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Making Technology Accessible Through Silent Films – A Study of Reconstructive Exploration in the Area of Technology in Science Teaching

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Abstract: The primary purpose of the project *"Experiencing technical events in silent films"* is to generate silent films on technology along with related didactic materials for use in the training and education of both teachers and primary pupils (Years 1–6) in Switzerland. The project (2017 - 2020) is taking place at the University of Applied Sciences and Arts, Northwest Switzerland. This article presents a case study that was conducted as part of the project. Year 5 pupils, in pairs, watched silent films on workstations. With the aid of a recently developed audiographic process for lesson observation the children's conversations were recorded and analysed. The article evaluates the study with regard to findings that are relevant to technical education in the primary school context. Its aim is to make these findings usable in the education and training of both teachers and primary school pupils. On the basis of this study potentially effective methods are being developed to support the abductive and inductive processes of exploration in the area of technology. This development is based on the thesis that reconstructive exploration processes are particularly suited to producing sustainable understanding. A form of teaching-learning conversation based on the socratic method is among the suggested methods for supporting this process. Known as maieutics the socratic method stimulates a process of questioning that leads to discussion. Visualisation and didactic materials are included in the process. In developing such proposals the importance of language in educational processes must be taken into account.

Keywords: Silent Films in Technical Education, Technology at Primary School, Online Technology Platform

1. Introduction: Reconstructive Approaches to Technology

1.1. Demand for Reconstructive Exploration Processes in Technology-Related Science Teaching

Technical education is regarded as an indispensable element of modern contemporary general education and elementary education [1-3]. Science teaching in Swiss primary schools should also include "exploring" technical objects and processes – exploring is a central concept of teaching science [4-5]. Knowledge that is acquired in a self-educating, reconstructive manner, i.e. through abductive and/or inductive reasoning, is regarded to be particularly effective and sustainable [6-7]. Accordingly, so-called inquiry-based and discovery-based teaching enjoys widespread support [8-10]. In this regard, Oevermann highlights the importance of socratically-maieutically backed education processes and explains the occurrence of transformation processes in the context of such education processes as follows: "Theoretical knowledge and methodical thinking, as well as insights into factual relationships are all the more effective, the more the learner realises them through their own problem solving. Thus, maieutic pedagogy aims primarily at creating awareness of problems by confrontation with unexpected situations or consequences, i.e. to break entrenched habits and beliefs with empirical and logical evidence and then put in motion individually-initiated searches for solutions. It is quite obvious that this is really the only way a real transformation of knowledge, experience and thought structures can take place through pedagogy knowledge transfer; such transformation actually tends to be inhibited by simply drumming information into pupils' heads. In 'funnel pedagogy', it is suggested to students that assimilating knowledge by mechanical learning and 'cramming', based on the very necessary model of learning vocabulary when acquiring a foreign language, are normal" [11].

1.2. The Aim of the Project

A case study involving children was conducted in a primary school in Switzerland. Year 5 pupils, in pairs, watched silent films on workstations. With the aid of a recently developed audiographic process for lesson and interaction observation the children's conversations were recorded and analysed. The article evaluates the study with regard to findings that are relevant to technical education in the primary school context. Its aim is to make these findings usable in the education and training of both teachers and primary school pupils. On the basis of this study potentially effective methods are being developed to support the abductive and inductive processes of exploration in the area of technology.

Science teaching is often based on the premise that children benefit from activity orientation, the learning experience that can be acquired through activities [12-14], as well as from original encounters [15-16]. In the study, the children were directed to explore technical interactions and functions relying solely on observation and discussion. It was hoped that with this setting, it would be possible to obtain information regarding what kind of support, e.g. in the form of stimulating questions for discussion or didactic materials, would be useful, in terms of potential, for pupils who are educating themselves or exploring technology in recontructive ways.

2. Methodical Approach

2.1. Data Collection and Analysis

Ten notebook workstations were set up in a Year 5 classroom with 16 pupils at a primary school in Switzerland – at each workstation a different silent film could be played on a video player: dowels, zip fastener, jack, hand pump, combine harvester, hand drill, glue gun, ballpoint pen, bicycle gearing system, snow chains.

The children worked in groups of two at the notebook workstations. They were instructed to watch the film in pairs on a workstation, try to understand the film and then talk about it. It was pointed out that it was possible to watch the film several times or pause it while watching. The children were also allowed – this was voluntary – to write down questions, observations and to make sketches. When the children felt that they had completed a workstation, they were able, in pairs, to independently move on to the next available notebook workstation. The children teamed up in pairs with the partner of their choice. The children's discussions were objectively and hermeneutically analysed.

The partner-work model is based on the idea of externalising thought processes. Educational research is often faced with the problem that children's learning processes take place as an inner process, as a dialogue with oneself, which therefore cannot be logged. In addition, analysing logs that include a high proportion of non-verbal sequences involves the risk of straying into the realm of speculation. To research childhood education processes, it therefore makes sense to activate externalisation in the communications framework setting from the outset so that one can directly monitor the process analytically and subsequently access the developing, ongoing reconstruction.

It is assumed that hypothesis-generating methods, such as objective hermeneutics [17], have significant knowledge generation potential, especially in areas where there is considerable need to produce knowledge. The objective hermeneutics method is, in contrast to a subsuming approach, a reconstructive method. It aims to decode the typical, i.e. characteristic, structures of the phenomena that are to be investigated. The method attempts to formulate interpretations regarding possible structures of meaning and, in this way, to generate hypotheses.

The children were filmed at the workstations and their conversations were recorded with the aid of a newly developed audiographic lesson observation process. Each pupil wore a USB memory stick-sized recording device which was attached to their clothing by a clip. Audiographic recording using this device was supposed to ensure that individual utterances were not lost. A synchronisation signal was used for all 16 recording devices so that the audio tracks could later be referenced on a common timeline. The sound recordings were edited on a computer with a multi-track sequencer, synchronised and cut. The edited MP3 recordings were then transcribed.

2.2. Silent Film Generation

Silent films generated in different ways and with specific characteristics were used on the notebook workstations. These films can be found on an online platform and are available for both the education and training of teachers as well as for use by schools and for further research [18]. All films have a total length of approximately 2 to 3 minutes and depict a technical process or an object. With the exception of the two real filmed videos "Bicycle gearing system" and "Hand drill", all the films used were animations. The "Snow chains" and "Zip fastener" films include both animated and live action sequences.

For the animated films, single images were created and displayed in such a way that viewers see a moving image. Animations analyse motion sequences that exist in reality, but not necessarily on a 1:1 basis. For example, it is possible to zoom in on individual details or change the playback speed in order to slow down very fast processes, thus making them easier to perceive. Interior views can be provided or interior and exterior views can be displayed simultaneously.

The "live action" film format shows activities/events involving real filmed or photographed objects. This has the advantage that viewers can be shown genuine objects without the need for any abstraction. The main aim here is to demonstrate an action or a technical event.

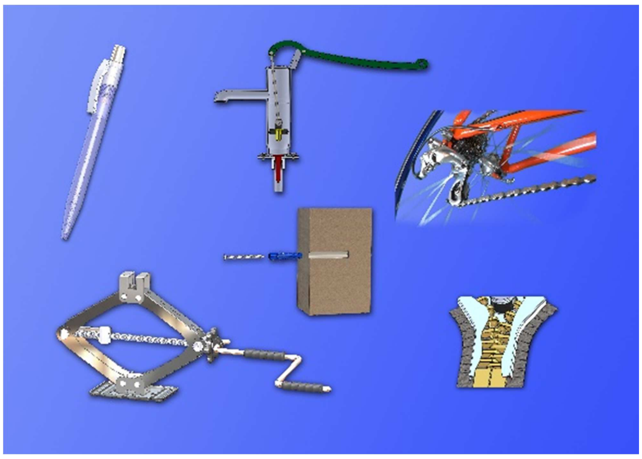

Figure 1. *Walk-through screenshots from different silent films.*

3. Analysis

In the following, the analysis of the conversation sequences by means of objective hermeneutics is shown in an exemplary manner.

3.1. Hand Pump

The silent film animation depicts the function of a hand pump, starting with an overview of the cross-section of the hand pump, pipe and groundwater; then the intake and pumping process are shown as a 3D animated Solidworks presentation.

Figure 2. *Screenshots from the "Hand pump" silent film.*

The selected conversation sequence is as follows: A (boy, 11 years old): That's a hand pump. The drawings are kind of cool, with the animations.

B (boy, 12 years old): Ah, now you can see the layout.

A: One part is going up and then down again. Eh? Now another part is going up and down again.

B: Now you can see the whole thing, in this cross-section.

A: Now the lever arm moves down, it compresses the one part, ah, and the water is then pumped up precisely because of that. Now I'll have to pause for a second. So now the lever is all the way down, then it goes up and presses the part down. Now it's up, and the lever pushes the part down.

B: And when it goes up, why does the other part go up? Ah, because air is sucked in, or what?

A: Then, the other part rises. When it goes back down again and, ah, when the lever goes up, the part goes down, and the yellow part goes up here.

B: And then the air can get out. And that's why air is sucked in again, and water with the air.

A: Hm.

B: And when it goes up, still more air probably comes in. No, I'll have to watch that again. So, a hand pump.

A: These animations are kind of cool, these images. Now you can see the pump. Awesome!

B: The whole thing as a cross-section with groundwater and... Ah, there's the pipe at the top of the pump.

A: Now the red part is going up and down again. So at least that's movable. Ah, and the yellow part as well, that also goes up and down. So, they don't seem to be fixed.

B: Now you can see the whole picture, all the pipes. A cross-section of everything. That lever is going up and down again now. Hang on. When the lever goes up, it presses the part with the yellow part down. But the yellow part goes up because the air tries to escape, probably. That means that the air then escapes. The red part is down. Ah, and then when it's up, ah, when you press down again, it obviously pulls the red part and then the water can get out too. Of course, because it pulls air and water.

A: The water then rises higher and higher into this pump shaft part and it obviously can't get back. Because when the pump goes down, yes (brief pause), when the lever goes up the red part goes down. That also can't get back, at least not so far. It then flows out there. Cool.

Boy A straight away uses the term "hand pump". The film depicts something he is already familiar with. He also knows the "animation" film format. The boy distinguishes between the content layer and the presentation layer and between live-action and animation. It can be assumed that he is familiar with animated representations from playing computer games. He finds the animation appealing ("cool").

Boy B states that one can see the "layout". He actually means that one can see the pump and the bore hole – both the above ground and below ground part – in the cross-section. The term "layout" particularly emphasises the technical drawing character – the boy characterises the events as being of a technical nature. At the same time, layouts are important in relation to spatial location, i.e. arrangement and size relationships – this spatial structure, for example the deep hole, is also characteristic of the "Pump and well" subject. The word "cross-section", on the other hand, emphasises, in particular, a cross-section through a body. When the relevant overlay is shown, boy B first perceives the spatial relationships of the technical design. Later on, he uses the term "cross-section" and, at that point, takes note of the detailed internals of the pump (in the first depiction this is very small and therefore difficult to see).

A and B are both fascinated by the "animation" film format and by the cross-section. Both of these are closely related – the section through the ground is only possible thanks to the way the animation is presented. "Now you can see the pump", "The whole picture", "A cross-section with groundwater", "There's the pipe at the top" express their fascination with the overall design, whose function is to move groundwater to the surface with the help of a hand pump.

In this shot, A comments on the clearly visible inside of the pump and the two moving valves. However, he does not know the names of these parts – he speaks of "a part" and the "other part". He aptly describes the handle as a "lever arm" because the lever rule expresses the movement of the lever. The extent to which he is familiar with and aware of the lever rule is difficult to say; notice that he subsequently expresses no thoughts about the need for leverage or the amplification of force. It is safer to assume that he is familiar with the verb "to lever" and that he associates the pump arm with this. In any case, he straight away chose a reasonable word that aptly describes what could be seen. A clearly recognises that the lever arm pushes the piston with the upper valve downwards. The "piston" and the "piston rod" are not mentioned in his description, nor is the leather seal (which is barely visible in the film). A relates the movement of the lever arm and the valves to the pumping up of water. At this point, however, he notices that the action is not sufficiently clear to him, and he makes use of the option to pause the film and freeze it.

Both boys clearly identify the interplay of the handle and upper valve, but they are unable to correctly explain the movement of the two valves, especially the lower valve. At this point B uses the terms "air" and "suction". Suction and pressure are not visible and are also not symbolically represented as forces in the animated film. In fact, suction and pressure play a decisive role; by using the term "air", the boy also expresses something else, namely "overpressure or underpressure" (also later on when he says: "Because the air tries to escape"). Suction and pressure conditions, or overpressure and underpressure, can occur only because the piston has a leather seal (which is barely identifiable in the film, see above) which makes the piston airtight. The complicated process is as follows: When the piston is raised by pushing down the lever arm, this produces a larger space in the cylinder. Negative pressure is created and water is sucked upward, pushing open the valve cover of the lower valve. The valve is released and allows water to enter. The inflow of water eventually compensates the vacuum and the valve cover of the lower valve is pushed down by the water above it and closes. Now, when the pump arm is pulled upwards, the piston goes down and this creates excess pressure. However, the water cannot escape downwards because it pushes against the lower valve which is a non-return valve – it opens in the upward direction and closes in the downward direction, in the opposite direction to the intake pipe. The more one pushes, the more tightly the lower valve closes. In other words, the upper valve must then open – in response to the pressure. The water gushes out and fills the chamber above the piston until finally there is so much water that it escapes from the outlet pipe. When switching between up and down movement of the piston, both check valves are simultaneously open for a brief moment, resulting in a small flow loss – but this is barely visible in the film.

The children find it difficult to relate the suction and pressure forces to the movement of the two valves but do assume that such a relationship exists. Both of them realised that the valves only ever open in one direction and that the water can therefore only flow in one direction, i.e. upwards or outwards. The fact that the opening and closing of the valves is crucial to the functioning of the pump is clear to both of them. The boys did not voice any further questions, such as "how is a well built", "how does the groundwater enter the pipe" or "how does the resulting cavern fill up with groundwater". The boys' conversation focused entirely on the content of the film.

3.2. Hand DRILL

The film shows filmed live action segments involving a hand drill in use. The selected conversation sequence is as follows:

A (girl, 11 years old): Now you can see a hand drill, which is already stuck a little bit in a piece of wood. And it is rotated by a hand that is somewhat visible in the image so that you can see it clearly from all sides. Now the hand drill is pushed in all the way, great.

B (boy, 11 years old): It's a pity it's not an animation.

A: Now you can see two hands. One hand's holding the top of the drill and the other hand is turning the handle. And that cranks a round gearwheel that turns another gearwheel, which makes it possible to drill a hole. Because the other gearwheel moves too. Yeah, how do you say that? Here you can see a close-up. Yes, these sprockets mesh with each other so the big wheel turns the small wheel. Thanks to the rotational movement which the person using the drill makes. And that's how the drill bit rotates, thanks to the little wheel. The rest of it is a fixed part; the whole thing doesn't rotate, only the bit below that small wheel rotates. The rest of it is stationary, of course, otherwise it wouldn't work.

B: But what's the use of a hand drill like that? Why not simply use a cordless drill?

At the beginning, A gives a description – one can see a hand drill and a piece of wood. The girl knows the term "hand drill". In her description she emphasises that one characteristic of the device is that it is operated by hand. Her description postulates the film maker's motivation – "So that you can see it clearly from all sides" because, in order to be able to really understand, one must also be able to clearly observe.

The boy expresses regret that it is not an animation. This reflects the fact that animations are especially appealing to children.

A then explains that one hand must hold the device, while the other hand turns the crank and the crank "moves a gearwheel" – with this type of description she emphasises movement and shape in particular. The girl refers to the cone gearwheel as the "other gearwheel" and therefore sees the structural shape and size difference and also recognises that, thanks to the combination of a large gearwheel and a cone gearwheel and the alignment of the gears ("because the other gearwheel moves too"), one can drill a hole ("makes it possible to drill a hole"). The meshing of the gears and the change in the direction of rotation are addressed relatively clearly, while the gear ratio is not addressed at all (the fact that one gear rotates slowly and the other rotates quickly) or is only mentioned indirectly when comparing the two different sizes of the gearwheels ("big wheel", "small wheel"). The term "sprockets" refers to the grooves or teeth which mesh – here A transfers a term with which she is familiar from bicycles to the hand drill. It is interesting to note that the term "sprockets" indirectly suggests gearing. A understood the transfer of rotational movement, i.e. the drive dynamics (the crank drives the large gearwheel which drives the cone gearwheel which drives the drill bit).

When he asks what the use of a hand drill like that is when there are cordless drills, B raises an interesting question, to which the most obvious answer would be that cordless drills make drilling considerably simpler, rotate faster and can be used for drilling holes as well as for screwing in screws; but they are also dangerous because they are powerful devices and drive sharp-edged drill bits at high speed and that children therefore work with hand drills, even though their use requires much greater effort. From a historical perspective, the purely mechanical procedure was, of course, the first development stage which was subsequently followed by the electrically-powered version. Hand drills are still widely used for certain tasks, for example, for restoration work.

3.3. Jack

The film, based on an animation, shows a jack in the foreground and a jack which is being used to lift a car in the background.

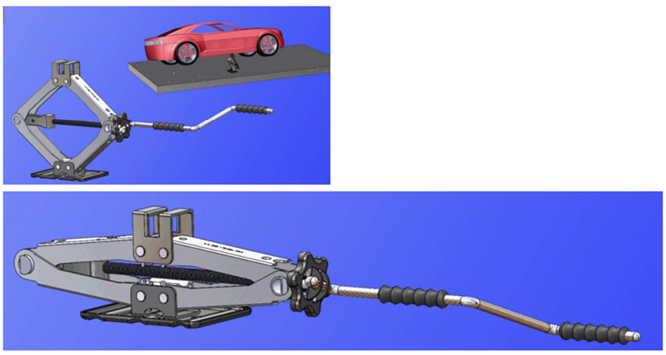

Figure 3. *Screenshots from the "Jack" silent film.*

One conversation sequence is as follows:

A (boy, 12 years old): Now you can see that it's a jack.

B (girl, 11 years old): Ah, that was quick.

A: You crank the crank. Yes well, and then you can tilt the car so you can access stuff more easily.

B: But how exactly does this work? We need to see it a bit more slowly. That's difficult.

A: But it takes a lot of strength to operate, I mean, you can't just simply tilt a car like that. So if you rotate it, that turns a thread. And the thread. Ah and now. So there's a thread. And if you turn. Eh? I don't understand. Somehow it... It has something to do with leverage, so it must actually be quite easy, you can't simply lift up a car by brute force. I didn't get it.

B: Me neither.

A came up with a name for the object immediately; he is already familiar with the term "jack". B says that the beginning of the depiction was too fast for her but does not make use of the option to briefly pause the film or view it again. B notices the crank and answers the implicit question of what is the purpose of the crank by answering that it is used to lift the car so that one can get underneath it. B states that she did not grasp the exact function of the "jack" and attributes this to the speed at which it was shown and the complexity of the operation.

A then identifies what is actually amazing about the jack, namely that, thanks to this device, lifting a heavy car requires only little effort. A is not familiar with the gearing principle – he sees the crank and recognises a threaded rod and the mating thread, but does not understand how the individual components work together/move as shown in the film. However, it should be mentioned that in the film it is very hard to see how the threaded rod fits in the thread. Nevertheless, A associates the power saving or relatively easy movement with the word "leverage". Power saving or ease of movement is something that cannot be deduced from simply watching the film; it is more likely that the idea of ease of movement is based on experience or logical reasoning that a car is very heavy but can nevertheless be manually cranked up here.

4. Summary of Case Study Results

The present study showed that, on the one hand, media have a focusing effect and offer many opportunities for good observation, but, on the other hand, content may be assimilated in a very superficial manner. It was determined that animations were extremely popular among children.

It was clearly evident in the present study that children are more likely to assimilate unfamiliar objects or processes if they proved to be easily decipherable on the basis of sensory perception and concrete logical thinking, even if there was a lack of prior knowledge and previous experience.

With regard to the verbalisation of observations and the choice of words in the context of descriptions, it should be noted that the children in the present study were easily capable of determining when a term was particularly apt or concise and managed to get by, even in exploration processes, without using technical terms.

In the dialogues, the common focus on the facts of the matter was particularly striking. The conversation sequences showed that the children proceeded mainly on the basis of observations and the verbalisation of observation. They do not leave this step out, even though it is conceivable that it might be omitted, if they were to adopt an approach like "we've seen that, we don't really need to mention it again". In fact, the opposite is true: the children communicate what they have seen to each other. The sequences often began with the children describing what was shown in the film. During the exploration process, the children repeatedly shared their previous experience and prior knowledge. Exchanging thoughts about the origin of their familiarity with something is clearly important to the children; in conversation, they encourage each other to activate memories, experiences and points of reference. By communicating, the children were also able to experience how others perceive and interpret the same facts, that there is a difference between "thinking" and "knowing", and that there are higher-level problems and sub-problems. The children were not afraid to admit moments of not understanding and assumptions which they were not sure about in dialogues.

Forms of abductive conclusions were more frequent, especially approaches involving conclusions by analogy. Evidence of this were phrases such as "It looks like", "It's similar to", "I know that from", "That also exists in". Most of the children had no finished concepts; rudimentary knowledge regarding the lever rule principle was evidenced most frequently (an example from the "jack" film workstation: "It has something to do with leverage, so it must actually be quite easy, you can't simply lift up a car by brute force").

When tracing connections, the children most often used operating principle logic [19] by moving forward step-by-step along the progression of an action – here is an example from the "Glue Gun" workstation: "Now the adhesive is in it. When you press, it's pushed forward, and when it's near the front it's heated and then it comes out in the front in liquid form, but at the back it's solid."

Besides questions about function, there were also "What is this?" type of questions. These prompt the children to ask what the name of something is (phonological elaboration). When the children begin to think about the meaning behind things, they ask questions such as "What can we use this for?", "Why do we need it?", "Why does it have a thread?", "How does it move?" (semantic elaboration).

Interestingly, there are some indications in the present study that girls can benefit in their educational processes from thorough exploration that also takes into account seemingly "secondary" aspects.

5. Ways to Enhance Exploration Processes in the Context of Technology Education at Primary Level

The question of whether children are capable of identifying key aspects by themselves during exploration processes and the question of when there may be a need for partial assistance is a science teaching didactic research topic in various debates that centre around the keywords "instruction" and "construction" [20]. The present study suggests that pupils who are engaged in an education process benefit from certain forms of support. The following outlines how reconstructive exploration processes, based on technical events, can be enhanced in addition to the "silent films" offering.

With respect to those phenomena or objects shown in the silent films which barely have any direct connection to the world in which the children live, in particular, reverting to or integrating the original encounter might be helpful. Exploring by oneself and intervening and/or manipulating are only possible on the basis of material that actually exists. For example, the principle of gear ratios which plays a role in, among other things, the films about the hand drill and the jack, can be experienced by the pupils by actually building gearwheel structures. Pupils who are engaged in an education process can simulate and observe how a gearwheel meshes with another gearwheel and drives it, what the direction of rotation of both gearwheels is, what happens if one changes the direction of rotation, or what happens when a gearwheel with 40 teeth meshes with a gearwheel that has 20 teeth and vice versa. This kind of exploration using objects and processes ultimately also improves concentration and precision of thought; assertions can often be checked by taking a look at the actual object.

Some questions can only be asked based on acquired experience, for example, the question why, in the case of the jack, a relatively large amount of force needs to be applied at the beginning and then increasingly less force is required to lift the car higher. Only by using an actual jack can one learn how futile it would be to try to rotate the threaded rod by hand. Or that the longer the crank, the easier it is to lift the car (in this case, snap-on cranks could be used to explore different lever lengths).

However, some principles and functions are not visible in the film or in the original and can only be explained using a model. If used in technology education at primary level, models should, with respect to their appearance and nature, be as little abstract as possible and as close as possible to the original so that their operating principles can be shown as unambiguously as possible.

Another option is to use supporting drawings. In the case of older primary school pupils, principles or mechanisms that are harder to discern can be explained by drawings, e.g. the structure and function of the chuck of a hand drill or how the ball is seated in a ballpoint pen. Drawings made by the children themselves also allow (self-)diagnosis of their understanding. It is reasonable to assume, for instance, that only pupils who have understood and consciously grasped the various components of a hand drill and how they interact are capable of drawing a hand drill from memory.

It was noted that children who, while exploring, hardly progressed beyond observation and description, frequently overlooked important details or failed to ask questions that were important for more in-depth exploration processes. Questions are a crucial way of providing an anchor point from where one can continue to observe and investigate an object. An example: Reconstructively examining a ballpoint pen can provide important knowledge if the question of why a ballpoint pen is called a ballpoint pen is raised. This question can trigger research and discussion about the ball and lead to further questions, for example why the ball does not fall out of the device or slide up into the pen or the possible reasons why a ballpoint pen does not write properly (e.g. no ink or the ball has dried and become stuck or the paper is so smooth that it does not provide sufficient resistance to allow the ball to roll). Questions encourage in-depth exploration, guard against superficiality and steer attention to vital details that are important for the technology concept at hand.

6. Conclusion

A concluding hypothesis: it is postulated that teachers who teach technology as generalists in primary schools can benefit from this approach of exploring technical objects and events reconstructively, if applicable with the support of instructors and/or an e-learning platform. However, this requires the courage to adopt an attitude that involves engaging unconditionally with the object or process that is to be investigated and, at least initially, abandoning familiar habits of drawing deductive conclusions.

Silent films make it possible to attempt to develop technical understanding by observing, describing and developing approaches to explaining the necessity, principles and modes of action of technology and technical events depicted and experienced in the silent films. If observations are to be reported and statements are to be formulated, one must have appropriate means of verbal expression for such observations and explanations. Discussions involving silent film clips can help teaching staff reflect on the relationship between concepts and terminology and make them more aware of the role that language plays in exploring technical events.

Some film logs are particularly valuable for reconstructive education processes because the film can, for example, be paused, thereby freezing a particular moment, or it can be slowed down or, in the case of animated films, it is possible to gain easy and immediate insight into internal workings. As a general rule, the quality of the underlying log plays a crucial role in construing and forming interpretations.

Silent films can be used very flexibly and are valuable tools throughout the entire education process. For example, they can be used at the beginning of a discussion about a certain phenomenon or subject, in order to trigger questions and encourage initial conversations about observations – in the spirit of Wagenschein who stated that one does not always have to start with what is self-evident and straightforward, but can instead confront children with complicated and problematic aspects before gradually identifying the underlying understandable and familiar aspects of a phenomenon or object [21]. Silent films can also be used midway through the education process to reflect on, for example, what features of an object have not yet been discussed and still require clarification. In addition, films can also have educational value at the very end of the education process, for instance, if a teacher wants to use a film to summarise the knowledge that the pupils have already acquired. Films that are viewed a considerable time after pupils first intensely and consciously tackled a technical event can help them remember a previously mastered reconstructive exploration process. Of course, it is also possible for pupils who are engaged in an education process to start out by making their own technology films and attempting to record phenomena of their choice in a film in order to clearly identify the basic principle on which they operate.

The present study also gives clear indications that pupils who are engaged in an education process can obtain a great deal of support in reconstructive education processes not only from media experiences such as silent films, but also in many other ways. Socratic-maieutic discussions, stimulating questions, models, real objects and the opportunity to touch/manipulate them or explore with them, drawings and factual texts are all suitable ways of ensuring pupils who are engaged in an education process become witnesses in the search for solutions. In education processes that include these forms of support, pupils who are engaged in such a process can experience how to arrive at potential interpretations of the world and acquire a model for examining ideas and theories.

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