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A framework for developing playfulness, experimentation and critical thinking within the concepts of Technological Comprehension and Computational Thinking

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ABSTRACT

This article draws on insights from cases of researching, developing and teaching Computational Thinking (CT) and Technological Comprehension (TC) within the Arts/Humanities; to show how a guiding framework might enable teaching and learning as a co-operative playful academic community in educational practice. The cases are a research project on implementing Technological Comprehension within the subject of Danish in elementary school (2018-2019); Computational Network Zealand (2019); a Master's course in CT and design processes at Aarhus University (2019-2020). The cases were selected within the context of integrating CT and TC in the educational system of Denmark. The article aims to create a guiding framework for scaffolding pedagogical processes and creating educational design patterns. Through the process of creating Educational design Patterns the educators are supported in creating curriculum development from a bottom-up perspective. This is done through tinkering and playfulness in design collaboratories with a pedagogical foundation submerged in the liberating bildung and critical pedagogy.
This article promotes a guiding framework for developing playfulness, experimentation and critical thinking within the concepts of TC and CT.

Introduction

This article is inspired and draws on insights from three cases of researching, developing and teaching Computational Thinking (CT) and Technological Comprehension (TC) in the primary, secondary and higher education in Denmark. First case (2018-2019): During Søren Baltzer Rasmussen's Master, he was a part of a research project implementing Technological Comprehension in the subject of Danish at Tingløkke public school in Odense. The project was initiated by the National Centre of Knowledge for Learning Resources and consisted of researchers from University City College Lillebælt, two Danish teachers and two 4th grade classes. The second case (January 2019 - March 2019): Likewise, Baltzer Rasmussen was involved within a "network for computational thinking", which was organised by IT-Center Fyn. IT-Center Fyn is an organisation in charge of the digital infrastructure of many secondary educational institutions in Denmark and also provides IT pedagogical and didactic inspiration for its members. The network consisted of educators from different high schools situated in Zealand. The focus in the network was to create a process, where the educators through design processes and design patterns, could transform computational thinking into real lesson plans. The last case (October 2019 - February 2020): Moreover, both Søren Baltzer Rasmussen and Merethe Haahr Francis was involved in teaching CT, design thinking and design processes at a Master's course at Aarhus University (2019-2020) for educators in primary, secondary and higher education. This case was a part of Merethe H. Francis's thesis which was a product thesis. All three cases focused on creating a guiding framework for the development of educational design patterns for CT/TC emphasizing playfulness and tinkering in the process.

Background

In 2017 the Danish Digital Growth Panel (an initiative by the Danish Ministry of Industry, Business and Financial Affairs) concluded that Denmark by 2030 will lack around 19.000 IT-specialists and a workforce with competencies in the technical and scientific field (Digital Vækspanel, 2017). These competencies were identified as STEM competencies (Science, Technology, Engineering, Math) and CT and TC are highlighted as necessary focal points in the educational system to achieve STEM competencies and as an important source for future national growth (Digital Vækstpanel, 2017).

Therefore, TC has been developed as a trial subject for primary and secondary education in Denmark in a trial period over three years both as an individual subject and as part of existing subjects. Over 40 schools are currently experimenting with TC as a part of the curriculum (EMU, 2019). And CT has also become mandatory and integrated in secondary, upper secondary and higher education (Vækstråd, 2016; Digital Vækstpanel, 2017).

Despite the wide-spread engagement with and integration of CT, there is still no proper definition of CT and TC (Lao et. Al., 2017:2 & Iversen, et. al., 2018:2) – However, it is mandatory in secondary, upper and higher education (Barr et al., 2011; Caspersen & Iversen, 2019).

> Implementing CT during the school day is a compelling vision, but there are substantial challenges to this, including existing curriculum standards, lack of opportunities for teachers to learn CT as part of their professional development, and lack of access to necessary infrastructure (Coulter et al, 2011:36).

TC originates from the Scientific - and Design domain (Nørgård, 2020:6). Which clearly shows in an analysis from teacher training courses focusing on TC across the Nordic countries for elementary and secondary education. These courses also make use of vocabularies, concepts, practices and activities originating from a STEM oriented framework, with a focus on programming and problem solving. (Bocconi et al, 2018:15).

In the wake of this one could ask the question: What happens with the signature pedagogies in the subjects of Arts/Humanities if the current TC/CT didactic is infused with definitions and concepts from the scientific and design domain focusing on problem solving? This could potentially leave little space for teachers' pedagogical interpretation and experimentation for developing a practice for TC within Arts & Humanities. The signature pedagogy of Arts/Humanities is often of a more philosophical nature focusing on imagination, Bildung and critical thought in expressing and developing the students' identities and being wondrous about other future alternatives (without necessary focusing on problem solving):

> Indeed, what we might call the humanistic aspects (...) the imaginative, creative aspect, and the aspect of rigorous critical thought—are (...) losing ground as nations prefer to pursue short-term profit by the cultivation of the useful and highly applied skills suited to profit-making. (Nussbaum, 2012:2)

In this article we try to develop a possible framework which might enable teaching and learning as a co-operative playful academic community in an actual educational setting (Laurillard, 2012; Sinfield, Burns & Abegglen, 2019). A CT/TC framework infused with critical thought and playfulness to open up for new ways of developing CT/TC didactics, activities and playfulness. (Brown et al, 2010). Where: "Spaces are created for discussions and alternative ways of being, and to inspire and encourage people's imagination to flow freely" (Dunne & Raby, 2013:2). Where the teachers involved created pedagogical design patterns (prototypes) for CT/TC situated in the signature pedagogy for ARTS/Humanities (Laurillard, 2012).

Introducing another framework for CT/TC

In Denmark the term CT is mentioned as a part of the term "Teknlogiforståelse" [Technology comprehension] in primary and secondary education and as a part of "Informatik" [Informatics] for upper secondary level. But there is no consensus about the didactisation or educational practices surrounding CT/TC (Bocconi et al, 2018). Which leads to a market for many "meso" level actors interpreting the concepts of CT/TC to educators:

> "There is a clear role for meso-level actors to develop the curriculum. Many teachers lack a professional language to critically engage with educational 19 policies (...) [the] role of meso-level actors [is] significant (...) what is needed is engagement with educational enquiry, both empirical and theoretical. (...) the theory dimension is particularly important in order to broaden and deepen teacher's discourses and vocabularies: the resources that play a crucial role in seeing, thinking, judging and acting"
>
> (Biesta et al, 2015:3460/439).

But the problem with courses designed for educators/teachers for CT/TC, is that they are mainly conducted by many meso level actors, these are private companies, public consultants and teacher training initiatives financed by the Ministry of Education. These courses mostly make use of concepts and practices from a STEM oriented framework focusing on the aspect of coding without or with very little space for development of teacher's pedagogical experimentation, interpretation and integration into their curriculum (Bocconi et al, 2018).

In Denmark, TC has been created as a standalone elective and a mandatory part of Math, Social Studies, Physics & Chemistry, Danish and Visual Arts (EMU, 2019). But the focus on TC is not restricted to primary education - its a political focus point throughout the entire Danish educational system (Digital Vækstpanel, 2017) TC consist of four dimensions: Digital empowerment, Digital design and design processes, Computational thinking (CT) and Technological knowledge and skills (see figure 1).

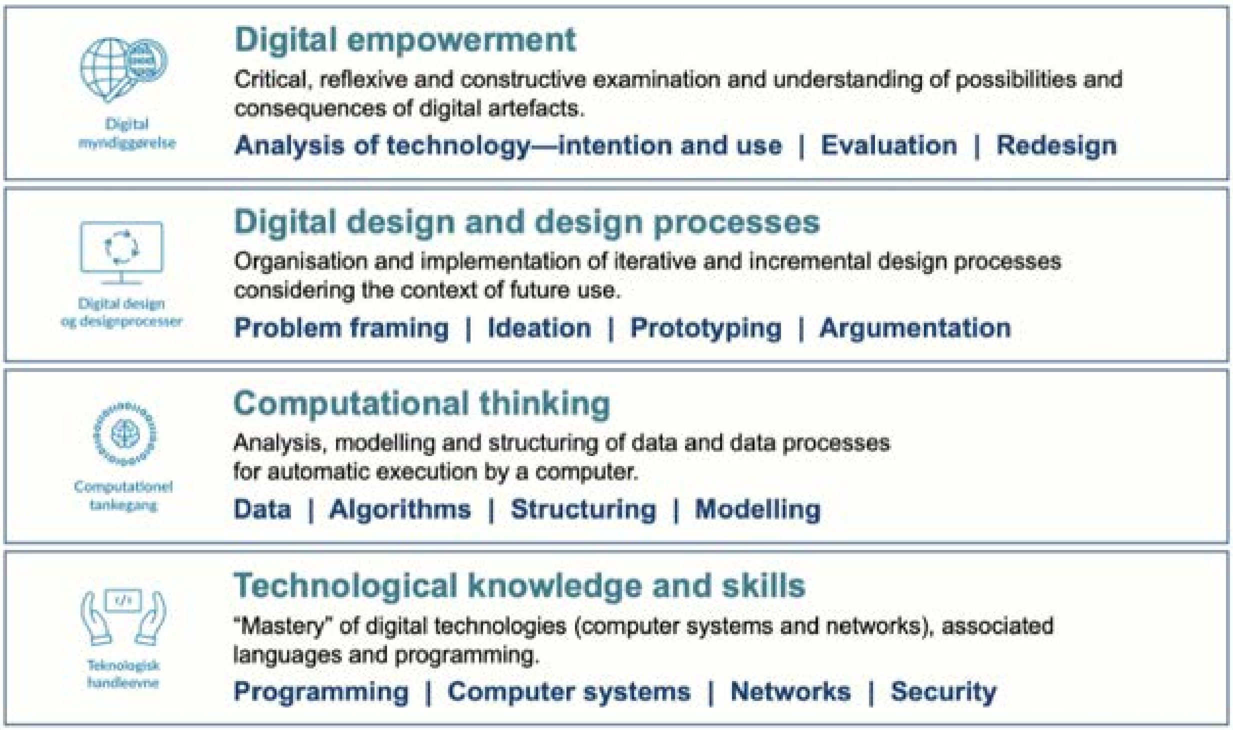


Figure 1: The four competencies in Technology Comprehension (Bossen et al, 2020:3).

At first glance this creates the perfect conditions for playful and creative pedagogies - just imagine what can be done when combining Visual Arts with Digital Empowerment and Digital design and design processes! But we need to take an epistemological look at CT/TC to understand the problem CT/TC might cause to the very core of Humanities and Arts. First of all CT/TC and the focus on CT/TC in all of the Danish educational system from primary school till higher education was initially created on the basis of a report conducted by the Digital Growth Panel (an initiative of the Danish Ministry of Industry, Business and Financial Affairs). This report concluded that Denmark in 2030 would lack 19.000 IT-specialists and a workforce with competencies in the technical and scientific field. These competencies are also known as STEM-competencies (Science, Technology, Engineering, Math) and the report emphasizes CT/TC as a focal point in the educational system and as an important source for future national growth in the business community of Denmark. (Digital Vækstpanel, 2017) As a result of this in 2017 the Ministry of Economic and Business Affairs appointed a new advisory group the Technology Pact to strengthen CT/TC in education on all levels and across the disciplines. The primary societal goal of introducing TC is to ensure technologically competent citizens that hold the necessary mindset, competencies and skill-set in current society and future worklife. This is the underlying ambition of the Danish Government for introducing CT/TC in education as well as the goal of launching the Technology Pact that is formed to ensure that 20% more youth get into STEM-education. Here, teachers and students are asked to struggle with technologies in ways that give students competencies and knowledge relevant for future worklife and the present digital society. (Digital Vækstpanel,A 2017:21)

This is in alignment with a political neoliberal view on education or a market logic so to speak: "First, neoliberal forms of governance have introduced a market logic into many professional fields, including teaching. (...) This is an approach that seeks to restrict teacher agency, to control, rather than guide or facilitate". (Biesta et al, 2015:2371) And especially Arts/Humanities struggles to prove its worth for society and education and creating students with competencies for the future job market. The Danish Minister of Trade and Industry underlined, when he created the Technology Pact that there must and should be an increased focus across the Danish educational system on the needs of the future job market. OECD put it this way:

> "The future is uncertain and we cannot predict it; but we need to be open and ready for it. Schools can prepare them for jobs that have not yet been created, for technologies that have not yet been invented, to solve problems that have not yet been anticipated" (OECD, 2018:2)

Throughout the decade, and even before, the Arts/Humanities have been struggling to keep its place and prove its worth for society and education. It finds itself under constant pressure to provide evidence for its socio-economic use value, its job market relevance and its contribution to society. (Cohen, 2016; Lekfeldt, 2018; Strauss, 2017). Barnett calls this a "financialization" of the academic world. (Barnett, 2018:62)

CT/TC is being incorporated into the educational system with the concepts, vocabulary, frameworks and practices that comes with it (see figure 1) and are being implemented in Arts/Humanities but with an epistemology foreign to them. (Nørgård, 2020:6) Which is also evident in the analysis of teacher training courses across the Nordic countries. (Bocconi et al, 2018:15). This of course leads to consistency in the implementation of CT/TC across the educational system, but it could also lead to a diminuir of the humanistic aspect (Nussbaum, 2012) and: "assimilation' of the Arts & Humanities by STEM & Design as whole vocabularies (Caspersen & Iversen, 2019), frameworks (Bossen et al., 2020:3; Caspersen et al., 2019:29), fields and disciplines (Dindler et al., 2019; Caspersen et al., 2018) are imported and implemented into the Arts/Humanities by way of TC." (Nørgård, 2020)

STEM & Design are visible in the four competencies in Technology Comprehension (see figure 1) (Caspersen, Iversen et. al, 2018; EMU, 2020; Nørgård, 2020):

- **Computational thinking & Digital design and design processes:** An immense focus on problem-solving and solution-making through finding and framing (complex) problems in order to devise and design solutions.
- **Technological knowledge and skills:** Focus is on students' developing the ability to programme and being able to utilize technology (computer systems, networks and digital technology) in order to create a solution.
- **Digital empowerment:** Focus is on students' ability to decode technology and creating a critical awareness in relation to how technology works, how it affects their lives and the intentions of technology.
- **Competent citizens & future society**: The primary societal goal of introducing CT/TC is to ensure technologically competent citizens that hold the necessary mindset, competencies and skill-set in current society and future worklife. This is the underlying ambition of the Danish Government for introducing CT/TC in education as well as the goal of launching of the *Technology Pact* that is formed to ensure that 20% more youth get into STEM-education.

In the article 'Critical Computational Empowerment: engaging youth as shapers of the digital future' (2017) Tissembaum et al. emphasize the need for developing "computational identity" and "critical computational literacy". Tissenbaum et al. invision an educational space focusing on creating: "conditions for young people to break silences, reveal obscured truths, and challenge unjust systems and conditions" and not the mechanics of coding (Tissenbaum et al., 2017:1707). And Paulo Freire accentuates that critical and liberating pedagogy is about building a framework which supports and enables futurity by creating an experimenting and playful space that invokes both educators' and students' imagination towards imagining a completely different world and a reconfiguration of total reality. (Freire, 2005:84) Which is another approach to CT/TC than focusing on problem solving and also according to Freire: "problem-solving can reduce human experience and humanity into a tool that effectively can solve society's problems - without problemising society itself" (Freire, 1974 :ix).

Inspired by the above we wanted to experiment with creating a guiding framework or process where teachers (in our cases both from primary, secondary and higher education) experimented with creating and developing CT/TC didactical design patterns, through tinkering and playfulness. We wanted to create a playground for the teachers sparking their technological imagination. Inviting the teachers to explore, play, experiment and fantasize with technologies in order to create CT/TC activities for their students with a focus on play, exploration and imagination. In order for students to be critical-creative shapers of technologies (critical computational bildung), capable of creating both fantasies and ideas about how they would like the world to be in the future. Where the students achieve critical computational empowerment and to experiment and develop their own computational identity - thus being able to participate as transforming agents of their own social reality with technology (Tissenbaum et al., 2017:1708). Giving students the opportunity to voice their own dreams and hopes.

Inspired by Nordic participatory design processes and Paulo Freire's term 'conscientizacao' we wanted through explorative and playful processes create a space for: "creation, capable of releasing other creative acts, one in which students would develop the impatience and vivacity which characterize search and invention." (Freire, 1974:39) So again, instead of CT/TC becoming a tool for problem-solving and solution-making; CT/TC becomes a way of imagining. Rather, than framing technology and design in a context of problem-solving and solution-making, Duggan et al. focus on performative prototypes (rather than functional prototypes) and design fictions as a way of imagining: "instead of designing solutions to problems, participatory design (...) practices might better be thought of as a (...) open spaces and opportunities for pupils to give voice to their concerns and be heard". (Duggan et al., 2017:21).

The guided framework has a playful approach to teaching and learning, as well as our research to develop this framework. This playful approach was in line with several initiatives launched in 2020 to be playful in Danish Higher Educations (Aarhus University, 2020). Miguel Sicart (2017) framed the playfulness as a state of mind: "What we want is the attitude of play without the activity of play" (p.21). We are convinced that the playful approach can help:

> "...to produce playful, creative graduates who can apply the same creative approach to their future careers as we enable in their learning. A student who feels safe to play will overcome challenges and think of new, innovative, solutions, compared to one who follows set paths who may always be reluctant to depart from that path and discover new knowledge, meet new challenges, develop new solutions" (Walsh, 2015).

John Dewey explained: "Playfulness is a more important consideration than play. The former is an attitude of mind; the later is a passing outward manifestation of this attitude" (In Resnich, 2019:129).

In our playful and exploring framework setup we used the theory about playgrounds. In this way we could create space for exploring, experimenting and collaborating to develop didactical design patterns for CT/TC (Resnich, 2019:130). Playgrounds are different from game spaces:

> "Playgrounds as metaphors also allow us to escape from game spaces, which are designed for the purpose of playing games but do not always allow the exploration of the creative and appropriative capacities of play. If play spaces are defined by something, from skater parks to Proteus, that is the openness to appropriation, the ways in which they let us play, giving us a place to be" (Sicart, -: 59).

As Miguel Sicart states:

> "Play matters when it is appropriative, taking over a situation and turning it into a context of play. Toys facilitate appropriation: they create an opening in the constitution of a particular situation that justifies the activity of play. Through toys, we realize that play is possible, and we start playing. The toy is a gate to the world understood through play. Toys (in the broad sense). "play media" and "loose parts"

are all objects that can inspire and help maintain play".

Inspired by the thoughts above, we wanted to experiment with creating "some sort" of guiding framework that could highlight our "take" on a Humanities/Arts approach on CT/TC. Not just a theoretical framework, we wanted to try this out in authentic settings with teachers, who teach students and create CT/TC didactical design patterns. And in this process we were very inspired by Laurillard, who accentuates that teachers themselves should be "drivers" of new knowledge - especially when it comes to technology - and share their design to other teachers (Laurillard, 2010) Thus creating new pedagogical and didactic knowledge situated in the midst of their signature pedagogy. Creating curriculum development for CT/TC from a bottom-up perspective.

The design collaboratory as a didactical, experimenting and playing laboratory

This framework has its foundation in the critical pedagogy and participatory design processes as a space for both democratic processes and being able to be playful and to "tinker" with technology. The framework can be seen as a design collaboratory. Bødker & Buur (2000) frame the design collaboratory as being a:

> "..supporting collaboration between a variety of persons, groups and competencies in the design process. The voices of the users [teachers] are represented in this, either through actual participation of users or through previous work in the users' sites. It is important for the design collaboratorium that it supports joint action through access to prototypes and other tangible means of "doing" [Computational Thinking designs] (Bødker og Buur, 2000, p. 302).

And in the design collaboratory and through guided design processes the educators would create didactical design patterns (prototypes) for CT/TC activities through tinkering, playfulness and shared reflections.

For guiding the design processes in the design collaboratory we chose a double diamond model and we tried to further develop the model so it would be suitable for design processes leading to the creation and sharing of the educators' CT/TC activities (see figure 3) (The Design Council, 2019). The classical double diamond model, (see figure 2), starts with a problem in this case: How to create CT/TC activities? The model consists of four phases which can be divergent or convergent. Discover is where a problem or an idea is being investigated through research and by using divergent thought processes. In this phase you are imaginative and open to new ideas and connections to the problem. Define is where ideas are evaluated and selected by using convergent thought processes. Ideas are narrowed down to only a few selections and a design vision is finally chosen. Develop is where the design vision is transformed or developed into a prototype that is tested and further developed. It's important to be open to new ideas and solutions during testing in this phase. Again, focus on divergent thought processes. And finally Deliver where the prototype has been selected, developed and completed - a convergent thought process.

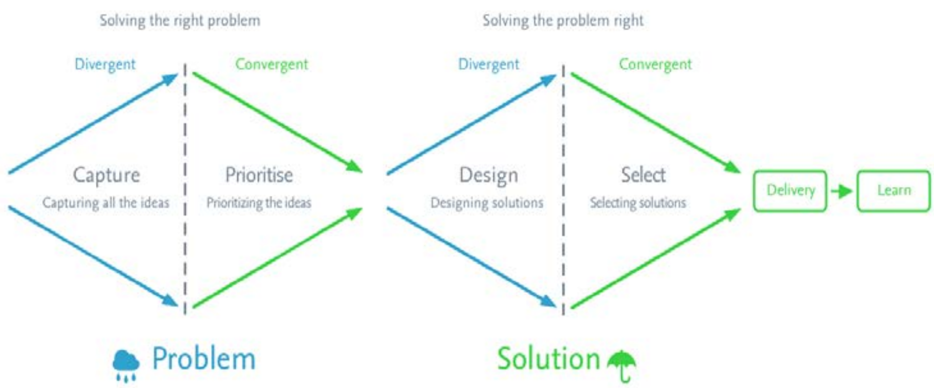


Figure 2. The double diamond model (The design council,2019)

In the design collaboratory for creating didactical design patterns, the patterns are created step-by-step through a four-phased and entangled design process using convergent and divergent design activities in alignment with the double diamond model (see figure 3). Through these design activities the educators played, tinkered, experimented with different kinds of technology and explored the theoretical, pedagogical and didactic concepts of CT/TC (see picture 1 and in the next chapter this will be unfolded). Through these design activities guided by the double diamond model the educators first developed a theory definition and a design vision for their CT/TC activity and secondly expressed this activity through a design pattern which was tested in their own practice and was shareable for other educators.

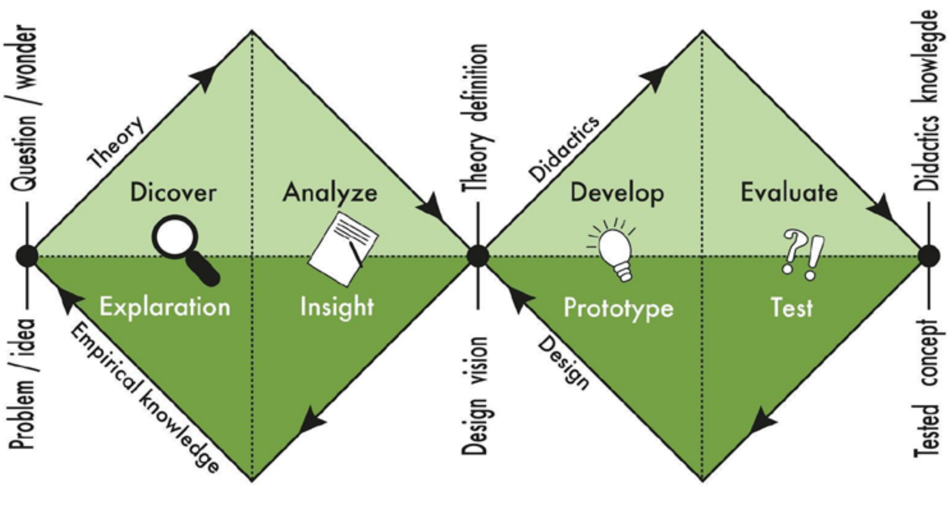
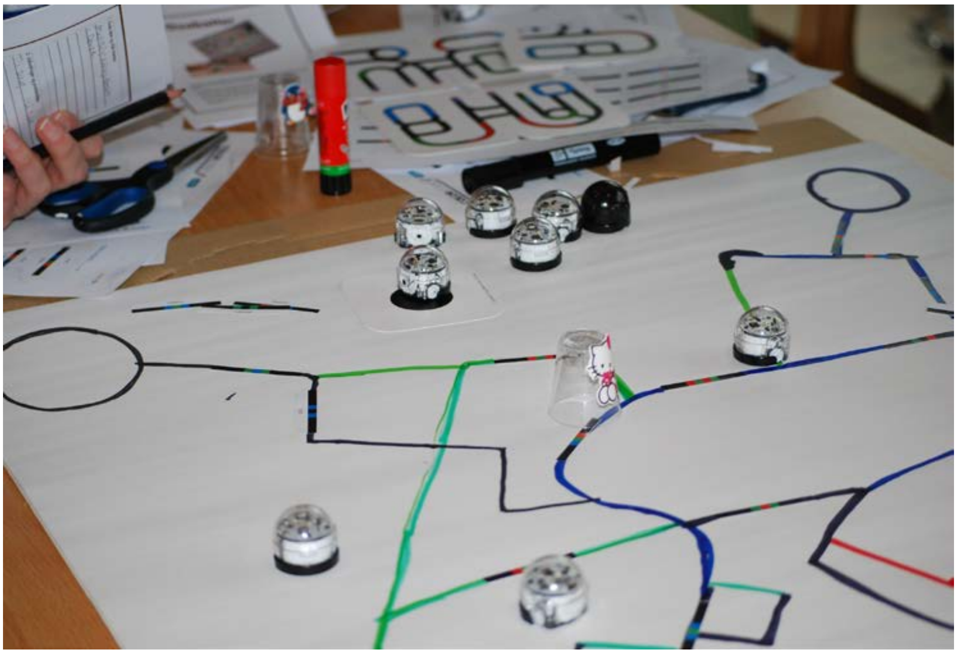
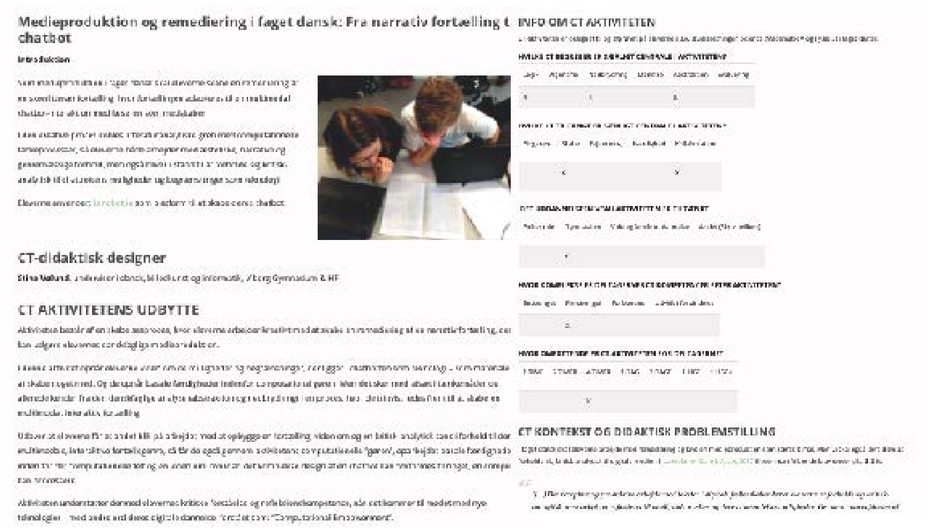


Figure 3. Design processes in a design collaboratory



Picture 1. Educators playing with technology

The lower part of the model illustrates the classical design process in the double diamond aimed at testing and creating a prototype. The upper part of the model is aimed at creating CT/TC didactical reflections and theory situated in the educators' own practice also called signature pedagogy (Laurillard, 2012:22). The arrows in the model shows that the phases in the model and the upper and lower part of the model are intertwined and connected to each other. The educator" didactical thoughts (upper part) and the outcome of the design process (the lower part) are depending on each other and can not stand alone. As shown in picture 2, the educators have described the design argument as well as describing the activity for the technology, in this case chatbot. (For further didactical design patterns see here[1]).


Medieproduktion og remediering i faget dansk: Fra narrativ fortælling t... chatbot

INFO OM CT AKTIVITETEN

CT-didaktisk designer

CT AKTIVITETENS UDBYTTE

CT KONTEKST OG DIDAKTISK PROBLEMSTILLING

Picture 2. One of the groups design argument and description of the activity with chatbot

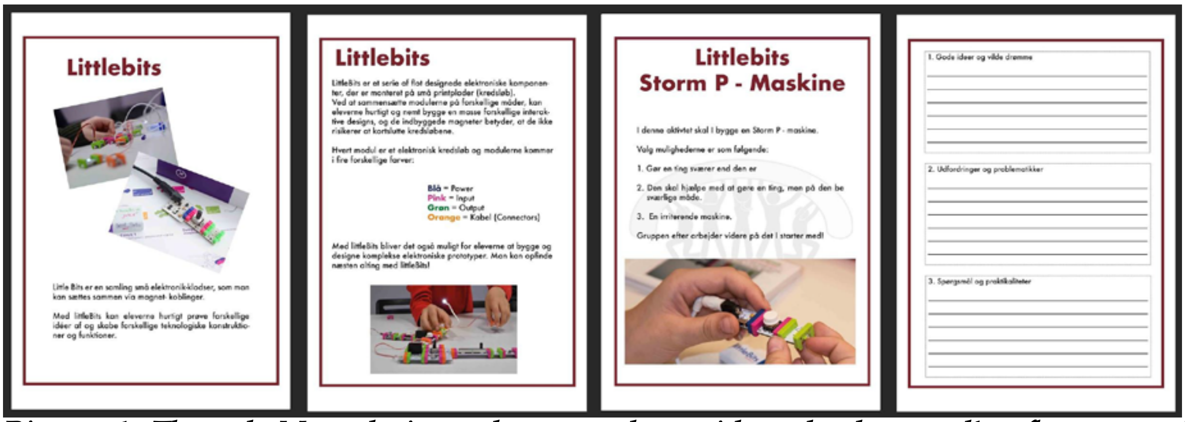
[1] https://open-tdm.au.dk/blogs/didaktiskcompthink/del-4/desingmonster-oversigt/

First phase: to discover, play and tinker

The first phase in this model focuses on "tinkering" and "discovering". In all of the empirical cases (See introduction) - the initial problem was the same for all the educators: How do we create CT/TC teaching activities in our subjects since no proper definition of CT/TC has been developed yet (Barr et al., 2011; Caspersen & Iversen, 2019). In this phase we start by going through theory describing CT/TC and infusing it with theories about playfulness, technology and critical pedagogy. And trying to relate but also further develop a CT/TC didactical approach from within the educators' own signature pedagogy. We tried to do this by using a divergent design activity in different technology workshops. Educators would be introduced to technologies in different workshops. e.g. Ozobots, Chatbots, Scratch etc. (See picture 3).

Picture 3: Workshops where educators tinker with different technologies

And the process was guided by participatory design processes. To guide the process we developed different meta-designs (Bannon & Ehn, 2008; Disalvo & Desportes,2017). In picture 4 is shown a meta-design for a technology card. In these the educators had to discuss the technology and in a preset playground playing around with the technology and reflect and relate it to their own practise (see picture 3).



Picture 4: Through Meta-designs educators play with technology and' reflect on and with the technology in relation to their own practise.

We wanted to create a space where CT/TC could be interpreted anew by the educators combining CT/TC theory, critical pedagogy and didactics through a value-driven learning experience where educators could bring both the knowledge of their practices and their values into the design process (See picture 5). Through these meta-designs educators reflected on the technology they experimented with in the workshops in combination with their own didactical ideas and values in relation to the Humanistic/Arts perspective on CT/TC.

Picture 5: A value-driven learning experience through meta-design

Thus creating a bottom-up process in the creation of CT/TC activities, through:" an experience that develops the agency of participants in the design of learning experiences" (Disalvo & Desportes, 2017:177). We call this a bottom-up process, because through these Meta-designs the educators started to get ideas about how to create a CT/TC activity situated in their signature pedagogy and their own didactical values.

Later on in the process this activity is further developed and tested in practice, and turned into a didactical design pattern to inspire other educators. Each technology workshop had a printed handout with a picture of the technology on the front side and on the other side, the educators could write the ideas they got through tinkering and playing with the technology. The ideas were discussed and further developed in the design collaboratory and tested in practice.

> "Thinking is integrated with doing. We think in the context of interacting with things, playing with things, creating things. And most thinking is done in connection with other people. We share ideas, get reactions from other people, build upon one another's ideas" (Resnick, 2017:91)

This was the first step of educators becoming designers of a CT/TC activity and the start of making a design pattern through tinkering, playing and shared reflections.

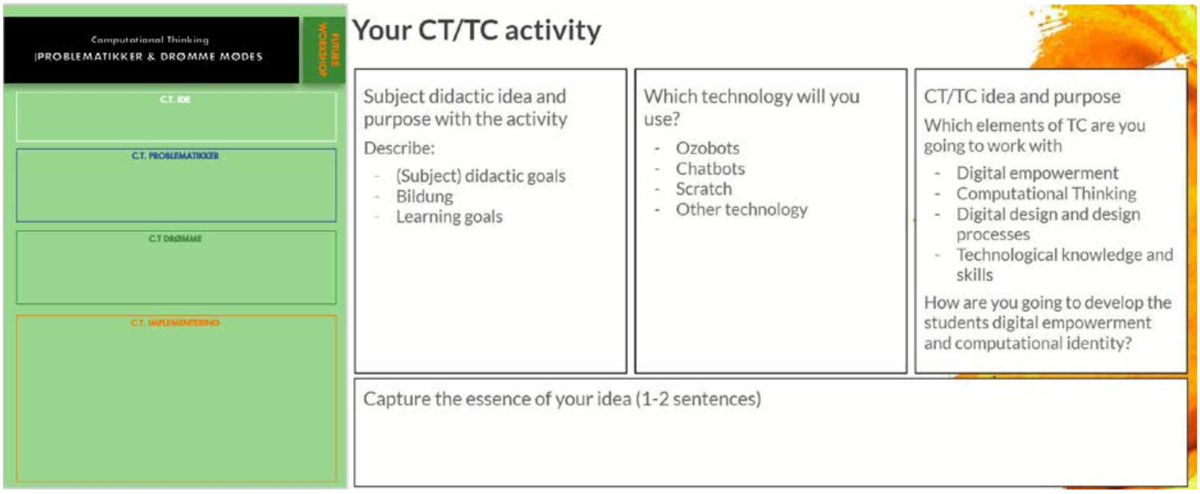
Phase two: Gaining insight and analyzing the CT/TC activity

In this phase a convergent design process took place. Now the educators' focus turned from playing with technology and discussing didactics, pedagogy and theory about CT/TC in general to focus on their own subjects and its didactical context. Likewise in a design collaboratory this process was guided by a meta-design to help the educators to create their own TC idea for their subject. In picture 6 & 7 is shown the meta-design used in this phase.

Picture 6: In these Meta-designs educators start to reflect on how to create HUM/ARTS TC activities combining technology with their didactial values

At workshops each educator filled out the meta-designs in collaboration with the other participants through participatory design processes.

Educators would discuss and brainstorm ideas with each other while relating to their own practice, (see picture 6 & 7). The educators were now a step closer to creating a design vision for their CT/TC activity - which is going to be expressed through a didactical design pattern in the next phase.



Picture 7: Meta-design: Educators' pre-design patterns

The educators in this phase have now already begun a bottom-up process of thinking, reflecting, playing and creating their own CT/TC activity. In this phase they begin to synthesize their own practice with a CT/TC idea and begin to describe this idea in a pre-design pattern through the meta-designs. And these pre-design patterns have come to be through a participatory design process where these educators have been involved and are participatory co-designers of each other's CT/TC activities. (Knutson & Ramberg, 2018; Bannon & Ehn, 2013). It has all taken place through experimentation, play, tinkering, shared commitment, discussions and design processes in the different groups in the design collaboratory (Gregory, 2003; Resnick, 2017). The educators created a CT/TC didactic in their signature pedagogy. (Laurillard, 2012). Since this process also could be seen as a playground we had set up for the educators, they were free to go for their own vision of what they thought was great within the constraints of their subjects.

> "Teacher agency approaches the question of good education from the bottom–up, seeking to enhance the intelligence of the overall operation of the system at all levels and thus offers an alternative that is radically different from the way in which much thinking and policy about educational improvement has been" (Biesta et al., 2015:3228).

Third phase: a Design Vision - Design patterns

In this phase the educators through the design collaboratories further developed their CT/TC activity into didactical design patterns, (see picture 8). Beneath we have explained the theory of didactical design patterns.

Picture 8: Pedagogical Design Patterns (Nørgård & Francis, 2019).

Didactical Design Patterns have their origin from the architecture of Christopher Alexander, who in his study of architecture and buildings, developed a pattern language to describe buildings and architecture (Gemma et.al, 1994). The definition of patterns was described of Alexander as:

> "...describes a problem which occurs over and over again in our environment, and then describes the core of the solution to that problem, in such a way that you can use this solution a million times over, without ever doing it the same way twice" (Alexander et al., 1977 in Goodyear, 2005:93 & Gemma et.al. 1994:2).

In this way Alexander saw patterns as a help to make a solution to an equal problem, without it was done in the same way. Later on in 1994 this way of describing solutions of problems was developed further by four programmers from the software engineers to make patterns for programming (Gemma et. al., 1994, Preface). Likewise, Peter Goodyear, Patrick McAndrew and James Dalziel, 2006, further developed patterns to fit to solutions to problems within the learning environment. In their work they describe a way to describe educational patterns:

> "i) A picture (showing an archetypal example of the pattern).
>
> ii) An introductory paragraph setting the context for the pattern (explaining how it helps to complete some larger patterns).
>
> iii) Problem headline, to give the essence of the problem in one or two sentences.

iv) The body of the problem (its empirical background, evidence for its validity, examples of different ways the pattern can be manifested).

v) The solution. Stated as an instruction, so that you know what to do to build the pattern.

vi) A diagrammatic representation of the solution.

vii) A paragraph linking the pattern to the smaller patterns which are needed to complete and embellish it"
(Goodyear, McAndrew og Dalziel, 2006:5)

Goodyear, McAndrew and Dalziel (2006) argue that Design Patterns can be shared, criticized and refined through collaborations which is the approach to design patterns we adopted to this framework (Goodyear, McAndrew and Dalziel, 2006:6).

In addition to this Peter Goodyear (2005) points, that Design Patterns hold a number of qualities:

> "Design patterns have a number of qualities which, in combination, give them the potential to be a useful way of sharing experience in the field of networked learning. A pattern is a solution to a recurrent problem in a context" 0(Goodyear, 2005:93).

The point is that Design Patterns can be useful in a way of sharing in a network of learning.

Pedagogical Patterns Project, 2007, describe patterns as: "... designed to capture best practice in a specific domain" (Pedagogical Patterns Project, 2007). Likewise, can Design Patterns encapsulate praxis throughout expert knowledge within teaching and learning, which can be difficult to share in praxis contests (Pedagogical Patterns Project, 2007). But still there has been no general way of describing pedagogical patterns. In these cases, it was very important that the developed CT/TC activities were thoroughly described and explained in the design patterns - almost plug and play for other educators to use. In this framework we wanted to:

> "capture the experience of experts about good or best practices and document these nuggets of wisdom in an accessible way for designers. Patterns are appreciated by academics and practitioners alike because they describe and reason about good designs in a way that makes it possible for others to understand and reuse it." (Europlop, 2018)

The CT/TC activities documented in the didactical design patterns were all tested in practice by educators in real life settings. Based on the testing - the design patterns were evaluated and finally delivered in the last phase of the double diamond model. (All the design patterns can be seen here[2]).

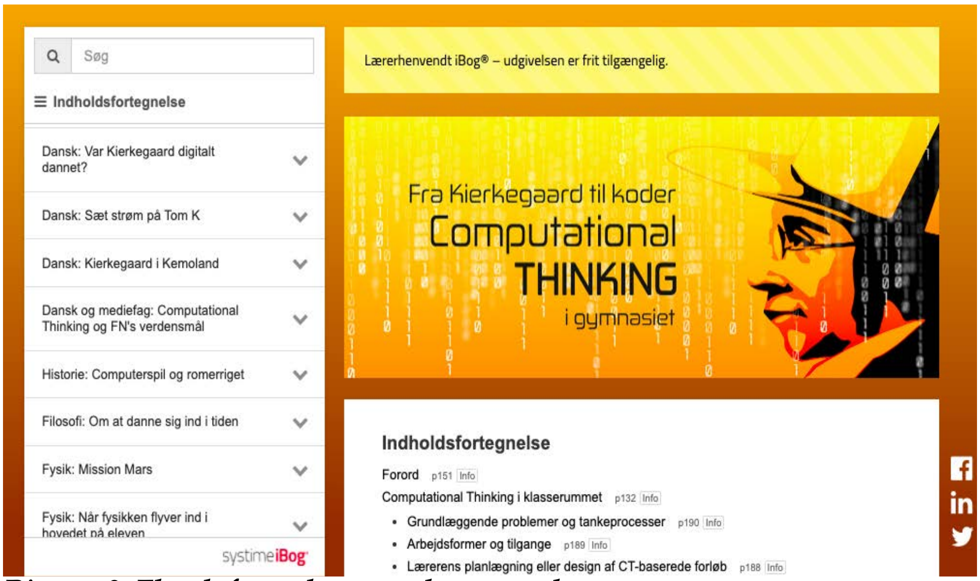
Phase four: Becoming design researchers

This is the end result in this design collaboratory; educators becoming designers of their own CT/TC activity

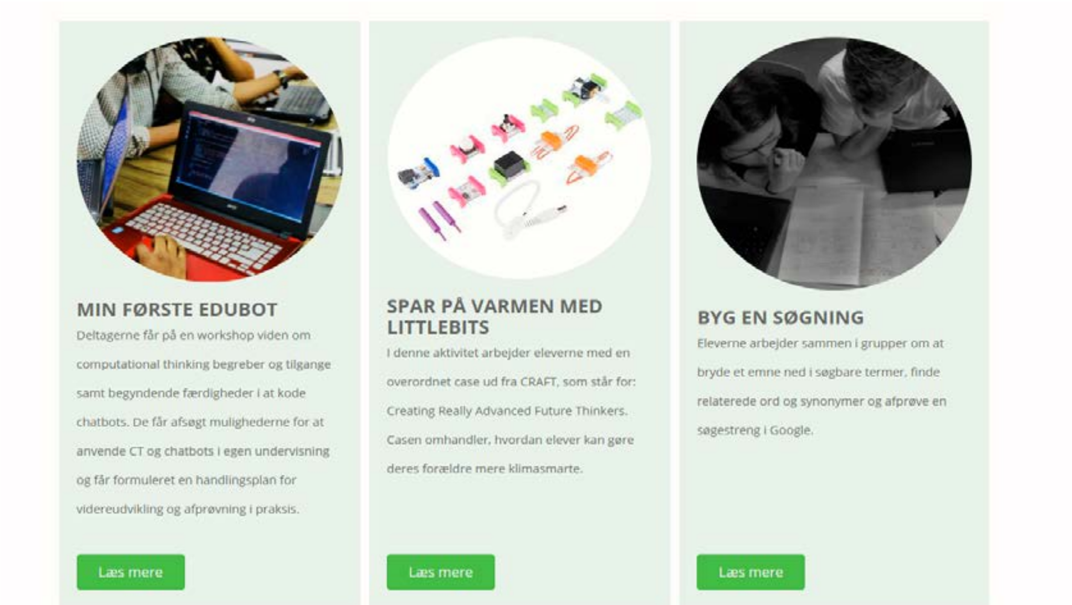
[2] https://open-tdm.au.dk/blogs/didaktiskcompthink/del-4/desingmonster-oversigt/

and able to "capture the pedagogy" that an educator has found to be effective. Creating a bottom up process for curriculum development, new didactic knowledge and expanding their educational teaching practice. And by documenting and sharing this knowledge through didactical design patterns (Laurillard, 2012:22,103).

Our first case study was our pilot study and developed didactical design patterns from this case that were not shared other than whom the educators share them with. The second case: "The network for CT" was all collected and has been published in an ebook[3]). The design patterns developed in the last case "The Master course" were all shared and can be reused on the webpage "[Open-tdm.au.dk]()" (see picture 10).



Picture 9: Ebook from the second case study



Picture 10: Shared examples of educators' design patterns from the last case study (DidakCompThink, 2020)

[3] https://computationalthinking.systime.dk/

Conclusion

We have in this article tried to introduce a guiding didactical framework - a design collaboratory - where educators through divergent and convergent design processes guided by the double diamond model developed their own CT/TC activities. These CT/TC activities are developed embedded in the educators' own signature pedagogies from a bottom up approach matured through meta-design thus creating new didactical knowledge and CT/TC activities exemplified and made shareable in didactical design patterns.

In these design collaboratories and through tinkering and playful processes the educators created CT/TC activities situated in their own practices and not necessarily in a STEM context with focus on coding. But CT/TC activities developed through the lenses of didactic, CT/TC theory and critical pedagogy with focus on developing the students' technological imagination, critical computational empowerment and computational identity. Activities that unfolds a creative space for students to play, create and design with and through technology, thus creating the space for students to experiment with transforming and developing their own social reality. Here CT/TC activities are not meant for creating a future competitive workforce, but focus on Bildung and strengthen the students':"...imaginative, creative aspect (...) and critical thought" (Nussbaum, 2012:2).

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