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Joining Technology at Primary School - Development of Teaching Ideas and Materials

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Abstract: The aim of the project *Joining technology at primary school*, which was conducted as part of the *EduNaT* strategic initiative at FHNW (University of Applied Sciences and Arts Northwestern Switzerland) in the period 2015 to 2017, was primarily to develop and test teaching ideas and materials for *technology in General Science classes*. The specific aim of the project was to reduce technophobia in teachers by making a tried-and-tested range of technical, didactic and media suggestions available to them on an online platform especially designed for this purpose. A collaborative approach was taken, with engineers and technicians from the FHNW engineering school, educators from the FHNW college of education and teachers from primary schools contributing their respective expertise - they worked together to develop teaching ideas and materials in the field of *joining technology at primary school*. The materials and ideas were then tested in workshops with 80 pupils from primary school classes. Audio and video recordings were made of the tests, which were then evaluated using objective hermeneutics. Observations made during the workshops led to a deeper understanding of the nature and essence of technical development processes in the participating children. It was possible to deduce from observation analysis, among other things, which joining techniques or elements are particularly suitable for the development of model thinking, which are better for gaining experience with technical design and which are better for understanding technical vocabulary. After evaluation, the teaching ideas and materials were reworked. The resulting teaching ideas and materials are now available through an online platform for qualifying teachers (training and professional development). The development process is presented here and insights are given into the ideas and materials developed by way of some examples.

Keywords: Joining Technology at Primary School, Online Platform Joining Technology, Technical Education

1. Introduction: The Demand for Technical Education and Its Justification

1.1. Demand for Technical Education

The word *technology* is derived from the Greek word *technikós* (skilful, practical) and covers various aspects, depending on context. Ropohl [1] distinguishes between a wide concept of technology, which includes all human activity, and a narrow concept of technology, which excludes human activity and only describes artefacts. He suggests that it is only appropriate to speak of technology for items that are man-made and used for certain purposes. In this case, technology is not an isolated field but closely linked with industry, society, politics and culture. For this reason, the ability to understand technology must become common knowledge [2]; for people need to understand technology in order to assess or anticipate its effects [3] [4].

The Association of German Engineers (VDI) [5] has formulated five areas of competence for technology as a school subject: (1) understanding technology (knowing and applying the goals and functions, concepts, structures and principles of technology), (2) designing and making technology (planning, designing, building, optimising, verifying and testing technical solutions), (3) using technology (choosing, using and disposing of technical solutions in accordance with technical standards and safety requirements), (4) evaluating technology (assessing technology from historical, ecological, economic, social and human perspectives) and (5) communicating technology (gathering and exchanging technological information specifically related to relevant issues for the respective target group).

For each area of competence, VDI formulates standards (different levels) to be reached by pupils when they leave school with an intermediate school leaving certificate.

Several competencies in the field of technology are found in curriculum 21 [6], the first common curriculum for Swiss primary schools in 21 cantons. Here, the focus is on making assumptions about the design and function of technical devices, describing technical correlations using objects and investigating technical principles.

The successful acquisition of competencies is best achieved in task-based lessons [7] [8]. Subsequent discussions about the activity reveal any incorrect reasoning, which, however, presupposes that the teachers themselves have understood the concepts.

1.2. Goals of Technical Education

The aim of technology classes is to enable pupils in primary school to actively engage with and reflect on technical phenomena and objects [9]. As a result, they should be able to develop an understanding of and a critical attitude towards technology. During this process, they should experience technology as something comprehensible and decipherable, as something constructed by human beings that can be changed by human beings. Questions about the relationship between technology and the development of humanity should be raised when considering technology; these include questions about inventions, questions about production, questions about usefulness and questions about risks to human beings through technology.

2. Access to Technology by Way of Example: Joining Technology and Composite Structures

2.1. Joining Technology

Joining technology is a basic technological process. It describes techniques for assembling functional structures from their individual parts. Every technical system consists of components that cannot be disassembled; an understanding of their function is necessary for the construction of complex functional units. Typical joining elements include, for example, paper clips, rawl plugs, Velcro fastenings, buttons, clips, nails, knots, zips, drawing pins, safety pins and screws. Typical composite structures in everyday life include, among other things, trailer couplings, ski poles with wrist straps, book covers and furniture in general (in the latter case, for example, connections between table legs and table tops). There is a wide variety of other joining elements and composite structures, as joining technology constitutes a very diverse topic area.

2.2. Joining Technology in Primary Education

There are many reasons why joining technology seems suitable for introducing pupils at primary level to the topic of technology. Joining technology is an aspect linked to the world of children, occurring everywhere and directly experienced by children. Popular toys at this age and stage of development, such as Lego, Playmobil, Fischertechnik and puzzles, are characterised by joining technology. Joining elements and composite structures can be found everywhere in everyday life. Children often witness connection procedures in everyday life. For example, they often experience how broken toys are repaired by being glued back together. At the age and stage of development in primary school, children are very strongly influenced by experiences and the reconstruction of these experiences. By dealing with the objects of this world, children can discover the objective representation of an object.

Joining technology also constitutes an example of a basic concept from technology-related disciplines in General Science classes. Understanding joining elements and composite structures is to a large extent possible on the basis of sensory perception.

The investigation of technological phenomena is possible during concrete logical development and works without abstract thinking for a long time. This counters the risk of the abstraction and mathematisation of technology taking place too early, which may interfere with a personal and emotional approach to the subject.

There are also a wide range of possibilities for task-based and everyday-related inquiry, which seems to encourage sensemaking. The subject matter with its phenomena and objects also meets the criterion of multi-perspectivity required for teaching practice [10] – thus, for example, connections can be investigated or newly developed from the point of view of their development history, functionality, application in everyday life or aesthetics.

The topic of joining elements and composite structures can also demonstrate culture-specific and cultural-geographical solutions (e.g. connections using different materials specific to a cultural environment); alternatively, it can be considered from economic aspects.

Joining technology is also a highly topical subject in research and development. As more and more new materials are invented and produced, the question arises how these can be combined with each other.

Dealing with joining technology calls for a variety of ways of thinking, working and acting. Pupils can invent composite structures, they can build and design, investigate, test, analyse, develop, experiment, repair, design, solve problems, compare, plan, build models, draw objects, interview experts, research and present. Task-based exploration is easily possible due to the low risk posed by objects and activities.

3. The Project: Background and Procedure

The aim of the project is to reduce technophobia in teachers by making a tried-and-tested range of technical, didactic and media suggestions available to them on an online platform especially designed for this purpose.

Engineers and technicians from the FHNW engineering school, educators from the FHNW college of education and teachers from primary schools worked together to develop teaching ideas and materials in the field of *joining technology at primary school*. The materials and ideas were then tested in workshops with 80 pupils from primary school classes. Audio and video recordings were made of the tests, which were then evaluated using objective hermeneutics. After evaluation, the teaching ideas and materials were reworked and finally made available on the online platform.

4. Outcome

4.1. Online Platform

The teaching ideas and materials that were developed and reworked are now available online as modules (https://web.fhnw.ch/ph/projekte/verbindungstechnik-primarschule/verbindungstechnik-primarschule).

Figure 1. *Screenshot of the online platform homepage.*

This online platform (Figure 1) is designed to help arouse enthusiasm in teachers for teaching ideas in the field of joining technology and to encourage them to use the ideas themselves. The platform contains interesting problems and aspects that teachers may not think of themselves. It also draws attention to startling phenomena and analogies. The platform also gives teachers suggestions so that they can offer a scientific explanation for experiences when viewing and exploring a joining element or a composite structure, enabling them to feel safe and to help pupils develop technical competence.

The online platform includes: (1) a didactic commentary, (2) documents on joining technology in general, including information on the history of connections, information on the principles of joining technology and hazard warnings, (3) documents on individual joining elements, including images and information material on principles and concepts, possible problems in the classroom, as well as building instructions and suggested materials, (4) short film sequences showing how pupils at primary level deal with certain tasks or problems in the field of joining technology, (5) film material (not accompanied by sound and text) that can be used for different questions in the classroom and (6) a template for a class booklet on joining technology (modular principle).

The film sequences are not *best practice* cases (exemplary teaching with exemplary children and teachers) but *real-life* cases – according to the view that there is no correct or best pedagogy.

4.2. Presentation of Some Teaching Ideas and Materials by Way of Example

In the following, four modules (*construction of a bottle carrier*, *clips*, *rawl plugs* and *buttons*) are presented, together with teaching ideas and materials.

However, these online modules are not intended to give the impression that proven practices and didactic materials alone induce learning. Conveying technical subject matter depends to a considerable extent on the quality of the working relationship (this includes, among other things, discussions to ensure the reciprocity of perspectives and the clarification of objectives).

4.2.1. Joining Technology in General: Building a Bottle Carrier

The module *Building a bottle carrier* presents a task for pupils to produce a carrying device for a PET bottle (Figure 2). Then load tests are done – the paper, which is joined in different ways, is subjected to loads and the different surfaces that fail to withstand the loads are compared with each other (i.e. the surfaces are examined, for example, and questions are asked: Where does it tear? Why?).

It is possible to produce the bottle carrier using, for example, paper glue, tape, staples, or screws, with or without washers. The task can be modified in numerous ways – for example, building the bottle carrier using only one joining technique (e.g. only screws) or building a bottle carrier using three different joining techniques.

Figure 2. *Teaching ideas for the module Building a bottle carrier.*

4.2.2. Clips

The clip is a pincer-like device for clamping or joining two or more objects. Most people know this joining technology from the clothes peg. This is used to attach laundry to a clothes line. In everyday life, however, there are many other kinds of clip: the paper clip, the staple or the fold-back clip, used for holding pages of paper together. There are also larger clips used for flexibly mounting objects like lamps.

The clothes peg is particularly suitable for exploring clips in the classroom. The normal clothes peg usually consists of two legs connected in the middle by a leg spring made of metal. The leg spring builds up pressure, holding the individual parts of the peg together. If the legs are pressed together on one side, the leg ends open on the other side.

When a rigid body is pivoted around a pivotal point, this is known as a lever. The clip is therefore a lever. In normal mode, one side is closed, clamping something; that is to say, there is a certain force acting on the object clamped between the front ends. To open the clip, it is necessary to press the rear ends on the other side. It is possible to imagine that the lower part (one wooden leg) of the clip is static. It is then possible to observe what happens when the upper part of the clip is moved. In the classroom, the clip can be investigated as a lever by putting different weights on lever arms of different lengths and comparing them (Figure 3).

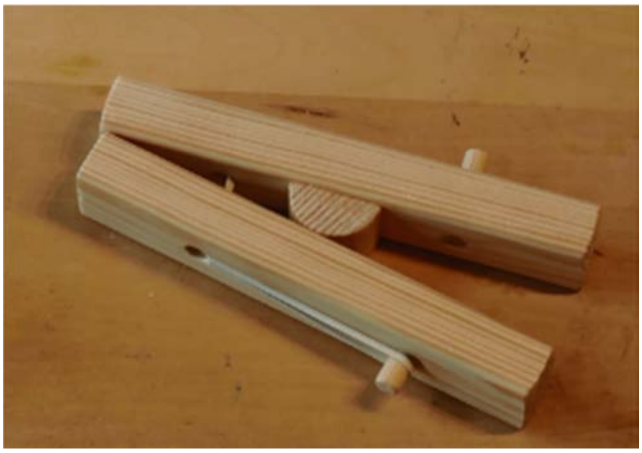

Figure 3. *Clip board and leverage.*

There are other ways to investigate the clip in the classroom as follows: the children can collect clips or they can observe where clips are used in everyday life. The children can try to build a clip themselves using different components (e.g. wood, rubber rings, springs) and tools. Functionality can be examined by trying to hang up laundry on a clothes line using this clip. As a further activity or alternative, the children can build a clip from wood (Figure 4).

Figure 4. *Self-built wooden clip.*

In the context of the clip, an exploration of springs is also conceivable; for example, the children can build a coil spring from wire themselves and load it with weights. It can then be observed how much load the springs will withstand and consider how this relates to the diameter of the coil spring and the thickness of the wire.

Finally, it is also possible to compare the different types of clip.

4.2.3. Rawl Plugs

The rawl plug is another way to combine materials. This usually constitutes a connection between materials. The rawl plug enables a connection to be made using a screw, while the wooden dowel, just like a nail, makes the connection itself.

Before the rawl plug was invented, holes were often chiselled in the wall and a piece of wood was inserted using plaster or mortar. The screw could then be screwed into this piece of wood. In 1913 John Joseph Rawlings patented his expanding rawl plug, which was then industrially manufactured as the first of its kind.

But when is a rawl plug used nowadays? This is always the case when a screw cannot be screwed directly into an object (for example, a wall). In such a case, a cylindrical hole is first drilled in the object, a rawl plug is inserted and the screw then screwed in.

Figure 5. *Bolt hook in a rawl plug – the screw causes the plastic rawl plug to expand radially outwards.*

The screw forms a mating thread in the inner part of the rawl plug, deforming the plug material plastically and displacing it outwards – it causes the rawl plug to expand (Figure 5). In the case of porous material, free areas are filled with the plug material, positive locking securing the rawl plug against extraction. However, this connection is mainly held in place by force or friction. The radial forces resulting in the plug material are mainly responsible for its elastic and radial deformation. The elastic forces act on the non-resilient material as a normal force, resulting in proportional static friction in a vertical direction. The elastic hollow cylinder between the screw and, for example, the masonry is sufficient for the radial forces to be distributed evenly on a rough hole. At the outer edge of the hole, radial forces steadily decrease so that even in brittle masonry no flaking can occur.

In the classroom, it is a good idea to observe, describe and reflect on the functioning of different types of rawl plug. The film “Screwing a screw into a rawl plug”, which was made as part of this project, may be useful. The film shows the cross-section of a wall into which a rawl plug is inserted and a screw then screwed in. It is also possible to insert different rawl plugs into appropriately prepared stones or polystyrene and to screw in a screw. Then an attempt may be made to extract the rawl plugs. Slightly older children can try to draw the way a rawl plug functions.

4.2.4. Buttons

Buttons have been in existence since ancient times and were simply used as an ornament in those days. Only later were fasteners invented using a button-loop combination. In the case of the button-loop combination, the button, sewn to one side of the fabric, is pulled through a loop matching in size on the other side of the fabric. Finally, in the 13th century, buttons with button holes (hemmed slits in the fabric) were developed in Germany. Nowadays, there are both buttons that act as fasteners and buttons that do not (decorative buttons). They can be distinguished by material (e.g. plastic, metal, wood, horn, glass or mother-of-pearl), use or shape and design (e.g., shank button, sew-through button, thread button, toggle and snap fastener).

In the classroom, the buttons can be treated in a variety of ways. For example, the pupils can collect buttons in everyday life or take photographs of buttons. The buttons can then be sorted, categorised and discussed. It is also possible to build a model of a snap fastener with the pupils (Figure 6) and to compare this with a real snap fastener. By way of follow-up, the children can make a fabric wristband fastened with a snap fastener they have attached themselves. It is also possible to visit a button collection or a tailor's shop.

Figure 6. *Model of a snap fastener.*

5. Testing: Childhood Learning Processes and Interactions in the Field of Joining Technology

Pupils from various primary schools were confronted with different materials and problems in the field of *joining technology* in workshops and this confrontation was observed and recorded [11]. Some of the film recordings form part of the e-learning platform. The film sequences are not *best practice* cases (exemplary teaching with exemplary children and teachers) but *real life* cases (according to the view that there is no one correct or best pedagogy). The observations showed in particular the following:

Approaches and solutions: When dealing with materials, technical phenomena and problems, individual children noticeably took very different approaches and arrived at very different solutions. For example, some children threw themselves straight into designing, some started by thinking, others based their activities on the existing material or the activities of their peers. With regard to the solutions, the formulation of certain requirements or tasks can be a means to creating an awareness for certain things. The example of building a bottle carrier illustrates this well. It is possible to formulate the requirements so that the function of the bottle carrier is to carry the bottle with one hand. But it is also possible to have a task requiring the bottle carrier to be as aesthetically pleasing as possible. If the requirements are varied in this way, the pupils will understand that similar considerations and requirements may play a role in product development and design. The children thus learn that input in the form of requirements has an impact on the entire design process. In particular, experimentation seems to be a mode that is suitable for many children at primary school age. By experimenting, they notice, for example, what works and what does not. Many children showed no interest in formulating hypotheses or making assumptions before the activity of experimenting. When experimenting, the children resorted, among other things, to trial-and-error procedures. Trial-and-error procedures are particularly suitable if the material used is cheap and available in large quantities. When experimentation is used, it is possible to modify the tasks or problems so that the aspect of *joining technology* is emphasised and communicated more strongly. After an initial phase of self-guided experimentation when building a bottle carrier, the children can, for example, be given the task of building a bottle carrier using at least three different joining techniques. Or they can be asked to build another bottle carrier using only screws for connection purposes (which may surprise the children as they will hardly be familiar with screws being used for paper from everyday life – this will have a kind of counter-intuitive effect, which can be stimulating). Or the children are asked to compare their designs. It is thus ensured that not all children work with the same resources, such as the stapler (Bostitch) or adhesives, and that the children's awareness of joining technology is raised. Little effort is required to vary the procedure.

Experience and development: Some children found correlations between different materials and joining techniques. For example, they declared that rawl plugs in the wall held in the same way a clamp held a piece of wood, only vice versa. Thus, they recognised the principle of force-locking. The children discovered certain principles or laws themselves or in discussions with adults. On the topic of Velcro fastenings, for example, one girl demonstrated that, when moved in certain directions, two superimposed foam sheets become snagged on one another and can hardly be moved against one another, but that this connection does not withstand certain other forces acting in other directions. She thus recognised the difference between static friction and peeling stress, without, of course, knowing or naming the terms. The fact that pupils were not clear about certain issues or functionalities showed especially in their verbalisation. Things that were unclear were simply not verbalised, as it were. They used substitutions (it, here, etc.) instead of using specific words or terms.

Creativity: It was noted that the pupils often developed very creative solutions. They seemed particularly creative and motivated when they seemed to sense that they might reach a conclusion or find a solution by themselves and were allowed to do so. For example, this aspect could be seen very well at the hose connection station. At this station, the children were asked to make a hose connection between two water barrels. This needed to be as tight as possible so that water could be transported from one barrel to the other with as little water as possible being lost. The children tested, for example, the tightness of their connection before use by blowing hard into the end of the hose.

Gender issues: It was shown when handling tools, for example, that some children, including many girls, had less experience of technology than others. Against this background, enabling children to learn from experience instead of pure cognitive learning gains in importance. Children with less experience must be given much more time so they are not under pressure, enabling them to gain their learning experiences in peace.

Observations made during the workshops led to a deeper understanding of the nature and essence of technical development processes in the participating children. It was possible to deduce from observation analysis, among other things, which joining techniques or elements are particularly suitable for the development of model thinking, which are better for gaining experience with technical design and which are better for understanding technical vocabulary.

6. Conclusion: Joining Technology as a Way of Accessing Technology

Joining technology can be seen and experienced everywhere in everyday life. The principles acting in joining technology (e.g. form-locking, force-locking, material engagement; e.g. fit, clearance fit, press fit, e.g. detachability, non-detachability) can easily be discovered by taking a predominantly exploratory approach. This can be done without imposing principles and concepts on the pupils from the outside in the sense of accelerated didactics, but giving them the opportunity to explore by themselves at their leisure.

It is sufficient if the teachers are just a step ahead of the pupils technically – just far enough so that they are well able to understand what causes the children problems in their individual attempts and where their individual comprehension problems may lie. A key point seems to be that the teachers themselves should be curious so they will be able to inspire themselves and the children in the subject matter.

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