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RESEARCHED BASED REPORT OF PRACTICE

COMPREHENDING DIGITIZATION AND DIGITALIZATION – DEVELOPMENT OF A PHENOMENOLOGICAL ACCESS TO ANALOG AND DIGITAL TECHNOLOGY

Svantje Schumann[1]

[1]University of Applied Sciences and Arts Northwestern Switzerland, School of Education, Institute of Primary School, Hofackerstr. 30, 4132 Muttenz, Switzerland
*Please adress all correspondence to svantje.schumann@fhnw.ch

STRUCTURED ABSTRACT
Background: "Digitization" (analog-digital conversion) and "Digitalization" (digital communication and the impact of digital media on contemporary social life) and "Digital transformation" (transformation processes) are frequent keywords nowadays. However, it is noticeable that the terms "digital" and "analog" are often not understood. In a preliminary survey, teachers were asked about their concepts about both terms as well as of the terms "digitization" and "digitalization". Uncertainty about these terms and the phrase "age of digitalization" seems to be widespread. A fundamental clarification of the terms "digital" and "analog" is an important basis for education and discourse. Understanding these terms and current developments is necessary to make decent sound decisions, e.g. regarding the handling of digital technology. Technical education serves not least the overarching educational goal of developing autonomy. Thus, it is an important goal for teachers to build technical content knowledge. The following is a proposal to make the terms "digital" and "analog" accessible and understandable for technical education teachers using the example of audio technology. Teachers worked out the proposed audio-technical stations and illustrative material within the framework of further training, especially in dialogue with the experts of the University of Applied Sciences and Arts Northwestern Switzerland. Interviews were analyzed using objective hermeneutics, and it was investigated whether and to what extent the materials and dialogue had supported the teachers in clarifying the terms "analog" and "digital" and improved technical content knowledge.
Within the framework of project-related contributions (PgB, 2017 - 2020), various universities of applied sciences and universities of teacher education in Switzerland are implementing cross-university MINT projects to train and further educate teachers. The aim is to encourage children and young people - especially girls and young women – to take a greater interest in MINT topics via the teachers. This requires teachers to have the appropriate content knowledge. This kind of knowledge can be acquired through phenomenological processes. However, there are few proposals for phenomenological access to technology for teacher training.

Purpose: The present study developed training content for technical education teachers in primary schools and aims to make the terms "digital" and "analog" accessible and understandable for them. The proposal was assessed by the teachers regarding the question if it was suitable to acquire knowledge and create understanding.

Sample/Setting: The approach was tested with 21 teachers from primary schools in the context of a teacher training program that was part of a PgB MINT education project of the PH FHNW (https://www.fhnw.ch/de/die-fhnw/hochschulen/ht/mint-bildung). In a preliminary survey, teachers were asked about their concepts about digitization and digitalization. After a one-day teacher training course, which was conducted by lecturers from the University of Applied Sciences and Arts (School of Education and University of Technology), open interviews were conducted with the teachers, in which they were asked to assess the training with regards to building up an understanding of the terms "analog" and "digital".

Design and Methods: The preliminary statements and the statements made by the teachers in the final interviews were analyzed using objective hermeneutics It was thus possible to monitor whether and to what extent the training course had supported the teachers in clarifying the terms "analog" and "digital".

Results: The educational training "Audio technology to clarify the terms analog and digital" improved teachers understanding of the terms "analog" and "digital". This could be a first crucial step to approach broader concepts of digitization, digitalization and digital transformation.

Conclusions: Even though the training course aimed at teachers, it seems to be possible to transfer some of the contents directly into school lessons. It seems worthwhile to develop further examples of phenomenological approaches in combination with Wagenschein's principles of "genetic", "socratic" and "exemplary" learning to understand analog and digital technology.

Keywords: *analog and digital technology; phenomenological access, socratic-genetic-exemplary learning, audio technology*

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1 INTRODUCTION

1.1 The contents "digitization", "digitalization" and "digital transformation" in technical education

"Digitization" is currently a major talking point. It refers to the conversion of analog signals to digital information. Through digitization, digitalization becomes possible: Brennen and Kriess (2014) define digitalization as digital communication and the impact of digital media on contemporary social life. Digitization and digitalization lead to digital transformation which is more about people than about digital technology (Chapco-Wade 2018): people must adapt to digital life. Living in a "technosphere" and the "intellectual mastery" of the digital world (Stuber 2016, 18, 11) requires responsible handling of technical artifacts and purposeful action. A responsible pedagogical-didactic approach is needed to reach the goal of "technical literacy" (International Technology Education Association 2000, 2): „Effective democracy depends on all citizens participating in the decision-making process. Because so many decisions involve technological issues, all citizens need to be technologically literate."

Arning & Ziefle (2007a, b; 2008) and Ziefle & Bay (2006; 2008) show that the use and operation of digital communication technologies is associated with considerable learning and comprehension difficulties as well as operation obstacles for many users. Negative experiences with digital technology are often reflected in low self-confidence and a negative evaluation of one's own technical competence. Indications exist that many teachers have low self-confidence when it comes to analog and digital technology, even though the BITKOM publication "Schule 2.0" (2011) shows that many teachers prepare lessons on a PC, do Internet research and have access to broadband Internet. Low self-confidence also has a negative effect on interest in technology (Arning & Ziefle 2007a, Bandura, Ross & Ross 1963, Beier 1999, Beyer 1999, Edelmann 2000, Schumacher & Morahan-Martin 2001, Ziefle & Bay 2008). Understanding digital technology is often a secondary goal of school lessons and only teached by teachers with an affinity for technology (Pfenning, Renn & Mack 2002).

This study investigates the concepts teachers have about the terms "analog" and "digital". This survey was followed by the conception of a subsequent teacher training course. The specific teacher training course especially aims at improving the content knowledge (Shulman 1987) of teachers with regard to "digitization" and "digitalization".

1.2 The initial survey and its methodology

In an initial survey, a random sample of 21 teachers of Primary Schools were interviewed in order to investigate their concepts of the terms "analog" and "digital".

The interviews were evaluated using objective hermeneutics, a reconstructive method (Oevermann 1996). The method further attempts to formulate possible readings/interpretations with regard to meaning structures and thereby generate a case structure hypothesis. Objective hermeneutics is a method of deciphering these objectively valid structures of meaning in an intersubjectively verifiable way using concrete, readable, audible and visible forms of expression (Oevermann 1996). It is assumed that hypothesis-generating methods, such as objective hermeneutics (Oevermann 1996), have significant knowledge generation potential, especially when there is a considerable need to produce knowledge.

15 interviewees frankly stated that they had no mental concepts of the terms "digital" and "analog" and that it was therefore hardly possible for them to explain the terms to other people or their students; 17 teachers talked about analog technology as an older technology. All teachers associated digital technology with modern technology. 5 teachers stated that digital technology had something to do with computers, 3 used the term "computer-based technology" when talking about digital technology. No teacher could clearly define the terms digitalization, digitization and digital transformation and differentiate between them.

10 teachers stated that they saw themselves more as users of computer technology and had little understanding of how computers work. 18 had no experiences with programming. 19 teachers stated that they saw their students mainly as users of computers and smartphones. 9 teachers attested a rather low self-confidence in handling technical equipment. 5 considered themselves to have little technical competence.

The thought of the future scared some interviewees. For example, some of them stated, that relatives or friends fear that they would lose their job because machines would replace human labor - although many of them realized that it is also a blessing when monotonous, physically stressful work steps are taken over by

machines. Fears also exist with regard to "intelligent" technology, e.g. driverless cars.

2 THEORETICAL FRAMEWORK: THE PHENOMENOLOGICAL APPROACH IN COMBINATION WITH WAGENSCHEIN'S PRINCIPLES OF "GENETIC", "SOCRATIC" AND "EXEMPLARY" LEARNING

The teacher training program focuses on the example of audio technology. Audio technology has had a long and ever-evolving history following a progress from analog phonograph recordings through the audiotape era and into the digital realm (Jones 2008). The program's aim is to build an understanding in a phenomenological educational process. In this process, participants deal with perceptible or tangible objects and processes from audio technology (Østergaard and Hugo 2008) combined with Wagenschein's principles of "genetic", "socratic" and "exemplary" learning (Wagenschein 1999, 2005).

The phenomenological approach in pedagogy is based on the phenomenology of Husserl ([1927] 2001) and was mainly extended by Schütz (1974) in the 1970s. Direct experience is regarded as epistemologically significant; objects and the world as such can be experienced. A fundamental element is the interaction of the opening subject with the object to be interpreted. According to Deckert-Peaceman, Dietrich and Stenger (2010, 46), "Phenomenology seeks to turn the mutual constitutional conditions of subject and object, of man and world, into research topics".

The holistic nature of interpretation, the ordinariness of experiences and the process of comprehension and interpretation are central characteristics of the phenomenological perspective. According to Seiffert (2006, 26), the term "phenomenological" describes a method that comprehends the human world directly through 'holistic' interpretation of everyday situations. The origin of knowledge acquisition is seen in immediate occurrences, i.e. phenomena on which "relations between a person (an "I") and the phenomena of the world" are established ("constituted") (Buck 2012, 49).

Langeveld (1965, 26) describes the term "phenomenological" as follows: "For the time being we clarify this expression by saying that we consider the phenomenon in its manifestation accessible to everyone [...]." According to Langeveld, the phenomenological method attempts to analyze a situation or object by ultimately breaking down the activity of cognition through observation, stratification and dialogue of the phenomenon itself. In the phenomenological view, learning is understood as a relationship foundation that "emanates from the subject and is 'intentional', i.e. directed towards the phenomenon of nature" (Buck 2012, 50). In the analytical observation of things, what stands out immediately (phenomenally) is adhered to.

Genetic learning refers primarily to historical-genetic learning, which involves the transformation from older technology to new technology and thus seeks to build understanding. It also includes the individual genetic perspective, whereby knowledge should be acquired primarily through independent thought and action (cf. Möller 2007, 258). By taking the socratic principle into account, much room is given to dialogue. The focus is not on finished knowledge but on the dialogical development of interpretations (cf. Duit & Treagust 1998). Exemplarity means a justified restriction to particularly clear, impressive principles or examples that embody the facts of a topic - in this case audio technology.

3 ANALOG TECHNOLOGY: FROM A RUBBER BAND GUITAR VIA A GRAMOPHONE TO A DYNAMIC PLUNGER MICROPHONE

The following section highlights how learning objects in the field of analog technology are developed.

3.1 The rubber band guitar

A rubber band guitar is composed of a (resonating) body and a single rubber string. If the rubber band is plucked, it starts to vibrate. The vibration amplitude and frequency depend on physical properties, such as length and strain.

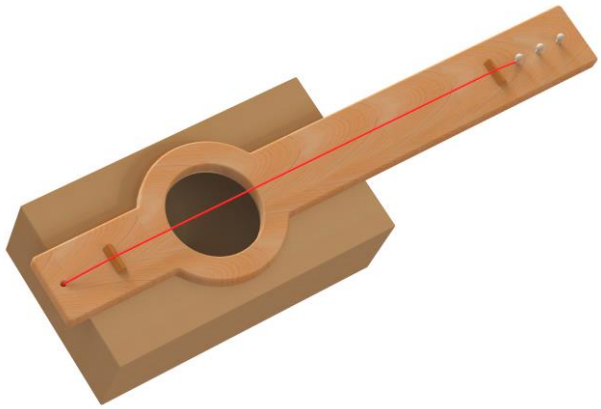

Fig. 1. Rubber band guitar with adjustable pitch (© Schumann)

The vibration of the rubber band is transmitted to the wooden body which in turn actuates air molecules. Although the string also produces changes in the surrounding air pressure, its surface is too small to produce audible sounds. From the body, the accelerated air escapes through the sound hole and becomes audible. The sound of the rubber band guitar thus results from processed oscillation and is purely "analog".

3.2 The gramophone

The gramophone is also a pure "analog" device, but is substantially more complex. Sound generation originated from the needle traveling along the spiral groove of the record, which has microscopically small ripples on the inner edges of the groove (which can be visualized using a microscope) (see Fig. 2).

The needle moves from right to left and transmits the vibration via a lever arm to a connected diaphragm. The resulting vibration of the diaphragm pushes air molecules in the direction of the horn. The opening shape

of the horn leads to a volume amplification as the moving air molecules (i.e. the "sound waves") have more and more space to spread (in a plain tube, the molecules would obstruct each other, reflected molecules slow down the others and no amplification would emerge). Finally, the molecules leave the horn as sound waves, travel through the surrounding space and eventually hit the eardrum.

However, the horn shape is not a real amplifier (no energy is added), but only “creates room" for the sound waves. Still it is true that the sound gets louder by traveling though the horn.

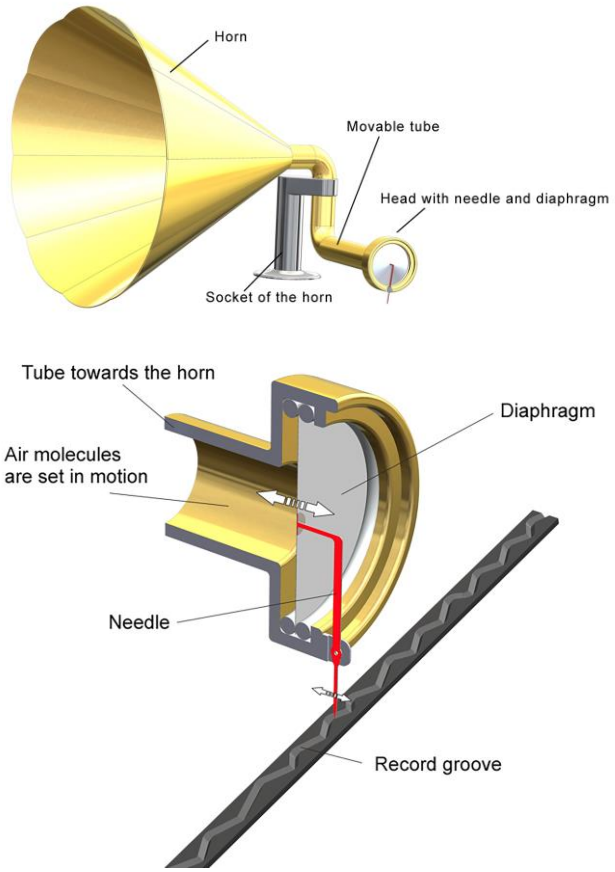

Fig. 2. Construction and functionality of a gramophone (© Schumann)

3.3 The microphone

Figure 3 shows the principle of a moving-coil microphone:

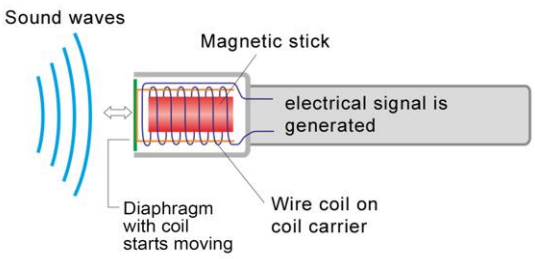

Fig. 3. Scheme of the moving-coil microphone (© Schumann)

The body of the microphone is composed of an elastic membrane to which a wire coil and a permanent magnet are attached. If sound waves (e.g. from a singer or speaker) hit the diaphragm, the attached wire coil starts to move. The moving coil inside the magnetic field of the magnet will in turn induce an electrical current. This current is passed on to an amplifier or pre-amplifier.

The moving-coil microphone thus converts the sound wave into electrical current. As there is no discretization happening in the signal transduction, the moving-coil microphone is an analog device. A basic principle can be seen here: Analog signals refer to a continuous-time base, digital signals in turn to a discrete time base. One can even state that all digital signals are discrete in nature, but not every discrete signal is digital.

4 CONVERSION «ANALOG - DIGITAL - ANALOG»: «AUDIO FILES ON A CD» AS AN EXAMPLE OF AUDIO TECHNOLOGY

The audio CD is used as an example to illustrate the transformation between analog and digital domains. At the beginning of the "production chain", there is the singer. The vocal chords and the resonance space of the head set the air molecules in motion when singing or speaking. With the microphone placed in front of the singer, the air molecules hit the microphone diaphragm, which picks up the vibration and induces the currents as explained above.

During a live performance, this electrical signal can now be passed on directly to a preamplifier and a main amplifier. The main amplifier transmits the signal to the loudspeaker. A loudspeaker consists of components identical to moving-coil microphones, but now current is injected into the coil and the speaker membrane moves in response to the changes in the magnetic field. The process of capturing, amplifying and outputting the sound is thus completely analog.

In order to produce an audio CD, the vocals must be recorded. Today, recording engineers use PCs to tap the electrical signal from the preamplifier and transfer it to an A/D converter (A/D = analog / digital) to sample the voltage from the microphone amplifier with a fixed frequency (discrete-time). This process generates a series of discrete voltage values with a constant time interval. The vocal acoustics can now be digitally stored and processed. The computer assigns a digital value to each recorded voltage. The quality of the digital signal increases with the sampling frequency and the bit depth. A higher sampling frequency increases the temporal resolution whereas an increase in bit depth produces more accurate amplitudes. The higher the quality of the digital signal, the more similar it is to the analog signal.

If the recording engineer wants to listen to the recorded material through studio monitor speakers, the digital signals need to be reconverted into analog voltages. Therefore, the computer feeds the digital signal into a D/A (digital-to-analog) converter. Here, each digital value is converted into a voltage and the inevitable discontinuities are smoothed. Finally, the signal is re-amplified and sent to the speakers. Figure 4 illustrates

the described function chain as well as the process of A/D and D/A conversion.

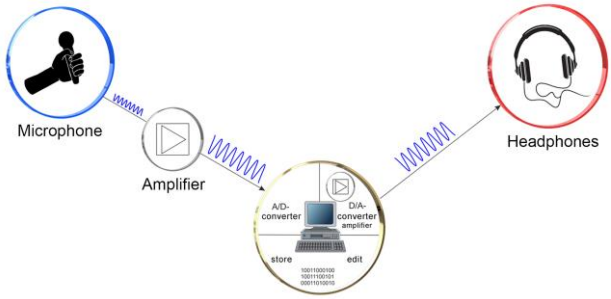

Fig. 4. A/D converting – D/A converting (© Schumann)

5 ASSESSMENT OF THE EDUCATIONAL OCCASION AND GAINED UNDERSTANDING

The majority of teachers stated that the example of audio files had helped them visualize the terms "analog" and "digital". All teachers used the general visualization aids used in the teacher training course to explain the terms "analog" and "digital": a) Analog signals are signals that can be imagined as a curve in a graphical coordinate system; the curve has an infinite number of points b) Digital signals are signals produced by a computer.

All 21 teachers stated that the chosen example "audio technology" was easily accessible and part of everyday life (example: “We all have music equipment before our very eyes”). Many teachers consider this visualization an important basis to build understanding. They agreed that examples and experience from everyday life were very helpful in the context of further training. The teachers believed that the exemplary focus on "audio technology" provided a stable framework for learning processes. They also assumed that this framework could be beneficial for students since a central theme can help them understand more complex processes. According to many teachers, the topic of "audio technology would allow multifaceted dynamics in the dialogue and personal contribution of experience. 19 teachers stated that the exemplary approach was very helpful in building their understanding. This assessment is consistent with the idea that the educational effectiveness of exemplary learning is based on clear, impressive principles or examples that accurately represent the subject matter, thereby offering a wide range of possible starting points. The dialogical character of the learning occasion has further sharpened the teachers’ awareness of the importance of a dynamic, situational-spontaneous, reciprocal dialog for educational processes. These 19 teachers also agreed that the educational training helped experience one’s own competence. Several female teachers were surprised because they had consciously experienced that they can understand technology for the first time if they have the opportunity to clarify all open questions.

18 teachers stated that the very simple equipment (e.g. the rubber band guitar) provided a good introduction to the subject. They appreciated the approach of starting with simple devices, and analyzing them together with other participants in order to draw coherent conclusions. According to 15 teachers, this approach generated self-efficacy and a sense of competence, which according to 12 teachers had a positive effect on satisfaction and interest. These statements underline the importance of historical-genetic learning for educational processes, as assumed in literature (cf. Möller 2007).

15 teachers particularly appreciated the conscious dialogue which helped provide explanations. 10 teachers stated that the dialogue was particularly well suited to compile the diverse experiences and background knowledge of all. They claimed that the group was able to make coherent assumptions or draw conclusions more quickly thanks to this dialogue. 8 teachers stated that it had been difficult to admit their lack of knowledge in the dialogue. Crucial elements of the educational occasion were sensual-perceptive, leisure investigations of object details as well as discussions. These were repeatedly emphasized as helpful for the development of understanding. 13 teachers said they had consciously experienced the reconstruction of knowledge and the nature of educational processes. All teachers said that they had acquired expertise. These results also implicitly reflect the assumption of phenomenology, according to which empathy which develops in dialogue and interaction is a prerequisite to make a foreign field comprehensible and understandable.

18 teachers claimed they understood analog and digital as real, existing, distinguishable forms of technology. 15 teachers said that they would appreciate being able to choose the most understandable object or visualization by themselves. 10 teachers said they were relieved because they only needed to understand basic principles, and not every example in detail, to explain the terms “digital” and “analog”. 16 teachers said they liked the discussed example of "audio technology" because it is sensually very impressive. This statement complies with the phenomenological dimension of physical experience, which is important for educational processes.

All teachers were able to define digitization as the conversion of analog to digital and digitalization as the impact of digital technology on social life. A typical definition of digitalization was: “Digitization in the broadest sense means using computers and decentralized data storage for as many applications as possible in everyday life - but also especially in industry and administration.”

All 21 teachers stated that it was very challenging for young children to imagine invisible principles and functions. All teachers agreed that technology education at primary level should work with simple, concrete and tangible models to unambiguously demonstrate their operating principles. 19 teachers stated that the educational event had enabled them to discuss digitization and digitalization with children. Accordingly, they would now dare to immerse themselves in conversations with heterogeneous groups

of children, detached from a "script" or a "one-way to the goal".

6 CONCLUSIONS: UNDERSTANDING AND CLASSIFYING DIGITIZATION AND DIGITALIZATION IN A PHENOMENOLOGICAL, SOCRATIC-GENETIC-EXEMPLARY WAY

The question arises how to critically reflect on digitalization in order to take an informed decision? Administrative institutions and authorities have repeatedly claimed that official procedures would be digitalized to save time otherwise spent in waiting rooms (for example registering a car or extending an ID document). However, digitalization can also mean that individual movements are registered, e.g. personal purchasing behavior is documented. Digitalization offers new possibilities, but also creates new risks. Personal advantages and risks of digital technology must be weighed carefully and critically.

Digitalization thus offers new possibilities to hand over decisions and actions to digital systems that surround us, so-called external systems. If we decide to delegate decision-making and action areas to digital technology, we have to trust these systems. To a certain extent, one delegates responsibility to them. Particular consideration is therefore required to decide how much responsibility and autonomy we are willing to transfer to these systems.

The educational training "Audio technology to clarify the terms analog and digital" improved teachers understanding of the terms “analog” and “digital” and could be a first step to approach the broader concepts of digitization, digitalization and digital transformation.

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