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IS "DIGITAL EDUCATION" THE RIGHT WAY FORWARD? – OR IS, MAYBE, POSTDIGITAL EDUCATION WHAT IS NEEDED!

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ABSTRACT

The use of "digital tools" have usually played an important role in the transformation to "emergency remote teaching" during the pandemic. However, even before the pandemic there has been a strong pressure that education should become more "digital". Nevertheless, we see several problems associated with the present discourse related to "digitalisation" of education. 1) It often unclear what is meant with "digital education", 2) very narrow view of "digital tools" too mainly be tools for information and communication neglecting other uses of digital technology, 3) unbalanced focus on "digital tools" there other tools are either neglected or seen as inherently inferior and "old-fashioned", 4) conflation between "digital" and "distance", 5) adherence to either a technological determinism or a pedagogical determinism (technology is a neutral tool).

Engineering students' courses of action have been videorecorded in design projects and in electronics labs at two universities. It can bee seen that students' use a wealth of bodily-material resources that are an integral and seamless part of students' interactions. They use bodily resources, concrete materials, "low-tech" inscriptions as well as "high-tech" ("digital") inscription devices. Our results challenge that by hand – by computer and analogue tools – digital tools should be seen as dichotomies. Our empirical evidence suggests that students should be trained to not only be trained to work with "digital" tools but with a multitude of tools and resources. We, thus, advocate that a postdigital perspective should be taken in education where the digital makes up part of an integrated totality.

1 INTRODUCTION

1.1 Digitilisation of education

For about about thirty years there have been a strong focus on, and a pressure to increase the use of, computers and internet in education [1-4]. In later years the buzz words "digitilisation" and "digital education" have been coined to describe this trend. During the Covid-19 pandemic many universities and schools world-wide transformed to "emergency remote teaching". This was enabled by the use of "digital tools" such as the internet, computers and other communication devices equipped with cameras and speaker/microphones leading to an even stronger focus on "digitilisation" of education.

Nevertheless, we see several problems associated with the present discourse related to "digitalisation" of education. 1) It often unclear what is meant with "digital education", 2) very narrow view of "digital tools" too mainly be tools for information and communication neglecting other uses of digital technology, 3) unbalanced focus on "digital tools" there other tools are either neglected or seen as inherently inferior and "old-fashioned", 4) conflation between "digital" and "distance", 5) adherence to either a technological determinism or a pedagogical determinism.

The aim of this paper is to be somewhat provocative and raise questions and issues related to the "digitilisation" of (engineering) education for debate. The paper is organised as follows: In sections 1.2 – 1.6 we, as a background, describe in some more detail (than is done in this section) some of the problems we see as exhibited in the present discourse related to digitilisation of education. In section 1.7 we argue for a broad view of digitilisation and demonstrates that it, indeed, is nothing recent but has a long history and in section 1.8 we briefly introduce the consequences we see with a narrow digitilisation as presented in sections 1.2 – 1.6.

In many ways the paper is a conceptual one but we support our argumentation with empirical data collected using video recording of engineering students in action in a design project and in an electronics lab. How the data was collected and analysed is described in chapter 2 and two episodes from the data are presented as results in chapter 3. Finally in chapter 4 we briefly discuss our findings in relation to postdigital theories. As this is a conference paper with limited space it has only been possible for us to briefly discuss the issues we want to address and the questions we want to raise. We have also only included a limited number of references.

1.2 Unclear meaning "digital education"

There is a lack of conceptual clarity regarding what is meant by "digital education". In a very early paper [5] "digital education" was used to reference the training of the dexterity of a dentists' hands (remember the original meaning of digit as finger). In the 70:s when the first author was an undergraduate student in engineering "digital education" was the learning about digital electronics (seen as distinct from analogue electronics). Neither of these earlier meanings are in the foreground in present day discourse.

Nowadays two main meanings of "digital education" can be discerned in the discourse: "Digital education" (and synonyms such as e-learning, technology enhanced learning etc.) can used for educational approaches that make use of digital tools and technologies during teaching and learning such as online learning and blended learning. "Digital education" can also denote the education of the learners to enable them to use digital tools in a skilled and comptent way. For example University of Edinburgh is using the first definition (with the add on that it should be "innovative use") [6] while the European Union in its Digital Education Action Plan use both meanings [7].

1.3 Narrow view of "digital tools"

What is apparent in many reports is what a quite narrow view of "digital tools" are purported. These are commonly described as being tools for transfer of information (in a narrow sense) and communication, i.e. ICT (information and communication technology). Other uses of digital tools such as the use of digital technologies for taking measurements, making observations, displaying and visualising results from measurements and observations, controlling measurements, modelling and simulations are seldom mentioned. Figure 1 displays a typical view of the meaning of digitalisation [8]. Indeed, Walan [9] in a study of "digital technology in science classrooms" only describes digital technology as information and communication tools and in a study performed by Henderson et al. [10] the digital devices the students reported to have used in the previous four weeks were laptop or desktop computers, smartphones, tablets, and in a few cases a dedicated e-reader. Although 47.8% of the students in the study by Henderson et al. were medical, science or engineering students no other use of digital devices were reported.

Fig. 1. From a publication by The Swedish National Agency for Education describing how the agency is working to digitalise schools [8].

Despite the heavy use of digital technologies (see section 1.7) for observation, measurements, regulation and control in health sciences, natural sciences, and engineering this usage is neglected in many common descriptions as reported above. Indeed, many successful projects for the learning of physical concepts built on the use of computers, with attached sensors, to make (real-time) measurements in real experiments. Such experiments were introduced in the teaching of physics in the mid 1980:s (see, for example, references [11, 12]) and the first author have reported successful use of such (digital) technologies with Swedish engineering students [13-16]. However, contrary to the narrow view of Walan [9] Kyza et al. [17] presents a much wider use of (digital) technologies that include technologies for data collection and analysis.

A wider view, but not complete view of digital tools are discussed in section 1.7

1.4 Unbalanced focus on “digital tools”

The narrow meaning of digital tools embraced in many accounts described in previous section is problematic. This limited discourse is often further extended by digital tools beeing portrayed as something positive and “modern” as opposed to substandard, inferior and outdated pre-digital tools and techniques [4, 18, 19]

1.5 Conflation between “digital” and “distance”

It is common to describe distance meetings (using, for example, computers and software such as Skype, Zoom, or Teams) as “digital” meetings. This has resulted that in many cases there is a conflation between between “digital” and “distance” and, for example, that planning for distance laborations are discussed as making the labs “digital”. This is *highly* problematic as many (on campus) labs in science and engineering already are digital in that sense that they make heavy use of digital technologies for performing (real) measurements, analysing data from these measurements, and controlling experiments.

1.6 Technological and pedagogical determinism

The topics of technological or pedagogical determinism actually are actually worth a paper in its own to be discussed in depth and have, indeed, been discussed by many authors. We have chosen to illustrate the issues involved by figure 2 taken from the works of Tim Fawns [20]. In short, technological determinism rests on the illusion that the use of a specific tool *pre-determines* the outcome. In our own research we have demonstrated that this is simply not true, but that the pedagogical design also matters [e.g. 16, 21]. On the other hand, in pedagogical determinism technology is seen as a neutral tool and the pedagogical method used *pre-determines* the outcome. In our own research we have demonstrated that different techologies, indeed, have the different affordances effecting what is possible for students to experience [e.g. 22]. In the debate and discourse regarding “digitilisation” of education both technological and pedagogical determinism can be found [e.g. 4, 20].

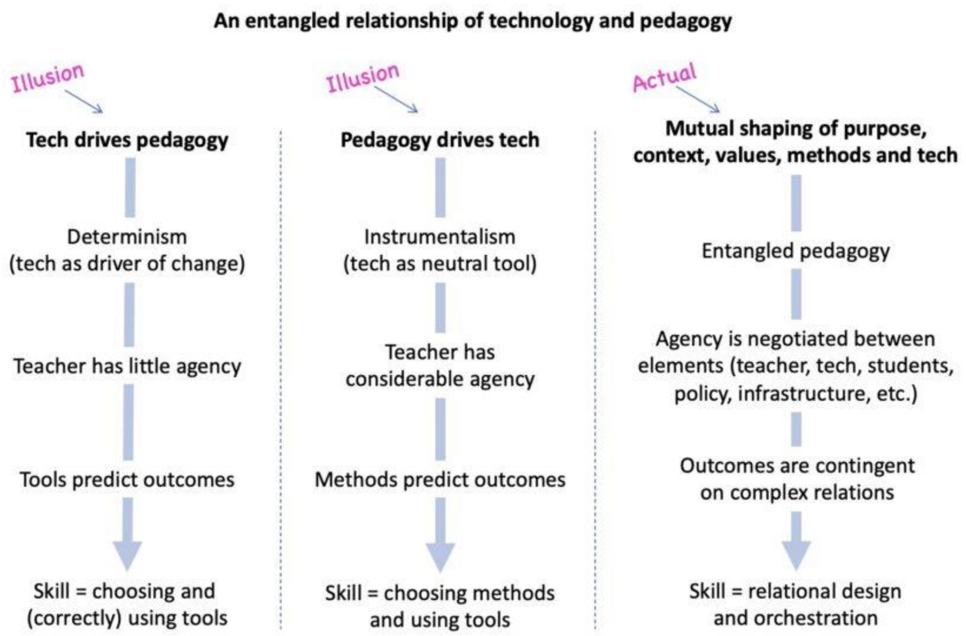

Fig. 2. An entangled relationship of technology and pedagogy (v3), CC BY SA, Tim Fawns, University of Edinburgh.

1.7 “Digitalisation” has a long history

In section 1.3 it was mentioned that often a rather narrow view of the meaning of “digital tools” are embraced. Commonly digital technology is described as a rather recent (and modern) technology and the digitalisation of society as a new phenomena. In part this is true for the aspects of digital technologies experienced by the general public. Indeed, that is seen by the public (and policy makers) is mostly digital tools as information and communication technologies. Most people are not aware about the amount, and features, of digital technologies that are operating behind the scenes and that are contributing to the well-beeing and affluence in modern society (at least in some parts of the world).

If we see digitalisation as meaning something that can be described by discrete, digital, units (as opposite to continuous, analogue, entities) it can be seen that “digitalisation” has a rather long history. One start is the invention in 1725, credited to Basile Bouchon, to use perforated tape to control looms for the veawing of ornamental patterns [23]. This idea was further developed over the following years and around 1805, using perforated cards, Jacquard was able to make the first really successful automatic weaving loom. As discussed by, for example, Randell [23] the control of the Jacquard loom inspired various developers of analytic engines manifested in 1944 with paper rools used to control one of the very first computers (Mark 1). Still, in 1973 when the first author as a first year engineering student learned programming (Fortran IV), punch cards were used to control the computer and execute programs.

There is, indeed, a rather continues line of development from the control of operating looms in 1725 by a rather primitive “digital technology” to the (automatic) control nowadays of our dishwashers, washing machines, heating, cars etc to the control of machinery, railways and even complete industrial processes. The difference is that the “card perforations” now are electromagnetically stored as zeros or ones (an intermediate step has been electrical sensing of card perforations). Digital electronics has enabled the control processes and things at a faster spead, larger scale, higher reliability and at a lower and lower cost. We claim that the use of digital tools for control is an, for society and our well-fare, important utilization of (digital) technology.

Another important use of digital technologies in modern society is the use of digital technologies in combination with suitable sensors for taking measurements and making observations and displaying results from these. This use of digital technologies are of great importance in industry as weel as in research. In health care it is almost impossible to imagine a modern intensive care unit without this use of digital tools. As mentioned in section 1.3 digital measurement technologies has been used in physics teaching [11-16] since the mid1980:s and is, thus, not something very recent.

1.8 Consequences

The greatest value of using digital tools for our society is perhaps not primarily as tools for information and communication but, in our opinion, as powerful (and often affordable) tools for control and regulation, measurement, observations, calculations and more. If these aspects are missed, there is a risk that we give students a false picture of what digital tools have provided for contributions to our prosperity and welfare. Furthermore, if these aspects are missed, there is a risk that the potential of using digital tools in teaching will not be fully utilized! (cf. references [4, 20])

2 METHODOLOGY

The intent of the background in our paper has been to present a more comprehensive and multi-facetted picture of what we see as digital tools. Based on this background, on scholarly literature [1, 4, 20, 24], and our experience from theaching our hypothesis is that the dichotomy between digital and analogue tools is artificial and barren. We, rather support the view argued by Fawns [4] (and others) that we need to take a "*postdigital* perspective [in education], in which the digital makes up part of an *integrated totality*" (our emphasis).

We have, over a period of more than 15 years, collected a rather extensive set of video recordings [25] of (primarily) engineering students' interactions during engineering design projects and during physics and electronics labs. This video data have been recorded in regular teaching sessions at two universities in two different countries.

We have re-analysed the videos driven by our research question what kind of tools contributing to their fullfilment of tasks, and contributing to their learning, are students' using? As the material is, indeed, very extensive we will in this paper present evidence from two episodes:

Episode 1: Students in the fifth semester of the PBL-based master's program Architecture and Design at Aalborg University, Denmark, have been videotaped. The students work in groups of 5–6 students and have the task of constructing a real office building.

Episode 2: Students in the fifth semester of the master's degree program Electronics Design at Linköping University, Sweden, have been videotaped during a laboratory in high-frequency electronics. The task is to make a model of unknown (analog) circuit.

Because of the importance to illustrate the materiality of the settings and students' use of different tools and gestures, the results are not represented by traditional transcript. Instead we have put student dialogue (translated from Danish or Swedish into English) into speech bubbles. All names are pseudonyms and not students' real names. Informed consent was obtained from all, involved, students and the material have been handled according to the laws, ordinances and other regulations valid in Denmark and Sweden. The results and our analysis is presented in the next chapters.

3 RESULTS

3.1 Episode 1

The episode is taken from a videorecording of a preparation (lasting the whole day) the students are making for a presentation in a feedback seminar the next day. In the excerpt four of the students are sitting around a table working individually for a while. In the first group of two pictures Ina calls for Mette's attention to discuss a design decision. Mette rools over to Ina and in the exchange they use an iPad, a drawing, a styrofoame model, and their own fingers to highlight the issues involved. In the next group of pictures they use a 3D-styrofoam model to reason around and the make ample use of gestures. In the next step they move over to Mette's computer to look at a CAD-drawing and Ina is using her fingers to "walk" around the building in the drawing and finally Ina is pointing to a photo on the board where the group keep materials used for inspiration. She is pointing to a similar design already implemented in reality.

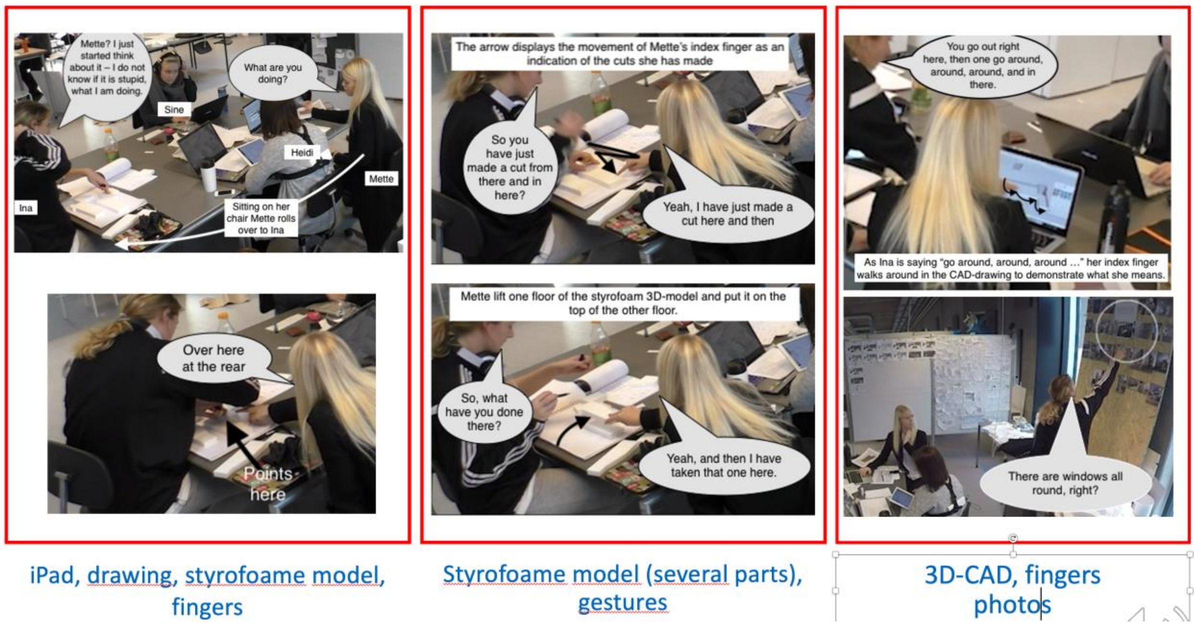

Fig. 3. Still pictures, with speech bubbles, taken from the videorecordings of a student group in a design project at Aalborg University. Below each pair of pictures are written the "tools" students are using.

We are here only showing a very short excerpt. A fuller presentation of this material can be found in references [24, 26-28].

3.2 Episode 2

In this episode students investigates an analogue high-frequency circuit with help of a digital oscilloscope and digital measurement technology. The task students are facing is to make measurements on several circuits consisting of unknown elements and to model the unknown circuit. For measurements a digital oscilloscope is used. The oscilloscope is connected to a computer enabling the results to also be displayed on the computer screen. A complication for the students in solving this task is that in high frequency electronics many of the idealization assumptions on which basic electric circuit theory and electronics are not valid.

In figure 4 a short excerpt from the lab is shown with the students Leif and Rune. In *a*) the oscilloscope can be seen in the upper left corner and the measurements are also displayed on the computer screen seen to the right. Moreover in *a)* Leif is responding to Rune by pointing at a graph feature displayed by the oscilloscope and in *b)* Leif continues by hand movements and gestures to indicate high and low frequency characteristics. He continues in *c)* by now indicating flank using a pen to point on the computer screen and moving the pen up and down. In *d)* Rune suggests that the circuit consists of a coil and a capacitance making a sweeping hand movement along the measured graph. For about a minute the students are continuing discussing the circuit, they go back to a previous measurement on another circuit to compare, and make some sketches. Finally they feel confident that the circuit consists of a coil and a capacitor and as a confirmation Leif points to the peak as displayed in *e*) and moves the pen as is indicated by the arrow.

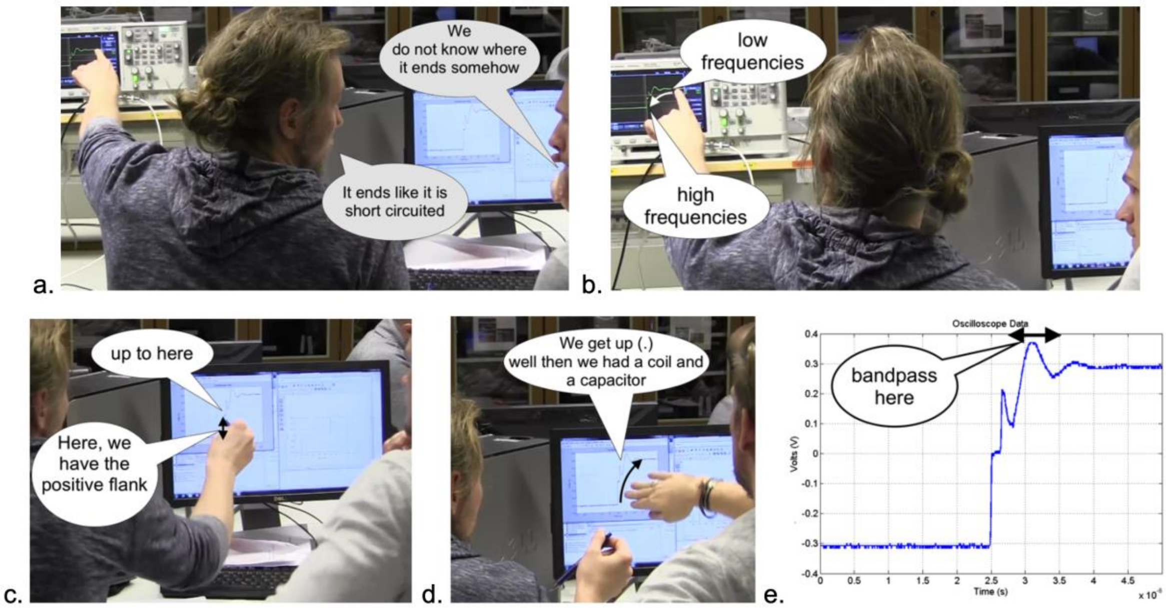

Fig. 4. Still pictures, with speech bubbles, taken from the videorecordings of a high frequency electronics lab at Linköping University.

We are also here only showing a very short excerpt. A fuller presentation of this material can be found in references [29, 30].

4 DISCUSSION

In both episodes, the students used in their interactions a rich repertoire of physical and material resources in an integrated and seamless way: Physical resources (eg. gestures, opinions, bodily orientation), concrete models (eg. 3D styrofoam models, paper models), low-tech inscriptions (eg. sketches, drawings on paper, post- IT notes) and equipment for "high-tech" inscriptions (eg. iPads, CAD drawings, digital measurement technology, simulations).

As mentioned in the introduction there is concurrently an urge that education (and society) should become more "digital". As a consequence, if tools and resources are considered at all, it is common to see these as synonymous with "digital technologies". For example, at the European engineering education conference 2018 in Copenhagen Flaata and Pitera [19] almost excused themselves for their students use of "old-fashioned" sketching and drawing by hand as they were supposed to become engineers in the "modern world". However, our study shows that a focus only on "high-tech" resources would be problematic and that we in engineering education research should rather attempt to understand how students use many and varied bodily-material resources and in engineering education encourage their use [cf. 31, 32]. An apparent finding in this study is that students made ample, efficient and fluent use of gestures, sketches and hand drawings and that these procedures seems to be beneficial to the design process and/or the learning process as different tools and resources had different affordances [see also, for example, references 32, 33, 34]. It is important to note that the students did not use the "low-tech" resources because they lacked the necessary skills to use the "high-tech" resources. On the contrary we argue that the students displayed that they were highly skilled in using digital tools, but they, in each situation, used the tools and resources they deemed to be most beneficial for the task at hand.

Indeed, more than 20 years ago Henderson [33] in her study *On Line and On Paper: Visual Representations, Visual Culture, and Computer Graphics in Design Engineering* offered a critique of the dominant ideology that paper was soon to be a thing of the past to be replaced by the use of digital tools. In her work she showed the centrality of sketching and sketches in professional engineering work and argued that CAD lacked the flexibility needed to fully support collaborative design. In our study we can see that the students use sketches and sketching, physical models and gestures as these tools and procedures offered greater flexibility and that the students mainly turned to 3D CAD drawing when finalizing design and make more (final) formal drawings.

Moreover, our results challenge that the distinction between by hand and by computer, between analogue and digital tools, should be seen as a dichotomy. Rather, our results show a blurred distinction. We see that it is essential that engineering students are trained to work "by hand" *and* "by computer" and that it is *not* a question of "by hand" *or* "by computer". Indeed, Fawns (and others) argue that we need to take a "*postdigital* perspective [in education], in which the digital makes up part of an *integrated totality*" [our emphasis, 4].

As we only, in this study, have studied two cases and only have looked on students' interactions (not on teachers') we can, of course, not draw a general conclusion (if this even can be made) of the optimal use of different tools. Neverheless, we suggest that engineering teaching should not be focused on "digitalisation" in a narrow sense, but should seriously consider a postdigital perspective where digital tools are part of an integrated whole together with other tools and resources. All the tools in the educational toolbox are needed and they are good for different things!

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