipline for lower secondary education. The curriculum was formulated by three experts representing teaching and research. TC was first piloted in 13 schools as an elective course during fall 2017. The teachers, who are assigned to teach TC, had not received supplementary or in-service training to teach the discipline. Between summer 2018 and 2021, TC will be experimented in over 40 schools to investigate three implementation options: *i*) an independent subject running from first to ninth grade, *ii*) an integrated discipline to existing subjects or *iii*) combination of both, where TC is integrated into other subjects between first to sixth grades and then as an independent subject from third to ninth grades.

The Danish Ministry of Education [2018a] has defined four mandatory topics that TC needs to address: *i*) The implications of technology and automation on society, including an understanding of security, ethical and consequences of digital technologies. *ii*) Computing as a knowledge area, including basic knowledge of networks, algorithms, programming, logic and algorithmic thinking, abstraction and pattern recognition, data modelling as well as testing. *iii*) Iterative design process as an interaction between gaining an understanding of the world that is being designed to and gaining an understanding of the digital technologies that are being designed with. *iv*) Complex problem solving, where children create

new digital solutions and, hence, learn to argue for their relevance through an understanding of design processes.

The Danish Ministry of Education [2018b] has also defined three learning objectives for TC: *i*) Students learn to produce and analyse digital products. *ii*) Students learn to develop, modify, evaluate and refine digital products through work with remixing, refinement, and production. *iii*) Students learn the possibilities and role of informatics as a catalyst for changes in society, in order to strengthen the capabilities for acting in a meaningful way in a democratic and digital society, including constructive and critical contribution in shaping the digital society.

TC has some intersections with computational thinking and computational concepts, practices, and perspectives [as defined in Brennan and Resnick 2012; Kafai et al. 2014; Wing 2006]. However, TC differs significantly from computational thinking in the following areas: Firstly, it treats computing and design as equal competency areas. Secondly, these two areas are dependent on each other, in order to develop students' capabilities to analyse, design, and develop digital products. Thirdly, it integrates the societal aspect, meaning the critical reflection of the societal impact of technology, as a part of the learning objectives. In this sense, TC is related to Schelhowe [2013]'s "Bildung", as a way of considering complex and sustainable learning. These three standpoints are all related to, but different from similar initiatives, such as CS4all in the United States, CoolThink in Hongkong, and Computing in the United Kingdom.

### 4 METHOD

The research is carried out as a co-financed research project, in collaboration between the Center for Computational Thinking and Design at Aarhus University and the Danish Ministry of Education, initiated in October 2017 (Figure 1). The overall goal is to investigate whether TC is appropriate for Danish lower secondary education. The research centre will develop support for the projects' schools and teachers, in order to pursue successful implementation of TC. This support includes establishing an understanding of professional competencies of TC and facilitating peer support among the teachers. Thus, the research perspective is focused on teachers' perceptions.

During winter 2017, we familiarized with the study context by conducting semi-structured interviews with 14 teachers, by following classroom activities of TC in 12 schools, and by sending a survey about the support that teachers would need [Merriam 2009]. Based on these preliminary investigations, we defined the following research questions: *i*) "How is Technology Comprehension perceived as a discipline by experienced teachers" and *ii*) "What opportunities and challenges teachers face when introducing TC in lower secondary education?"

**Figure 1: Specifications of TC in lower secondary education.**

- Trial period from 2017 to 2020
- 13 public schools in Denmark, selected by the Ministry of Education to represent different geographical areas and socio-economic diversities
- 20 teachers and 303 students in the first year of the project
- In 2019, 45 schools will have TC as a compulsory program
- In 2021, TC will be compulsory for K-9 students

We designed a six-hour workshop to provide support for the teachers and to collect data for the study. At the beginning of the workshop, we informed all participants about the data collection. The workshop was executed two times at different regions of Denmark, once in Aarhus (19th February, 2018) and once in Copenhagen (21st February, 2018). In Aarhus, there were nine participants from seven schools: eight teachers and one pedagogical consultant. In Copenhagen, we also had nine participants, of which seven were teachers and two school principals (Table 1).

Our first research question holds the assumption that the workshop participants have previous knowledge and expertise in TC related contents, even though they have not received specific training for teaching TC. Thus, we needed to validate this assumption. We designed a self-assessment questionnaire and provided it to the teachers at the beginning of the workshop. The questionnaire consisted of four Likert scale question sets [Cohen et al. \[2013\]](#). To find how the participants perceive their competence in using digital tools in education, we accustomed the first question set from the digital competence model [Røkenes and Krumsvik \[2016\]](#). The digital competence model does not consider programming, thus, the second question set examined participants perceived programming skills. Two final question sets examined the participants' perceived capability to teach design and computing related concepts.

Answers to the Likert scale questions were analysed with IBM SPSS Statistics. First, "I don't know" answers were excluded as missing answers. Then, frequencies, frequency distributions, and portions were calculated. The question sets were combined into four Likert scale constructs to calculate the means and standard deviations. However, the internal consistency of the constructs could not be verified, due to the small sample size. We also compared the two workshops using the Mann-Whitney test and found no statistically significant differences.

**Table 1: Participants' teaching background (n = 18)**

#	Subjects	Teaching experience
<b>Workshop 1 - Aarhus</b>		
1	IT pedagogy	over 10
2	Math, physics, chemistry, history	3-5
3	History, societal, physics, chemistry, IT	over 10
4	Math, physics, chemistry, TC	over 10
5	Languages, math, sports, household, nature and technology	3-5
6	Math, sports, IT/Fablab	over 10
7	Math, nature and technology, religion, crafts and design, TC	over 10
8	Danish, music, fablab	over 10
9	Math, nature and technology, science	over 10
<b>Workshop 2 - Copenhagen</b>		
10	English, history, crafts and design	5-10
11	Nature and technology, TC	0-2
12	Music, english, TC	0-2
13	Danish, religion, sports, music, TC	0-2
14	History, religion, nature and technology, biology	0-2
15	Math, physics, chemistry, TC	5-10
16-18	Unknown	unknown

The qualitative data consisted of open questions in the self-assessment survey and a theme discussion during the workshop. The open questions were about learning methods, positive or negative experiences, needed skills, and contents of TC. The theme discussion was arranged within the workshop and it served as our main data source. The topics of the theme discussion were: What is TC as an elective course for you, how do you incorporate TC in your current teaching, how do you perceive the competence goals, and what should TC be in future? For the theme discussion, we supplied the participants with a handout of TC learning objectives. The discussion was moderated by one of the authors and recorded with two video-cameras.

The theme discussion was translated and transcribed into English because all authors are not fluent in Danish. To answer the research questions, we conducted a collaborative content analysis [\[Cohen et al. 2013\]](#). First, we negotiated the high-level objective of the analysis. Then, we watched the discussion on a video and made individual notes. After watching the video, we discussed different interpretations and constructed themes that answer the research questions.

Finally, we went back to the answers in the self-assessment survey and further developed the themes.

## 5 RESULTS

We start by describing the competency of the participants and then continue by reporting the findings for the research questions.

### Participants' perceived competency

15 participants answered the self-assessment questionnaire. As can be found in Table 1, seven participants had more than ten years, four participants had three to ten years, and four participants had less than two years of teaching experience. The participants had taught the following subjects: TC, Math, Physics, Chemistry, History, Crafts and Design, Social studies, IT, Danish, Sports, Fablab, Nature and Technology, Religion, German, Music, Biology and Food Literacy.

The participants perceived their competence to use digital tools in education high (Table 2). 90.7% of the answers to the five questions were either competent or highly competent. As mentioned earlier, the digital competence model does not include questions about computing skills. In programming competence questions, Almost all (14) participants answered that they had at least some competence with visual programming languages, such as Scratch. On the other hand, most of the participants (10) had no competence in programming with text-based language. This reveals that, while the participants considered themselves as digitally competent, most had expertise only in using visual programming language. We also asked how the participants perceive their competence to teach TC concepts. Over 60% of the answers to teaching the design concepts were at least competent. In contrast, only 31.1% were at least competent in computing concepts. Consequently, the participants perceived their competence to teach design concepts higher than computing concepts.

Besides the presented competencies, it is worth noting that two of the participants had been part of the expert group in Danish Ministry of Education, which had formulated the exact competency areas, competency goals, proficiency goals and knowledge goals for TC. As a conclusion, the participants perceived high digital competence and most of the participants had a lot of teaching experience and from a broad range of subjects. The participants considered themselves more competent in teaching design concepts than computing concepts.

### Participants' perceptions of TC as a discipline

Two of the Danish Government's implementation options positions TC as an individual discipline. Despite this, the participants addressed TC as a part of some other subject. For example, a participant reduced TC as mere programming

or other separate skill: *"We created programming and math course that starts in the first grade and runs through all grades. Programming is okay, but should not be a standalone subject, it should be part of the other subjects. A tool."* Likewise, when the participants discussed TC in the context of integrating it into other subjects, they considered TC as a tool for learning other subjects' content: *"I think a lot about how it can be part of the natural science subjects. Currently, I am also teaching crafts, where I think that it could fit in. But, as I said, I also think that having it as a part of the natural science would be very exciting for me."* This also became apparent when the participants talked about the tasks that they involve the students in, as noted by a participant: *"they [students] created math games."* Another participant had integrated other subjects, such as entrepreneurship, into TC: *"I tend to focus on the Design part of the subject because that is what I find awesome, this entrepreneurship and I try to keep asking the students questions if they claim that they are done 'Design a Logo', 'Find a company name', 'Create a business model'."* As a conclusion, these perceptions indicate that the participants lacked formalised ways of addressing TC as a distinct discipline, as explicitly coined by one of the participants: *"This new thing that is starting, I think about it as part of the existing subjects."*

As indicated by the previous examples, the participants explicated mainly episodic knowledge of TC. The participants' arguments derived from their own, or others, practices of using technology in education. Even when the learning goals of TC were handed out to the participants, the arguments manifested personal beliefs, experiences, and interests. When considering the learning objectives of TC, the participants with design background emphasised design goals, participants with computing background computing goals, and participants with humanistic background societal goals. Thus, the participants did not have a mutual understanding what TC is currently, or what it should be in the future, but instead relied on personal preferences and episodic knowledge.

### Opportunities of TC

Most of the discussed opportunities were confused with technology-supported education. The participants referred to examples how technology can support students: *"I can have students that are creating a paper booklet, and right next to them another group that works with creating a blog. Both make equal sense. Then you do have students that are able to concentrate for more than 25 minutes because you have access to different technologies."* Another example was using technology to engage students with special needs: *"I had an experience, where mother of a dyslexic child contacted me. Usually, when the girl had to make presentations, she was embarrassed by doing it. She used the computer to make the*

**Table 2: Perceived competencies of the participants ( $n = 15$ ).**

		1	2	3	4	$\Sigma$	Mean	SD
Digital competence	$f$	0	7	26	42	75	3.47	.48
5 questions	$f/n$ (%)	0.0	9.3	34.7	56.0	100		
Programming competence	$f$	18	13	9	2	42	1.93	.64
3 questions	$f/n$ (%)	40.0	28.9	20.0	4.4	93.3		
Teaching design concepts	$f$	3	11	27	1	42	2.62	.60
3 questions	$f/n$ (%)	6.7	24.4	60.0	2.2	93.3		
Teaching computing concepts	$f$	27	30	28	2	87	1.76	.68
6 questions	$f/n$ (%)	30.0	33.3	31.1	2.2	96.6		

Scale: 1=not competent, 2=little competent, 3=competent, 4=highly competent

presentation and felt more capable of presenting due to the auto-correction tools." In addition, the participants brought up the opportunity to motivate students, who use digital tools in spare time or to concretise abstract topics, such as perceiving the coordinate system using Scratch.

The participants presented several narratives how TC engages different students. For example, a participant said: "We have had some boys that were very hard to engage in other subjects, that have been very engaged and therefore also very cooperative on this matter." This was followed up by an example in special education context: "I have never gotten them to focus for more than 25 minutes, now they have been working for 90 minutes". In general, the participants agreed on the fact that TC is an engaging discipline, as concluded by a participant: "[TC] is fun, and a lot of students get engaged by it."

A recurring theme was that TC opens up for more student-centred learning. A participant elaborated on the 9th graders' sense of ownership towards making Math games to 1st graders: "We were making math games with Scratch, it was obvious that older students had a sense of ownership to this assignment. The 9th graders were supposed to make a math game for 1st graders. The day before, 9th graders used their lunch break to go 1st graders and check if the level was too hard. Then 9th graders went back and adjusted the games. That's very uncommon to 9th graders to do something like that in own time." This was also exemplified by another participant, highlighting how TC integrates topics that are relevant to students: "My focus is to have a starting point that the students can relate to, for example, in the Odense municipality we are establishing the new light-rail. The students were concerned about what if a blind person should cross the light-rail, can we be sure that

the train will stop. So they tried to build some sensors with Micro:bits. This was the classical problem-solving setting that the students could relate to." These examples demonstrate the opportunity to actualise TC as a design process that integrates computing, the societal aspect, and problem-solving.

As illustrated by the previous quotes, the participants appreciated the fact that TC combines computing, design, the societal aspect, and problem-solving together. They pointed out that, normally, computing-related curricula are designed by people with the computing background. Hence, the learning objectives tend to address mere computing goals. TC opens up for holistic discipline goals when it is designed by stakeholders from various disciplines.

### Challenges of TC

Several challenges emerged from the data. The participants' conceptions indicated uncertainty about the meaning of the societal aspect in TC. The participants discussed the societal aspect primarily as a means to contextualise the subject with real-world problems. They referred to topics that were familiar from previous teaching experiences in other subjects, such as "fake news" in social media, election meddling, and the earlier example about the light-rail track in Odense. Thus, the participants considered the societal aspect of TC as a means to contextualise classroom activities, instead of a learning objective as such.

The participants proposed students' varying skills as a major challenge. A participant told that: "I have some boys in my elective course and even before I started the teaching they had downloaded the files we should use. At the same time, I had a girl who did not know what a file is. The students had very different skills for participating in this field." Another

participant noted that if TC is first introduced in seventh grade, the prerequisites of the subject are necessarily low. Otherwise, lack of basic skills, such as basic computer use, will prevent those students to pursue the actual learning goals: *"I would like to be better at presenting the students with a problem as a starting point, where they can analyse, design and develop. Currently, they have mostly worked with learning the different technologies."* A participant concluded that if the basic computing skills are to be taught in TC, it leaves less space and time for other learning objectives.

Another challenge was that students have different needs regarding the structure and guidance of TC learning activities. Some students want to be challenged and to be provided with less guidance, while others are incapable of acting without clear structure and instructions: *"Some of them expect to be challenged, some of them expect to get everything served on a silver plate. That is one of the biggest challenges I have to get them to be better."* This indicates that TC, as a new discipline, calls for high level of individual differentiation of the learning activities.

Finally, other identified challenges were: gender issue, teachers' need for time and peer support. As manifested by the earlier quotes about students' varying skills, gender issue is an existing topic also in TC. A participant stated: *"A lot of students want to participate in 4-6th grade, in 7-9th grade, it is primarily boys."* The participants' conceptions distinguished between boys, as being interested and knowledgeable, and girls as not necessarily interested, or engaged, in TC. The participants pointed out that teachers need more time, peer support, and scaffolded teaching instructions to be able to implement TC as a new discipline. As concluded by one participant: *"[TC] is a new subject and a new way of thinking in primary school. It requires more preparation time than the 'normal subjects', where you can adopt a lot of existing teaching material from various learning portals into your own work."*

## 6 DISCUSSION

Our findings derive from the first year of scaling TC into a national initiative. Despite the fact that we are early in the project, the teachers provided us with important practice-based knowledge for scaling TC and, thus, to our research questions: How is TC perceived as a discipline by experienced teachers and what opportunities and challenges teachers face when introducing TC in lower secondary education? Consequently, our empirical findings suggest that: *i)* teachers do not perceive TC as a distinguished discipline, *ii)* TC opens up for interdisciplinary and engaging learning activities, and *iii)* TC challenges teachers' existing competencies in relation to the discipline and students' prerequisites and needs.

**Teachers do not perceive TC as a distinguished discipline.** Technology Comprehension is a term coined by the Ministry of Education and, thus, not well-known among teachers or in research. Our research results reveal that teachers do not see TC as a distinct discipline, but rather as a set of skills that can be integrated into other disciplines. This finding can be related to what [Smith et al. \[2016\]](#) considered as the impediments to integrating making into K12-education. Whereas [Smith et al. \[2016\]](#) found that teachers generally lack a sufficient understanding of digital technology and complex problem solving, our study indicates that teachers do not possess an understanding of the disciplines (computing/design/societal aspect) related to digital technology. The insufficient understanding of the disciplines is not a challenge to the teachers, but rather, it is a challenge to the entire TC initiative and ultimately to research.

**TC opens up for interdisciplinary and engaging learning activities.** As stated above, TC has similarities with current research incorporating computing and design into curriculum based and formal education [[Smith et al. 2015](#)]. We found that teachers identified several opportunities in implementing TC: it encourages children to be creative with digital technology, to work with authentic and complex problems and to take responsibility for their learning process. Moreover, the participants thought that students perceive TC learning activities as engaging, inspiring, and fun. TC shares [Schelhowe \[2013\]](#)'s reasons for introducing making in curriculum-based education: developing skills related to computing and computational thinking, but also to digital citizenship, in relation to a digitized and post-modern society. In this way, TC embraces digital competencies as well as critical and reflective personal skills that relate to [Schelhowe \[2013\]](#)'s "Bildung", [Iversen et al. \(2018, in press\)](#) Computational empowerment, [Blikstein \[2013\]](#)'s empowerment, and also [Brennan and Resnick \[2012\]](#)'s and [Kafai et al. \[2014\]](#)'s computational perspectives. The opportunities to address digital technology from a critical and societal point of view are discussed by the teachers. However, the teachers do not feel capable of bridging between hands-on activities and more abstract discussion of computational perspectives. To fulfil the opportunities, scaffolding activities such as in-service training of teachers, development of textbook material, and online resources are required to support this effort.

**TC challenges teachers' existing competencies in relation to the discipline and students' prerequisites and needs.** We identified the following challenges: lack of shared understanding of the meaning of the societal aspect in TC, students' varying skills and needs, and paradox between instructional structure and freedom, and lack of girls' involvement. The challenge of balancing between creative Making

activities and formal education's structure is already known in research considering Making in education [Hjorth et al. 2016; Smith et al. 2015, 2016]. Furthermore, some of the challenges, such as the need for teachers' support to use digital tools and to teach computing concepts, students' varying skills, and gender issues, are well known in other fields [see Cox 2013; Hsu 2017; Uluyol and Şahin 2016; Wastiau et al. 2013]. Our study contributes by pointing out the imminent need for considering how the societal aspect, including topics like ethics, empathy, responsibility, and accountability, are defined as concrete learning objectives to provide teachers with tools to assess how they are being met.

## 7 CONCLUSION

This study contributed to the FabLearn community by reporting the first research results from the government-initiated research about introducing Technology Comprehension into a national curriculum. Based on interviews, surveys, and theme discussion with highly experienced teachers, we found that teachers do not perceive TC as a distinguished discipline, TC opens up for interdisciplinary and engaging learning activities, and TC challenges teachers' existing competencies in relation to the discipline and students' prerequisites and needs.

We identify the following shortcomings in our study: Our findings derive solely from interactions with teachers and does not include principals, policy-makers, or students. We have not taken into consideration that many teachers will ultimately teach TC without prior experiences or any compulsory education in TC. This will inarguably further emphasise the need for better means to support teachers. Due to the scope of this paper, we have not conducted an in-depth and systematic literature review that goes beyond the recent literature in Fablearn and Making. A next step would be to systematically survey on literature within Computer Science Education, Technology Design with Children, and other relevant research communities to identify what could be gained from similar studies in these areas of research.

The challenges of implementing the political agenda to offer TC to all students in Denmark, even by the highly experienced teachers, should be addressed merely as a general lack of research about TC. Consequently, our study raises several questions for researchers within Fablearn and Making fields: What is TC as a discipline and how do we merge previous research on computing and design education to develop TC? How do we develop a curriculum and supplementary training for pre-service and in-service teachers to support their TC teaching practices? How do we incorporate the critical and societal approach of TC as concrete learning objectives, of which accomplishment could be assessed?

How do we balance between the obscure structures of Making, computing, and design with the formal curriculum in education?

## ACKNOWLEDGEMENTS

We want to thank the Danish Ministry of Education and, especially, the teachers who participated in the study.

## REFERENCES

- Alfred V. Aho. 2011. Ubiquity symposium: De computation and Computational Thinking. *Ubiquity* 2011, January (jan 2011), 1. <https://doi.org/10.1145/1922681.1922682>
- Douglas Ball, Colby Tofel-Grehl, and Kristin A. Searle. 2017. Sustaining Making in the Era of Accountability: STEM Integration Using E-Textiles Materials in a High School Physics Class. In *Proceedings of the 7th Annual Conference on Creativity and Fabrication in Education (FabLearn '17)*. ACM, New York, NY, USA, Article 2, 7 pages. <https://doi.org/10.1145/3141798.3141801>
- Alexander Berman, Brittany Garcia, Beth Nam, Sharon Chu, and Francis Quek. 2016. Toward a Making Community of Practice: The Social Aspects of Elementary Classroom-Based Making. In *Proceedings of the 6th Annual Conference on Creativity and Fabrication in Education (FabLearn '16)*. ACM, New York, NY, USA, 9–16. <https://doi.org/10.1145/3003397.3003399>
- Paulo Blikstein. 2013. Digital Fabrication and 'Making' in Education: The Democratization of Invention. In *FabLabs: Of Machines, Makers and Inventors*, J. Walter-Herrmann and C. Buching (Eds.). Bielefeld: Transcript Publishers, 1–21. <https://doi.org/10.1080/10749039.2014.939762>
- Paulo Blikstein and Dennis Krannich. 2013. The makers' movement and FabLabs in education. In *Proceedings of the 12th International Conference on Interaction Design and Children - IDC '13*. ACM Press, New York, New York, USA, 613. <https://doi.org/10.1145/2485760.2485884>
- Susanne Bødker, Christian Dindler, and Ole Sejer Iversen. 2017. Tying Knots: Participatory Infrastructuring at Work. *Computer Supported Cooperative Work (CSCW)* 26, 1-2 (feb 2017), 245–273. <https://doi.org/10.1007/s10606-017-9268-y>
- Karen Brennan and Mitchel Resnick. 2012. New frameworks for studying and assessing the development of computational thinking. *annual American Educational Research Association meeting, Vancouver, BC, Canada* (2012), 1–25. <https://doi.org/10.1.1.296.6602>
- Sharon Lynn Chu, Francis Quek, Elizabeth Deuermeier, and Rachel Martin. 2017. From Classroom-Making to Functional-Making: A Study in the Development of Making Literacy. In *Proceedings of the 7th Annual Conference on Creativity and Fabrication in Education (FabLearn '17)*. ACM, New York, NY, USA, Article 3, 8 pages. <https://doi.org/10.1145/3141798.3141802>
- Louis Cohen, Lawrence Manion, and Keith Morrison. 2013. *Research methods in education*. Routledge.
- M. J. Cox. 2013. Formal to informal learning with IT: research challenges and issues for e-learning. *Journal of Computer Assisted Learning* 29, 1 (feb 2013), 85–105. <https://doi.org/10.1111/j.1365-2729.2012.00483.x>
- Danish Ministry of Education. 2018a. Kommissorium for den rådgivende eksperterkrivegruppe for forsøgsprogram for styrkelse af teknologiforståelse i folkeskolens obligatoriske undervisning. (2018). <https://www.uvm.dk/-/media/filer/uvm/udd/folke/pdf18/jan/180124-kommissorium-for-raadgivende-eksperterkrivegruppe-teknologiforstaaelse.pdf>
- Danish Ministry of Education. 2018b. Teknologiforståelse valgfag – Fælles mæl og læseplan. (2018). <https://www.emu.dk/modul/teknologiforst>
- Eva Eriksson, Carl Heath, Peter Ljungstrand, and Peter Parnes. 2017. Making space in school—Considerations from a large-scale national testbed.

- International Journal of Child-Computer Interaction* (2017), 1–7. <https://doi.org/10.1016/j.ijcci.2017.10.001>
- Deborah A. Fields, Yasmin B. Kafai, Tomoko Nakajima, and Joanna Goode. 2017. Teaching Practices for Making E-Textiles in High School Computing Classrooms. In *Proceedings of the 7th Annual Conference on Creativity and Fabrication in Education (FabLearn '17)*. ACM, New York, NY, USA, Article 5, 8 pages. <https://doi.org/10.1145/3141798.3141804>
- Michail N. Giannakos, Monica Divitini, and Ole Sejer Iversen. 2017. Introduction for the Special issue on 'Maker technologies to foster engagement and creativity in learning'. *Entertainment Computing* 18 (jan 2017), 143–144. <https://doi.org/10.1016/j.entcom.2016.11.001>
- Mikala Hansbøl and Stine Ejsing-Duun. 2017. Hovedrapport: Coding Class - Dokumentation og Evaluering. (2017). <https://itb.dk/sites/default/files/Rapport>
- Mikkel Hjorth, Rachel Charlotte Smith, Daria Loi, Ole Sejer Iversen, and Kasper Skov Christensen. 2016. Educating the Reflective Educator: Design Processes and Digital Fabrication for the Classroom. In *Proceedings of the 6th Annual Conference on Creativity and Fabrication in Education (FabLearn '16)*. ACM, New York, NY, USA, 26–33. <https://doi.org/10.1145/3003397.3003401>
- Shihkuan Hsu. 2017. Developing and validating a scale for measuring changes in teachers' ICT integration proficiency over time. *Computers & Education* 111 (aug 2017), 18–30. <https://doi.org/10.1016/j.compedu.2017.04.001>
- Netta Iivari and Marianne Kinnula. 2016. Inclusive or Inflexible: A Critical Analysis of the School Context in Supporting Children's Genuine Participation. In *Proceedings of the 9th Nordic Conference on Human-Computer Interaction (NordiCHI '16)*. ACM, New York, NY, USA, Article 63, 10 pages. <https://doi.org/10.1145/2971485.2971531>
- Yasmin B. Kafai, Eunyoung Lee, Kristin Searle, Deborah Fields, Eliot Kaplan, and Debora Lui. 2014. A Crafts-Oriented Approach to Computing in High School: Introducing Computational Concepts, Practices, and Perspectives with Electronic Textiles. *Trans. Comput. Educ.* 14, 1, Article 1 (March 2014), 20 pages. <https://doi.org/10.1145/2576874>
- Eva-Sophie Katterfeldt, Nadine Dittert, and Heidi Schelhowe. 2015. Designing digital fabrication learning environments for Bildung: Implications from ten years of physical computing workshops. *International Journal of Child-Computer Interaction* 5 (sep 2015), 3–10. <https://doi.org/10.1016/j.ijcci.2015.08.001>
- Lee Martin. 2015. The Promise of the Maker Movement for Education. *Journal of Pre-College Engineering Education Research (J-PEER)* 5, 1 (apr 2015). <https://doi.org/10.7771/2157-9288.1099>
- Sharan B. Merriam. 2009. *Qualitative Research - A Guide to Design and Implementation* (3rd ed.). Jossey-Bass, San Francisco. 320 pages.
- National Research Council. 1999. *Being Fluent with Information Technology*. National Academies Press, Washington, D.C. <https://doi.org/10.17226/6482>
- Rikke Toft Nørgård and Rikke Berggreen Paaskesen. 2016. Open-ended education: how open-endedness might foster and promote technological imagination, enterprising and participation in education. *Conjunctions : transdisciplinary journal of cultural participation* 3, 1 (2016), 1–25.
- Sofia Papavlasopoulou, Michail N. Giannakos, and Letizia Jaccheri. 2017. Empirical studies on the Maker Movement, a promising approach to learning: A literature review. *Entertainment Computing* 18 (jan 2017), 57–78. <https://doi.org/10.1016/j.entcom.2016.09.002>
- Jennifer A. Rode, Mark Stringer, Eleanor F. Toye, Amanda R. Simpson, and Alan F. Blackwell. 2003. Curriculum-focused Design. In *Proceedings of the 2003 Conference on Interaction Design and Children (IDC '03)*. ACM, New York, NY, USA, 119–126. <https://doi.org/10.1145/953536.953553>
- Fredrik Mørk Røkenes and Rune Johan Krumsvik. 2016. Prepared to teach ESL with ICT? A study of digital competence in Norwegian teacher education. *Computers & Education* 97 (jun 2016), 1–20. <https://doi.org/10.1016/j.compedu.2016.02.014>
- Jean J. Ryoo, Lianna Kali, and Bronwyn Bevan. 2016. Equity-Oriented Pedagogical Strategies and Student Learning in After School Making. In *Proceedings of the 6th Annual Conference on Creativity and Fabrication in Education (FabLearn '16)*. ACM, New York, NY, USA, 49–57. <https://doi.org/10.1145/3003397.3003404>
- Michael Scaife, Yvonne Rogers, Frances Aldrich, and Matt Davies. 1997. Designing with or Designing with? Informant Design for Interactive Learning Environments. In *Proceedings of the ACM SIGCHI Conference on Human Factors in Computing Systems (CHI '97)*. ACM, New York, NY, USA, 343–350. <https://doi.org/10.1145/258549.258789>
- Heidi Schelhowe. 2013. Digital realities, physical action and deep learning-FabLabs as educational environments. *FabLab: Of Machines, Makers and Inventors* (2013), 93–103.
- Rachel Charlotte Smith, Ole Sejer Iversen, and Mikkel Hjorth. 2015. Design thinking for digital fabrication in education. *International Journal of Child-Computer Interaction* 5 (sep 2015), 20–28. <https://doi.org/10.1016/j.ijcci.2015.10.002>
- Rachel Charlotte Smith, Ole Sejer Iversen, and Rune Veerasawmy. 2016. Impediments to Digital Fabrication in Education: A Study of Teachers' Role in Digital Fabrication. *International Journal of Digital Literacy and Digital Competence* 7, 1 (jan 2016), 33–49. <https://doi.org/10.4018/IJDLDC.2016010103>
- Elliot Soloway, Mark Guzdial, and Kenneth E. Hay. 1994. Learner-centered design: the challenge for HCI in the 21st century. *interactions* 1, 2 (apr 1994), 36–48. <https://doi.org/10.1145/174809.174813>
- Edna Tan and Angela Calabrese Barton. 2017. Designing for Rightful Presence in STEM-rich Making: Community Ethnography As Pedagogy. In *Proceedings of the 7th Annual Conference on Creativity and Fabrication in Education (FabLearn '17)*. ACM, New York, NY, USA, Article 8, 8 pages. <https://doi.org/10.1145/3141798.3141807>
- Edna Tan, Angela Calabrese Barton, Myunghwan Shin, and Carmen Turner. 2016. Probing Participatory Partnerships: Equitably-consequential Making by, for and with Marginalized Youth. In *Proceedings of the 6th Annual Conference on Creativity and Fabrication in Education (FabLearn '16)*. ACM, New York, NY, USA, 1–8. <https://doi.org/10.1145/3003397.3003398>
- The Royal Society. 2012. *Shut down or restart? The way forward for computing in UK schools*. Technical Report. 1–122 pages.
- Çelebi Uluyol and Sami Şahin. 2016. Elementary school teachers' ICT use in the classroom and their motivators for using ICT. *British Journal of Educational Technology* 47, 1 (2016), 65–75. <https://doi.org/10.1111/bjet.12220>
- Patricia Wastiau, Roger Blamire, Caroline Kearney, Valerie Quittre, Eva Van de Gaer, and Christian Monseur. 2013. The Use of ICT in Education: a survey of schools in Europe. *European Journal of Education* 48, 1 (mar 2013), 11–27. <https://doi.org/10.1111/ejed.12020>
- Jeannette M Wing. 2006. Computational thinking. *Commun. ACM* 49, 3 (mar 2006), 33. <https://doi.org/10.1145/1118178.1118215> arXiv:=-