Enhancing Engagement for All Pupils in Design & Technology Education
Structured Autonomy Activates Creativity

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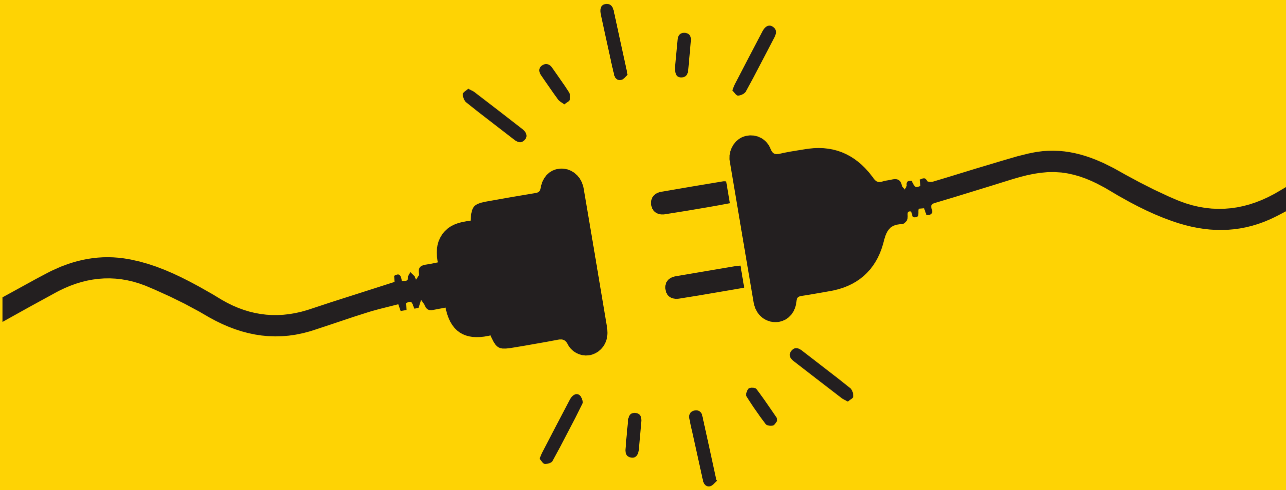

Structured Autonomy Activates Creativity

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Enhancing Engagement for All Pupils in Design & Technology Education:

Structured Autonomy Activates Creativity

Proefschrift

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Chapter 1

General Introduction

General Introduction

1.1. Introduction

In the past decades, many countries have introduced a subject Design & Technology. The subject has different names in different countries, but in each country it is intended as a response to the felt need to make the future generation more technologically literate. The aim of Design & Technology education is that pupils acquire knowledge, skills and attitudes related to technology as they encounter it in daily life and later in professions. Some of those skills can be instructed, but others need to be taught until understanding emerges. For instance, drawing straight lines is a rather simple technique, but the skill of designing is not a simple trick.

Designing is a way of thinking with many aspects. Creativity is one of them. Creativity is defined as the tendency to generate or recognize ideas, alternatives, or possibilities that may be useful in solving problems, communicating with others, and entertaining ourselves and others. (Franken, 1994, pp. 396). Hereby entertaining can also be read as engaging. Design can be seen as the imagination of ideas in reality. Arendt (Nixon, 2020) calls that "enlargement of the mind". Thinking happens in one's mind and is invisible. According to Arendt (Nixon, 2020) a decision must be made before a thought can be expressed. That is why designing requires making decisions, so that the design can be expressed. Not only design requires making decisions, but also other Design & Technology activities do so. Deciding is an important subtask of designing, solving and making, which requires a lot of practice before it can be done in an informed way. Therefore, Design & Technology education must provide pupils with opportunities to practise decision making broadly. If decision making is practised widely, Design & Technology education can have great potential for the entire primary education system, because making an own decision is not only important in Design & Technology but also in other school subjects. When pupils have learned how to make their own decisions, and they have the freedom to do so, every pupil can make their own decisions, anytime, anywhere.

Another important feature of Design & Technology education is that it makes use of the interaction of hand and the mind. This characteristic distinguishes it from most other school subjects. In addition Design & Technology education can take many different forms. A Design & Technology task can be a discovery task, a design task, a making task or a combination of these. This is particularly interesting for the education of younger children. Applied to a young child, a task can lead to an understanding of a phenomenon such as gravity, or to a solution for, say, the collapse of a construction, or to a product such as a gift for mother's day. Design & Technology education can also have many different starting points. An occurring situation can be a starting point, but also a situation created by the teacher. As such, design can have many functions. Design can be used to do research and construct knowledge, to think out solutions and make them, or to re-create reality to someone's personal taste. In turn technology is an important means to experiment with the design in reality to fine-tune the knowledge or idea.

Children go to school to prepare for their future lives. So personal development should be an important goal of learning. Then tasks are needed that focus on this. The exercise of deciding for themselves how to approach design and technology is useful for personal development. Design & Technology education can offer such exercises. In this way, children can discover that it is enjoyable to be able to decide for themselves. By being allowed to decide for themselves how they learn, pupils can make use of their strengths and work on their weaknesses. They can also discover that it is useful to be able to decide for themselves. Through the discoveries made during exercises in deciding for themselves, their personal development grows. The result, a well-matured personal development, will manifest itself in social behaviour, flexibility and creativity.

Although Design & Technology activities have a huge potential, many teachers experience that children are not always engaged in these activities. That is a problem because without engagement, learning is impeded This problem is however not often reported in scientific studies and elsewhere. In this chapter we will have a look at engagement and disengagement in Design & Technology activities because without engagement, learning is hindered. In section 1.2 two occurrences of absent or low engagement in a Montessori class are described and analysed. This is followed in section 1.3. by a search for explanations of the absent or low engagement. For this we turn to the Self-Determination Theory (Deci & Ryan, 2000) and on other sources that explain that various psychological needs of pupils have to be satisfied. In section 1.4 potential solutions towards engagement are described. It also describes their value to younger and older children. Relevant ideas for creating greater engagement in Design & Technology education from the Montessori method and from other educational approaches are presented. Section 1.5 describes the research questions and the motivation. Because the research in this thesis focuses on how engagement can be created, section 1.5 also describes the connection to the Self-Determination Theory (Deci & Ryan, 2000) and to the Montessori Method (in Gutek, 2004). Section 1.6 describes the used methodology. This chapter is ended with the outline of the dissertation in section 1.7.

1.2. Two occurrences of absent or low engagement in class.

'The recipe' task

Design & Technology class provides many opportunities for pupils. Yet in practice, there is often a lack of engagement in the classroom.

The first time that I experienced the absence of engagement during Design and Technology education was in 2003. At the school, where I was teaching as a Montessori teacher, I used a new teaching approach called 'technology boxes'. This approach consisted of a collection of various boxes containing the necessary material for executing prescribed tasks. Each box worked like a ready to use package, accompanied by a recipe that described a sequence of steps towards an outcome.

These technology boxes had a number of advantages. They were user-friendly for both teachers and pupils as a handy whole. Additionally they offered the pupils a wide variety of different techniques and research activities controllable for both pupils and teachers during class.

Figure 1.1 De Techniektorens. Source: Creative Kids Concepts, retrieved from https://creativekidsconcepts.com/detechniektorens

The disadvantage of the technology boxes appeared to be 'the recipe', that demands one way of performance. 'Recipe' approaches do not provide space to pupils to determine their own way of working. As a result the attention of the pupils was targeted towards the 'road' (the recipe) instead of towards 'finding a road'. A side effect was that attention for alternative 'roads' was completely absent.

The effect on the class was that I started with an enthusiastic class (as customary in a Montessori context). The first thing that I noticed was that not all pupils started working at once. In addition, their pleasure in doing the tasks gradually decreased. These occurrences were accompanied by a decreasing peaceful atmosphere in class. The problem of a number of passive, distracted pupils and the problem of a restless atmosphere in class appeared to be connected. Due to the fact that the distracted pupils sucked away the attention of the teacher and of their peers, all participants started to become restless. Once the disengagement was resolved, the atmosphere in the classroom improved immediately.

I then concluded that the technology boxes were unsuitable to initiate engagement for all pupils in class, as they appeared to be totally unsuitable for some pupils in class, with all the associated consequences for class as a whole.

The open design task

Also 'open design' approaches appeared not to initiate engagement for all pupils in class.

I observed an 'open design' approach in the role of assistant of an Arts and Crafts teacher on another Montessori school. The task given was 'make a canvas painting in the style of a given Dutch Master'.

The first thing that I observed was either distress or absence of interest among all pupils combined with noticeable reluctance of a part of the pupils. The distressed pupils expressed that they had creative ideas, but that they were unable to transform these ideas into practice.

The teacher scaffolded the transformation of ideas into practice for the distressed pupils. She did that by questioning the pupils. However, their process of designing and making later on showed decreasing enthusiasm. They were enthusiastic at the start, but over time they were losing enthusiasm and started to show disengagement.

The initial disinterested pupils were observing the work of the active pupils. They gradually showed increasing interest in the assignment. After a while most of them started working on copying a painting or making their own painting. Their enthusiasm was varied.

Especially during the first session I noticed that the Arts and Crafts teacher was expressing feelings of unease. This observation triggered me to see this open assignment from her viewpoint. If I would have been the teacher I would have felt the same uneasiness.

Therefore I questioned the teacher during our reflection on the first part of the assignment. I questioned her in order to get additional information about the principles underlying the format that she had created for the assignment. The teacher told me that she learned at the Arts and Crafts teacher training that the structure of the assignment had to be complex, multifaceted and changing in order to promote creativity among the pupils. She had also learned that the assignment had to be unfamiliar, ambiguous and open to interpretations. In addition she learned that the pre-definition of solutions should enable variable outcomes. With all these ideas in mind she had created the assignment.

The observations about the pupils and the teacher, supplemented with the information gained by the dialogue with the teacher, made me realize that this type of assignment was too open, too overwhelming for both pupils and teacher and therefore unsuitable to initiate engagement for all pupils in class.

Conclusion

Both the recipe and the open approach fall short in achieving engagement.

Additionally, a lack of engagement is not only a problem for individual pupils, but also for those around them, their peers and the teacher. During classes where pupils are using body, hand and mind, and are collaborating, a disengaged pupil is more likely to get in the way than in other classes.

Therefore this thesis will focus on the development of ways to engage all pupils in class during primary Design & Technology activities. To do so we will first search for an explanation of the lack of engagement.

1.3. Explanations of lacking engagement

In both cases, not all pupils were enthusiastic and motivated. Some pupils were not enthusiastic and motivated at all. Where the presence of enthusiasm indicates a feeling of satisfaction, the absence of enthusiasm might indicate a feeling of dissatisfaction. One possible explanation of absent feelings of satisfaction may be that making one's own decisions is absent. This is likely because the psychologist Ryan, the co-author of the developers of the Self-Determination Theory (Deci & Ryan, 2000), already wrote in 1995 that self-determination improves the experience of satisfaction. Self-determined behaviour comes from intentional, conscious choice, and decision (Hui & Tsang, 2012).

Self-determination refers to volitional actions taken by people based on their own will (Hui & Tsang, 2012). An opportunity for self-determination is created by offering free choice on how to do the task. The philosopher, psychologist, and educational reformer Dewey (1938) states that curiosity and questions have to be raised in order to achieve the self-expression, which is part of an own way of handling a task. That can be accomplished by offering free choice. When pupils are able to decide for themselves how to do a task, they are also able to use their strengths to work on their weaknesses.

Self-determination improves the experience of satisfaction (Ryan, 1995). The use of self-determination is therefore profitable for education and manifests itself in engagement. Then, following an approach devised by someone else with his/her other strengths and weaknesses, does not make sense. Such an approach blocks the ability to do the task in the best possible way. Such an approach does not help in learning to learn to choose the best possible way.

In 2000, the psychologists Deci & Ryan (2000) together wrote about the 'what and why of goal pursuits'. In this publication the backgrounds of the already by Ryan (1995) mentioned self-determination are described in detail. The theory designed by them, the Self-Determination Theory, assumes that the psychological needs of learners are an important factor for self-determination. This theory states that self-determination depends on the satisfaction of three innate psychological needs. When lonely, people may explicitly seek out companionship. When controlled, people may explicitly seek out autonomy. When feeling ineffective, people may explicitly work to become more competent (Deci& Ryan, 2000). The needs for autonomy, competence and relatedness have to be satisfied to obtain self-determination. When people are experiencing reasonable need satisfaction, they will be doing what they find interesting or important (Deci& Ryan, 2000). Self-determination emerges when there is sufficient autonomy, competence and relatedness to feel free to decide for ourselves.

- Autonomy concerns the experience of integration and freedom and is an essential aspect of healthy human functioning (Deci & Ryan, 2000). The extent to which a person feels wilful. The organinismic desire to organise experience and behaviour oneself and to make activity correspond to one's integrated sense of self (Angyal, 1965; deCharms, 1968; Deci, 1980; Ryan & Connell, 1989; Sheldon & Elliot, 1999).
- Competence refers to the possession of required skill, knowledge, qualification, or capacity. The extent to which a person feels effective.
- Relatedness is the interpersonal dimension. The extent to which a person feels that one is connected to others, has caring relationships, and belongs to a community. Relatedness refers to the desire to feel connected to others – to love and care, ant to be loved and cared for (Baumeister & Leary, 1995; Bowlby, 1958; Harlow, 1958; Ryan, 1993)

When relatedness is not an issue, for instance if a person is alone by choice, experiences of autonomy and competence, are sufficient for the enjoyment of an activity. That means, that if someone would do something that interests him/her, one would experience spontaneous pleasure as long as the activity is self-organising and the task appropriately challenging (Deci & Ryan, 2000). An activity is self-organising if someone can take up things in a way that they are good at. In this way, people's strengths are utilised, and people can get the most out of themselves. A task is appropriately challenging when a cognitive conflict is created (Vygotsky, 1978). When a child has an expectation about a situation based on the knowledge it has and this expectation does not correspond with the facts , a cognitive conflict arises.

Concluding, we can state that self-determination improves the experience of satisfaction (Ryan, 1995) as long as an activity is appropriately challenging (Deci & Ryan, 2000). Stimulating self-determined ways of handling tasks during Design & Technology class, could therefore lead to greater engagement. Moreover, using self-determined ways of handling tasks is conducive to personal development. Conversely, it will be clear that the ability to use self-determination is positively influenced by well-developed personal development skills. Therefore, making use of the theory behind self-determination (Deci & Ryan, 2000) can provide a basis to develop workable solutions for achieving engagement for all pupils in Design & Technology education.

1.4. Solutions for lacking engagement

Not only in the examples described in section 1.2, there appeared to be a lack of engagement, but other Design & Technology educational studies also identified a lack of engagement in class. For instance, Lindfors, Heinola & Kolha (2018) observed in every Design & Technology class studied some pupils with avoidance orientation. On the basis of the self determination theory, one can expect that these pupils are likely to remain passive as long as they feel incapable of becoming active and/or when they are not challenged to become so. Therefore, a study that finds solutions for lacking engagement would be useful.

The goal of finding solutions for lacking engagement pushes the research in this thesis in the direction of satisfying psychological needs, complemented by the generation of interest.

This thesis assumes that a holistic approach will be required to obtain engagement. That assumption is partly based on the Self-Determination Theory. From this theory it follows that the needs for autonomy, competence and relatedness all have to be satisfied to enable self-determination during the execution of a task. In addition the task must allow for self-organisation and has to be challenging to enable the experience of spontaneous pleasure, what could be visible in engagement.

If we want all pupils to be engaged in the classroom, we should also make demands on how they treat each other in the classroom. These demands could not only contribute to individual engagement, but also could have added value to the class as a community. Sharing ideas and knowledge and working together will create a growth of relatedness.

If we want engagement not to stop when the task is finished, we should have to think of ways to renew the challenge of the task.

In order to be able to meet all these requirements, I have combined ideas from the Montessori method (Gutek, 2004) with various insights from more recent literature in this research.

For Montessori, the needs of children were the starting point of her approach. She saw the need to find out to find out 'how' to function autonomously as a natural human urge. According to Maria Montessori, the child's most important wish was: "teach me to do it myself". She designed her method with this wish in mind. That wish is a clear demand for competence. But behind this demand lies the desire for autonomy. Autonomy can only be used if, at the same time, there is sufficient competence to allow a sense of effectiveness. Therefore, the intention of the Montessori method is to offer useable autonomy, not just for one child, but for the whole class.

Satisfying autonomy and competence, in other words creating useable autonomy for the whole class, is something that is might solve the problem of engagement for Design & Technology education.

How did Montessori arrive at autonomy and competence for the whole class? The Montessori method (Gutek, 2004) aims at satisfying the need to 'do it yourself'. She wanted to achieve this because she assumed that 'doing it yourself' would provide insight into the consequences of actions. She saw 'doing it yourself' as a form of discovery. In order for a child to be able to figure something out for itself, it needs permission and the competence to do so. Moreover there must be something interesting' to find out in order to start doing it yourself. In order to prevent the child from breaking things or hurting or disturbing others, there were conditions attached to the permission to figure it out for yourself. In this way, a child can simultaneously discover how to do something itself and how to do it in a harmless way. The effect is twofold; the child learns to do something himself and to give others the freedom they need to have autonomy. The effect is twofold; the child learns to do something itself, and to give others the freedom they need to have autonomy.

Montessori devised tasks, in which autonomy and competence could be present for all pupils in class. Relatedness was taken care of by Montessori primarily by offering liberty to the children at all times. Liberty is the condition wherein individuals behave according to their will and govern themselves, taking responsibility for their actions and behaviours. Therefore, in the original approach of Montesori pupils are at all times free to carry out a task or not. The conscious or unconscious choice not to perform a task is respected at all times by the teacher. The conscious or unconscious choice to not carry out a task can then be expressed by the children in copying the results of others or in doing something else. The freedom not to perform the task helped in cases where competence was insufficient. This extra freedom allowed the children to gain sufficient competence at their own time and in their own way.

Montessori also paid attention to the design of the tasks as this influences self-determination. She avoided low competence by not giving too much information resulting in ceasing self-expression (Dewey, 1910). She offered concrete tasks as "give me a spoon". (Every child has an image of a spoon and of the verb "give").

She avoided low autonomy by offering clear success criteria (Hattie, 2012) as "a spoon that can be used to eat soup with" (Every child has an image of eating soup).

The knowledge to be used during a task must be present. Both concrete experiences and insights can fulfil that requirement. Grounded knowledge is especially important. According to Barsalou & Wiemer-Hastings (2005), insight is a kind of abstract knowledge. The underlying concrete knowledge has become grounded; embedded in understanding. The use of hands and minds during an activity can be helpful to create insight (Jones, 1997). For instance; if you have learned to hold your pen properly, you are familiar with holding the pen in a proper way and will do it automatically when writing.

The devised task is tailored to the existent competencies of the learner, so that the learner immediately can understand the purpose of the task (Krauss & Chiu, 1998; Côté-Lecaldare et al., 2016). Understanding the purpose of the task gives the learner the feeling of 'I can do the task'. Understanding the purpose of the task helps to enable learners to think for themselves how to carry it out, e.g. it leads to self-determination. If the task challenges them and if they are also given the liberty to carry out the task in their own devised way, interest and self-determination would arise, expressed in a feeling of 'I want to do the task'.

Success criteria can provide information about the desired outcome of a task (Hattie, 2012) and can lead to feeling competent. These success criteria might be further used to achieve formative learning. However, Montessori does not describe any solutions for formative learning in her method. One way of organising formative learning is through the sharing of ideas. In this way, others are introduced to new ideas.

A practical method for sharing ideas might be found in the ideas of Arendt about education (Nixon, 2020). Sharing ideas is according to Arendt an exercise in 'enlargement of the mind'. An enlarged mind not only contains an expanded range of varied knowledge, but also expanded understanding. A way to achieve such an 'enlargement of mind' is joined-up thinking (Oldfather, 1992) before the activity starts. Another way is a joint presentation at the end of class as described for Japanese lesson study (Doig & Groves, 2011). A joint presentation gathers differing ways of handling and outcomes of a brief, simple and objective task. Both, joined-up thinking and a joint presentation, are exercises in sharing ideas without judging the ideas of other people. The required absence of judging other participants' ideas demands understanding and acceptance of the ideas of other people. Thus, the result of the exercise of sharing ideas also is growing relatedness Joint presentations are thus expected to support competence and relatedness.

Collaboration might be another way to benefit the sharing of ideas. De Miranda (2004) argues that a collaborative classroom ethos will benefit the social distribution of expertise in the Technology Education classroom. The social distribution enables the growth of individual knowledge. As a result the knowledge growth generates a growth of the number of ways to handle a task towards ongoing exploration. To achieve both active pupils and socially distributed expertise, instruction must focus on the process of learning in doing rather than just on doing (de Miranda, 2004).

The intention of the Montessori's approach is self-determination for all pupils in class, whereby autonomy is the starting point. Thus the by her developed concrete educational interventions could be helpful to shape Design & Technology tasks. The intention of Arendt's ideas about sharing ideas is growing understanding and relatedness. Thus Arendt's proposed practice of 'enlargement of mind' could be helpful to shape the sharing of ideas and knowledge in design and technology education. Through a series of case-studies, the effect of interventions based on the Montessori approach and on the ideas of Arendt are examined in this thesis, see table 1 for the interventions studied and how they are related to the psychological needs of autonomy, competence, relatedness.

The previous sections are suggesting that autonomy, competence and relatedness together are necessary to ensure that children can decide for themselves how they will perform a task. In addition, motivation is needed to want to start a task. This motivation can be generated by a challenge towards interest. Interest is the engine for competence development. However, interest is not the same as competence, as competence in itself does not necessarily spark interest. Interest however it does requires sufficient competence present, sufficient autonomy and sufficient relatedness. Therefore, in each case study, I always strived to arouse the feelings of being allowed, being able and wanting in all the pupils in the class.

Table 1.1. *Overview interventions used and their origin*

Intervention	*function*	*Origin*
Iteration	The repeated performance of a task that improves the result	Repetition leads to completion. (Montessori in Gutek, 2004, p. 57). Design concepts emerge and become complete through iteration of analysis, synthesis and evaluation ((Chusilp and Jin, 2006)
Groundwork	If there is insufficient competence to perform a task, or if the intention of the required competence is not clear, a joint	Through detours via achievable goals, all desired learning objectives can be achieved. (Montessori in Gutek, 2004)

	preparation can lead to the required competence.	
Verbal expression	Initiation of the skill of verbalization, so that verbalisation can be used during joint presentations.	Onboarding experience phase in gamification (Chou, 2013)
Stepwise approach	Dividing a complex task in a series of well-defined tasks	Through detours via achievable goals, all desired learning objectives can be achieved. (Montessori in Gutek, 2004; Dolin et al, 2018)
Demonstration	A way of acting with emphasis on focus points of attention and success criteria is shown.	Showing a way of acting is more instructive than a description, because words have no meaning without an associated experience. (Montessori in Gutek, 2004; Van Gog, 2013)
Joint presentation	Each participant presents his own idea or product. The other participants do not judge them. They do try to understand them.	'The Greek Solution' (Arendt in Berding, 2017)
Joined up thinking	Beforehand, there is a joint reflection on an idea in order to arrive at a shared proposal for implementation.	Sharing the Ownership of Knowing (Oldfather, 1992)
Offering liberty	The pupils can behave according to their will and govern themselves, taking responsibility for their actions and behaviours.	"Real discipline comes through activity directed to spontaneous work in which the child through his of her own efforts (often repetitive ones) accomplishes his task." (Montessori in Gutek, 2004, p. 57)

In the table below we have summarised the interventions studied in this thesis and related them to the (expected) satisfaction of the human need for autonomy, competence, relationship and interest.

Table 1.2. *Overview of the expected relation between the needs of autonomy, competence, relatedness and interest and the characteristics of the interventions complemented by the occurrence in the case-studies*

Need for	*Characteristics of interventions related to need*	*Case-study*
Autonomy	Tasks that allow decisions to be made on how to approach the task and allow free elaboration. The road is not prescribed.	All case-studies
	Liberty in doing the offered task or doing something else and also in their own pace.	All case-studies
	Liberty in choosing a partner and in amount of iterations.	Case-study 1
	Joint presentations: allowing to express own ideas without being judged.	All case-studies
	Joined up thinking: allowing to express a thought or not.	Case-study 1, case-study 3, case-study 5
	Joined up thinking: allowing to express a thought or to repeat the idea of someone else.	Case-study 2, case-study 4
Competence	Iteration	Case-study 1 Also present in case-study 2, 3, 4, 5
	Groundwork	Case-study 2, 3, 4
	Demonstration.	Case-study 1, 2, 3, 4
	Verbal expression	Case study 4
	Well defined task through: • Building on existing knowledge • Success criteria related to the outcome of the task • Focus of attention during the performance of a task	All case-studies **Success criteria:** Case study 1: floating with a high weight Case study 2: seeing something unseen before Case study 3: feeling a difference in strength needed to lift something in different ways Case study 4: having words to express thoughts Case study 5: leading to a solid, comfortable chair

		The focus of attention during the performance of the task(s) Case study 1: the transition from floating to sinking Case study 2: seeing something unseen before Case study 3: feeling a difference in strength needed Case study 4: the cuddly toy viewed from a specific perspective determined by the colour of the thinking hat Case study 5: Successively: What does your favourite chair look like? Which parts does it consist of? How do you fasten the parts securely together? Will the chair be strong and comfortable? How do you cut cardboard? How do you fix cardboard parts firmly together? How do you finish your chair so that it looks attractive?
	Stepwise approach	Case study 5
	Joint presentations:	Case-study 1, 2, 4, 5
	Observing classmates	All case-studies
relatedness	Joint presentations: This way of sharing knowledge and ideas leads to understanding others and a growing sense of belonging	All case-studies
	Using own liberty leads to practicing giving freedom to others	All case-studies
	Collaboration: The sharing of knowledge and ideas leads to understanding others and a growing sense of belonging	All case-studies
interest	A task that is appropriately challenging: When a child has an expectation about a situation based on the knowledge it has and this expectation does not correspond with the facts, a cognitive conflict arises.	All case-studies
Case study 1: “the marble-boat”, Case study 2: “observe as an artist”, Case study 3: “wheels at work”, Case study 4: “talking about my cuddly-toy”, Case study 5: “the making of a mini-chair”		

Four studies were conducted to answer the central research question *‘How can we engage all pupils in class during Design & Technology activities?’*.

All studies took place in a situation where it was customary for all pupils and teachers to apply the principle of liberty at all times. This had already created a basic attitude of the pupils in which a lot of autonomy and relatedness could be recognised. Moreover, during the studies, this principle of liberty was applied very consciously. This provided even more autonomy and relatedness.

The studies are taking different approaches to competence, e.g. the first one focused on iteration, the second and third case-study investigated two forms of groundwork while the fourth study focused on obtaining well-defined tasks by subdivision of tasks. All studies have in common that the scheduled sharing of knowledge took place by joined-up thinking or joint presentations. The unscheduled sharing of knowledge took place by collaboration.

The first and fourth study were investigating how an ongoing character of a self-determined way of handling could be achieved. The sharing of knowledge took place by joint presentations and by collaboration.

The second and third study were studies that built the grounded knowledge base that was necessary to enable the pupils to start a self-determined way of handling during following tasks. Groundwork satisfied relatedness by joined-up thinking. The third study, that examined how verbal expression could become initiated, is a type of groundwork.

The first three studies look at the engagement of pupils of four to eight years old. The fourth study looks at the applicability for older pupils of the in the first three studies found successful interventions. The age of the older pupils was nine to twelve years old.

1.5. Research Questions and motivation

The guiding research question of this study is: *'How can we engage all pupils in class during Design & Technology activities?'* In table 1.1 we have given an overview of the expected relationship between the needs for autonomy, competence, relatedness and interest and the characteristics of the interventions. Based on this, we can now formulate the sub questions for the chapters.

The main research question of the second chapter was: '*What is the effect on the design performance when the same task is presented multiple times to 6-8 years old pupils*?'

The main research question of the third chapter was: *How to shape groundwork in design and technology education for children aged 4-8 year?'.* The sub research question was: *'What are the effects of groundwork on the subsequent process of exploration and learning?'*

The main research question of the fourth chapter was: '*How can a teacher initiate verbal expression in young children in Design and Technology education?'.* The sub research question was: *'Can we scaffold the existing expertise of 4-6 years olds?'.*

The main research question of the fifth chapter was: *'What is the effect of dividing a complex Design and Technology assignment into well-defined tasks, combined with joint presentations?'.* The sub research questions were: *'What is the effect on the design performance of pupils aged nine to twelve years old?', 'What is the effect on collaboration in class?*' and *'What is the effect on the teacher?'.*

Chapter two describes the first case study 'the marble boat'. The intervention 'iteration' is reflected in the title of the study 'The effect of iteration on the design performance of primary school children', and researched the main research question: '*What is the effect on the design performance when the same task is presented multiple times to 6-8 years old pupils*?'. This study examined the effect of iteration on insight about floating an sinking. Besides the effect of iteration, also the effect of other interventions was researched. The interventions were joint arranged presentations, mandatory and free collaboration, and presenting the performance of the task in front of the camera. The function of recording was threefold: the pupils were enabled to roleplay, the video could be replayed during instruction of the pupils, and the video functioned as a third eye for the teacher.

The motivation to start this study was the absence of research into iteration at primary school level. Nevertheless, at that moment iteration was already considered to be one of the most basic features of a design process (Chusilp & Jin, 2006). Engineers are usually practice iteration to optimize their design. Design concepts emerge and improve through the iteration of analysis, synthesis and evaluation. The effects of synthesis and evaluation broaden by applying them in joint discussions. At secondary school level one study was found showing that iteration can be a part of the didactic strategy (Bamberger & Cahill, 2012). Teachers at middle school level included redesigning and rebuilding in their didactic strategies with a positive result. By discussing the weaknesses and strengths of the designs with each other, the pupils were gaining insights that they could employ for redesign.

In the spontaneous playing behaviour of children engagement is almost always high. If you look closely, you can see a lot of iteration in it. That is because playing includes experimenting, with small variations, with the same object, over and over again. Every repetition of the experiment delivers an improvement of the performance. Playing together brings new elements in the performance resulting in more substantial variations. During play children learn by doing and experimenting.

During play product and process are equally important, because an important characteristic of play is purposelessness. Therefore Dewey (1899/1976) advocated providing children with room to play. He states that during play children can express themselves freely, because they have the autonomy to do so.

Chapter three describes two case studies ‘observe as an artist’ and ‘wheels at work’. The intervention ‘groundwork’ is reflected in the title ‘Groundwork: preparing an effective basis for communication and shared learning in design and technology education’. This chapter describes the research of two possible formats of groundwork. Therefore the main research question was: *How to shape groundwork in design and technology education for children aged 4-8 year?’.* This study examined the effect of groundwork on engagement during following tasks. The intervention was a demonstration accompanied by a question designed to induce joined-up thinking. In the case-study ‘Observe as an artist’ the groundwork was the sharing of knowledge during a joint technique exercise of *‘how*’ to perceive something unseen before. The groundwork was followed by the application of the technique in daily classroom practice. In the case-study ‘Wheels at work’ the groundwork was a demonstration of feeling the differences in strength required to lift a weight. The groundwork was followed by feeling the differences in force needed to lift a weight, applied to different ways of lifting, such as with a lever. This exercise was followed by a design task, which failed.

The motivation to start this study was a proposal to modify the goal of the Dutch Design & Technology Education curriculum towards ‘Science and Technology is a view on the world commencing at wonder’. This view led to an increased need to find guidelines to activate "wonder" during Design & Technology class. It also gave rise to the need to encourage pupils to explore different possible outcomes of a task. The proposal linked Science and Technology to the development of the so-called 21st century skills (PO Raad, 2013).

The activation of exploration demands competence in the form of grounded knowledge. The grounded knowledge may concern the initial situation of the task, the success criteria of the outcome of the task, or the focus of attention during the performance of the task. If the required grounded knowledge is lacking, a way must be found for the pupils to acquire it. By using groundwork, the required grounded knowledge can be created and competence will appear. A simple definition of groundwork is: Something that is done at an early stage that makes later work or progress possible. If the ground work is done with the assembled group, the teacher can use joined-up thinking to share thoughts and knowledge with the pupils. In this way the teacher can motivate pupils by making them feel ‘I can think. I can know. I can have wonderful ideas.’ (Oldfather, 1992).

The sub research question in this chapter: *‘What are the effects of groundwork on the subsequent process of exploration and learning?’* is answered by the description of the explorations that the pupils made after the groundwork.

Chapter four describes the fourth case study ‘talking about my cuddly-toy’. The intervention ‘verbal expression’ is reflected in the title of the study ‘Initiation of verbal expression in young children in Design and Technology education: A case study’. This chapter researched the main research question: ’*How can a teacher initiate verbal expression in young children in Design and Technology education?’* and also examined the impact of groundwork in the form of the initiation of verbal expression, on the implementation of subsequent tasks. The purpose of the groundwork was to develop the skill and shared language needed to articulate thoughts. One of the used interventions during the groundwork towards competence was the teaching of the rules and means of the procedure ‘how to divide a complex view into simple views’. This resulted in a focus of attention, defined by a particular colour of thinking hat, on a familiar object; one's own cuddly toy. However, knowing the rules and means of the procedure ‘how to divide a complex view into simple views’ is not enough to be able to use the right words. Therefore the main research question led to the following sub research question: *'Can we scaffold the existing expertise of 4-6 years olds?'.* The scaffolding of the articulation of thoughts and ideas was meant to further support competence. These two interventions should lead to usable autonomy and should enable pupils to take the lead in discussions.

Pupil's presentation of the views on their cuddly-toy took place in the assembled group and was video-recorded. The effect of recording was threefold: the pupils were roleplaying with their cuddly-toy, the video could be replayed during instruction of the pupils, and the video functioned as a third eye for the teacher.

The motivation to start this study was that in a class not all pupils will have the same level of social and communicative experience nor the same vocabulary (Mercer, 2013). That is especially the case at preschool level. The problem of young pupils is that they only have a small repertoire of shared words and habits. This small repertoire can easily evoke feelings of unease and disconnection, when they have to communicate about a subject. It is common knowledge that feelings of unease and disconnection are blocking communication. On the other hand, well-functioning communication is 'paved' with social interaction and related language (Lemke, 2001). A related question was 'Does it matter who takes the lead in interaction?'. The teacher can design a setting and invite the pupils to discuss a given context, but the teacher can also invite the pupils to discuss their experiences of a familiar object. The latter strategy gives pupils the lead and prevents a mismatch in thinking between the teacher and the pupils, which may lead to difficulties in starting a dialogue (Krauss & Chiu, 1998).

The theoretical foundation for these considerations is that according to Hiebert & Stigler (2000) and Scheer, Noweski, & Meinel (2012) teachers can influence the quality of interaction by teaching the rules and means of verbal expression. This idea can be compared with the way digital game developers circumvent feelings of unease and disconnection due to incompetence. Most games start with an onboarding procedure in order to avoid unwelcome feelings of participants. Onboarding is meant to evoke feelings of curiosity and competence. Onboarding is a way to accomplish self-determination. After onboarding, the pupils are competent enough to start working on a task. In our case the intended result of onboarding was well-functioning communication (Mercer, 2013, p. 164).

Chapter five describes the fifth case study 'the making of a mini-chair'. The intervention 'A stepwise approach' is reflected in the title 'How focus creates engagement in Primary Design and Technology Education: The effect of well-defined tasks and joint presentations on a class of nine to twelve years old pupils' with the main research question: *'What is the effect of dividing a complex Design and Technology assignment into well-defined tasks, combined with joint presentations?'*, with the first sub-research question being: *'What is the effect on the design performance of pupils aged nine to twelve years old?'*. The study investigated the effect of a focus point, combined with simple tasks and joint presentations on older pupils' engagement. It also studied the effect of the intervention and the pupils' resulting behaviour on the teacher's behaviour. The context of all tasks was the making of a self-chosen mini-chair. Other interventions used were that all tasks focused on one technique at a time and that all pupils had the same tasks, which allowed for collaboration during the lesson.

The motivation to start this study was the occurrence of disengagement of pupils at a newly started Montessori school. The occurrence of disengagement attracted my interest. The first three studies in this thesis took place in a school where pupil engagement was initiated by the Montessori context and had consequently become normal in all classes. Therefore, during those studies and pilots, I had experienced the influence of liberty, competence, focus points, success criteria and sharing of knowledge on engagement. If elements had a negative influence, engagement disappeared to a greater or lesser extent. As a result of these past experiences, I was able to see disengagement as a signal of one or more unmet innate psychological needs. Innate needs are independent of age. I therefore hoped to meet all the psychological needs of pupils aged nine to twelve by providing tasks with the same elements of liberty, competence, focus points and success criteria.

The theoretical foundation for these considerations are based on the findings of Dolin, Black, Harlen and Tiberghien (2018) who proposed to view learning as making steps, and on the findings of Doig & Groves (2011), who are describing how the subsequent learning steps can be linked together through joint presentations. The division of the learning about a complex Design and Technology topic into brief, simple and objective tasks, focusing on one technique at the time, is a way to satisfy the need for autonomy and competence. By doing this, the topic changes into a collection of tasks. The ‘steps’ (Dolin et al, 2018) are helping to make sense of new experiences. The Japanese Lesson Study method confirms the effectiveness of brief, simple and objective tasks (Doig & Groves, 2011). An important contribution of this publication is that it clearly describes how subsequent ‘steps’ are connected to each other by joint presentations of solutions with related results. In line with Gopnik's (2012) theory that scientific thinking is simply the human way of figuring things out, it was assumed that older pupils are also capable of scientific thinking through the testing of hypotheses. However, because this age group is used to scholastic learning and is at a different stage of knowledge development than younger learners, it is not obvious that they will use hypothesis testing in their learning. Therefore, the question was whether they would actually use this method. That was also the reason for the next sub- research question *‘What is the effect on collaboration in class?*’. Pupils who are used to scholastic learning have become accustomed to being tested individually. It is therefore likely that they are no longer used to sharing ideas and collaboration. To answer these sub-questions, joint presentations were chosen to provide for the sharing of knowledge and to stimulate collaboration (Krauss & Chiu, 1998; Lemke, 2001; Mercer, 2013).

As by increased collaboration the performance of tasks requires less affirmation from the teacher, it might provide the teacher with expanded operational freedom during class. That could result in an increase of opportunities for the teacher to support students in their thinking and making processes during class. Therefore the third sub-research question was: *‘What is the effect on the teacher?’*

1.6. Methodology

The used methodology of the case-studies was ethnographic research. The educative design used in case studies 1, 3, 5 was developed in a prior pilot. Ethnographic research is a qualitative methodology which requires the researcher to interpret the real world from the perspective of the informers in the investigation (Dobbert, 1982). To get usable information from the perspective of the informers, the ethnographic researcher has to be acquainted with the perspective of the informers. In all cases I was familiar with all pupils in class, and with the school culture. This situation enabled me to perform Arendt’s ‘representative thinking’ in a realistic way (Nixon, 2020). As a result I was able to imagine interventions that generally worked out well. This situation also allowed me to interpret the actions of the pupils in "two-in-one thinking". The interpretation took place during and after the implementation of the interventions. This continuous interpretation allowed a deep understanding of the mechanism of engagement.

The first four case-studies reported in chapter 2, 3 (second and third case study) and 4, took place at a Montessori school, where I, the researcher, was a teacher. Two case-studies took place in a preschool class, where I was the group teacher. Two case-studies took place during Arts and Craft class with seven to nine years olds.

The pilot of the last study was conducted in Arts and Craft classes with seven to nine years olds. The last study itself was conducted in Arts and Craft classes with nine to twelve years olds. In both these case studies, I was not the group teacher but acted in the role of Design and Technology teacher.

The last study was conducted at a school, which was in a transition towards the Montessori approach. I was familiar with the school culture, because I worked there as an after school teacher. I acted during the research as an assistant of the Arts and Crafts teacher. This Arts and Crafts teacher was trained as an Arts and Crafts teacher, but not trained as a Montessori teacher.

In all case studies I mainly used observation to gather information about engagement of the pupils. I used questioning to find out the perspective of the pupils.

In the last case study I also collected information on the engagement, exploration and self-monitoring of the Arts and Crafts teacher. I did that by sharing my observations with her and questioning her to find out her perspective. I also questioned her about eventual improvements.

In case-study 1, 4, 5 videotaping of the proceedings of class took place. The proceedings of case 2 'Observe as an artist' and 3 'Wheels at work' were not videotaped but photographed and annotated. Also the last session in case-study 5 was not videotaped, but documented through a post-interview with the teacher.

The purpose of the videos was to gather information through an additional eye, which could afterwards further clarify observations already made. The recorder had a fixed place. In case 1 the recorder offered the pupils a stage to try out their product in public. No analysis of the videos took place and the privacy of the filmed pupils was guaranteed in all cases.

In three of the described cases, the intervention was applied thrice, in parallel classrooms. This provided more comprehensive data on the effects of the intervention offered. The comprehensiveness of the effects of the intervention was thus increased.

In a traditional Montessori school, teachers are used to creating situations where autonomy can be present by always offering liberty in circumstances that use existing competence. These circumstances also create relatedness. In addition, in every Montessori task there is a clear point on which the pupils can focus their attention. Interest is generated by making the task challenging. Also, the design of the same task provides criteria for the learner to know when the task is successfully completed. The characteristics of a Montessori task, with the conditions provided, combine to create engagement.

However, on the one hand, not all Montessori schools use all the described traditional Montessori characteristics. On the other hand, there are also non-Montessori schools that offer the pupils the same competence, autonomy and connectedness, supplemented by the stimulation of interest.

Therefore, we can say that the same results can be achieved in all schools that apply the principle of creating situations in which competence and interest are present and that put freedom first during the learning process. Thus, if schools use or imitate the 'Montessori' conditions for the learning situation and the task, they could achieve self-determination and engagement with our interventions.

The case studies show how the interventions work under the conditions mentioned above.

1.7. Outline of the thesis

This dissertation focuses on how engagement of all pupils in class can be accomplished during Design & Technology activities. The structure of the thesis is visualized in figure 1 showing the theme of the chapter and the specific case-studies conducted.

To answer the main research question *'How can we engage all pupils in class during Design & Technology activities?',* Montessori principles, supplemented with recent insights from educational literature, were used to create five case-studies in four research articles. The second research article covered two case-studies.

Chapter two describes a qualitative study with the main research question: *‘What is the effect on the design performance when the same task is presented multiple times to 6-8 years old pupils?’.*

Chapter three describes two qualitative case studies on groundwork. The main research question was: *How to shape groundwork in design and technology education for children aged 4-8 year?’.* This chapter includes two case studies: ‘*Observe as an artist’* and *‘Wheels at work’.*

Chapter four describes a qualitative study with the main research question: ’*How can a teacher initiate verbal expression in young children in Design and Technology education?’.*

Chapter five describes a qualitative study with the main research question: *‘What is the effect of dividing a complex Design and Technology assignment into well-defined tasks, combined with joint presentations?’* and the three sub research questions: *‘What is the effect on the design performance of pupils aged nine to twelve years old?’, ‘What is the effect on collaboration in class?’ and ‘What is the effect on the teacher?’.*

Where the first case studies focus on four to eight year old pupils, the last case study in chapter 5 is an elaboration of the findings of the first four studies for nine-to twelve years old pupils.

In the conclusions and discussion of chapter 6, the research question ‘How can we *engage all pupils in class during Design and Technology activities?’* is answered. This chapter ends with recommendations and implications for educational practice, and recommendations for further research.

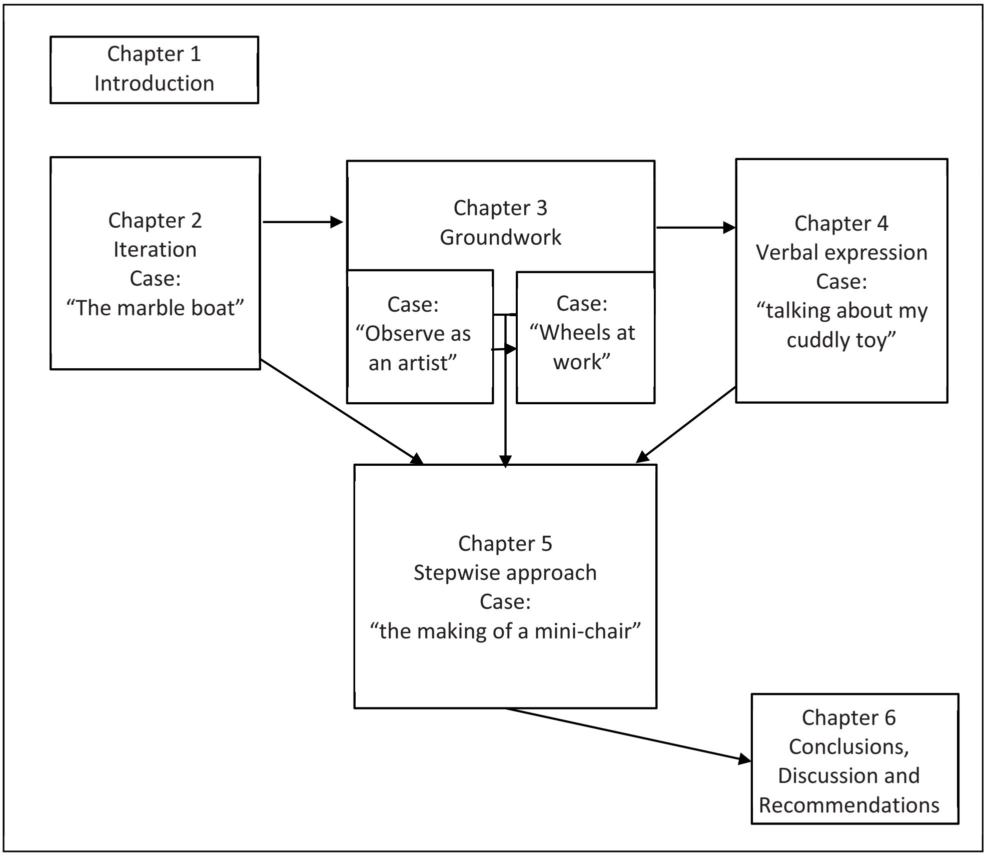

Figure 1.2 Dissertation flowchart of the five studies

Chapter 2

The Effect of Iteration on the Design Performance of Primary School Children[1]

[1] Based on: Looijenga, A., Klapwijk, R.M., de Vries, M.J. (2015). The effect of iteration on the design performance of primary school children. International Journal of Technology and Design Education 25(1), 1-23. doi: 10.1007/s10798-014-9271-2

This chapter presents the first case-study. Inspired by children's playing behaviour, the study investigated the effect of iteration on pupils' design performance under pre-defined conditions, such as clear commitments and a prepared learning environment. Examples of the prepared environment were the availability of several water tubs to try out buoyancy, many marbles, many sheets of aluminium foil and a video recorder on a fixed place. The pre-defined conditions obviated external control during the design performance of the pupils in order to illuminate the spontaneous behaviour of the pupils. Which additional factors enhance iteration? Which additional factors stop iteration? Which additional factors enhance understanding of the content? What do the pupils tell about their products?

2.1 Introduction

At the time of this study Design activities in Primary Education were not yet common practice. In some countries this kind of activities was not practiced at all, in other countries they were applied since two or three decades (Jones et al. 2013).

Design activities are important for developing skills, knowledge and better understanding. Effective knowledge expansion comes by thinking about already acquired knowledge and the other way round by searching for definitions and explanations of not yet understood knowledge. Both activities are practiced during design activities.

There has been some research on design activities in Primary Education, but not much. At Middle School level more research is done. Bamberger & Cahill (2012) are describing the practice of teaching engineering design. Their strategy includes a stage of redesigning and rebuilding. Also communicating is part of the strategy. The children learn from discussing the weaknesses and the strengthens of the designs with each other and gained insights are employed for redesign. At Primary level no explorations of such a practice are found, so at this level nothing is known about the effect of iteration of a sequence of design steps. That is strange, because iteration is one of the most basic features of a design process (Chusilp & Jin 2006). Design concepts emerge and become complete through iteration of analysis, synthesis and evaluation. A reason to research iteration in design activities in Primary Education could be to identify its value in terms of pleasure and better performance. What is the effect on the children and the results when they have the opportunity to improve and optimize their design in their own way and their own speed?

Recently, the National Research Council (2011) emphasized in a document the ideas and practices of engineering. They signal recognition of the importance of understanding engineering design and the links among engineering, technology, science and society. In Science Education it is important to distinguish Technology and Engineering. Technology is 'any modification of the natural world made to fulfill human needs or desires' and Engineering is 'a systematic and often iterative approach to designing objects, processes and systems to meet human needs and wants.'

In the spontaneous playing behavior of children there is also a lot of iteration to observe. Playing includes experimenting the same thing, with small variations, over and over again. Every repetition of the experiment gives improvement in performance. Playing together brings new elements in the performance showing in more substantial variations. On top of this the children's attitude during playing is cheerful and enthusiastic. They learn by doing and experimenting and they have fun. About a century ago John Dewey (1899) already pleaded to give children room to play. In play the child can express itself without pressure from society. The absence of pressure is a condition for playful behavior, because an identifying mark of play is purposelessness. While playing, process and product are in importance alike. According to Dewey especially constructive play is important for developing strong senses and observation skills. Furthermore it helps to develop 'personal responsibility' for the own learning and developing process. Games can be taught to a child, but nobody can teach play. Play is behavior.

Apart from the absence of iteration in education, all classroom activities happen sequential and are initiated by the teacher. However, there are school methods where teachers use the same strategy as engineers do. These teachers have a managing strategy for simultaneous activities and make use of the overlap possibilities of components of the process (learning activities) to reduce the lead time of

the whole (learning) process (Cao at all 2008). The Montessori approach is an example of such a strategy.
The leading pedagogic idea of Montessori is to educate children to respond to their call for help by doing things themselves (Montessori, 1949). In this way the child becomes independent from the teacher and education becomes self education. The role of the teacher is not a leader, but a coach. In her approach the skill of doing things and discovering solutions yourself is more important than knowledge, because this skill enables the child to find and construct the own knowledge. This kind of learning is efficient, because of the design of the learning environment and materials not much time is spend on instruction (environment and materials are mostly self instructing) and correction (environment and materials are often self correcting). In this way an ever iterating process of learning arises and intervention of the teacher is not necessary. Furthermore in the Montessori approach children have the opportunity to collaborate. They inform each other by sharing observations through talking, acting and playing. They collect new knowledge by observing the learning material from the perspective of the other. This new knowledge stimulates to go through a next cycle of learning. Gurnani & Lewis (2008) wrote from engineering perspective about this subject. According to them collaboration with excellent communication and full cooperation has been seen as an important factor to provide the best possible solution of a problem.

At a Montessori school the children are used to self initiated iteration of the learning cycle and to collaboration. This makes a Montessori classroom the perfect environment to research the effect of iteration in a design activity with ample room for collaboration.
Within this context a qualitative study in a handicraft classroom was thought out, seeking what kind of things can occur, in an optimized situation. The situation was optimized by defining as many variables as possible to meet the children's bounded rationality as described by Simon (1997). The problem solving process was kept as simple as possible by choosing a clear problem formulation, educating the knowledge needed for solving the problem through playing and collaborating, limiting the design goal to one, limiting the amount of information and resources. Furthermore, I provided the children with sufficient time to come to accurate decisions and limited the amount of alternatives.
The children's age was 6-8 years. Some iterations in the design process were initiated by me, the teacher and other iterations by the children themselves. Different perspectives of observing have been brought in by varied collaboration. Some collaboration was initiated by me and other collaboration by the children themselves.

In this paper I present the results of the qualitative study of how an iteration loop impacts the performance of a design assignment with regard to motivation, pleasure and focus. I was part of this study myself and therefore I used an ethnographic method of analysis. Because of this the only option to write about this study is in first person instead of third person objective. Once we know the outcome of this research, we can later on, in a more quantitative study find out what happens in which situation. This can help us to develop pedagogic strategies that sorts out results in Primary Science Education.
The paper is organized as follows. Section 2 reviews the knowledge base used for the research design/theoretical framework. This contains a pedagogical component, (a review of the Pedagogy of Montessori), an experience component (observations and experiences during the development of Science Education on a Montessori school) and a creative thinking process component. Section 3 describes the research design. In section 4 collected data will be described and analyzed. Section 5 is an interpretation of the results based on knowledge from literature. In section 6 the results are further discussed. Because I diagnosed the interpretation of section 5 as too little, results are later on this section also explained by and compared with literature about capability development and metacognition theory. Section 7 contains conclusions and recommendations for designing education and further research.

2.2 Knowledge base used for research design

The leading pedagogic idea of Montessori is that the purpose of educating children is to learn them to respond to their call for help by doing things themselves (Montessori, 1949).

Some conditions are necessary to let them reach independency by themselves. One is the distinction of the Sensitive Period of Development of the child. The education has to be in tune with this period. The education has to be tuned to the child and not the other way round. This makes the child competent to be active itself in learning.

The Prepared Environment is another condition. The educator has to prepare the environment of the child, so the child finds meaningful and useful things to do in his environment. The most important aspects of the environment the child has to deal with, are the group of children, the school, surroundings as nature, village and town, didactical materials, and the teacher (Montessori, 1912).

Furthermore Freedom due to self discipline is necessary. According to Montessori freedom does not mean: 'Do what you want to do', but 'freely doing good'. Children can make their own choices, take initiative for learning themselves and can choose to be active. The limit of their freedom is the freedom of the other. In this way the child learns to observe from the perspective of the other, resulting in knowledge needed for self discipline. Once a child has learned to move freely and appropriate in a regulated environment, the child will develop all aspects of his personality. The self discipline makes punishment and reward unnecessary.

During a period of six years (from 2005 to 2011) I worked as a teacher at a Dutch Montessori school. I gathered knowledge by observations during execution of design assignments and technical assignments. These assignments were executed in small groups of two to four children. The objective of my observations was to develop Science Education tuned to the Montessori method. The age of the children was 5-12 years. A positive effect on performance was noticed by providing variation in working together. I concluded this positive effect was caused by the created divergence in perspective of thinking, because the best results sorted out by collaboration between different learning children. For example; a child at the start learning by doing remarks different parts of the assignment than a child at the start learning by reading the manual.

During this period our school participated several times in a Technical Science Tournament. I observed that a team of four different learning children, each with their own specialty, achieved the best results. Together they formed a winning team.

Design activities are important for developing skills, knowledge and better understanding. Effective knowledge expansion comes by thinking about already acquired knowledge and the other way round by searching for definitions and explanations of not yet understood knowledge. Both activities are being practiced during design activities.

There are several sources describing the function of time in the creative process. For instance, to come to divergent thinking, time for experimenting and thinking over is necessary (De Bono, 2009). Presenting in essence the same design challenge more than once, with the objective of improving the own results, can be a way to fill that time in a useful way. By iteration, a sequence of activities is repeated over and over again, while the knowledge is increasing. A changing perspective gives an impulse for a next iteration. This can be achieved by varied collaboration.

Wallas (1926) describes the investigation of information relating to a problem in all directions during the stage of “preparation”. After an incubation period (unconscious period) a solution (illumination) may arise apparently out of the blue. After this, in the verification stage, the solution is evaluated, analyzed and extended. For this process time is needed. Cropley (2001) reports about the function of intuition. Unaware thinking, which may lead to implicit learning, is possible with intuition. In this way a raw sketch of a solution can be acquired already. After this, time is needed to refine the sketch to an effective solution.

2.3 Research design
Montessori principles and knowledge about the creative thinking process have been used for shaping the research and the conditions and interventions to provide iteration and freedom of choice. The conditions have been enriched with knowledge gained by experience about variation in collaborating and about presenting.
This resulted in a study to answer the question: *"What is the effect on the design performance when the same assignment is presented multiple times to 6-8 years old learners?"* This theoretical question got transformed in a suitable practical question found on the Dutch website Technology Tournament (http://techniektoernooi.nl): "Fold a piece of aluminum foil dimensioned 30 by 50 centimeter so it can hold the weight of marbles when it lies on the water. The more marbles it can hold the better." The design assignment had a very concrete goal, namely: "Make a carrier or bowl, which can hold as much marbles as possible." An easy perceptible challenge laid in the countable result, which was not difficult to improve. This caused an opportunity for self improving.
The same assignment was planned and executed thrice, in three sessions of forty five minutes. Further on I will refer to them as phases of the assignment.
Two weeks before the starting of the design assignment, the children had been working on their floating knowledge by playing with a set of experiments. During the *first phase* each child had to make its one carrier, while cooperating and deliberating with another child, chosen by itself. In the *second phase* they had to make the carrier together with a child, chosen by the teacher. The carrier had to hold more marbles than one of the first phase. The *third phase* offered the children a lot of freedom of choice. They were allowed to make a carrier on their own or in pairs. They also could choose to do an alternative handicraft assignment instead of the design assignment.
The participants were 41 boys and girls in the age of 6 to 8 years from a Montessori school. The children were used to self initiated working and to collaboration. The school is situated in an average to low income neighborhood. The educational level of the parents is relatively high. From the research group it was known that a lot of the children in this group needed extra challenge in their education, because of high intelligence. For the occasion of the design assignment three groups with children of the same grade (6-8 years old) were made. The children came from four classes with 5-10 years old children. Additional reasons for choosing these 41 children were the fact I was more of less familiar with all these children and because this age group is not often subject of research.
Some conditions were the same during the whole research: The assignment took place in the handicraft room of the school. The camcorder was seated in a small space (2,5 by 2,5 meter) with a sink, next to the handicraft room. The time of the year was the end of October, the beginning of November. The research was on Thursdays. Each group had 45 minutes for every phase. This is in total up to 135 minutes for the whole assignment.
The lessons were supervised by a technical teacher and a handicraft teacher.
The materials needed for the assignment were pieces of aluminum foil dimensioned 30 by 50 centimeters, marbles, bowls filled with water for trying out the carriers and a camcorder.

In the study several *relevant conditions* can be distinguished. The most important one was that the children were allowed to *execute* the assignment *multiple times*, as many times as they liked. Furthermore, there was *freedom of choice*, but not the whole working time; the children could choose doing one or more times the design assignment in phase one and two. In phase three they could choose for doing or not doing the design assignment. In all phases they are allowed to work on a handicraft assignment; in phase one and two after finishing at least one design assignment.
The children had to *work together* in order to provide incentives for explanation and negotiation. During the phases they were more or less allowed to choose who to work with. The first time the children had to work with a self chosen partner. The second time the children had to work with a partner assigned by the teacher. The third time the children could choose a partner or no partner.
The children were allowed to *try out* their product in a wash tub *in front of a camcorder*. Before filling with marbles they had to tell how they made it and why they made it that way. After this telling was

done, they put in the marbles till the "boat" sunk. The presenting children could be watched by waiting children.
Besides these four main characteristics there were some supplementary features. The assignment was performed with minimal materials and there was plenty of room for learning by experience, because several wash tubs for testing the product were present in the handicraft room. The assignment required little work from the teacher and a lot of work from the children (the teacher did not have to review the products). Data collection took place by observation from eavesdropping, peeking and interviewing during the lessons and afterwards from photos and the tapes from the camcorder.
I will refer to the working method of the children with the term 'trial and error' when I mean repeated, varied attempts which are continued until success (or end of phase period) stops trying. It is a heuristic method of obtaining knowledge. By 'result driven' I mean that the knowledge, about how to make a well performing marble carrier has grown to such an optimum, that the children were able to make a well performing carrier. By 'slightly result driven' I mean some knowledge had been gathered, but the knowledge is not yet optimal.
I will refer to the teacher behavior as 'structuring' when I mean asking questions to draw attention to detail and as 'confirming' when I mean acknowledging correct and important findings of the children. By 'feedback' I mean critical assessment on produced carriers in order to draw attention to significant details to deepen knowledge. 'Feedback' presumes the existence of targeted knowledge, 'confirming' presumes the absence of targeted knowledge. 'Encouraging' is used, when structuring and feedback are not necessary nor appropriate anymore and only encouragement is appropriate to show appreciation for the children's actions.

2.4 Data analysis

To make sure all children had on the start of the first phase of the research a comparable level of knowledge and skills about the scope of floating and sinking, certain rules had to be clear to every child. Coincidental, earlier that same year there was a school wide project week about water. This week the children already gathered some knowledge about floating and sinking. With the view to brush up and to extend this knowledge, a set of six experiments about floating and sinking was presented to the children, since knowledge and skills are acquired by perception (Cropley, 2001). At the start of this lesson the teacher demonstrated in five minutes what had to be done at every experiment. The children made pairs and walked through all the experiments. Near every experiment an illustrated instruction card with a short explanation could be found.
The experiments were selected on handling the physical principle 'Density' http://www. proefjes.nl/. Density of a material is its mass per unit volume (q= m/V). Different materials usually have different densities. Less dense fluids float on more dense fluids if they do not mix. This concept can be extended, with some care, to less dense solids floating on more dense fluids. If the average density (including all air below the waterline) of an object is less than water it will float in water and if it is higher than water it will sink in water. So a mandarin is floating by its skin and sinking without the skin. A human is sinking, but in a boat he is floating. Molding clay is sinking when it is formed like a ball, but floating when it's formed like a bowl.
Two weeks after the experimental circuit the design assignment was introduced. The 41 children were divided over three groups. One group was a combination of all the fourth grade pupils from two classes, the second group existed of the fourth grade pupils from one class, just as the third group. Referring to the experiments the teacher demonstrated that a piece of aluminum foil floats on the water. When a marble is put on the floating foil the marble rolls off or the foil slowly sinks. After the demonstration the assignment is given: "Can you make this foil keep floating with marbles on it?" "Try to let float the foil with as many marbles on as possible." Asking the children how to name the formed foil, they answered "Marble carrier", "Marble bowl". After this the children started working with a self chosen partner. It did not matter if they made a carrier together or a carrier by themselves alone. They were allowed to make as many carriers as they liked. Children were not allowed to work alone. If they did not have a partner, they could work together with two other children.

During this first phase most of the children were not aware of the importance of a big surface of the formed foil. They were playful and enthusiastic. By trial and error they formed the foil up to a marble carrier which could held some marbles on it. They could make as many attempts as they liked, because another piece of foil was easily picked up.
On video, the children had not much to tell about the making of the carrier. Most children only mentioned their name and then started counting. For instance, one girl only told the following: "I made a tray because of the assignment". She said nothing about the used technique.
Only three children used the whole surface of the foil (See fig. 2.1).

foil folded like a candy wrap | up folded edge and corners wrinkled together

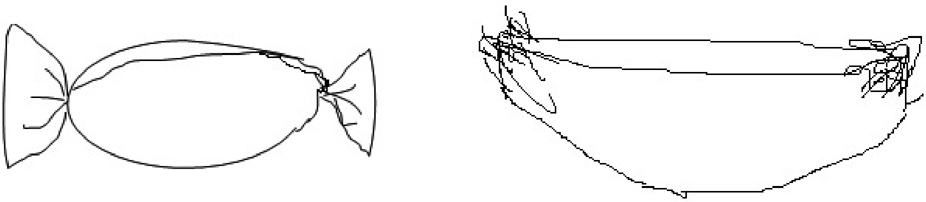

Fig. 2.1 Two samples of a carrier made of singular foil

One boy folded the corners together. His carrier was just like a candy wrap with marbles instead of candy in it. He told me that he assumed this was a good way to fold up the foil to hold marbles, because people use the same way to fold up plastic foil to hold candies. Another boy folded and molded only the edges up; the rest of the foil was untouched. He told me that this form was similar to the form of a boat.

Up folded edge with one sharp fold | Molded like clay into a bowl | Flat bottom with molded edge

Fig. 2.2 Samples of carriers made of double folded foil

One girl ('girl A') knew exactly what to do; she made in a few minutes a big carrier with neatly up folded edges. Her formed foil carried 128 marbles! It was obvious that she knew about herself that she did well, because she wrote on the observation sheet of the teacher "'girl A' is the best". Although she was not interviewed while doing, the handicraft teacher observed that all children, working in her neighborhood, had a look at her technique and in the second phase they appeared to be inspired by this. Most children first double folded the foil (See fig. 2.2). After this folding a lot of children (16) molded the foil like clay into a bowl. This technique is similar to the technique they experienced during the experimental circuit with real molding clay. Other children molded only the edge (16). Twelve children neatly folded the edge up. One of these children explained: "This makes the carrier firm". Two girls tried to make a box by folding the foil like a sheet of paper. This was well thought out, but not working, because the foil crinkled too much.
After making the first carrier, the children could decide themselves to make another carrier or to do an alternative handicraft assignment. This to be sure that every child has been given as much opportunity to improve themselves as they wanted. A lot of children made carrier after carrier. Some carriers were demonstrated, others did not work out as expected and were directly thrown in the trashcan. This was not a problem, because another piece of foil was easily picked up. The children were told to count the amount of marbles their carrier could bear without sinking. Because of the weight of the marbles the

foil could get deformed into a sack instead of a boat (See fig.2.3).When this happen and the carrier was touching the bottom of the bowl filled with water increasing amounts did not count.

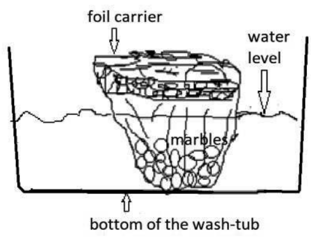

Fig. 2.3 Foil deformed into a sack, which touched the bottom of the wash tub

At the end of the lesson the children were gathered for an evaluation. The carriers were shown from little to a lot marbles carrying. The children were asked to tell if they could see the reason why one carrier is better than another in bearing marbles. At first some children thought that a high edge had priority, so the marbles could not roll off. Later on the review the importance of a large bottom had become clear to all children, but still not every child thought this had priority. Some still thought that a solid bottom was more important than a big bottom, because this would prevent sack forming. After this the children were told that they could improve their results next week. Then, they were going to work together with another child. The teacher would tell them with who they are going to collaborate.

Phase two: Repeating the design assignment with a new partner. In each of the three groups the children were linked in pairs. To make a couple, the teacher chose two children each with a different approach to the assignment the first time. This resulted often in a couple of a boy and a girl, because generally speaking boys and girls showed different approaches. By making the pairs the teacher paid attention how well the two children were getting on in general.
Each couple had to make one carrier together. After this they could chose to make as many carriers as they liked (including zero). The children who finished the design assignment had to do a handicraft assignment.
In this phase, the three groups were different in their approach, motivation and enthusiasm. The first group was still as enthusiastic as the first time, although they unsteady started the working. They still liked experimenting and playing and they made a lot of carriers. In the second group a lot of children complained about working together. They started fast to do the assignment, but made only a few next carriers.
The third group (the combined group) was slightly enthusiastic and worked structured. They mainly used the same technique; a sharp folded edge. Striking detail was the fact of the presence of 'girl A' in this group and the fact that a lot of children of this group took the opportunity to peak at her approach during phase one. Another striking detail was that the whole group used about the same technique, although the members came from two separate classes. This whole group was fast working and made only a few next carriers.
It was funny to see how collaboration in all groups developed. At first kids did not show much motivation and enthusiasm. The start was unsteady; the children showed shyness and wanted to see how it goes. They were careful in making contact for consulting each other. Often there was one who took the initiative and the lead. Later on they started really collaborating. In the test phase most children were enthusiastic and motivated again, because all pairs improved their record of the last time with ease. On video one boy, supported by the girl who he was collaborating with, was counting the marbles while putting them in the carrier. At the sinking-point he said: "Oh yo, 88, we are really going to win! We will make one with more than 100 in it!" Later on he imagined to have a carrier with 220 marbles in it. Because of the high amounts of marbles in the carrier another big challenge for these children was to collaborate in orderly counting. The next carrier the last mentioned team

showed in front of the camcorder carried 94 marbles. The collaboration in counting had improved; the boy and the girl were both on his/her turn counting. This team took a third chance to improve their result in front of camera. This time the boy and the girl were perfectly collaborating in counting and the carrier held 125 marbles. They were very cheerful and did a lot of giggling; they were playing and at the same time they were working result driven.
The used techniques changed as well. In the first phase a lot of molding or folding of the whole carrier was seen, this time most children only molded or folded the edge what resulted in a flat bottom. Therefore the average size of the carriers extended significantly. The edge was most of the times folded twice. Another change in technique was more use of folding instead of molding. One girl from a team of two girls told on video about it: “I crinkled and pressed the edge, but I paid attention that the whole form would stay large.” Although several children thought at the end of the first phase that a high edge was needed for carrying a lot of marbles, only three pairs actually made a high edge. The girl of a team of a girl and a boy told on video: “We have done some extra building. I told my friend to make the edge high, otherwise the carrier would sink.” In the same time when she was speaking the boy carefully formed the carrier for the last time, while the carrier already laid in the water, before the marbles were put in. This team had (as well as many other teams) a very good collaboration in counting and putting the marbles in the carrier in turn. The boy put marble one in and counted one, the girl put marble two in and counted two, the boy marble three and counted three etc.
Ten pairs made sharp folds to form the edge, so a rectangular carrier or a boat formed carrier, with the front and/or the back in a pointed end instead of rectangular end, arose (See fig.2.4). These carriers could hold most marbles, with a maximum of 248!
The carrier that contained 248 marbles without sinking was made by the couple with ‘girl A’ in it. ‘girl A’ told on video: “This boat can float very well. I made this boat before.”

Rectangular carrier	Boat formed carrier

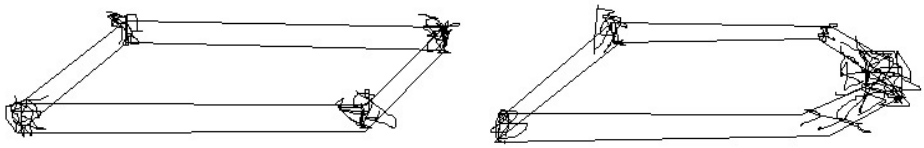

Fig. 2.4 Samples of carriers with sharp folds to form the edge and corners folded solid together

A boy from another team, formulated the making and the specifications as following: “The pointed end and front of the carrier are making it firm, the edges are strong but low.” In this team collaboration in counting was not easy, because the boy wanted to do it all. They nearly started to quarrel about it. The carrier held 88 marbles, but the boy said on video “we will tell our carrier held 110 marbles” and both children were laughing. One couple of a boy (‘boy B’) and a girl (‘girl B’) had a special collaboration. Together they were a good team, because they made a potentially good carrier, which unhappily sunk with 48 marbles in it, because of clumsy behavior of ‘boy B’. ‘girl B’ was very patient and cautious in the collaboration. She did not even show agitation then their beautiful made carrier sunk by ‘boy B’s clumsiness. The video shows that ‘boy B’ had great difficulty to tell about the carrier. I had to do the speaking for him, because he wouldn’t say his name and nothing about the carrier. But while I was telling what I observed: “ a nice folded edge…” he suddenly said very fast “That is my work”. ‘Girl B’ told on video that she made the ends.
Eight pairs made a fairly flat surface with a molded edge. One boy tells about it on video: “We made the corners and after that we …. (no words, but pointing at the edges)… to get a trunk”. The carrier they made held 185 marbles. A few other results: One couple molded the whole carrier, including the bottom. One clever couple used three sheets of foil together to make a firm carrier. One couple double folded the foil “to make a firm bottom” (their own words) and molded the edge. One couple of a boy and a girl called their carrier in front of the camcorder “speedboat”. One couple of two girls gave their (not so successful) carrier a funny name, “Flippy”. By this they concentrated attention on the funny

appearance instead of poor buoyancy. They knew themselves why the buoyancy was poor, because on video one of the girls told they fumbled the carrier too much.
At the end of the lesson some children were unsatisfied about their results. During the evaluation several children told me “Because I had to collaborate, I have not made the carrier I should have made on my own”. Fortunately there was some good news: “Next week every child, who wants to do so, can make another carrier and they can choose to do that alone or together with someone self chosen.”

The next Thursday phase three started. Children, who wanted to, could make another carrier. They could choose to do that alone or together with a friend. The children who did not choose, at the start or later on, the design assignment had to do an handicraft assignment. 18 out of 41 children made another marbles carrier. The whole second group of phase two did want to do a handicraft assignment instead of a design assignment, so only two groups worked on another carrier to try to improve their own result. This time the children had to tell to the camcorder not only the amount of marbles the carrier was able to contain, but also why they made another carrier again, what is different and if they wanted to make more carriers. One girl told “We like making another carrier, because we want to improve the carrier more, to get a new record.” Another girl told “I liked making carriers very much and I thought I could do better.” Most children said: “Because I like it very much.” A team of two girls told on camcorder that they especially liked working together. Some children still said little or nothing. Later on some children started to tell on camera more and more things for fun, which did not make sense. Others still tried to improve their carrier. One girl was fed up with collaboration after the second boat. While standing together with her friend in front of the camera she told: “This a boat with a bow. I made the boat, my friend did not really help.” The next boat she made on her own with a cabin on it. On camcorder she told “So you stay dry if it is raining.” These ‘boats’ of her were creative by appearance, but not so much by effectiveness. Two boys together made four other carriers. Asking them “Why?” they told me they would make a lot more. I think these boys did not make carriers to improve their own result, but for the fun of experience. One boy especially liked showing his product on camcorder. A couple of two boys made a little show together. They spoke on turn and said funny things like “Here we were again with one boat more.”
Again all children worked enthusiastic and concentrated on the design assignment. ‘boy B’, last time interfered by agitation, succeeded together with another boy in making a carrier that held 400 marbles! An absolute record! His friend was telling to the camcorder that they liked making boats again and again and achieving record after record. Another pronouncement of this friend was: “This carrier has become stronger than the former.” ‘Girl B’ made a new carrier as well. She did this together with another friend. The friend was telling to camera: ”This carrier is longer and bigger. We like to make more carriers.” ‘Girl B’ did not speak in front of the camera, except for mentioning her name. This time ‘Girl A’, who was previously successful in making carriers which could carry lots of marbles, rather did the handicraft assignment.
The children improved their technique again. Generally the carriers were big with a neat small edge. Most of the time edges were folded once and not twice as in phase two. The corners were well formed (See fig.2.5).
The children told about it on video. One boy said: “It has become bigger and the edges are higher.” He comment upon the next carrier he made “It has become smaller and the edges are higher.” Two girls together said: “The carrier has become larger.” Another boy told: “This is my third boat this time. It is entirely flat with a small edge.” A girl told about her first carrier this time: “I folded the edges solid together”. About her next carrier she told: “This one is larger. I like to make more carriers very much”. Still not every child did so. One couple made a carrier of double folded foil. I asked them for the reason and they said “So it is more firm and prettier.”

Fig. 2.5 This carrier could hold 360 marbles without sinking

Both teachers observed a more and more quiet atmosphere during the lessons. On top of that the children were working hard. Apparently the repetition of designing marble carriers had a good effect on the work behavior of the children. In phase two and three the children showed increasing sense of control, which resulted in increasing quiet behavior during working. This side effect was still working after the end of the design assignment during the next handicraft lessons. The handicraft teacher told me that all children were more motivated and quieter than before during handicraft lessons.

Table 2.1 Schematic analysis of the observations

Number of children participating: 41	PHASE 1 Range of number of completed iterations: 1 - 2	PHASE 2 Range of number of completed iterations: 1 - 4	PHASE 3 Range of number of completed iterations: 0 - 4
PROCESS			
working method	37 x trial & error 2 x slightly result driven 1 x result driven	2 x not result driven 8 x slightly result driven 10 x result driven	6 x in turn: result driven and playing and experimenting 12 x result driven
used technique	3 x using whole surface of the foil 37 x double folding the foil after this action: 11 x molding like clay into a bowl 12 x molding only the edge 12 x folding the edge up 2 x folding like a paper folding box	8 x flat bottom with big surface and a molded edge. 10 x flat bottom with big surface. Edge neatly folded with sharp folds 1 x flat bottom with half of the surface. Edge neatly folded 1 x in shape molded bowl.	17 x flat bottom with big surface. Edge neatly folded up with one sharp fold. Especially the corners have been paid attention to. 1 x half surface with neat edge
CREATIVITY			
creative for appearance	Sometimes by coincidence. Almost none of the children tried to deliberately make a special carrier.	The variation in appearance was most extreme this phase. 1 x a couple made a carrier formed like a speedboat. 1 x a couple concentrated attention on funny appearance instead of poor buoyancy	4 out of 18 carriers got a deliberately made special appearance
creative for effectiveness	Practicing the children increased their knowledge. Every next product was more effective.	The overall increase of buoyancy of the carriers was considerable	The children had a detailed insight what to do for maximum result, but not all children used their insight for making the product.
creative for performance	Amount of marbles: 0 - 128 Average amount of marbles: 40	Amount of marbles: 22 - 248 Average amount of marbles: 116	Amount of marbles: 36 - 400 Average amount of marbles: 149

KNOWLEDGE			
use of knowledge and insight	The way they tell about what to do to make the material float and the appearance of the products made clear that the children used the knowledge they gathered during the experimental circuit.	The children used what they saw on other children's products	The children showed much skill, knowledge and insight by producing well formed and an as big as possible carrier. Only 1 child thought solidity more important than bigness, so she still first double folded the foil before forming the carrier.
BEHAVIOR			
children's attitude	At the start playful and enthusiastic with rather low concentration. Later on concentration increased.	In the beginning varying from enthusiastic to complaining. Later on motivation was showing in cautious collaboration. In the test phase mostly enthusiastic and concentrated, however some dissatisfaction was expressed. This whole phase the children showed little playfulness.	Enthusiastic and concentrated. Mostly motivated to perform optimal and sometimes playful.
children's presentation in front of the camcorder	At the start the children did not have much to tell about the making of the carrier.	Some children could tell detailed about the used technique and their points of attention. Some children made a show of their presentation. Most children liked presenting a lot, except for one. Not all children spoke in front of the camera	Most children made a real show of presenting. More children spoke in front of the camera, although it not always make sense. They did tell a little more details about used technique and used points of attention.
teacher behavior	Structuring (helping to think step by step) and confirming. At the end of phase one the carriers were shown to the gathered children in an arranged way from few marbles carrying to a lot marbles carrying. The children were pointed at the various forms of the foil in relation to the account of marbles the carrier supported without sinking. They were stimulated to formulate the things they noticed.	Structuring and giving feedback in order to help the children discover the scientific rule they are searching for. The children were made aware of the effect of distributing the marbles over the whole surface of the bottom of the carrier.	Encouraging.

By doing the assignment the children were discovering the concept that increasing surface of the bottom the carrier allows to support more weight, without sinking. At the same time the weight the carrier can support per cm^2 is constant.
During the first phase one child was already aware of this rule, most children were not aware of this rule and two boys had a beginning insight.

2.5 Interpretation of the results

The results are related to the characteristics of this research. These characteristics affected separately and together the design performance. In this section I will attempt to describe the contribution of the characteristics iteration, freedom of choice, presentation and collaboration to the answering of the research question *"What is the effect on the design performance when the same assignment is presented multiple times to 6-8 years old learners?"*. At first I use -for me- well known knowledge to come to an interpretation. This knowledge comes from literature and former class experience. Later on in section 'discussion' I will attempt to relate the arisen interpretation to additionally read literature.

Iteration is the first characteristic to look at. The collected data showed that half of the children voluntarily worked on the design assignment for the third time and some of them would have for a fourth and fifth time; various children asked me even weeks later: "When are we going to make

another marble carrier?" The third phase all children made the carrier with such a level of attention for details, that a good result was within reach for every child. They also filled very cautiously the carrier with marbles and paid attention to a good distribution of the marbles. Their perception and insight had been growing by repeating and seeing the results of their own products and the products of other children. The average amount of marbles which a carrier could hold advanced from 40 in the first stage till 149 in the last stage (see table 2.1 for a schematic analysis of the observations).
On iteration two aspects can be distinguished; 'spending more time doing something' and' doing the same thing more than once'. 'Spending more time' can be achieved through freedom of duration of activities, recommended by Montessori (1912). The child has not to be disturbed in his activity till he himself chooses something else. Wallas (1926) describes a time demanding stage in the problem solving process, which he calls the 'preparation' stage. In this stage information relating to the problem is investigated in all directions. Cropley (2001) reports about time in relation to intuition. Intuition makes it possible, that unaware thinking leads through implicit learning to a raw sketch of a solution. After this, time is needed to refine the sketch in order to achieve an effective solution.
'Doing the same thing more than once' can be achieved by making it possible for a child to control himself the correctness of the result of an activity (Montessori 1912). Controlling the correctness oneself implicates having the opportunity to repeat the activity till correctness is achieved. In this way correctness becomes something that is interesting to reach and intrinsic motivation arises. Wallas (1926) reports about 'doing the same thing more than once' that the evaluation, analyses and extension of the solution take place in the 'verification' stage. So the 'verification' stage can enclose multiple iteration.
In this research the observed effect of iteration was growing perception and insight together with the presence of intrinsic motivation and is in accordance with Montessori (1912), Wallas (1926) and Cropley (2001). Furthermore the growing perception and insight made the approach of the children develop from trial and error in the first phase to more and more result driven.
Another aspect of growing perception and insight is the development of the capability to explain about what is happening. Therefore one can expect that it will become easier for the children to explain their insight in words as far as possible on their age. (On the age of seven not all children, who have sharp insight, have adequate words to express their insight.)
In this research the observed variation in verbal development was high. Some children already in the first phase were capable of telling about the process of making their carrier. In the second and third phase this amount of children increased. The children's acting showed growing insight in floating and sinking, but most children did not show this growing insight in front of the camera by verbal output. This is in accordance with Maria Montessori's observation (1912) that children first have to experience before they are able to explain and identify in words. Their verbal development goes from passive recognition of an object by its corresponding name, through active naming, to applying the name in other contexts.

The iteration also had an effect on variation and originality of the designs. The largest variation was found in the second phase. After the first designing every child tried to improve the carrier and started to add detail to their design. In the third phase most children used all the details found in the second phase and by watching the results of the products of other children to optimize their marble carrier. Because of this, the variation in the appearance of the products decreased. In the third phase the designs looked more the same. This is in accordance with the findings of Wallas (1926), who saw after an unconscious period (incubation period) a solution (illumination) arising apparently out of the blue. In the 'verification' stage (by evaluating, analyzing and extending the solution) he saw selection and optimizing of the solution taking place.

Freedom of choice is the second characteristic to look at. In the third phase the children had the most extended freedom of choice of all phases, but... in this phase only half of the children chose the design assignment, the other half chose to do the handicraft assignment. So the freedom of choice did not make all children choose the design assignment. Why? Because experimenting was no longer challenging to these children? Their concept of floating and sinking did not contain any obscurity to them anymore? A fact was that most of the children with good results in the second phase did not choose the design assignment in the third phase. Only one girl still had spirit; she tried to make a special appearance of every next carrier. For instance 'a boat with a bow'.

A striking element was the working behavior of all children; them doing the design assignment and them doing the handicraft assignment. All children operated quiet and concentrated on the chosen assignment. This is in accordance with literature. Montessori (1912) described increase in intrinsic motivation and sustained activity as an effect of freedom of choice together with making it possible for a child to control himself the correctness of the result of an activity. In this way correctness becomes something that is interesting to reach and intrinsic motivation arises for self improvement. When children get freedom of choice to go on with the activity or not, motivation will be high and will stay high. Motivation can even still become stronger, because self guiding is increasing. Cropley and Urban (2000), who developed an holistic model on creativity in classrooms, also emphasized the importance of sustained activity. Motivation and commitment to a task are needed for the development of creative solutions.

Presentation in front of camcorder is the third characteristic to explore. My former classroom experiences showed as effects of presentation; 'calling for arguing', 'calling for critical thinking' and 'calling for reflection '. Interaction between children showed the same effects, added with 'calling for diagnosis'. Normally children have direct interaction in classroom, but in front of the camcorder interaction is indirect. While waiting for their turn to present, children can eavesdrop and observe what other children are telling to camcorder. In this way all children benefit and reflect: the ones presenting for the camera and the ones watching and listening. I saw the children being excited about explaining their carrier on video and demonstrating how it worked. Because of this most children became more and more motivated to explain as best as they could. Some of them liked presenting as a play and what they said not always made sense. Another observed effect of iterated demonstration in front of the camcorder was increased pleasure and skill in presenting.

Varied format of collaboration is the fourth characteristic to examine. My former classroom experiences showed 'calling for consulting each other' as an extra effect of collaboration above 'calling for arguing', 'calling for critical thinking', 'calling for reflection ' and 'calling for diagnosis' as an effect of interaction between children. Through consulting each other the children look at their own work from the perspective of the other. The result is more accurate and detailed observation of the own results.

In this research not all children liked to collaborate at all times. In the second phase the children were bound to collaboration and this did not make them all happy. A good side effect of this was extra joy in the third phase for having all choice possible. Another observed effect of iterated and varied collaboration was increased pleasure and skill in collaboration.

Summary

What are our key findings? How did iteration, freedom of choice, collaboration and presentation contribute to the children's performance? The most original designs were found in the second phase and to a lesser extent in the first phase. In the third phase the children were focused on maximum effectiveness and/or playing in front of the camcorder.

The amount of marbles hold by the carrier was improved each following phase. During the third phase a maximum amount of marbles in a floating carrier was reached. Also, the design goal was achieved all the time.

During the first phase the children improved their design by trial and error. Step by step they understood better how their design could hold more marbles. During the last phase almost all children were working result driven. On video they could explain more or less why they thought their carrier worked better than one before. Some of the children master the language better than others.

Other things the children practiced were collaboration and presenting. This resulted in increased pleasure and skill of both.

The taken facilities to design the learning environment made the children independent in their experimenting. This, together with the verbal given challenge, which held a clear goal for every child, resulted in self dependent, motivated and goal oriented children. The motivation together with language aspects like dialogue, video recording, group reflection, thinking and talking it over at home, made all children knew how to come to a good result.
In other words, the learning effect was “a more or less detailed insight in the necessary transformation of the foil to make it float with as much as possible, well distributed on the surface, weight on it.”
The children get more and more sense of control in phase two and three. The consequence of this was quiet and concentrated behavior of the children.
During phase three all children, who chose to do the design assignment, showed a detailed insight in what to do to reach maximum result. Besides, some children made deliberately their carrier in a special shape and told about it on camcorder.

2.6. Discussion
The results of this study can be looked at by several theoretical perspectives. So far two perspectives had been chosen, a pedagogical and a creative thinking one, but the effect of presenting and collaboration was only answered by previous experiences and not by literature known by me at that moment. Therefore I had to look for additional supportive literature.
Various aspects of Montessori education, but also some new insights were found in the literature of Hannaford, an American biologist and educator. In “Smart Moves. Why learning is not all in your head” (2005) she emphasizes the role of the child’s development in their learning capability. This is in accordance with the ideas of Montessori.
Apart from these insights Hannaford gives a detailed description of the development of functions of both brain hemispheres from birth to adulthood. Hannaford describes extensively how effective learning arises by collaboration of Logic and Gestalt Hemisphere. For instance; the Gestalt of a person provides coherence between facts gathered by Logic to let the person imagine a picture of all facts together. When Gestalt tells something is missing or the picture is fuzzy, the Logic of the person provides new facts by searching for it to make the picture complete or more detailed. After the Gestalt of that person is satisfied with the picture, Logic helps to form a linear logic story, which can be communicated to other people.
Kimbell & Stables (2007) wrote about this issue from a different perspective, the designerly perspective. They describe the interaction of mind and hand during designing. They model thought and action in an iterative and interactive relationship. In their view designerly thinking has immense potential for learning, because by iteration of the interaction between imaging and modeling inside the head and confronting reality outside the head, an haze impression has the potential to develop to more developed thinking together with more developed solutions. They also emphasize the need for teachers to be aware of the difference between reflective and active skills and the value of the iterative switching from the use of reflective to active skills. Children have to be supported to develop skills that enable more balanced performance characterized by switching from active to reflective focus.

By looking at the results by three perspectives, the pedagogical, the creative thinking and the capability developmental one, it still was impossible to formulate a coherent and usable story to colleague teachers about the interpretation of the research.
Literature on metacognition provided additional insights on motivation. Recently an extensive study has been published, “Metacognition in Science Education Trends in Current Research”, which contains articles of several authors (Zohar & Dori (eds.) 2012). These metacognitive studies all make clear that ‘to be allowed to choose yourself’ (Schraw et al., 2012), ‘work self dependent’ (Whitebread & Grau Cardena, 2012) and ‘diagnose of incorrectness can be done by the child himself’ (Schraw et al., 2012; Grotzer & Mittlefehldt, 2012; Herscovitz et al. 2012) are important aspects to come to self guiding.
These research studies show that motivation to reach a goal stayed high, when children themselves

were in command to decide what to learn to reach the learning goal. For being and staying in command it is necessary to be able to evaluate the own work and decide what is necessary to learn to become better. Another chapter handles the use of strategies. People can be motivated to use a certain strategy by telling them about the usefulness of the strategy. Furthermore activities, needed for collaboration and presentation, such as reflection, discussion and arguing, appear to be important activities in a successful process of learning (Norris & Phillips, 2012, Grotzer & Mittlefehldt, 2012, Chiu & Linn, 2012, Zohar 2012). Judging another's actions is a function of these activities. According to common psychology judging another's actions is far easier than judging your own actions, so you cannot effectively improve yourself without the feedback of another person. Another function of reflection, discussion and arguing is that it provides the need for changing perspective. By changing your thinking perspective and trying to look at your own actions from the perspective of the other, you can find persuasive arguments for these actions.
This findings are also found by Falk & Brodsky (2013), who researched the effect of inquiry based science instruction on the development of the capability of arguing. This capability includes the skills 'being able to critique' and 'being able to weigh alternatives'. A scientific argument forms the meaningful connection between the practice of inquiry and the content. As students focus on the construction of the argument, they learn (by addressing a question and seeking and evaluating evidence to construct increasingly complex explanations) to practice critical thinking skills. After this, they are not only capable to find a right answer, but also the best answer that relies on the best available evidence.
Supplementary a constructivist perspective elucidates the children's playing behavior in the third phase. The children's play created a new relationship between the semantic and the visible, that is between the situation in thought and the real situation (the assignment) (Vygotsky, 1966). That is why some children chose to do the assignment to practice presenting. According to Piaget (Piaget & Inhelder, 1972) a seven year old child is learning from the physic world. The learning can happen spontaneous and can happen deliberately taught. Most of the time children of this age do not reason in a logical of a fully mathematical way, but by drawing attention to occurrences they can develop; they are nearby reaching the stage of operational thought. In this stage the child is not only concerned with the results of action but also with understanding the processes by which a result is achieved. Some children expressed this interest by doing the assignment over and over again with little concern for the results.

The pedagogical, the creative thinking, the capability developmental and the learning theoretical perspectives demonstrate that both Montessori education and education inspired by the interaction of mind (Logic) and hand (Gestalt), include a lot of elements to come to effective and efficient education, according to metacognition and constructivist theories. Hereby the view of Hannaford and Kimbell & Stables is complementary to the view of Montessori. Furthermore increased motivation and self guidance lead to development of creativity (Urban & Cropley). The importance of ample room for playing behavior, especially for this age group, is emphasized by the constructivist view of Vygotsky and Piaget & Inhelder.

The *four characteristics of this research*; iteration, freedom of choice, collaboration and presentation had been chosen, because of knowledge about the pedagogy of Montessori, creative thinking and science education experience. Literature about capability development and metacognition confirm the value of these four characteristics.

2.7. Conclusion

Iteration, freedom of choice, collaboration and presentation are conditions that improve the children's learning process in design. From the supplementary literature study, it can be concluded that designing an assignment, using elements of Montessori education, provides intrinsic motivation for redesign. Key elements are tuning to the aptitude and the development of the child and the self controlling facility of the correctness of the results. The amount of marbles in the boat is a clear goal to

the children and evokes iterations to find the adequate process for optimum performance. Iteration in combination with interaction provokes motivation for further redesign, because of new insights gained by interaction.
Further on motivation is needed for the processes of *reflection, critical thinking and developing metacognitive skills.* These three processes are necessary for the development of fundamental knowledge.
Reflection, critical thinking and developing metacognitive skills concern:

- Considering worthwhile challenges, issues, or problems.
- Building knowledge claims and making sense of the natural and constructed world.
- Analytical reasoning, critical thinking, problem solving, and troubleshooting.
- Creative thinking that involves generating possibilities and alternatives.
- Planning, evaluating, and justifying inquiries, designs, explorations, investigations, actions, performances, etc.
- Deliberating evidence, criteria, standards, opinions, and arguments leading to claims.
- Observing, measuring, inferring, predicting, representing, and investigating.
- Judging and explicating the sufficiency and congruency of criteria, alternative beliefs, and actions and then refining them as needed.
- Critical analysis of claims, procedures, measurement errors, evidence/reasons, data, and information sources, etc.
- Justifying data as evidence for/against a claim based on sufficiency of the theoretical backings/warrants and the congruency of evidence, judgments, and claims.
- Thinking about and logging specific intellectual resources used in deliberations, judgments, and justifications; evaluating their personal effectiveness toward the goal; and identifying other situations for which they might be helpful (Ford & Yore, 2012).

All this shows that it is useful to teach children how to control their own work. This can be done by giving them time and freedom to iterate their performance. Interaction and interplay give incentives for further iteration and therefore further optimizing of the performance. Moreover it is useful to learn children to argue why they think an answer is right or wrong. Only comparing with written answers in an answer book does not give the same learning effect and this method leads easily to inaccuracy. Additional advantage for teachers is that it cost them less time to go through written work with the objective to correct.

The model of the interaction of mind (Logic) and hand (Gestalt), seems to be a clear model to shape the various activities of the design assignment. Be sure to provide activities which provoke interaction of mind and hand, such as naming experiences and representing what is heard. Extend this with interaction and interplay between children in order to provoke collaboration. The importance of formulating and discussing is proved with emphasis by the metacognition research. Knowing how to get to your point and to know when you are right is important metacognitive knowledge.

Recommendations

The findings of this research can be used for the optimization of every design assignment on primary schools. Effective and deep learning are more likely when an assignment is designed to enable self control and iteration with variation in collaboration. Another important finding is that children develop essential skills, such as self initiating effective behavior, arguing, reflecting, self controlling, creative thinking and planning, by doing design assignments in collaboration. ‘Problem posing’ is an example of the styling of a design assignment that enables self control and iteration eventually in collaboration. Ample room for playing behavior, especially for children till the age of eight, is also important for the learning capability development.

Our case study shows that iteration, freedom of choice, collaboration and presentation improve the effectiveness of design and technology activities. I expect that the use of these conditions in other

learning areas, e.g. math, grammar and geography, will also lead to intrinsic motivation and the development of metacognitive skills in particular learning areas. Additional benefit is that the structure of learning in several disciplines becomes uniform. In this way an association arises between various learning areas. This makes it easier for children to recognize the required routine to start, persist and finish learning something. This has also a positive effect on self initiating effective behavior.
The model of the interaction of mind (Logic) and hand (Gestalt) seems to be a clear model to shape education in various disciplines of learning. A natural way of interaction of mind and hand is generated by playing; give children time and opportunity to play and experiment with the subject material. Also formulating and discussing need to have an explicit place in daily classroom practice to increase the output of education.

It is not only profitable for children to be creative in their thinking, but for teachers as well.
In this way they can find creative solutions for annoying problems like lack of time, extra demands on education raised by government or parents. Zooming in on the details of such a problem does not always provide a solution, while, in turn, zooming out and seeing it in a broader perspective can. It is better to focus on education as a whole in turn with a focus on the learning material in detail.
It is likely the teacher's activities will change. Preparing method lessons and correcting them will (partly) have to change in equipping the classroom and observing the children during work in order to be able to diagnose the next step in learning the children have to make. The observations can be made direct, but also by camcorder or webcam, because even a teacher can just see one thing at a time.
Make use of the power of interaction and collaboration. Children can learn a lot of each other. Let the group work for the teacher instead of merely letting the teacher work for every individual child.

After this study items are left for further research, such as:

- "Do children gain extra knowledge about floating, sinking and density by executing the design assignment?" The knowledge of children who only did the experiment circuit can be compared with the knowledge of children who experimented and executed the design assignment.
- "Do the children reach more variation while reaching the same level of deep knowledge, when the design goal is less explicit?" In this study divergent thinking was leading to convergence of the appearance of the products, maybe because of the explicit design goal.
- "Is it possible to motivate every child to go through the design cycle thrice?"
- "What happens when presenting the same design challenge thrice to older children, for example 11 to 12 year old children?" This children are in a different phase of development (Piaget, InHelder, 1972).
- "How to determine a skill is optimal developed?" Is it necessary to define as many details of the skill and skill parts as possible?

Concluding, I found that games can be taught, but that nobody can teach playing. At the moment that the concept was rather clear for all pupils, their curiosity faded away. Pupils lost their interest and engagement stopped. The pupils appeared to need slightly differing challenges to continue play. Specifically, by focusing on role-play some pupils developed a slight change in the challenge themselves. They showed continued iterating, where other pupils stopped iterating.
The same applies to education. Methods can be taught, but no teacher can teach learning. A teacher only can facilitate learning. The facilitation in this study was realized by the prepared learning environment and clear commitments. Further facilitations, such as shared knowledge at the start of the assignment, were unnecessary.

Chapter 3

Groundwork:

preparing an effective basis for communication and shared learning in design and technology education[1]

[1] Based on: Looijenga, A., Klapwijk, R.M., de Vries, M.J. (2017a). Groundwork: Preparing an effective basis for communication and shared learning in Design and Technology Education. *Design and Technology Education: An International Journal 21(*3). Retrieved from: https://ojs.lboro.ac.uk/DATE/article/view/2157)

This chapter presents the second of four studies and includes two case studies on the accomplishment of shared knowledge in preparation for a Design & Technology lesson. In both case studies the groundwork is followed by activities that make use of the shared knowledge. The description of the following activities show the effect of the groundwork.
The motivation for the first case study “observe like an artist” was to find out more about pupils’ specific demands when a teacher wants them to start discovery. Does groundwork help them to start discovery in following activities?
The motivation for the second case study “wheels at work” was to find out more about the necessity for verbalisation of pupils and teacher during designing. Is the power of the cooperation of the hand and the mind, and the power of collaboration sufficient to enable an ongoing design process in following activities? Can pupils hands on start discovery without verbalizing the concept? Can teachers guide them in a non-verbal way? Knowing more about the necessity of verbalisation enables teachers to make better informed decisions about the format of instructions and interventions.

3.1. Introduction

This chapter presents the second of four studies and includes two case studies on the accomplishment of shared knowledge in preparation for a Design & Technology lesson. In both case studies the groundwork is followed by activities that make use of the shared knowledge. The description of the following activities show the effect of the groundwork.
The motivation for the first case study “observe like an artist” was to find out more about pupils’ specific demands when a teacher wants them to start discovery. Does groundwork help them to start discovery in following activities?
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At the time of the study, the Dutch Design & Technology (D&T) Education curriculum, that originally focused on Technology activities, was changing to Design Learning and problem solving with technology. The Council for Primary Education formulated this view as “Science and Technology is a view on the world commencing at wonder” and related it to the development of the so-called 21st century skills (PO Raad, 2013). Thus, there was a need to find guidelines for teacher education to activate “wonder” and to enable children to explore different opportunities.
One requirement for the activation of wonder is readiness in the pupils. This readiness was sought by two kinds of approaches, that were practiced in education at large and in Design & Technology;

- one starting with wide-ranging exploration of a context and
- one with formalized instruction.

Both approaches can be based on a realistic or a constructivist view of learning. The realistic view regards the learner as an independent observer of the context and the constructivist view regards the learner as a part of the context, with an ever changing view on that context. However, experience with D&T education in various Dutch schools learns that both approaches have a number of important drawbacks. The first approach is too open and overwhelming for most pupils, while the second approach does, in general, not lead to wonder and questions arising from the child (Dewey, 1938). Too much information has an overwhelming effect, swamping student’s already existing vital though small experience, and stops self-expression (Dewey, 1910). Lately this opinion is confirmed by scientific research, concluding that the mind cannot handle too much information at one time (van Gog, 2013). Therefore, we developed an alternative, namely the groundwork approach. A simple definition of groundwork is that something is done at an early stage that makes later work or progress possible.

A foundation for wondering and collaborative exploring has to be laid at an early stage. We looked at factors that improve readiness of the children and evoke wonder. A way to achieve this is to conduct groundwork; a set of activities taking place prior to the actual start of the assignment aiming at joined-up thinking. Through these groundwork activities the teacher shares thoughts and knowledge with the students and motivates them by making them feel “I can think. I can know. I can have wonderful ideas.” (Oldfather, 1992). To ensure sharing, the binding factor in groundwork must be careful, small communication. One must realise that the experience of the student is, at this age, basic in comparison to the experience of the teacher. Inundation should be avoided. Apart from being modest, the information has to fit through the straight and narrow gate of sense-perception and motor activity (Dewey, 1910). For this reason, we expect that small, shared, physical experiences are an ideal way of shaping this communication-link between teacher and student, between students, and between students and subject, in order to achieve readiness and further exploration.

Educational D&T literature does not yet cover the groundwork topic for four-eight year olds. Since the above cited literature demonstrates the importance of groundwork, our central questions are; “How to shape groundwork in design and technology education for children aged 4-8 year?” and “What are the effects of groundwork on the subsequent process of exploration and learning?”.

The paper is organized as follows. In the section ‘theoretical framework’ I develop the theoretical framework about the various components of groundwork. In the section ‘two case-studies’ the implementability and the benefits of groundwork in practice is showed by describing two case-studies, that were executed by means of ethnographic research. Each case-study handles groundwork in a different way. Furthermore the observed effects of groundwork, supplemented with an interpretation of these effects, are described. The last section contains conclusions and recommendations for the design of educational experiences in D&T.

3.2. Theoretical framework

How can we prepare the pupils for exploring, creating and learning by means of groundwork? A key element to prepare pupils for wonder and shared exploring is the development of an effective communication link between teacher and student. Effective communication is characterized by shared, common thoughts and knowledge concerning a subject. To make this happen, incomplete knowledge has to be completed and various aspects of knowledge need to be transformed, to become shared knowledge. To accomplish the transformation from isolated to shared knowledge five principles are important:

1. context - simple or familiar with a focus on one aspect;
2. integration of acting and thinking - enabling the construction of personal meaning;
3. communication - effective by means of shared language and shared skills;
4. presentation of the instruction - handling the process more than the content;
5. presentation of the problem - clear and simple.

Taken together these five principles, presented in a modest and illustrative way, can make groundwork successful. Below, we show insights from the field of science teaching, D&T education, educational psychology and pedagogy on these five components.

The context

Within the field of science education a study by Cakir (2008) deals with the fact that learning commences with the own natural ability and interests of the learner in order to be effective and draws the conclusion that for education, on a group basis, various learners have at the same time and in different ways to participate actively in learning. In the field of educational psychology, it is known that at a group level the offered data can have the same content, but at an individual level this same data can have a different meaning to various learners (Piaget, 1978; Vygotsky, 1978; Ausubel et al., 1978). This can be bridged by a well-chosen context, which is attractive for the whole group of students. Then the context can be discussed leading to a shared meaning of the context. Such a context can be found in ordinary classroom problems about toilet-use, organization of the class-activities, whose turn it is, how to handle class material, etc.. Also ordinary household problems are a rich source of contexts. The teacher should either concentrate on one aspect of a familiar context, or make the context easy to oversee (Montessori, 1912). These contexts offer space to try out different mental models and methods to connect abstract knowledge with concrete applications, thereby being able to convert and apply abstract and general principles (acquired through instruction) in meaningful and responsible actions in life (Scheer et al., 2012).

Integration of acting and thinking
A study in the field of D&T education research (Mioduser, 2009,) claims that integrated acting and thinking is the skill of learning technical problem-solving (TPS) and is essential to everybody, as the world is filled with designs, inventions and machines. Thus technology influences everybody. To integrate acting and thinking the learner has to recognize a task as a means, instead of as an end. The effort for the student is to understand why the task has to be done, instead of just performing the task (Aalst and Truong, 2011). McCormick (1997), an author from the field of D&T, stresses the fact that learning is a mental process for students, structured by context, activity, available tools and the interactions with other people. Therefore, in daily life, technology-knowledge is structured by the use of technology. McCormick cites Vygotsky (1986), who sees an interrelated relationship between knowledge and action. Kimbell and Stables (2007) speak of the interaction of mind and hand. The learner images and models the knowledge inside the head and confronts the knowledge with reality outside the head. Hannaford (2005) describes a similar process. She uses the terms Logic and Gestalt. She views human functions connected to one of the two brain-hemispheres. Lave (1988) however, sees more of a development of a social anthropology of cognition in practice. At school introduced concepts cannot be plainly transmitted to students, but students have to become active and make an attempt to fit the introduced concept into their own already existing models.

Communication
In the field of science teaching, Lemke studied the importance and effect of shared language. A well-functioning communication link is 'paved' with social interaction and related language (Lemke, 2000). In the field of D&T at Primary level Levy and Mioduser (2007) considered the development of the ability of young children to explain complex behaviour of a self-regulating robot composing a shared language during the 'warming up' phase. This shared language was used later on to facilitate the discussion of tasks.

The presentation of the instruction
In the field of D&T I encountered an interesting project, making use of demonstration to instruct, not in the scientific literature, but on YouTube. The teacher connects the assignment to the YouTube film demonstrating the building of a seat, according to a Catalyst (the structural support for a chair). After this demonstration the student is tasked with finding materials and developing construction skills, in order to build a seat him/herself (www.wikiseat.org). To begin the problem is simple and clear, but the elaboration can be handled in various ways. In the field of pedagogy, this type of instruction is characteristic for Montessori education. Montessori designed arrangements to make 'how to learn to do' possible. In such arrangements, all instructions have to be given at the start and the overall purpose of the project has to be addressed (Montessori, 1912). A recent study in the field of educational science, handles demonstration as a way of instruction (Van Gogh, 2013) at the start of the task. According to these various sources, demonstration appears to be an effective way of instruction.

The presentation of the problem
The presentation of the problem has to be modest and uncomplicated, enabling it be tried at home by the students. Above this, the problem has to be open. The solution to the problem must not be controlled by the teacher, but should grow through self-expression.

Besides these five components, the presence of some further aspects are necessary to make groundwork a success. To start exploration, a preparation process (enabling group attachment, sufficient self-expression, social behaviour skills and attention skills) is needed. This preparation process needs many learning processes and is a team effort. Its strength lies in the growth of shared experience accompanied by a shared language of the experience. Social behaviour skills in handling work atmosphere and bonds are necessary to make group attachment possible. By paying attention to the various aspects of the work atmosphere, and deciding as a group how to handle each aspect, a common understanding of this atmosphere arises and enables social interaction. In addition, attention skills are necessary with regard to focusing on an offered task. The focus can be the ability to recognise elements to set oneself a task. Another focus can be the ability to recognise a personal challenge. Feeling attached, together with well-developed focus/attention skills, makes a child ready for self-expression.

3.3. Two case-studies

Research context

Next, two case studies have been developed in which these five principles have been applied, each handling groundwork in a different way. The first one deals with self-expression through development of shared perceiving skills, accompanied by shared language. The second case-study deals with self-expression through 'hands on' learning, under the condition of ample room for experimenting, collaborating with and observing other students.

The applied research methodology was ethnographic research. I did not apply any exclusion of children; the whole group participated in both case-studies. The type of school was a Primary Montessori school. The traditional Montessori doctrine, of freedom with discipline, creates control of behavioural, perceiving and organizational skills (Montessori, 1948). In this way, the teacher avoids the separation of thinking and its experiential context, which often leads to drudgery. In the publication ‘Education for a New World’ Montessori expresses this idea as following: “The directress must help the child to act for himself, will for himself, think for himself; this is the art of those who aspire to serve the spirit.” (Montessori, 1946, p. 69). The teacher's role is to prepare the environment and to adapt it if necessary, in order to enable the children to start their own learning. The children need to know where to focus on to start the learning the teacher has in mind. Montessori named it: ‘Open the window (the focus) to give a view on the world.’ The children’s role is, if necessary, to collaborate; the more experienced children are supposed to help the less experienced ones.

The first study was executed with approximately twenty five pre-school children, in the four to six years old age group. At the time of the case-study, I was their regular teacher for five days a week. There was no special time set aside for the activities; they took place within the everyday teaching situation.

The second study was executed with approximately forty children in the seven to eight years old age group. These children were divided into three similar research groups of eight to twelve children. The children were assisted by myself (as technique teacher) and their regular handicraft teacher. The children’s previous knowledge was pulleys. In the educational museum, Museon, they experienced the use of pulleys in the Roman period. A special part of the week was set aside for the activities, during handicraft-hours.

3.4. The first case-study: perceiving exercises

Set-up

The perceiving exercises are based on the book of Keri Smith (2008), ‘How to be an explorer of the world’ Her main message is that, by exploration, people are able to perceive things from various perspectives, while non-explorers perceive only from one perspective. The small perception classroom experiments used in the case-study are all explorations from Smith adapted to pre-school children.

Execution

- *Testing the usability in a daily teaching situation:*

figure 3.1 floor

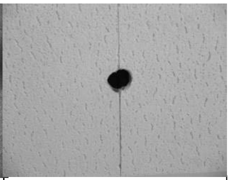


figure 3.2 ceiling

Week one. In a spare ten minutes, while all children were sitting in a circle, I tried out one exploration (Smith, 2008, p. 29) by saying “Look around you. When I call your name, mention one thing you have not seen before”. The children had various observations such as a small hole in the ceiling (see fig. 3.2), screws in the walls. All children mentioned something, even the youngest. The assignment for the following week was: “Lets 'look around', all the time, in order to solve all sorts of problems in the classroom.” I applied the intense observing to the exercise of the conative skill ‘controlling oneself’ (Marzano and Heflebower, 2012) by regularly asking the whole class: “Look around, who is behaving as agreed to be nice for everyone in class?” Most of the time, the out of control children copied the controlled behaviour of other children. If they did not do this immediately, they started to copy, when other children drew their attention to nice behaviour, by verbalizing it. For instance; ‘holding all needed stuff close to you’, ‘speaking softly’, ‘check your surroundings, avoid injuring a classmate by toning down play’ Guided perception thus led to increased control of oneself.

- *Expanding perception:*

Week two. I read to the children an adjusted description of Corita Kent of the creative process (Smith, 2008, pp 38): “An artist never is bored. He/she explores and collects everything. He/she rejects nothing and is uncritical. Experiencing a problem, an artist is going through his collections till he/she finds something useful for the problem. The ‘something’ from another collection is given new meaning and so every problem can be solved.” I connected this description to the theme of 'look around' and said “You are a real artist in an activity when you know how to carry out that activity or when you know very much about the activity, along with the ability to observe the activity” The next instruction was to tell in turn; “In what activity or subject are yóu a real artist?” They often mentioned a hobby, like horses, building huts, drawing. But also behaviour in class or at home was verbalized, like; tidying up, comfort my little brother. This batch wise, but individual defining of a real artist brought us to shared view about a real artist and resulted in shared language . With the shared language we were able to apply it to other situations. For example; ‘not know how to choose or how to do something, resulting in not doing anything’. We came to the conclusion that in such a case ‘Look around and check what other children are doing and then choose yourself’ could be a possible solution. If children chose something, but are unaware how to do it correctly, they can watch other children doing the same activity or ask a classmate to show them how to handle the material. As a result, most of the time problems were solved

I concluded that trying to be an artist led to an increased ability to manage oneself, a conative skill (Marzano & Heflebower, 2012).

- *Focus on details:*

Week five. A third experiment took place a few weeks later. I read an exercise on intense exploration, called ‘one thing’ (Smith, 2008, p 48), covering and solving boredom. I adjusted it into: "You have to observe for some time the upper section of an object and later on the underneath section. If you find it boring, you have to double the observing time. When you continue to find it boring, you double the time again. You should repeat these steps, until you stop thinking about the object as boring and start discovering new details.” After the instruction I demonstrated the exercise myself using a souvenir pencil

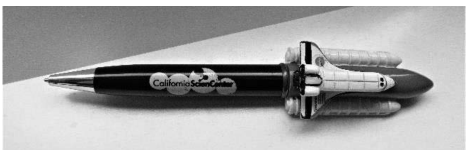


Figure 3.3. Souvenir pencil

(see fig. 3.3), which a child of my class gave me after visiting the U.S.. I held the pencil in my hand and said; “this pencil is from the U.S.”. “First I observe the upper section for a while.” “Oh, yes, familiar, the space-shuttle. I have seen it before, boring….” “So I have to observe for longer, until I stop finding the object boring.” “Oh, I see the American banner. I also see the windows in front. Not boring at all!” “Now I have to observe the underneath section.” “Oh yes, I can use that part to write with. That is familiar, boring!" "Observe for longer." "Oh, I see letters, 'California ScienCenter'. And I see a golden end on a black pencil. I begin to see more and more. What would happen if I turn the space shuttle round?" The children were strikingly quiet. I concluded at this point that the effects were uncertain. But, after these exercises continuous effects were showing during regular activities. For example, two weeks later I told a story, concerning little dissimilarities in humans and showed an illustration with a lot of fishes on it. The children were observing these fishes for a long time, before they started to verbalize. They noticed several differences between the fishes. I interpreted the children's behaviour as a spontaneous reversion of a first glance into a thorough observation. I asked the children "What made you all observe in such an accurate way?" Several children mentioned the exploration 'one thing' as the reason.

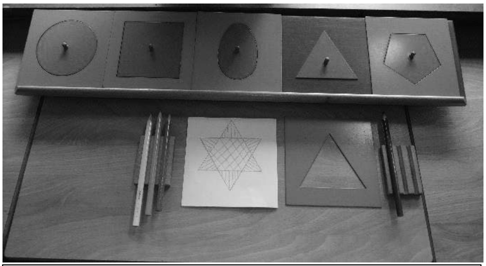


Figure 3.4 Inline-forms

In week nine it seemed that two thirds of the class were spontaneously drawing geometric figures. I asked the class why they were all making this figures at the same time. One child answered that he discovered the inline forms (see fig. 3.4) while looking for interesting material and that the other children joined him. The children observed each other, and worked together, invented new variations in form and colour. In week ten, during a project week about sea, dunes, sand, we arrived at an activity, where we were supposed to watch a movie "The most beautiful fish of the sea". I gave the children the choice; first watching the movie or colouring. Twenty six out of twenty seven children chose …. colouring! They took their time to fill in the figures. Just one child was scratching in order to finish quickly. That movie; we did not watch it at all. In week twelve I detected that the skilfulness of observing in an artist way was spreading to home situations. A mother reported, that she noticed her child observing the light falling on the walls in his bedroom. Not once, but several times. He did this in a particular way asking himself how the light fall would fall if the walls were placed differently.

Interpretation and results

The case-study covered a period of three months and illustrates that sharing knowledge about a process such as perceiving enforces skilfulness, because it leads to collaboration and shared language. The achieved skilfulness was unusual for children of this age. The modest style of the three teacher guided exercises enabled all children to express their observation. In three months, the children discovered how to observe accurately and work in a neat and thorough way, resulting in motivation and enthusiasm to do so.

3.5. The second case-study

The communication link in this example of groundwork is a batch wise demonstration of a clear, small problem, accompanied by a simple question. The most important features of the problem are simplicity and the chance to try it out at home. The whole case-study was designed in such a way, that the children could execute all stages autonomously.

The case-study encompassed four episodes. The first episode was a demonstration to start the reflection about the key principle. The following two episodes were in experimental hours. The last episode was in a tinkering hour.

Execution

- *First episode: Demonstration to set an anchor for shared thinking on the key-principle*

I started with a demonstration of lifting a weight hanging on a rope. At first I was standing on the floor. Later on, I was standing on a chair. I asked the children: "When do I have to pull harder; standing on the floor or standing on a chair?"

- *Second episode: Experiments to make the children figure out the mechanism behind simple phenomena:*

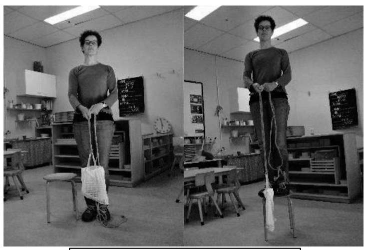


figure 3.5 Demonstration

This second episode took place a week later. I started with a demonstration of the various exhibited machines and tools and I verbalized rules, covering danger or possibility of break down. Then, I repeated the question of the demonstration: “When did I have to pull harder; standing on the floor or standing on a chair?”, I asked the children to vote (by raising a hand) for standing on the floor. After counting and discussing the rules, the task was set: “Try all sorts of material and think about the function of the used wheel(s). Collaborate, if you want to.”

figure 3.6 windlass

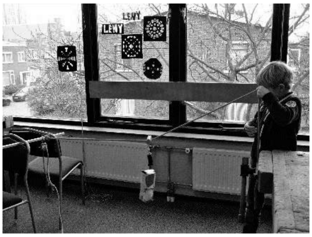


figure 3.7 pulleys

figure 3.8 gearing wheels

figure 3.9 K’nex

figure 3.10 hand-drill

figure 3.11 corkscrew

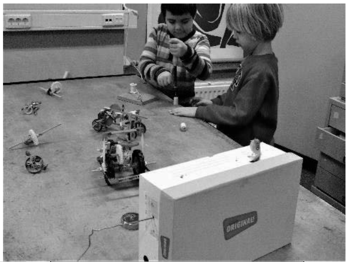


figure 3.12 crankshaft game

In the handicraft classroom, two installations made from scrap-materials from the book “Wheels at work” of Bernie Zubrowski (1986) were displayed; one windlass installation and one with pulleys. Also other tools and machines were displayed, e.g. a gearing wheels box with about thirty gearing wheels of the same size that could be combined. On another table was a pulleys installation constructed with K’nex and on the last table were tools and applications such as a lever corkscrew, hand drill, K’nex cars with various gearing wheels and a crankshaft game. The children played with all machines and applications. The three pulley K’nex installation particularly provoked experimenting (observing and analysing effects of actions). The big installations provoked playfulness (the installation performed a role in a role-play). During the activity, I sometimes asked questions to draw attention to phenomena or suggested collaboration. Children who were finished with the machines could choose a handicraft task, but this did not happen. All children worked in a serious and concentrated way.

Some children were quick in discovering new appliances of the machines, other children got caught up in researching the working of tools. Some children showed at first untargeted activities, like watching, feeling and searching. They started researching after finding something familiar, like the corkscrew or the hand drill. After manipulating these daily life tools, they started researching other machines.

- *Third episode: experiments to make the children perceive mechanism in complex phenomena.*

figure 3.14 windmill

figure 3.15 waterwheel

figure 3.16 music machine

figure 3.17 pinwheel

In the classroom, a windmill installation, a water wheel installation and a music machine were displayed, all built according to Zubrowski. At the start, the windmill installation was driven by a fan, but the fan did not make the windmill turn. Because of that, children tested a cold hair blow dryer. This made the installation work well and with a screen held half in front of the wind mill, it turned even harder. The children could also play with a number of installations that I designed and put together myself; two small water wheels from waste material, and two music machines from K'nex. Besides this, the children could fold three varieties of paper pinwheels. The pinwheels were not that easy to fold, but the result was firm and easy to handle. The music machines did not work very well. Even so the children tried to get music from the machines.

- *Fourth episode: Tinkering hour to bring forth the results of the hands-on learning.*

figure 3.18 water wheel, driven by marbles

In this last episode, the children had to make something themselves. The given instruction was: "After experimenting you have to make something yourself. You can make what you want. I am interested to see what you are going to make. It is nice, when you make something that has several combinations, and all the parts making a big machine. You are allowed to use material and components you experimented with earlier". The children could choose between the making assignment described above or a handicraft task. Thirty nine of the forty children choose to do the making assignment The fortieth child first chose the handicraft task, but after ten minutes she selected the making assignment, because a plan to make a guitar came up (see fig. 3.19). All children started quickly. Eighty percent of the children worked till the end of the working time on the task. The children spontaneously collaborated in groups of four, three or two children. Some children preferred to work alone. When asked, they informed me, that they wanted to make a special machine. I saw a lot of interaction and interest in each other's work: other children passing them by, watching and asking them questions.

I do not have many quotations of the children, because, when questioned, most were unable to verbalize their actions. They gesticulated, but did not have appropriate vocabulary to express their experiment. All children invented something new and not seen before. They often used the principle of chain reaction. Sometimes they applied the lever principle.

The children's enthusiasm to make things that produced sounds was especially remarkable. Sometimes they fantasised about lifting something, that could drop water or sand in order to make another thing move, but they did not actually know how to make it. Two girls managed to create something new. One girl tried to make a music machine with strings (see fig. 3.19). She could explain her plan very well, but a successful execution was too difficult. Another group made a musical water-wheel, driven by marbles and buttons, instead of water (because water was forbidden). The wheel was winding a rope, led through a pulley on the ceiling (which already was there…) to a set of sound making objects on the other end of the rope (see fig. 3.18).
Another girl made an underground litter bin (see fig. 3.20) with an above-ground part with various lids, which opened when trash was deposited in it. She showed great involvement and enthusiasm. This was remarkable, because most of the time this girl does not show self-expression and she needs lots of stimulus during working in class. All children worked in a serious and concentrated way.

Interpretation and results
The most important features of the first episode appeared to be simplicity of the demonstration, the absence of an answer and the chance to try them out at home. The second and third episode evoked interest in making and developing original machines. It was notable that all children chose to do the 'making' assignment and in all episodes ALL children worked in a serious and concentrated way.

The attractiveness of the not properly working sound machine was remarkable. Was the imperfection waking inquisitiveness? In the last episode all children were very creative in inventing something new and not seen before. The inventions showed a lot of practical insight, based on the knowledge, gathered during the playing and collaborating in the first and second hour. My plan, to make the children construct parts, which could be put together to make a bigger machine, did not work out as I expected. Apparently the children were still in a trying out phase.

Last but not least, even children, with a passive stance during regular courses, started active, enthusiastic and targeted (see fig. 3.19 and 3.20).

figure 3.19 music machine with strings

figure 3.20 underground litter bin

3.6. Conclusion and recommendations for the design of educational experiences in D&T
From the results of the two case-studies we learn that, by using the groundwork model with its five components, every teacher can educate in such a way, that it has high impact on all students. By applying groundwork, the dilemma, that a teacher has to choose between starting exploration in a too wide-ranging context or starting exploration with a too formalized instruction, is by-passed.

Because of the groundwork provided, the level of teacher engagement can stay low in the subsequent exploring and creating processes, while at the same time the level of student engagement is high. The case-study findings show that groundwork made the children motivated and even compelled to search for meaning and mechanism of a phenomenon. Groundwork makes activities and tasks grow from just finishing an assignment to experimenting (Aalst and Truong, 2011).

The above described behaviour is the consequence of the effective communication link, produced by the groundwork approach, and characterized by shared thoughts and knowledge. The combined application of five components; precise handled context, integrated acting and thinking, effective communication, the small presentation of the instruction and the small presentation of the problem lead to the completion of incomplete knowledge and transforming of various, individual knowledge into shared knowledge.

Comparing the two case-studies, it is worth mentioning, that the first case-study worked well, because of the application of the perception experiment in daily practice and the verbalization of it by all children. This element is missing in the second case-study. As a result the children did not have enough words to express their activities. This showed especially during the tinkering hour.

This can be explained in the following way. The contrast between the two case-studies is that the learning process of the first case-study was a marked team process, initiated by the teacher with a demonstration of the instruction 'how to observe', followed by verbalizing of the personal observations by all participants. This lead to intense focusing and shared language. The team process contributed to the development of the skills, noticing, controlled colouring and pro-active self-direction.

In the second project the teacher set up the environment, but not the tasks. The task was 'play'. As a result the learning process was in some respects a team process and in other respects undefined. The initiation of the learning process, the demonstration of the simple problem, was attended as a group. Batch wise demonstration of instruction was absent.

The two cases are similar with respect to working in groups, combined with free choice in how to experiment; individual or in collaboration. According to literature working in groups is profitable, because socialization and a shared language originates from collaborating in groups; students can discuss between themselves all the ins and outs (Lemke, 2000).
For effective collaboration, free choice is important, because collaboration is the consequence of interest in the view and actions of others, aiming to increase one's own self-expression. Free choice is vital to enable inquisitiveness and interest and teachers should allow a level of free choice in the start activities as well as in the subsequent processes.

This principle also determines effective teacher communication. When the teacher communicates on an equal level with the children and instruction is small, the ideas of the children get the chance to affect the ideas and further instruction of the teacher. Then genuine communication can take place (Dewey, 1910) and joined thinking occurs.

From the result of the first case-study is to learn that the increase of fine motor control smooths the way to self-contentment and increases self-expression. This confirms the assertion, that skills and knowledge are best developed in advance to enable self-control. Control of the unknown is impossible. Skills and knowledge concern all dimensions of the environment; classmates, teacher, tools, furniture, books, teaching material, the arrangement of the classroom, playground, building and so on.

Some practical recommendations:

- Plan small, targeted instruction, before starting a task.
- Use demonstration to instruct ‘how to do something’.
- End the instruction with verbalizing of personal ideas or observations by all participants.
- Plot a small, simple problem, to start the thinking about a phenomenon.
- Use demonstration to set the problem.
- Working in groups furthers collaboration and discussion.
- End the working with reflection in the gathered group. Verbalizing of personal ideas and observations by all participants leads to shared thinking.
- Free choice furthers playful behaviour, inquisitiveness and feeling attached.
- Small questioning can help children to verbalize ideas.

These two case studies elucidated especially the important role of joined-up thinking to enable collaboration and ongoing discovery. To make this happen, incomplete knowledge had to be completed and differing knowledge required transformation towards shared knowledge. The transformation from isolated to shared knowledge succeeded by utilizing small and simple instructions, existent expertise and the construction of personal meaning.
Verbalization appeared to be necessary for effective joined-up thinking and for insight.

Chapter 4

Initiation of verbal expression in young children in Design and Technology education: A case study [1]

[1] Based on: Looijenga, A., Klapwijk, R.M., de Vries, M.J. (2017b). Initiation of verbal expression in young children in Design and Technology education: a case study. *Australasian Journal of Technology Education 4*. Retrieved from: a http://dx.doi.org/10.15663/ajte.v4i1.47)

This chapter presents the third study. Inspired by the findings of chapter two and three, that the verbalization of thoughts and ideas could make a significant contribution to engagement, collaboration and ongoing discovery, this study investigated the enabling of verbalization of complex thoughts. The enabling depends on several factors. One factor is the prevention of confusion, another factor is the offer of clear procedures and a third factor is the avoidance of feelings of insecurity. By enabling pupils to take the lead during verbalization the avoidance of mismatches in thinking would be realized. By teaching the pupils the rules and means of verbalization, the pupils would be offered clear procedures. By avoiding absence of knowledge or abilities the avoidance of feelings of insecurity would be realized.

4.1. Introduction

Designing is a thinking activity that seeks possibilities (Parkinson, 2007) and benefits from broad subject related thinking and sharing ideas (Kangas, Seitamaa-Hakkarainen, & Hakkaraine., 2013). Both subject related thinking and the sharing of ideas need sound strategies to enable them to be implemented in the classroom.

The induction of broad subject-related thinking needs a teaching approach which offers provocative activities that enable pupils to discover how to think and reason (Hiebert & Stigler, 2000; Dewey, 1938). Teaching approaches focusing on the prevention of confusion and offering clear procedures (Hiebert & Stigler, 2000) will obstruct broad subject related thinking and interaction (Gopnik, 2012) and are therefore inappropriate for introducing a design activity. Starting the design activity with teaching the rules and means of the procedure together with interaction, instead of instructing only one way to proceed (Hiebert & Stigler, 2000; Scheer, Noweski, & Meinel, 2012), may lead to an integration of exploring and creating, resulting in broad thinking.

A related question is 'Who takes the lead in interaction?' The teacher can design a setting and invite the pupils to discuss this context, but can also invite the pupils to discuss their experiences of the subject matter, followed by building a setting based on the experiences expressed. The latter strategy gives pupils the lead and prevents a mismatch in thinking between the teacher and the pupils, which may lead to difficulties in starting a dialogue (Krauss & Chiu, 1998).

Computer gaming is a fine example of the effect of teaching rules and means instead of teaching one way to proceed. In computer gaming, a beginning is known as onboarding (Chou, 2013) and is considered successful in so far as the user’s attitude changes from curious to smart and competent. On-boarding is about teaching users the rules and tools to play the game. If a user feels stupid during on-boarding, the game designer is fighting an uphill battle along with the user (Chou, 2013). This also applies to education in that teachers are fighting an uphill battle along with pupils, who are feeling incompetent.

The research described in this article on the initiating of a learning activity was inspired by game designers’ ideas about onboarding. A translation of their ideas to Design and Technology Education could be 'changing pupils’ feelings during the introduction of an assignment from curious into smart and competent with respect to the execution and completion of the assignment.'

Teachers can influence the quality of the interaction by teaching the rules and means of verbal expression. This is important, because not all pupils will have the same level of social and communicative experience nor the same vocabulary (Mercer, 2013). In order to establish interaction, ideas need to be verbalised into informative expressions that are recognisable as such by the whole class. Well-functioning communication is ‘paved’ with social interaction and related language (Lemke, 2000).

This teaching of rules and means of verbal expression will also support a larger goal; “It is in the interests of society that children are taught how to become effective 'interthinkers' by using or educating the social brain” (Mercer, 2013, p. 164). In this paper we describe ways of inducing thoughts in young pupils, followed by the transformation of those thoughts into verbal expressions.

Research questions

The central question of this research is:

> How can a teacher initiate verbal expression in young children in Design and Technology education?

Verbal expression is seen as a two-step process: first thoughts have to be induced, then they have to be transformed into verbal expressions. The sub-questions are therefore:

> How can teachers induce subject-related thoughts in pupils?

And:

> How can teachers enable the transformation of those thoughts into informative verbal expressions?

Format of this paper

Expressive behaviour is related to autonomy and natural learning. The objective of “making the pupil feel smart and competent,” translated from game design, can be realised in a learning situation where verbal expression is welcomed (Krauss & Chiu, 1998), pupils’ autonomy is standard (Greene & Azevedo, 2007), and natural learning is recognised (Gopnik, 2012, 2016). The following section on the theoretical framework contains a discussion of the literature dealing with autonomy, verbal expression, and natural learning, their mutual relations, and their consequences for the learning process.

The subsequent case study section discusses the introduction of the “thinking hats” (De Bono, 2009) as a tool for verbal expression, applied to cuddly toys in a primary class of 4 to 6 year old pupils. It describes the participatory observation of an induction of expressiveness in young children and the subsequent development of informative verbal expression. The last section contains conclusions and recommendations for implementing these approaches in order to stimulate verbal expression at the start of a design activity. This section ends with implications for further research.

4.2. Theoretical Framework

Autonomy can support feeling smart and competent by providing pupils with room to act from their actual experience, needs, and knowledge. In this way, it can also support expressive behaviour (Krauss & Chiu, 1998) and natural learning (Gopnik, 2012). Children basically learn by looking and by listening (Gopnik, 2016), and through imitation and conversation. They develop hypotheses which they subsequently test. This natural learning process is, however, disrupted by loss of autonomy. Authority can overrule the self-development of knowledge and can obstruct proper understanding (Gopnik, 2012). Below, the concepts of autonomy and natural learning are further explained.

Autonomy

When pupils have a choice about the task: its starting point, the target, the end situation and the way the task is evaluated, they are enabled to think about the task from their own actual experience, needs and knowledge. Consequently they will experience autonomy, which enables them to be more active. Student choice can be provided before the start of a task phase by teachers consulting pupils, but also during a task phase. The latter method offers pupils choices in assignments and/or in ways of handling assignments. The likelihood of feeling smart and competent during the entire assignment will grow through autonomy. The grade to which a pupil can be active in all phases of a task determines the grade of academic achievement (Greene & Azevedo, 2007).

Autonomy is a key for promoting the self-management of a task into the self-direction of a process, whereby the task is treated as a means rather than as an end (Scheer et al., 2012). Dewey (1938) regarded these autonomous pupils as plan builders; they are building their own plan towards mastery, while the teacher feeds in content and responds to demands. Mert (2014) argues that active participation in the identification of aims, rules and feedback on the task enables pupils to develop their maximum potential.

Candy (1987) notes that in a learning situation, two types of autonomy can be distinguished: situational and epistemological.

- *Situational autonomy* comprises two dimensions: self-management skills and personal autonomy. Self-management skills are practical skills necessary for the pursuit of the pupil's own targets, while personal autonomy has a pupil component: assertiveness, and an external component: low external constraints, pressure and direction.
- *Epistemological autonomy* involves anticipatory schemes and learning strategies. Anticipatory schemes help pupils to make informed judgements about the content to be learned, and learning strategies help pupils to employ appropriate strategies of inquiry.

Natural learning

Children's learning can flourish through autonomy. Gopnik (2012) shows in research on scientific thinking in young children that very young children's learning and thinking are strikingly similar to much learning and thinking in science, because young children already have mental models of the world. These mental models assist hypothesis testing and experimenting. Gopnik describes an experiment in which an adult woman showed infants a box filled with white and red balls. With eyes closed she randomly took some balls from the box. These balls were put in a small empty bin. Next she showed the content of the bin. When the distribution of balls in the bin matched the distribution in the box, the infants looked for a short time. When the distributions did not match, the infants looked for a longer period (Gopnik, 2012). This shows that even young infants have expectations and mental models about distributions.

Another experiment shows that by watching what other people do and what happens as a result, children develop their own ideas about causal relationships:

> In a lab study (Buchsbaum, Gopnik, Griffiths, & Shafto, 2011), 4-year olds saw an experimenter perform five different sequences of three actions on a toy, which was activated or was not activated according to each action. A statistical analysis of the data would suggest that only the last two actions were necessary to activate the toy. When children got the toy, they often produced just the two relevant actions, rather than imitating everything that the experimenter did. (Gopnik, 2012, p.1626)

When pedagogical content was added to this experiment by saying "Here's my toy, I'm going to show you how it works," a remarkable effect occurred. The children tended to assume that everything the adult did was causally effective and to imitate all her actions (Gopnik, 2012). This experiment shows that children are sensitive to the intentions of others, particularly to their intention to teach. They may draw different conclusions from the evidence that teachers give them than from the evidence they gather themselves (Gopnik, 2012). These experiments suggest that the way early childhood education takes place is extremely important. The pedagogical content of structured and academic early childhood programs can kill broad exploration. Early childhood education should scaffold children's probabilistic approach during exploration and play (Gopnik, 2012).

In the field of Design and Technology Education, research into the programming comprehension of young children has come to a similar conclusion (Strawhacker & Bers, 2014). The researchers concluded that children were able to understand the concept of repeat loops as an abstraction of a linear program. They saw this level of abstract understanding as an indication that the children realised that their robots abstractly represented animals. Observation of children's spontaneous play showed that the children had no trouble with switching between talking about the robot as a living animal and as an inanimate object.

In 1929, Piaget concluded that symbolic reasoning is absent until the age of seven. These recent findings raise doubts about this finding. Piaget's conclusion may hold when open questioning is used. However, when focused questioning about an everyday context is used, pre-schoolers already are able to provide an answer by using abstract thinking (Gopnik, 2012).

Hypothesis testing and education

These recent studies (Gopnik, 2012; Buchsbaum et al., 2011) show that it is natural for children to develop and test ideas (hypotheses) about practices. This is very relevant for Design and Technology Education, because hypothesis testing is an important feature of Design and Technology Education (Parkinson, 2007).

The ability to test hypotheses is influenced by autonomy, because by hypothesis testing, selfdeveloped conclusions may differ from conclusions drawn from evidence provided by teachers. Explicit teaching can result in bias and hence loss of autonomy. Hypothesis testing is appropriate for all ages; it can be used consciously by very young children, when an adequate task structure is presented. The conclusion of research by Howe, Tolmie, Duchamp-Tanner, and Rattray (2000) was that hypothesis testing needs a setting where pupils are required to formulate conceptual knowledge into researchable ideas, investigate ideas through manipulation (procedural knowledge growth), prediction and observation, and evaluate ideas in the light of evidence. In such a setting, hypothesis testing can facilitate the integrated acquisition of conceptual and procedural knowledge. For instance, when they are learning about electricity, the pupils need a researchable idea such as 'When the power circuit is closed, what happens to the lamp? Will it light up or not light up?' When testing this idea, pupils learn by manipulating their conceptual (What happens when the circuit is closed?) and procedural (How can I close the circuit?) knowledge about power circuits.

The implementation of hypothesis testing in education is not that easy; conceptual growth needs debate and dialogue (Piaget, 1985), whereas procedural growth needs guidance, with carefully tailored and individualised attention (Vygotsky, 1978). As has been discussed, in the context of children’s natural learning processes, authority figures may tend to have an undermining effect on dialogue, because explicit teaching may tend to encourage children to consider fewer hypotheses than they otherwise might have done. It seems that students in a “discover” orientation learn more than students in a “listen” orientation (Schneider, Bumbacher, & Blikstein, 2015). Giving a detailed explanation of a science phenomenon does not prompt scientific thinking, whereas encouraging play, presenting anomalies and asking for explanations might well do this (Gopnik, 2012, p. 1627). An effective design task encourages children to puzzle instead of passively listening. For instance a teacher can, after demonstrating a phenomenon, ask the pupils for an explanation.

The tension between guidance and dialogue may be resolved by implementing non authoritative guidance, which serves the pupil's goals rather than requiring coping behaviour. This modest guidance also allows teachers to have a productive dialogue with pupils on a more or less equal level of authority (Howe et al., 2000). A teacher acting as a well-informed passenger can enable a pupil to drive. Research on computer supported collaborative learning has demonstrated that a team of an experienced passenger and an inexperienced driver (student in a discover condition) achieves similar learning goals to those of a team of an experienced passenger and an experienced driver, and much more than an inexperienced passenger (student in a listen condition) and an experienced driver (Schneider et al., 2015).

A hitherto undiscussed aspect of this modest guidance by teachers is the guidance that supports the verbal expression of the children’s thoughts.

Expression

Expression, “the act of transforming ideas into words” (Collins English Dictionary, 2014), is an important means for sharing ideas in the process of learning. Competence in verbal expression is gained by practice. Both these concepts are relevant for Design and Technology Education, because sharing ideas is an important feature of designing, and competence in verbal expression enhances the process of sharing ideas.

In general, sharing ideas among pupils and between pupils and teacher also benefits class dialogue (Krauss & Chiu, 1998), collaboration, non authoritative guidance, and formative evaluation. Another important aspect of competence in verbal expression is the improvement of pupils’ insights, because verbal expression is a thoughtful, deliberate process, whereby the expressed ideas are the result of reflection on spontaneous thoughts.

Without verbal expression, interaction between pupils and teacher is not possible. Therefore, this article, and the case study described below, focuses on inducing verbal expression.

4.3. Case Study

Context

The case study was conducted at a Dutch Montessori school where the researcher was a primary teacher for 15 years. Her speciality during that time was the development of Montessori adapted Design and Technology Education for all classes. Dr. Montessori believed that children have an innate ability to learn (Association Montessori Internationale, 2016). This proposition is shared by contemporary researchers like Gopnik (2012, 2016) and Strawhacker and Bers (2014). Montessori intended her so-called “cosmic education” to support the natural development of the human being from birth to maturity. Therefore self-guided and self-controlled discovery plays an important role in Montessori education. It can be argued that Design and Technology Education historically has a natural place in Montessori education.

Montessori teachers are guides; primarily by being observers monitoring development, and recognising and interpreting pupils needs. The teacher provides a link between pupil and environment by introducing elements of the environment in a detailed way (Assocation Montessori Internationale, 2016).

Besides being a guide, the Montessori teacher is a facilitator, whose task is to support pupils in their process of self-development.

Methodology

This case study formed part of the project 'Design your own cuddly toy.' Data were collected by the researcher through participatory observation, accompanied by video recording. The analysis was by transcribing the pupils’ attitudes, gestures and speech shown on video. After transcription, all collected data were interpreted.

All the research was conducted in one Montessori primary class of 28 boys and girls aged four to six years old. Eight of them were 4 to 4¾ years old, ten pupils were 4¾ to 5¾ years old and 10 pupils were 5¾ to 6¾ years old. The researcher was the class teacher for all these pupils from their start at school onwards.

The participatory observations took place in the last week before the start of the 2016 summer holidays.

Case study design

Design your own cuddly toy

Pupils needed to know the desirable features for a personal cuddly toy, before they were allowed to start designing one. Therefore the pupils had to find out what made a cuddly toy appealing.

To provide familiar objects, the teacher asked the children to each bring in their favourite cuddly toy. To provide simplicity, the six thinking hats of de Bono were used (de Bono, 2009), because these hats enable the wearer to focus on one aspect of an object at a time.

1. White hat: Facts. Calls for information
2. Yellow hat: Benefits. Explore the positives.
3. Black hat: Caution. Spot negative things, difficulties and dangers.
4. Red hat: Feelings. Express emotions and feelings.
5. Green hat: Creativity. Focus on possibilities, alternatives, new ideas.
6. Blue hat: Process. Big picture, thinking about thinking.

To provide modest guidance, the teacher opted to demonstrate the function of the hats beforehand. During this activity she asked simple questions in order to help the children remember exactly what each hat meant.

Execution

The hats were made from simple paper strips in the appropriate colours. The blue hat was left out, because it seemed too complicated to explain the purpose of this hat to the four to six year olds.

First the teacher demonstrated the hats to the assembled class. She took three dolls from the play corner: a black and a white baby doll and a fairy tale doll, Snowy White. The teacher put the red hat on her head and said: “With this red hat on I look at the dolls with feeling. Which doll do I like and which one don’t I like? Do I think a doll is funny or lovable or comforting?” She picked the black baby doll and said: “This one has adorable eyes, because of his eyelashes. It’s as if he’s looking at me and saying ‘Hold me!’ That’s why I like this one the most.”

Then the teacher put on the yellow hat and said: “With this yellow hat on my head I pick out the good things or nice things. When I touch something, what feels nice? When I look at something, what is nice or good to look at?” She picked up Snowy White and said: “She feels really nice.” Then she picked up the white baby doll and said: “She has a beautiful dress.”

Then the black hat. With the black hat on, the teacher said: “With this black hat on I pick out silly or nasty things. When I touch something, what doesn’t feel nice? When I look at something, what looks ugly or unattractive?” She picked up the black doll and said “She is stiff and rigid. I don’t like that.” She picked up Snowy White and said “She is dirty.”

Next was the white hat. “With this white hat on, I describe facts, such as softness or smoothness or roughness or the details I can see.” The teacher picked up Snowy White and described: “I feel softness, I see blue eyes, brown hair, a yellow collar, a blue dress.”

Last was the green hat. “With the green hat on, I think of any unusual things I can do with these dolls. Normally you cuddle a doll or pretend it’s someone in a make-pretend game.” The teacher picked up Snowy White and threw her in the air, saying: “but I can throw it in the air as well." She caught her again and said while looking around: "I can give her to a sad person to comfort her.”

First try-out: Familiar dolls

After demonstrating this, the teacher invited the children to talk about one or more dolls while wearing one of the hats. Half of the class (approximately 15 children) wanted to do this. Queena (6¾ years old) was the first one to choose a hat. She took the red one. Her attitude was enthusiastic, but she could not find any words to express her feelings about the dolls.

Next was Vos (5¾ years old). He chose, without any hesitation, the black hat and he was glowing with pleasure with the hat on his head. When it was his turn to mention the silly or nasty things about a doll, he chose Snowy White and said: “This is the ugliest doll.” The teacher asked him why. At first he did not have many words to explain what he meant, but he played his role as a presenter with so much pleasure that the teacher dared to ask him why over and over again. After some time he mentioned, while handling the doll in a suitably expressive way, some ugly features of the doll: “The colours of the doll. Yellow, red, pink and black are all silly.”

Imke (6¼ years old) chose the yellow hat. She did not show much emotion. The nice things about a doll were easily verbalised in a rather contemplative way: “I like the princess, because of her colours: red, blue and yellow. These are my favourite colours. I like the white baby doll because it has black hair. I like the black baby doll because it’s easy to play with.”

Brecht (6 years old) chose the white hat. Wearing this hat she gave a detailed description and while she was talking she seemed to open up and see more and more details. Her attitude was calm.

The green hat was not very popular. Eefje (5¾ years old) took up the challenge. She came up with a nice new idea by making two dolls quarrel with each other: “Baby doll is frightened out of her wits by seeing Snowy White. She never saw a doll like this before.” Her expressive role-play game with the dolls made everyone laugh.

Then time was up. The teacher invited the pupils to bring in a cuddly toy from home over the coming days, in order to talk about it while wearing one of the hats. The teacher promised to record all their presentations on video.

Second try-out: An unfamiliar cuddly toy

The next day none of the pupils brought in a cuddly toy. Some of them told the teacher that although they wanted to bring one, their parents did not let them do so, because of the class rule not to bring personal toys into the classroom. The teacher had expected this, so she brought in a cuddly toy herself, a monkey.

The class sat in a circle and the teacher put the monkey on a carpet in the middle. Again five pupils were given the opportunity to choose a hat. Melanie (5¾ years old) chose the white hat. She started hesitantly. The teacher had to question her (“What do you see?”) to get her to verbalise some of the features (“I see brown hair. Eyes. Nose”). After pointing at the feet of the monkey, she said “hands.” After being asked what this animal is called, she responded: “Monkey.”

Then it was Imke’s (6¼ years old) turn, with the red hat on. She did not have much to say either. The only thing she said was: “It makes me happy” (but she did not display happiness).

Matthijs (6½ years old) wore the yellow hat. Normally he is a verbally skilled boy, but now he did not say much at first. After starting to touch the monkey, he began to speak. “I like how it feels, soft” (touching the fur). After being questioned about nice or pretty aspects, he said: “It’s a funny cuddly toy, because he feels so soft.”

Sjoerd (5½ years old) put on the black hat and was very eager to say something, but his talking was also hesitant at the start. The teacher asked him “What is silly?” He answered “I don’t know.” The teacher asked “Ugly?” He answered “I don’t know.” The teacher said: “Okay, grasp the monkey and look closer.” He did. He took some time to get acquainted with the cuddly toy. Then a provocative element of his personality took over and he started to act up, while voicing his disapproval: “The brown eyes are silly.” Holding it high, he dropped the toy on purpose.

The green hat was first worn by Jessie, a 4½ year old girl. She was eager to say something, but did not manage to express herself in either words or behaviour, except for “I don’t know.” Sharona, a 6¼ year old girl, took her place. Her provocative side took over and at first her behaviour expressed aversion (black hat behaviour). So the teacher questioned her: “What would be funny for Monkey?” Then she came up with some creative ideas: “He has to wear a nice hat for his first birthday” and “He has funny fur.” After being asked “What else can you do with this monkey?” she answered: “playing zoo.”

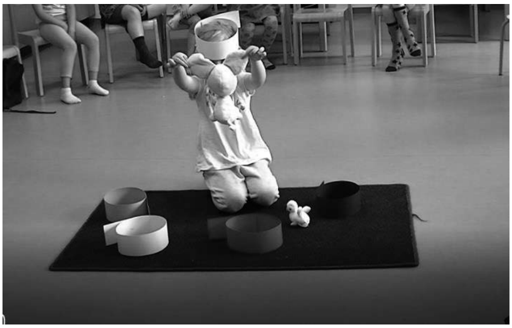


Figure 4.1: Pupil discussing familiar cuddly toys (2016)

Third try-out: Familiar cuddly toys

Over the next three days ten pupils each brought in their cuddly toy. They were allowed to discuss their toys with as many hats on as they liked. It was remarkable that both younger and older pupils, boys and girls, wanted to talk (see Figure 1 above).

Stefan (5½ years old) with a cuddly snake.
Black: I think it’s silly, because it has orange spots. And its red tongue is silly too.
Red: Nice tongue (grasping it), it feels very gentle.

White: I see a mark, a hole in his chin, the bottom is red.
Yellow: It's nice that he has a big head, a nice shape, a nice mark.
Green: Tomorrow it's winter [in reality it was midsummer at that moment!] and then I'll wear my snake as a scarf.

Eefje (5¾ years old) with a bag in the shape of a sheep.
Black: I think it's silly that he has this hair (she grabs the hair and shakes the cuddly toy), I can hit something with this sheep, that's why I think it's silly, because I think he's lovely. This white colour is strange! Real cuddly toys don't have zips and can't open up.
Green: Sheep stay warm in winter. Funny that he has the same colour as the white hat. Funny that the eyes have the same colour as the black hat.
Yellow: He can get nice and big when I put things inside him. He just did a wee-wee.
Red: Normally I feel sad when I see him, because I want to hold him very much. He's so sweet! Do you know he really can speak to me? But today I feel happy about what he's saying, because he's always telling me 'please take me to school with you' and today it was allowed!

Kiki (5¼ years old) with a cuddly dog.
Red: [She hugs the dog] He has gentle ears, that makes me happy and I can hug him. [She grasps the tail and moves it back and forth].
Green: [Looks and thinks, and plays a make-pretend game with her dog, without words].
White: I see ears, tail, a white tummy. I see him laughing.

Koert (4¾ years old) with a cuddly bear.
Red: He's lovely, because he has two different eyes.
Black: He's silly, because he has two different eyes.
Yellow: He's funny, because he has tufts of hair on his ears.

Marilene (4 years old) with a cuddly bear.
Black: [softly] He's silly because he has black eyes. [The teacher asked her if she wanted to say anything more] No, it's too difficult.

Fourth try-out: comparison of one familiar cuddly toy with two unfamiliar ones

The last day was a bring your own toys day. This was a complicating factor because it caused distracting unrest in class. The younger pupils showed expressive, difficult to correct behaviour; they became their own car, doll, etc. Very noisy!

Three girls – Queena (6¾ years), Imke (6¼ years) and Eefje (5¾ years) – wanted to talk about their cuddly toys on video. Because all three were just under or just over 6, the teacher decided to check out their comparison skills. The teacher seated them together with their toys (a pink bear, a Barbie doll, and a pink troll with a pulling string) on a table. The teacher told them to pick a hat in turn and talk about their own toy.

Subsequently, with the same hat on, they had to compare their own toy with the other two and mention similarities, contrasts and differences. Queena started, with the red hat on. She did not know what to say. So the teacher told her to choose a different colour. She chose the black hat, but she still did not know what to say. She was looking to the other girls for help. Eefje whispered something in her ear. Afterwards she chose the green hat. She said about a toy with a pulling string: "I think this one needs a battery." When the teacher asked her what kind of funny things could be done with the toy, she answered: "Turning round." When the teacher asked her what funny thing can be done with all three dolls, she answered: "Turning round." Wearing the yellow hat she said that all three dolls made her happy.

Then it was Eefje's turn with a yellow hat. She pulled the hair of the troll with the pulling string. Spontaneously she said she liked this hair. Then the teacher asked her to talk about something that all three toys have in common. At first she started to talk about the eyes. When the teacher asked the other girls as well, she suddenly said: "I know a good way they're alike: all three are pink!" Then with the white hat: "All three have eyes, they all have legs." Next the black hat. With a naughty look on her face and her hands on her hips, she said of the toy with the string that its hole was silly. When the teacher asked her to mention something silly about all three toys, she said it was silly that one is human and the other one is not. She said nothing about the toy with the string. All this time Queena was staring, not involved. The other girl (Imke) tried to direct her in verbal and non-verbal ways.

Imke put the black hat on. She said spontaneously that it was silly that one toy had whiskers. When the teacher asked whether they all have something silly, she answered that she did not know. So then she put on the white hat. Now she saw that all three toys had something black. After this she wanted the yellow hat. With this hat on she spontaneously said that the funny thing about one toy was that it could clap its hands, the funny thing about the toy with the pulling string was that it showed its tongue, and about the Barbie doll she said something that the teacher did not understand. The teacher asked in what way they were alike. She answered: “I don’t know.” The last hat she put on was the red hat. She said that it made her happy to pick up the cuddly toys. This did not count for the Barbie doll. After this hat she was finished.

4.4. Interpretation

In the case study, the teacher used familiar objects (cuddly toys) and non-authoritative guidance (instruction by demonstration without adding pedagogical content, while welcoming expressive behaviour). A simplifying instrument (the thinking hats) encouraged the pupils to act and speak. Free choice was allowed in the colour of the hat to be worn in order to enhance the pupils’ autonomy. While the pupils were expressing themselves, the teacher provided modest guidance by means of simple questions to support the pupils’ procedural knowledge about the meaning each hat.

There was a marked difference between the pupil's behaviour when handling the unfamiliar cuddly monkey and their own familiar toys. The unfamiliar toy caused some hesitance in the pupils’ expression. This hesitance was decreased by touching. Apparently, touching the toy helped the pupils to overcome their hesitance. They handled their own cuddly toys in a decisive way. It was striking that the pupils did not handle their own toys as objects, but started to role play using two characters, one for the toy and one for themselves.

Difficulties arose when comparing their own toy with two other toys. When playing with their own toys, the pupils were expressive, but expression about the unfamiliar toys was poor. It is important to note that during this activity the class was really noisy and distracting, maybe because this was a bring your own toys day.

After being instructed about the thinking hats, all pupils were invited to talk about the toys in front of the camera. In practice, not all pupils got the chance to do this. The two-thirds of the class who got the chance all managed to be expressive. Compared to the older pupils, the younger pupils wanted to talk about the toys just as much and knew which ones to choose, but they verbalised fewer features of their own toys and showed more uneasiness. The younger pupils also chose fewer hats (one to three) to wear.

The older pupils were very expressive and chose four or five hats to wear. Five pupils started talking about their own toys with the black hat on, three with the red hat on, one boy with the yellow one and one girl with the white one. The black hat gave rise to plenty of fun and made the pupils lively and cheerful when discussing the features of their own cuddly toys in a negative way. When discussing their toys with the yellow hat on, they often mentioned the same features but in a positive way. Not all pupils liked to be negative about their own cuddly toys; these pupils chose to be loving or positive or factual. For the older pupils, the green hat evoked creative ideas. For one six year old girl the green hat had the same provocative effect as the black hat.

4.5. Conclusion

Designing, a core activity of Design and Technology Education, needs verbal expression to enable broad subject-related thinking and the sharing of ideas. The central question of this research was “How can a teacher initiate verbal expression in young children in Design and Technology education?” The sub-questions were “How can teachers induce subject-related thoughts in pupils?” and “How can teachers enable the transformation of those thoughts into informative verbal expressions?”

How can teachers induce subject-related thoughts in pupils? The literature indicates that feeling smart and competent due to familiarity with the subject matter, in conjunction with modest guidance, is the best way to achieve autonomy, natural learning and expressive behaviour at the same time, together with a subject-related question, this can lead to the induction of subject-related thoughts.

The research data show that in the case study a setting was created where all pupils could feel smart and competent.

The research question for the pupils, “What makes a cuddly toy attractive?” together with the use of familiar objects (their own favourite cuddly toys) induced subject-related thoughts. The instruction by prior demonstration of the function of the hats without adding pedagogical content, together with simple questioning during pupil expression, constituted modest guidance. The questioning during pupil verbal expression supported the pupils' procedural knowledge in terms of remembering the meaning of a particular hat. For instance, the teacher asked “What do you see?” for the white hat, or “What is ugly about this cuddly toy?” for the black hat, or “What is attractive?” for the yellow hat. The pupils exhibited expressive behaviour and motivation to express themselves, which can be regarded as a particularly relevant result. Evidence for the importance of familiarity for feeling comfortable can be found in that there was a marked difference between pupils’ behaviour while handling the unfamiliar cuddly monkey and their own familiar cuddly toys. The unfamiliar cuddly toy caused hesitance in their expressing.

How can teachers enable the transformation of those thoughts into informative verbal expressions? According to the literature, the transformation of such thoughts into informative verbal expression requires the sharing of ideas and competence in verbal expression.

To start this transformation, the pupils have to be capable of sharing their ideas. Given their age, in general, their capability would be low. Therefore, simplicity was necessary for them to be able to discuss their ideas. A simplifying instrument, the six thinking hats of de Bono, was used (de Bono, 2009) to create a simple and clear focus for expressing themselves. This worked for the older pupils, but for the younger ones the transformation was difficult. Compared to the older pupils, the younger pupils wanted to talk about the toys just as much and they knew what to choose, but they verbalised fewer features of their own cuddly toys and showed more uneasiness. The younger pupils also chose fewer hats (one to three) for their talks. The older pupils were very expressive and chose four or five hats for their talks.

Overall, the hats proved to provide a good structure for enabling pupils to be expressive, followed by their informative verbal expression. The pupils could choose from five differently coloured hats. The free choice at the start of the task enhanced the pupils’ autonomy and consequently fostered their expressive behaviour.

The expressiveness of some of the pupils was surprisingly rich. The teacher’s role was limited interaction, only intervening when a pupil’s verbal expression needed further clarification or when the pupils needed guidance. This resulted in growing familiarity with the hats, which in turn contributed to the growth of the informative value of pupils’ verbal expressions. The need for guidance decreased over time. Familiarity with the cuddly toys combined with growing familiarity with the hats was reflected in less hesitant and more exuberant behaviour.

We can conclude that the question “How can a teacher initiate verbal expression in young children in Design and Technology education?” can be answered by “Ask a clear and simple question and use a structuring medium, such as the thinking hats of de Bono, in the search for possible answers.” All this should be done in a setting where all pupils can feel smart and competent, because of their familiarity with the subject matter and the modest guidance by the teacher. Growing competence in verbal expression, together with gentle support, will enable the pupils to produce informative verbal expressions.

4.6. Discussion

Limitations

Not all pupils who showed interest in giving a talk got the chance to do this, so it is not certain whether the plan of instructing the pupils in how to express by demonstrating the procedure of verbal expression worked for all pupils. It did work for the two-thirds of the class who got the chance to give a talk.

Ideally, modest guidance requires familiarity between pupils and teacher. Because the data was collected through the participatory observation of the researcher in the role of teacher, the guidance must be considered as close to ideal (Hoepfl, 1997). Therefore, in order to repeat this research, a researcher could not replace a class teacher; it has to be done by a teacher who knows the pupils well. A teacher could, however, be supported by a researcher, for instance, through lesson study.

There is no close relationship between the findings of this research and other Design and Technology Education literature about verbal expression. Existing literature is mostly on making and sketching. A strongly related source is found in earlier literature about the use of visual cues to help autistic children to self-initiate speech ("Stimulus control is at the heart of this cueing procedure" (Matson Sevin, Box, Francis, & Sevin,, 1993, p. 395)). The visual cue acts as an anchor for building a sentence. This is essentially comparable to the research described in this paper, namely the provision of the simplifying structure of the coloured hats in order to support verbal expression.

Implications for education

The use of the thinking hats resulted in rich verbal expressions about a familiar object. This finding is important for classroom practice, because the introduction of the thinking hats can act as a starting point for developing procedural knowledge about how to express oneself. When pupils became more used to expressing themselves, verbal expression about unfamiliar objects would also improve. Secondly, the hats can be referred to when discussing other subjects or problems.

Literature study combined with observation provided a new perspective on passive silent behaviour. When teachers better understand the mechanism of enabling informative verbal expression, they can support their pupils in developing their expressiveness and in taking the lead in their learning.

This is important for the process of task co-creation, but also for the process of formative evaluation. The formative evaluation process makes use of the ongoing verbal expression of pupil reflection. In this way formative evaluation gives rise to a self-enforcing process of learning (Akker, 2013). A side effect of the iterative production of verbal expression of evidence is that it furthers the familiarity of the context and the use of commonly understood ways of expressing one's own image (Black & Wiliam, 2009).

Each hat colour had its own function in discussing the object.

- The black hat was most suitable for making pupils express themselves freely, reflected by cheerful behaviour.
- The white hat was best for making the pupils aware of a growing amount of detail. This hat is best for practising observation and analysis.
- The red hat was attractive for the pupils, but disappointing in provoking verbal expression.
- The green hat was only suitable for the older pupils and led to unusual and funny ideas.
- The blue hat (which the teacher in the case study left out) is a suitable hat for the moderator, the person who offers modest guidance.

In this way, the hats supported the handling and describing of various distinct aspects of an object. But there was more: the colours changed the pupils' thoughts about the toys. The black hat had the strongest effect on pupils' expressive behaviour; the attitude of some pupils was totally transformed, as if they were actors in a play. It was remarkable that the black hat evoked much fun and that the pupils felt so comfortable about being negative about their own cuddly toys.

Competence in verbal expression assists not only Design and Technology Education but also the development of strong social skills, such as the two related twenty-first century conative skills of "understanding and controlling oneself" and "understanding and interacting with others" (Marzano & Heflebower, 2012). People have to be aware of their own personal knowledge and assumptions before they can look from a different perspective; a prerequisite for collaboration. People manage to interact with others when they are able to express their thoughts about a process and discuss those thoughts with others; a prerequisite for expanding their own knowledge. The results show that the pupils easily developed competence in verbal expression when starting from their actual experience, needs and knowledge.

4.7. Recommendations

Practical recommendations for furthering autonomy

Familiarity is furthered through pupils' participation in the composition of the context. The pupils will choose appealing objects on the basis of usefulness, usability and/or desirability (Buchanan, 1999). For example, in the case study, the teacher asked the pupils to each bring a personal toy.

Autonomy is provided by creating shared situational autonomy through instruction and/or demonstration of specific knowledge, and through shared decision-making. This is necessary because when a learning situation is introduced, the situational autonomy is not the same for all participants (Candy, 1987). For example, in the case study, the various hats were demonstrated with a classroom toy, and bringing a cuddly toy from home was a shared decision.

Autonomous behaviour is furthered by valuing it explicitly for its level of autonomy and by valuing the thinking process more than the results. For example, although an effort may remain ineffective, a teacher can praise the initiative and verbalise the good thinking.

Offering non-authoritative guidance causes pupils to be, and remain, active and autonomous. The teacher has to open up to pupils' verbal expressions. In this way, the pupils' verbal expressions can organise or reorganise the teacher's thinking, leading to an alignment of their thinking and the designing or redesigning of assignments. For example, in the case study, it was important for the teacher to notice hesitance and offer guidance towards feeling smart and comfortable; whenever the teacher presumed that an object was unfamiliar, an assignment enabling the pupil to become familiar with the object was needed. In the case study, the teacher said "Okay, hold the monkey and look closer." The effect was that the pupil held the monkey and after some time, the touching apparently caused a connection reflected in expressive behaviour. The pupil started to act up, accompanied by disapproving talk: "The brown eyes are silly." Holding the monkey high, he dropped it on purpose.

Limiting the complexity of the learning context is recommended, because complex situations call for multiple partial solutions to be designed. When the situation is simple, the focus is on one problem and calls for the designing of one solution. Less is more. The Montessori principle of isolation of quality can be used (Montessori, 1912) for this purpose. Zooming in on the details of an object is another way of limiting complexity. For example, in the case study the wearing of one coloured hat at a time made the pupils focus on single aspects of their toys.

Practical recommendations for furthering the informative value of a verbal expression

Knowledge of the language that comes with a situation enables one to speak about the situation (Mercer, 2013). Therefore, connecting the knowledge expressed during interaction and debate with commonly understood ways of verbal expression is an essential part of a lesson (Lemke, 2000).

Questions aimed at focusing on particular components of a situation are a way to synchronise knowledge and correct existing bias (Lemke, 2000). For example, in the case study, the teacher regularly questioned the pupils about the function of the hat they were wearing.

Ample room should be given for all sorts of bias; knowledge bias, but also behaviour bias. Detecting this creates an opportunity for getting onto the same wavelength as the pupils (Krauss & Chiu, 1998). For example, if pupils are distracted at the start of an activity, the teacher can ask what their personal goals are for the coming lesson and subsequently connect teacher goals with pupil goals.

Recommendations for further research

As discussed under Limitations, this research was done within a relationship of familiarity. What can be done to create such a relationship when researchers are unfamiliar with the group they want to research? One way is for researchers is to cooperate with an adult who has a relationship of familiarity with the group they want to research and can deliver modest guidance. In education, a researcher could organise a lesson study for the teachers, focused on modest guidance and verbal expression, and support this lesson study by theoretical and practical input. In both cases, insights into the guidance that furthers expressive behaviour could be obtained.

After the successful use of the hats as a simplifying tool for these four to six year old pupils, it would be interesting to research the application of this tool for guiding passive and contemplative pupils towards expressing themselves. If their behaviour is a result of insufficient skilfulness in expressing themselves, the hats might meet their needs. This also applies to pupils with a poor cognitive structure. The use of these hats, combined with non-authoritative guidance, might lead to improvement.

The hats could also assist the development of engineering habits of mind, like collaboration, teamwork, and concern for the societal and environmental impacts of technology (National Research Council, 2009, p. 131).

Additionally, it would be interesting to research the actual effect of the use of the hats in the 'describe the problem' phase of the design process. Do they make the problem clearer? Do they speed up the design process? What is their influence on the quality of the final products? What is their effect on interim evaluation?

Sound strategies for implementing design activities in the classroom not only benefit verbal expression and sharing ideas in Design and Technology Education, but also verbal expression and sharing ideas in society.

Teachers are able to influence the quality of the interaction by teaching the rules and means of verbal expression. In order to establish interaction, ideas need to be verbalised into informative expressions that are recognisable as such by the whole class. In general, sharing ideas among pupils and between pupils and teacher will benefit class dialogue, collaboration, non-authoritative guidance, and formative evaluation.

Another important aspect of competence in verbal expression was the improvement of pupils’ insights as a result of verbal expression as a thoughtful, deliberate process, whereby the expressed ideas are the result of reflection on spontaneous thoughts.

Chapter 5

How focus creates engagement in Primary Design and Technology Education:

The effect of well-defined tasks and joint presentations on a class of nine to twelve years old pupils [1]

[1] Based on: Looijenga, A., Klapwijk, R., & de Vries, M. (2020). How focus creates engagement in Primary Design and Technology Education: The effect of well-defined tasks and joint presentations on a class of nine to twelve years old pupils. Design And Technology Education: An International Journal, 25(2), 10-28. Retrieved from https://ojs.lboro.ac.uk/DATE/article/view/2690

This chapter presents the fourth study. This study investigated the effect for older pupils of in the former studies found factors, that provided engagement for young pupils. Do the same factors lead to engagement, as observed in the first three studies with younger pupils? Do these factors solve existing disengagement? To comply with the factor of well-defined tasks, a complex assignment was divided in ten simple well-defined tasks. A well-defined task satisfies the need of pupils for situational autonomy when they have to experiment. A supplementary benefit of well-defined task is an absent or low need of pupils for teacher assist.

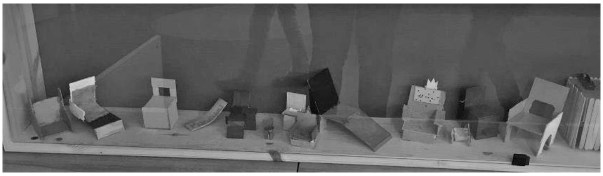


Figure 5.1: Exposition of chairs

5.1. Introduction

Creative hands-on work, creating something with a technique as a means, is an essential element of the Design and Technology class. When pupils in class are disengaged, they not only signal absence of creative thinking, but they are also unready to instantly start creative hands-on work and they can distract other pupils in class.

An important part of creative hands-on work is discovery towards insight. Discovery only can arise when pupils are experimenting. To allow experimenting, liberty is necessary. Pupils have to be in charge of the determination of the focus of their attention to be enabled to accomplish the spontaneous activity that accompanies experimenting. The hampering of pupil's liberty, by forcing or nudging them to do something in a certain way, blocks the process of discovery. Not only liberty determines pupils' situational autonomy (Candy, 1987), but also the complexity of the learning environment. Overwhelming them stops the process of discovery (Dewey, 1910). Both the learning situation and the demands of the teacher can overwhelm them.

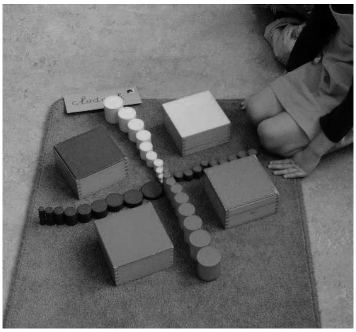


Figure 5.2. Montessori learning material for learning to sort from large to small, thick to thin, high to low

Montessori views a task as an experiment. In the Montessori tradition it is therefore common practice to apply the principle of liberty and the principle of avoiding overwhelming complexity. According to Montessori, liberty will lead to spontaneous activity. Therefore freedom of procedure during the performance of a task is required. The provocation of unnatural effort hampers liberty and blocks spontaneous activity (Gutek, 2004, p. 124). For the avoiding of overwhelming complexity pupils require brief, simple and objective tasks (Gutek, 2004, p.124). About her method, Montessori writes: "*(my) pedagogic experiments are designed to educate the senses*" (Fig. 5.2) "*(From earlier research with 'deficients' I know that) the education of the senses is entirely possible*." (in Gutek, 2004, p.153). "*(With* *normal children) it (the education of the senses) provokes auto-education*" (in Gutek, 2004, p.154). Auto-education is the opposite of training. Auto-education could be defined as self-constructing the own knowledge.

Design is another part of creative hands-on work. Design by its nature is adapting reality. For adapting reality is insight required. Insight can be acquired by experiment. Insight has to be understood as an accurate and deep understanding of reality. Insight can function in unknown situations as an anchor. The deep understanding of a situation can be applied to a comparable situation (Barsalou & Weimer-Hastings, 2005).

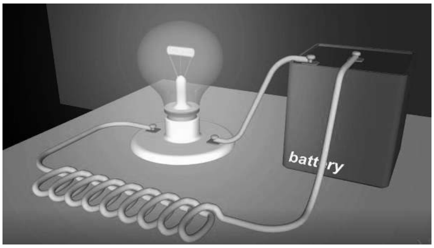


Figure 5.3. Electrical circuit. (The Editors of Encyclopaedia Britannica, n.d.)

A simple example of a Design and Technology task that enables both aspects of creative hands-on work is the making of an electrical circuit (Fig. 5.3). When the pupils have a battery, a light bulb and wires, we can give the pupils the task to make the light go on (brief, simple and objective). The focus is on connecting the light bulb to the battery in a suitable way (technique). Experimenting is desirable. The pupils first have to discover the effect of the battery on the lamp. For that reason they have to design a circuit and try it out. Trial and error, tinkering with the wires, design and failure will lead to the discovery of a stable circuit and to growing insight. Ongoing experimenting will lead to an efficient stable circuit and to accurate and deep understanding of the phenomenon of conductivity of electricity.

Discoveries are required to guide insight. Thus one profit of the practice of creative hands-on work during a Design and Technology class is the generation of insight.

Applying the idea of Montessori that her experiments are designed to educate the senses, for the Design and Technology class we can design experiments that educate the techniques. Thus another profit of the practice of creative hands-on work during a Design and Technology class can be the practice of the tasked technique.

According to the Montessori approach a well-defined Design and Technology task will be brief, simple, objective and designed to educate one technique. Dividing the mastery process of a complex Design and Technology topic into brief, simple and objective tasks, focusing on one technique, can be a way to achieve creative hands-on work towards mastery. Such a division naturally leads to a collection of tasks (Fig. 5.4). The tasks can differ from each other by variation in tasked technique, but also by variation in the requirements of an objective associated to the topic. The differentiation of tasked technique can result in a stepwise approach, but also into a collection of tasks around a theme. The differentiation of requirements of the objective will result in iteration of the performance of the task.

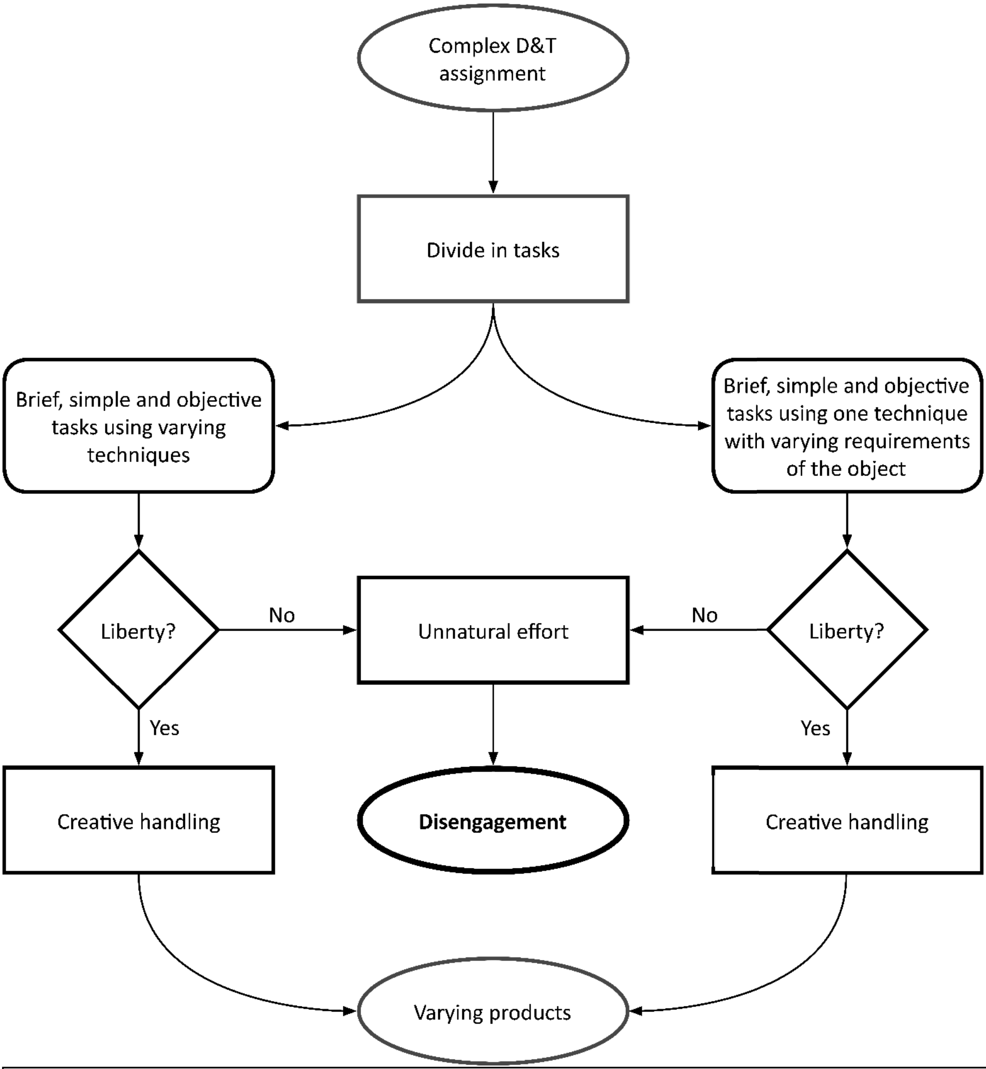


Figure 5.4. The transformation of a complex assignment in a collection of well-defined tasks

Formative reflection serves iteration, but also a stepwise approach. To get this done regular non-judgmental data collection is necessary. A joint presentation delivers an excellent opportunity for data collection, followed by reflection (Fig. 5.5). When the data collection is discussed on the basis of the question "What can we learn from this data?" followed by the question "What more do we want to know/accomplish?", increasing insight can arise for all participants. Such a joint presentation and discussion offer opportunities for active dialogue. Active dialogue transforms knowledge towards shared knowledge (Krauss & Chiu, 1998; Lemke, 2000; Mercer, 2013). Therefore, dialogue facilitates the increase of insight of all participants. On the base of shared insight, the participants together can determine the requirements of the next objective. Thus the formative reflection triggered by the questions "What can we learn from this data?" and "What more do we want to know/accomplish?" helps to set the next well-defined task.

As we have already researched a variant of this approach without variation in tasked technique, but with variation in requirements of the objective, with six to nine year olds, resulting in ongoing discovery and well-considered products (Looijenga, Klapwijk & de Vries, 2015), we wanted to know if a stepwise variant of the approach also should work. We also wanted to know if the approach should work for older pupils in a somewhat different stage of their knowledge and personality development than six to nine year olds are. Therefore we selected pupils nine to twelve year olds. If the underlying assumptions are right, the well-defined tasks should also work for these older pupils.

The paper is organized as follows. In the second section we describe the theoretical framework. In the third section the research design of the case study is presented. Section four follow with results and in section five the conclusions. We end with a discussion and implications for education and further research.

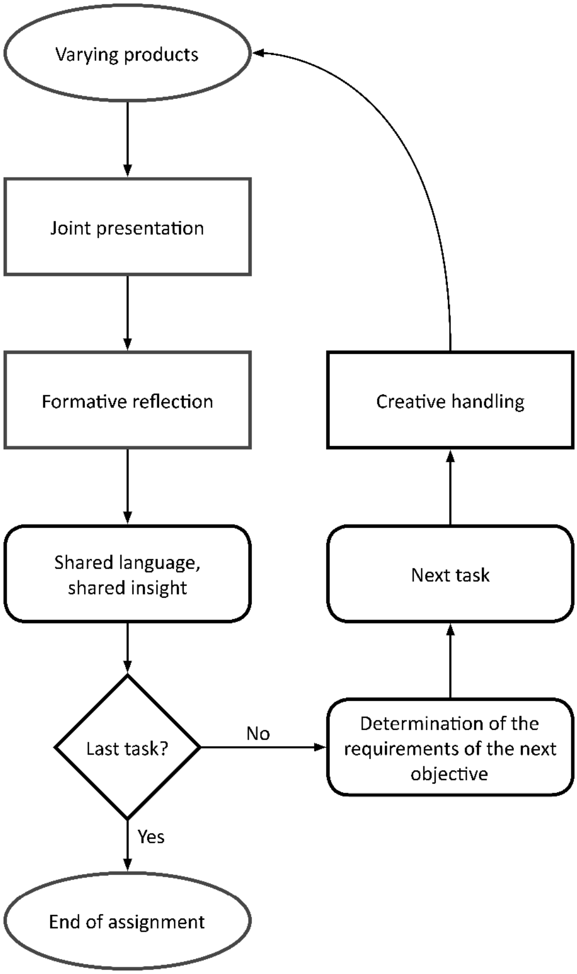


Figure 5.5. The functioning of joint presentations

5.2. Theoretical framework

Literature supports the importance and the feasibility of creating well-defined Design and Technology tasks. A teacher can create curiosity at the start of an activity by questioning pupils about an isolated detail of their everyday reality. Such an approach can start - even for young children - creative hands-on work (Chusilp & Jin, 2006). Presenting young pupils with design challenges that make use of their knowledge and skills can result in ongoing, iterative creative hands-on work (Strawhacker & Bers, 2014).

By starting with a focus on an isolated detail of their everyday reality, the elimination of curiosity - as a result of overwhelming information - is avoided (Dewey, 1910; Kirschner, Sweller, Clark, 2006; Wade & Kid, 2019). When the task also encompasses clear requirements of the objective, referred to by Hattie as success criteria (2012), situational autonomy arises (Candy, 1987). This situational autonomy is exactly the autonomy pupils need to start and continue creative hands-on work.
The effectiveness of the Montessori practice to divide a topic in brief, simple and objective tasks, is confirmed by Dolin, Black, Harlen and Tiberghien (2018). They view learning as making sense of new experiences. To make progress, learning has to be seen as making steps. Decisions about these steps are informed by evidence of what pupils already know and can do, in relation to short-term goals of activities of a particular lesson. Japanese Lesson Study also confirms the effectiveness of brief, simple and objective tasks (Doig & Groves, 2011). Goal setting and planning are the critical underpinning of a Japanese Lesson. According to Takahashi (2006), “a Japanese mathematics lesson is designed around solving a single problem to achieve a single objective in a topic” (p. 40).

Additionally, Japanese mathematics lessons make use of joint presentations of all data, followed by formative reflection. The collection of the individual presentations results in a data set. Then, the data set is discussed on the basis of the question “What can we learn from this data?” followed by the question “What more do we want to know/accomplish?”.

“In the structured problem-solving approach, Japanese teachers emphasise that one of the most important roles of the teacher during a lesson is to facilitate mathematical discussion after each student comes up with a solution. When the teacher presents a problem to students without giving a procedure, it is natural that several different approaches to the solution will come from the students. In order to do this, teachers need a clear plan for the discussion as a part of their lesson plans, which will anticipate the variety of solution methods that their students might bring to the discussion. These anticipated solution methods will include not only the most efficient methods but also ones caused by students’ misunderstandings. Thus, anticipating students’ solution methods is a major part of lesson planning for Japanese teachers. Towards the end of a lesson, a teacher often lead the lesson to pull all the different approaches and ideas together to see the connection. Then, he or she summarises the lesson to help students achieve the objective of the lesson. The teacher often asks students to reflect on what they have learned during the lesson.” (Takahashi (2006, p.42)

Joint presentation by means of active dialogue are in line with an aspect of the Montessori approach, figured out by Maria Montessori after the Second World War. She added active dialogue to her approach with the objective to provide children with experimental insight towards peace (Montessori, 1972). The active teacher acts as a representative of society and provides the pupils with opportunities to discuss and transform their opinions towards insight in responsible well-thought out opinions. This approach is highly topical, because current social challenges such as racism, discrimination and so forth, call for responsible well-thought out opinions. In this active approach the teacher not only creates a learning environment and defines tasks, but also participates in class through dialogue with the pupils. Such teachers not only prepare themselves inwardly, but are also open for the essence of dialogue; knowledge transformation towards insight (Christensen, 2019).

The idea of joint presentations is clearly elaborated in a book about the significance of Hannah Arendt at work. The essays on professionalism in education, care and well-fare highlight the important role of having different point of views around the table. Hannah Arendt calls this way of discussing ‘the Greek Solution’ (Berding, J. 2017; Arendt, 1958/1998). Around the table all participants can ‘en plein public’ explore a question. This exploration ideally results in a sharing of experiences and perspectives on the topic, whereby truth, in the form of solutions and answers are of less importance. An important characteristic of this joint presentation of thoughts and ideas is therefore the absence of moralising. Such a joint presentation leads to critical self-reflective thinking and understanding.

For Arendt, as for Aristotle, education is the means whereby pupils achieve personal autonomy through exercising independent judgement and attain adulthood through the recognition of others as equal but different. The teacher takes, during education, the role of a representative of society (Nixon, 2020, pp. viii).

> "The teacher's qualification consists in knowing the world and being able to instruct others about it, but his authority rests on his assumption of responsibility for that world. Vis-à-vis the child, it is as though he is a representative of all adult inhabitants, pointing out the details and saying the child: This is our world." (Arendt, Kohn, 2006, pp. 186).

We can find the same idea of joint presentation in the appendix to the Dutch lesson "geblinddoekte race" (blindfolded race) in the "Buitenlesbundel-2018" (Outside lessons collection 2018) (Jantje Beton & IVN, 2018) from the project "The power of play". This project is a collaboration of the Dutch organization "Jantje Beton" and the international organization "Right to play". The appendix describes the RCA method, that is used at schools in Rwanda. RCA stands for Reflect, Connect, Apply. This methodology puts the child at the centre of their learning. After participating in an activity, children are led through a series of questions, encouraging them to consciously reflect on the activity, connect the gained knowledge to earlier gained knowledge and then think about future applications.

5.3. Research design

The case study reported in this article has a history. A few months before the case-study even was considered, the researcher, a trained Montessori teacher, did a pilot study on a different location of the Montessori school, where the final case-study should take place. The idea was to find out more about the relationship between the format of activities in class and the engagement of pupils in class. For that reason the researcher cooperated with the Arts and Crafts teacher at that location, who taught several classes of six to nine year old primary pupils. The cooperation resulted for the pupils in increased engagement and, for the researcher and the teacher, in enlarged insight on the effects of the format of a task on the engagement of the pupils. The researcher learned from the teacher that focusing a task on a technique enabled the pupils to design freely. The teacher learned from the researcher that a single problem combined with a single objective created the required situational autonomy to enable pupils to start designing.

In response to the success of the pilot study the school board requested a case study of the nine to twelve year olds on another location. The Arts and Crafts teacher on that location agreed to participate in study. The school board granted permission for the publication about the case study and for the associated off-line video recordings.
In preparation for the case-study an orientation period took place, in which the researcher assisted the Arts and Crafts teacher concerned in order to get acquainted with her approach and the situation during her Arts and Crafts classes. During the orientation period the researcher noticed the existence of confusion and disengagement in class, probably partly due to missing shared routines and language (the Arts and Crafts lessons had only just started at this location).
The researcher concluded that this particular situation would offer an excellent chance to research if the stepwise variant of the approach with well-defined tasks and joint presentations should work. In addition, it could be researched if this approach also should work for older pupils of none to twelve year olds. If the underlying on active Montessori approach based assumptions are right, the well-defined tasks combined with joint presentations should have a positive influence on creative hands-on work, showing in engagement of the pupils.

The goal of the case study was to identify the effect of an intervention in which the teacher – with assistance of the researcher – introduces a design assignment in the form of a series of well-defined tasks combined with joint presentations at the end of each lesson. The central research question was:

> *"What is the effect of dividing a complex Design and Technology assignment into well-defined tasks, combined with joint presentations?".*

The sub questions were:

- *"What is the effect on the design performance of pupils aged nine to twelve years old?"*
- *"What is the effect on collaboration in class?"*
- *"What is the effect on the teacher?"*

If the approach would turn out to have a positive effect, we can continue with quantitative research in order to find out more details about the effect of well-defined tasks in the Design and Technology class.

Participants and intervention

The preparation and implementation of the lessons, by means of dividing an entire assignment in ten brief, simple and objective tasks, each centred around a specific technique, was done by the Arts and Crafts teacher assisted by the researcher (the first author of this article).

The STEAM assignment "Make a mini chair" (Fig. 5.1) (Petiet, 2009) was chosen, because it suited the dividing in tasks. It also suited the specific experience of the teacher, because the Arts and Crafts teacher was an experienced furniture designer, who did an additional study to become a qualified Arts and Crafts teacher. Each task was brief, simple and had an unambiguous goal, defined by clear and concrete objectives (Table 5.1). The objectives linked the tasks to the use of specific techniques. The subject 'chair' was chosen, because a chair is a familiar object. At the same time a chair can take many different forms and offers pupils freedom to design and model the object in an individual way.

Table 5.1: task succession in case-study "Make a mini-chair"

Nr	task	objective
1	design a chair on a piece of paper	Sketch a 2D chair, that can be transformed to 3D parts
2	draw the components of the chair on paper	The components fit in a 3D construction of cardboard
3	cut out the components with scissors	The components are replicable in cardboard
4	assemble the components with glue	The assembled paper chair fits together
5	if necessary; re-design	Replication to cardboard parts towards a firm and comfortable chair is possible
6	draw the components on cardboard	The paper components are replicated on the cardboard in a fitting way
7	cut out the components with a knife	Handle the knife in an appropriate way
8	assemble the components with glue	The cardboard parts fit together
9	if necessary; solve construction problems	The chair is firm and comfortable
10	paint and finish your chair	The chair is good looking

The same lesson took place three times a day to groups of eight to thirteen pupils, all aged nine to twelve years old, in total forty-nine pupils. Each group received four different lessons. The composition of the groups was done by the two class supervisors. Each group comprised of pupils from both school classes.

Data collection and analysis
The type of research was action research, because of the (corresponding to the active Montessori approach) required active role of the researcher and the teacher. Data was collected in real time by the researcher through observation and questioning of the pupils. After the lesson additional data was collected by the researcher through discussing the events with the teacher. During the first three sessions the researcher observed and noted in a log the course of the class with special attention for pupils' engagement as an observable expression of creative thinking. The researcher shared her observations on the fly and after class with the teacher and noted the discussed observations and the teacher's reactions also in the log. During the verbal sharing of observations the researcher highlighted the relationship between the course of the class and the accompanying appearance of engagement as an expression of creative thinking. All sessions were video recorded from a fixed place, with the objective to have an extra, impartial eye to review the sessions. At the fourth, last day of the sessions the researcher was absent, but the teacher reported the events to her, by phone, after the lessons.

5.4. Results
The proceedings during the four sessions for the three groups are described below.

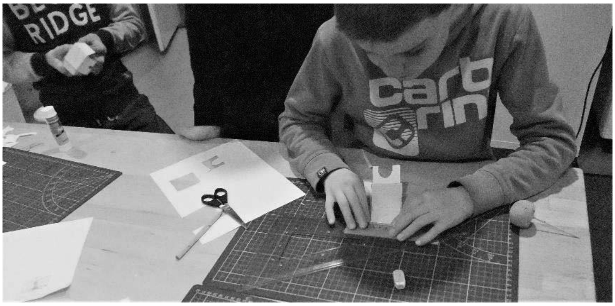


Figure 5.6: Working with paper

The first session. The teacher started the lesson with a PowerPoint introduction about the function of a chair and the purpose of the assignment. Then, in short, she presented all ten tasks to each group of pupils. Next all pupils started the first task, 'designing a chair on a piece of paper'. When finished, they could start the second task, 'drawing the components of the chair on paper'. After this, they were allowed to continue with the third task, 'cut out the components with scissors' and subsequent task 4, 'assemble the components with glue' (Fig. 5.6). Dependent on pupils' contentment with their paper model, they could 're-design' (task 5) or start to 'draw the components on cardboard' (task 6). At the end of the first session the pupils were working on various tasks of the assignment. Where a single pupil was already getting around with task 7, 'cutting the cardboard components', one third of the pupils were still in the 'draw components on paper' task 2. A few pupils did not get past task 1 'design a chair on paper'.

During the first part of the first session many pupils had trouble to start the sketching of a chair in an experimental way. When asked, they answered that they thought they had to produce a nice chair in one attempt. The teacher and the researcher were busy with explaining to the pupils that the task was meant as an experiment towards the objective, using sketching as a means to get a feasible design.

An example of this situation is a dialogue between the researcher and three pupils. The researcher showed some samples made by other pupils and guided these pupils' attention to the details that make chairs solid and comfortable to sit in. This guidance did not result in them working. Therefore the researcher suggested that they leave class and come back another time, because the pupils apparently were not intending to start working as there was only 10 minutes working time left. Starting a new task would not be very meaningful. Responding to the suggestion of the researcher, Pupil 1 asked “Can I transfer my sketch to the cardboard now?”. The researcher answered: “No, you first have to make a proper paper sketch of a chair, that meets the objective of solidity and comfortable sitting. When you have managed to make such a sketch, you can start making a carton copy.” Pupil 1 responded; “It is already proper”. The researcher responded: “I cannot see anything that is proper; your sample can only lay down.” Pupil 1: “You should make one that stands up.” In response the researcher showed him the carton copy of the chair she constructed as an example to show during the lesson. The pupil responded with: “Of course that one stands up; it is made of carton!” The researcher explained that she started with a paper exemplar and that she met many problems. She solved all these problems, one at the time, until the chair was solid when standing up. Subsequently she guided the three pupils’ attention (Pupil 2 and Pupil 3 were attentively listening) towards the specific dimensions of the parts of the chair and the differences between the dimensions of the parts of the original chair and the chair that Pupil 1 had designed. After that she guided attention to the different specific angles between the parts of both chairs.

After this instruction Pupil 1 told the researcher that he was willing to make a table. Pupil 2 agreed with him. Pupil 3 hesitantly started task 2, ‘draw the components of the chair on paper’. The researcher did not agree with the proposal to make a table instead of a chair. She made the pupil choose between an immediate redesign of his chair in class or taking time by thinking it over and bringing in a redesigned chair during next class. Pupil 1 remained distracted. In response to his distraction the researcher advised him to take some rest outside class and continue the task later on. Pupil 1 left the classroom. Then Pupil 2 started task 2 ‘draw the components of the chair on paper’, and finished task 3 ‘cut out the components with scissors’ and task 4 ‘assemble the components with glue’ very quickly (five minutes!) resulting in an original, solid chair. He even managed to finish task 6 ‘draw the components on cardboard’. The same applied for Pupil 3; he also delivered a solid chair at the end of the session.

In general, at the end of the first session the intention was to share all processes of transforming the 2D model into 3D parts. However the lesson was over before there were enough produced to share. Therefore the teacher and the researcher decided to omit the moment of sharing in all three groups.

The second session. At the start of the second session a smaller number of pupils had difficulties in starting the task. The researcher discussed the reasons of their passiveness (one at a time) with pupils who had not started. After having looked backwards, the researcher asked these passive pupils to propose a solution that would not disturb their class mates. Then, the researcher and the passive pupils discussed the proposed solutions. After this discussion most former passive pupils were enabled to hesitantly start working. It was noteworthy that the subsequent hands-on work of these pupils sometimes showed awkwardness. The scaffold of the these pupils resulted in the disappearance of hesitance. Some other pupils started with looking at peers to see how they continued the assignment. Then they started working.

An example of the effect on passive pupils of looking at peers, is the spontaneous presentation of a pupil, who had already finished the assembly of paper components with glue (task 4), to three new starting pupils. This pupil told the others about his design and creation-process. While he continued working, the new starting pupils watched his working and asked him questions. The task he was working on, was the transfer of the paper components to the cardboard (task 6) and later the cutting with the knife (task 7). The freshly started pupils watched the process of transfer from paper components to cardboard components and realised that not every 2D thought out chair would be suitable to be made of cardboard components. The effect of this realisation was that they redesigned their original design sketches.

From the moment that the teacher and the researcher experienced the effect of looking backwards, through asking for reasons of passiveness and on looking forwards through asking for their own solutions, the teacher and the researcher realised that this method not only was suitable for passive pupils, but also the other way around for stagnating pupils. They started to deploy the method of looking forwards and then backwards to support pupils’ thought processes.

An example of looking forwards and then looking backwards during task 2 was first focusing on the objective of task 9 “The chair is firm and comfortable” and then focusing on the objective of task 1 “Sketch a 2D chair, that can be transformed to 3D parts”. This was done by talking about a pupil’s design in terms of “Is it easy to make?”, “Will it be firm?”, “How do you sit on it?”. Then the pupil was questioned about the cause of to be expected failures. Looking forward helped the pupils to anticipate conditions and looking backwards helped the pupils to discover flaws in earlier stages of the assignment, leading to an eventual redesign of the chair. From this moment on the pupils also applied this support in their collaborations.

During the second session most pupils managed to start cutting out the components with a knife (task 3). At the end of the session in all groups all pupils had finished tasks 1, 2 and 3. Some pupils already managed to assemble the cardboard components with glue (task 8).

A short sharing of results and applied procedures ended this session. The focus of attention of the teacher and the researcher during the main part of this session was on the transformation from 2D to 3D and on the correct use of a knife.

The third session. During the third session all pupils were working on cutting and assembling. One pupil told the teacher that he would rather have skipped the lesson. Responding to his remark the researcher sat next to the pupil and asked him about the reason for his feelings about the lesson. She began with saying: “Your obvious aversion does not feel good for me. Are you aware of the unpleasant effect?”. Then: “Is the task clear to you?”, “Do you think the task is feasible?”, “Have you already thought out a nice design?”. Meanwhile she assisted him in the cutting job. Although the pupil did not say much, he relaxed and started concentrated working. After 5 minutes he was enabled to work without assistance.

Figure 5.7: wobble chair “Wiebeline”

Most pupils were showing a lot of joy during working. The pupils regularly came up with creative ideas like a ‘wobble’ chair (Fig. 5.7). Another pupil did a remarkable lot of measuring and redesign to make her chair solid. During solving construction problems (task 4 and 8), some pupils got ideas for fixing stability problems.

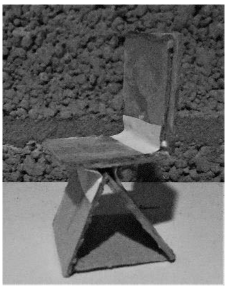


Figure 5.8: The use of paper strips to fix connections

For instance, paper strips were creatively used to fix absent cardboard connections (Fig. 5.8). Other pupils had simple ideas for a new design and started the process of making a chair all over.
Half the pupils finished their chair completely. A significant number of pupils could already colour and finish the chair (Fig. 5.1).
At the end of the session, during joint presentation, every pupil showed his/her work and reported shortly about their creation and plans for the next session.

The fourth session. During the fourth session, most pupils finished their chair and proceeded with a self-chosen job. Some pupils had to finish their chair in a fifth session or in class. The teacher told the researcher on the phone that the class-atmosphere was really good; pupils showed pleasure in working. The teacher also told the researcher that where she felt stressed and insecure during the first sessions, she was feeling calm and decisive during the third and fourth sessions.
At the end of the session, during a joint presentation, every pupil showed his/her work and reported shortly about the creation. The teacher made a small exhibition in the central hall (Fig. 5.1).

5.5. Conclusions
To answer the question: *"What is the effect of dividing a complex Design and Technology assignment into well-defined tasks, combined with joint presentations?"* we can conclude that in this case study the well-defined tasks resulted in growing insight in the possibilities and impossibilities of the used techniques with regard to the design challenge, showing in well-considered designs and products. From the moment that the joint presentations were deployed, a significant increase of collaboration, accompanied by an intensification of discovery, appeared.
The offered liberty caused varied ways of creative application of the tasked technique resulting in varied design ideas. Figure 1 shows examples of the variety of ideas.

To answer the sub question: *"What is the effect on the design performance of pupils aged nine to twelve years old?"* we can conclude that the quality of the design performance of these nine to twelve years old pupils improved by the focus on techniques and the offered liberty. Not only the quality of the designs improved, but also the intensification of the performance. The quality showed in well-considered designs and products and the intensification showed in an increase of engagement, interest and collaboration.

To answer the sub question: *"What is the effect on collaboration in class?"* we can note that from the moment that the joint presentations were deployed, collaboration was evolving. During the joint presentations every pupil showed his/her work and reported shortly about the creation. Because the tasks were the same for all pupils in the class, the design processes and design products were comparable. As a result the joint presentations were enriching each pupil's individual knowledge. The rise of shared language about shared knowledge fed the increase of collaboration.

An example of evolving collaboration was the growing attention of pupils for their peers. An example was the pupil who showed attention for the needs of three newly starting pupils by talking about his design and creation-process during working. While doing so, the fresh starting pupils watched his working and asked him questions, to which he patiently replied. This initiated their awareness about the fact that not every 2D thought out chair could be made of cardboard components. The awareness was followed by redesign.
Another example occurred during the third session in the second group. One pupil showed other pupils how to handle the knife.
To answer the sub question: *"What is the effect on the teacher?"* we can conclude that the increasing engagement of the pupils created increasing room for focus on pupils' execution of the techniques, resulting in active support of hesitant pupils. For instance, during the second session the increased room for assistance enabled the teacher to assist the pupils in the transformation of the designed chair into chair parts (task 2) and the correct use of the knife (task 7).

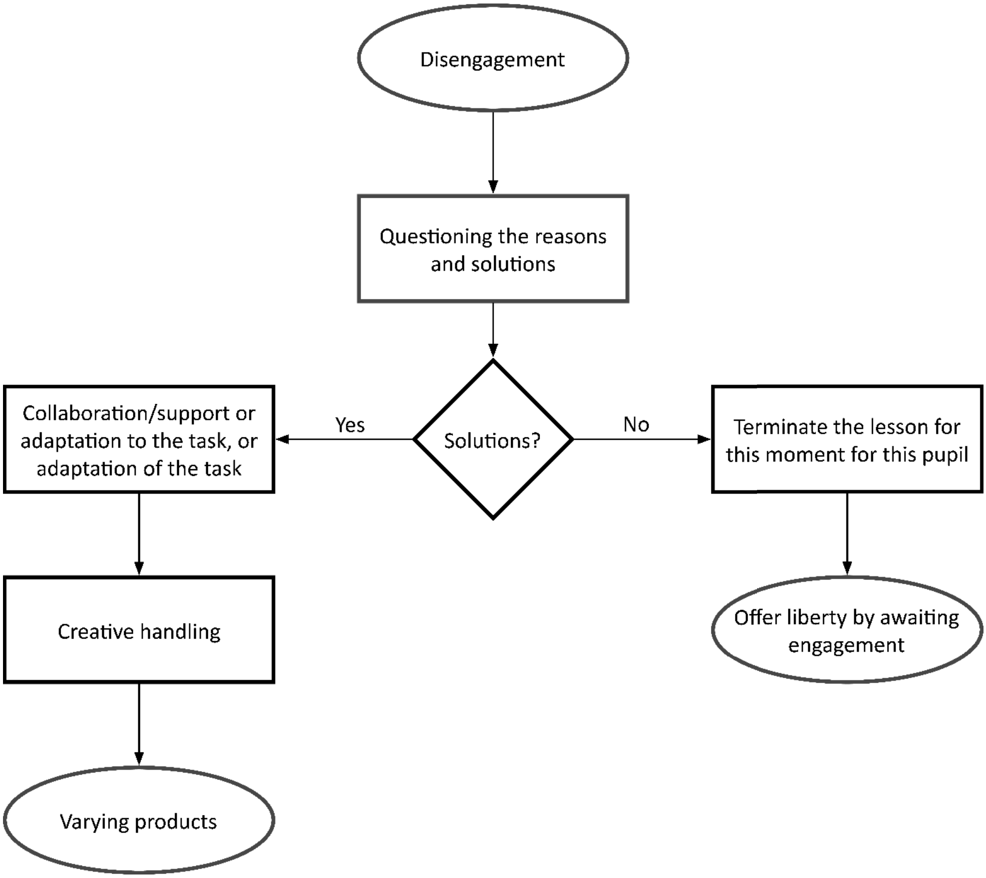


Figure 5.9. The functioning of liberty

Furthermore, the application of the Montessori view on the importance of the liberty of the pupils, helped the teacher and the researcher to accept the disengagement of pupils. Instead of investing energy and time in forcing or nudging to stop the disengagement, this acceptance helped the teacher and the researcher to question the disengaged pupils about the causes of their disengagement (Fig. 5.9). This acceptance and questioning worked out well. The waiving of a demand for unnatural efforts prevented resistance. The absence of resistance left the teacher and the researcher even more time for the active support of pupils.

5.6. Discussion and implications

5.6.1. Class atmosphere

One major observation during this case study was that especially the atmosphere in class easily improved. At the start dominated disorientation and passiveness the class-atmosphere, but during the third session the pupils were showing focus and enjoyment. During this session the pupils were finishing the by themselves thought out chairs. This is an outcome of great significance, because improvement of class atmosphere is a well-known subject in the general pedagogic and educational literature. These sources often mention the strategy to improve class atmosphere through the development of positive teacher-pupil relationships. According to Wentzel (1998) positive teacher–pupil relationships correlate to motivation and school success and are therefore important for pupils. Positive teacher–pupil relationships are according to other authors also important for teachers, because they allow teachers to experience more job satisfaction (Veldman, van Tartwijk, Brekelmans & Wubbels, 2013), teacher wellbeing (Gu & Day, 2007), and lower levels of stress (Yoon, 2002).

Where these literature sources focused on the creation of positive teacher-pupil relationships, we focused on the definition of brief, simple and objective tasks and we combined the tasks with joint presentations. We started with the creation of well-defined tasks. Secondly, during the lessons, we tried not to hamper the liberty of the pupils in any way whatsoever. Thirdly, we used joint presentations towards increasing collaboration.

As a result, we found in this study a gradually lowering level of stress in the pupils accompanied by an improving level of engagement of all pupils in the class. In addition the researcher observed a gradually lowering level of stress in the teacher and an improving level of decisiveness. Both facts benefitted the teacher-pupil relationships.

Therefore, we can say that we found a different way of achieving a positive class atmosphere. We think that the employment of well-defined tasks, combined with respecting pupil's liberty will provide opportunities to start dialogue between teachers and pupils. The joint presentations fed collaboration. Both occurrences contributed to positive relationships, showing in a positive class atmosphere.

5.6.2. Further research

The use of well-defined tasks will lead most pupils to creative hands-on work. In this study some cases of passiveness showed up. Additional measures, such as the questioning of reasons for their disengagement, and asking pupils to invent solutions for their disengagement, appeared to be necessary. Further research is useful to understand the effect of additional measures on creative hands-on work during a Design and Technology class, and how they can be best combined.

Our observations during the case-study indicate that well-designed tasks combined with offering liberty suit creative hands-on work during the Design and Technology class. Combined with the use of joint presentations the well-defined tasks appeared to lead to a multiplication of ideas, and to developing collaboration. These observations implicate that the well-defined tasks in combination with joint presentations are probably also applicable in creative classes in other domains. Further research is necessary to investigate this idea.

Another interesting item for further research could be reproducibility. The described effects on the pupils in a Design and Technology class are found in a Montessori school. In the Montessori tradition it is customary to enable pupils to start their learning through hands-on work, with a focus on a separated feature of the used learning material. (fig. 5.3). After this start, application of the gained knowledge on other aspects of reality has become possible. Thus, first the hands and then the mind becomes active, resulting in the achievement of grounded knowledge (Barsalou & Weimer-Hastings, 2005). It would be interesting to research the effects of the same intervention on pupils in a Design and Technology class in schools that pursue a more traditional educational approach. What will be the similarities and what will be the differences between the findings in our case-study and these schools?

The case-study reported in this article deals with one researcher and one teacher. Other researchers and other teachers could investigate the applicability of the approach and fine-tune the factors of the task definition and the joint presentation.

5.6.3. Transfer of the findings to other teachers

A suggestion, arisen from experiencing the successful collaboration with the Arts and Crafts teacher, is that it is worth trying coaching in class using well-defined tasks and joint presentations. This help can come from an expert coach or an expert colleague teacher. In class, both the coach and the person being coached will meet the same problems, but may have different interpretations of liberty and inability. This facilitates dialogue. Teachers can, for instance, through this coaching start to see new possibilities to handle pupil's disengagement. By drawing attention to clear occurrences of disengagement, coaching can help teachers to transform restraining assumptions. For example, the teacher in this case-study observed the effect of accepting the disengagement of pupils. Through this observation the teacher became enabled to transform her assumption that pupils require forcing or nudging in order to start them working. Instead she was enabled to question disengaged pupils about the reasons of their disengagement. She also asked the pupils to invent solutions. These interventions led to engagement (Fig. 5.9).

The well-defined tasks led to engagement of all pupils in class and in well-considered products. By focusing on one technique at the time also the intensification of the performance improved for these nine to twelve years olds. The joint presentations obviously offered shared knowledge and shared language, showing in extended collaboration.
When teachers have room for giving attention to the needs of the pupils during class, they can experiment with satisfying that needs, for instance by support. That resulted in further flourishing engagement.

In chapters two to five, five different case-studies have been presented that all focused on engagement. Although the approach taken in each study was unique, all case studies started from shared knowledge and used principles as well-defined tasks, joint presentations and liberty. The design of the task, the learning environment and the clear commitments were based on the Montessori method. In the next chapter, overall conclusions about factors contributing to engagement followed by a discussion are presented.

Every study delivered new insights, that were used in the following study. The second study included two very different case-studies. These two case-studies appeared to be complemental. Together these two case-studies delivered a deep insight about the function of shared knowledge, the main issue of the second study. The end results of this thesis tell us something about the function of all investigated factors for the rise of human engagement. Because of the use of quite different contexts, the outcome of this thesis is rather sure about the rightness of the statement that engagement is possible for all pupils in class during Design & Technology activities.

Chapter 6

Conclusions, Discussion, Limitations and Recommendations

Conclusions, discussion, limitations and recommendations

This study was started because we expected that it would be possible to engage every pupil in a class in Design & Technology activities by fulfilling the needs of autonomy, competence, relatedness and interest. In this chapter, the findings of the different studies are combined and linked to primary education as a whole. In section 6.1 the answers to the research questions are given. Section 6.2 provides a discussion. Section 6.3 concludes the chapter with recommendations for education and for further research.

6.1 Conclusions

In order to answer the research question; '*How can we engage all pupils in class during Design and Technology activities?'* five case-studies were described in four chapters.

6.1.1. Answers to the research questions of the four articles

Chapter two on iteration

The research question of the first case study was: *'What is the effect on the design performance when the same assignment is presented multiple times to six to eight years old learners?'*. The task was 'Fold a piece of aluminium foil so it can hold the weight of marbles when it lies on the water. The more marbles it can hold the better.' The study showed that performing the same task multiple times had a positive effect on the outcome, providing engagement takes place. In this case study, engagement was the result of giving pupils the means to do things their own way, as often as they wanted. The resources were a brief, simple and objective task, that guided the pupils' attention. A challenge, which was regularly renewed, ensured repetition of discovering, whereby possibilities and design solutions were considered over and over again.

The specific technique, that was used during the task to defining the mass of the marbles at the changeover point, was counting. By focusing on the changeover point between floating and sinking, while putting and counting marbles in the boat, the pupils were enabled to find the relationship between size of the floating area and buoyancy. The focus of attention (changeover point) and the concrete technique to define the outcome of the task (counting marbles) enabled experimenting. In addition, the repeated testing of designed and redesigned boats enabled the pupils to construct and refine their knowledge.

The use of brief, simple and objective tasks and the use of a facilitating learning environment restricted and controlled the level of complexity of the finding out processes. The limited complexity granted the pupils to use the liberty to do things in their own way. In other words, restriction is needed to achieve engagement. Without it, the task would have been too overwhelming.

Working in pairs and the filming of the presentations of the pupils brought new elements into the performance, such as interaction, consulting each other, observing and 'listening-in', reflection and verbalization. All these elements evoked evaluation and the sharing of knowledge among the pupils. As a result these elements furthered a knowledge growth towards a more abstract level of understanding. Also the rise of community was benefitted.

Each of the three sessions was concluded with a joint presentation, whereby the boats were put in an arranged way. That was leading to further sharing of knowledge and a refinement of insight.

The combination of a facilitating learning environment and arranged presentations enabled iteration and collaboration. The results showed that the approach used was also efficient for the teachers, as comparatively little instruction and correction by the teacher was required. Moreover, an acceleration of the class progress was observed. The autonomous handling of the pupils, supported by the facilitating learning environment, resulted in engagement.

Chapter three on groundwork

The research questions of the second study were: *'How to shape groundwork in Design and Technology Education for children aged 4-8 years old?'* and *'What are the effects of groundwork on the subsequent process of exploration and learning?'.* Groundwork is something that is done at an early stage and that makes later work or progress by pupils possible. When a teacher expects students to lack the required shared knowledge for an upcoming, planned assignment, groundwork can provide a solution. Without groundwork, engagement may be impossible to achieve.

Key characteristics of successful groundwork are interaction between teacher and pupils and between pupils. The interaction will lead to joined-up exploring, creating and thinking. It also will lead to an increased motivation to learn. Groundwork activities can result in shared knowledge. After this groundwork, the students are able to start an assignment that uses the shared knowledge.

The groundwork study comprises two case-studies. Both case studies, reported in chapter three, showed that the groundwork led to shared knowledge. The studies clarify the role of demonstrations, of brief and simple tasks, and of pupils verbalising their findings, in groundwork.

Both groundworks were preceded by a demonstration, which was accompanied by a question. The demonstration was followed by the task. The task was to find an answer to the question. In the case study 'Observe as an artist' the exploration took place in class. In the case study 'Wheels at work' exploration took place individually. The case studies both showed that a demonstration gives learners a clear idea of the technique being demonstrated when the attention is also drawn to a concrete point of perception.

The result of the brief, simple and objective task in the case study 'Observe as an artist' was the participation of all pupils in class. The following joint presentation of answers, delivered the sharing of language and views. The demonstrated and joint practiced way of 'how to see a former unseen thing' resulted in trained pupils. The pupils showed in new situations spontaneously that they could 'observe as an artist'.

The demonstration in the case study "Wheels at Work" showed lifting the same weight with a longer rope and with a shorter rope. The task was to find out the difference in force required. The result of the demonstration and the accompanying brief, simple and objective task was that the pupils were motivated to search for the mechanism behind the demonstrated leverage phenomenon.

The case study 'Wheels at work', was very informative in an unexpected way: the value of joint presentations became clear. During the third session engagement faded away and the pupils reacted with gesturing when asked to explain what they wanted to make. Their reactions reflected insight, but also the absence of appropriate words for their newly obtained knowledge. An explanation for the decrease of engagement and the absence of words could be the absence of joint presentations. During joint presentations pupils verbalize their findings. By verbalizing their findings, pupils are reflecting on their findings. Reflection provides the transformation of concrete knowledge into more abstract knowledge. Sharing findings provides joint knowledge and joint language with a joint meaning.

This case study provided insight into the importance of joint presentations for ongoing engagement. The research showed that by missing joint presentations, pupils missed out on (joint) knowledge and joint language with a joint meaning to be able to talk about the task. They also lacked knowledge at the right level of abstraction to imagine new applications. These two problems led to a lack of engagement during the third session.

Chapter four on the initiation of Verbalization

The awareness of the importance of verbalization as a skill that enables interaction and engagement, resulted in the research question of the third study: *'How can a teacher initiate verbal expression in young children in Design and Technology Education?'.* This question led to two sub- questions: *'How can teachers induce subject related thoughts in pupils?'* and *'How can teachers enable the transformation of those thoughts into informative verbal expressions?'*. Designing is a thinking activity that benefits from verbal expression because this serves interaction and abstraction.

The case-study 'talking about my cuddly toy' showed that two things are necessary to initiate verbal expression in young pupils. Firstly, the induction of expressible subject related thoughts is necessary. Pupils have to feel smart and competent to enable the emergence of expressible thoughts. Secondly, focus on the development of a shared vocabulary is necessary.

The induction of expressible subject related thoughts was accomplished by providing a familiar object and a simple view to look at the object. The familiar object was a cuddly toy. The class cuddly toy turned out to evoke less expression than the own cuddly toy. The simple view was taken care of by using the thinking hats of De Bono. The measure of dividing complexity into five perspectives on the cuddly-toy led to a sort of role-play.

A shared vocabulary was achieved by a demonstration of the rules and means of getting clear thoughts. By using the thinking hats complex thoughts changed into simple thoughts. Each colour of hat stood for a specific point of view. Also the verbalisation of the thoughts was demonstrated. Then the pupils were allowed to tell about their cuddly toy. The teacher helped them to use the thinking caps correctly and to choose the right words.

The result of the use of the own cuddly toy and the scaffold of the teacher was the emergence of a shared instrument to discuss issues in class with. At this age such an instrument is important, because children still lack the vocabulary to discuss issues with. When teachers enable them to express their thoughts in an understandable way, they will be able to talk about other issues as well, for instance about 'how to solve a quarrel'. When pupils can discuss a quarrel out of the different points of view of the pupils involved, using the Bono hats or a similar instrument, a shared solution can be easily found.

Interlude

The results of the case study 'Observe as an artist' and 'Talking about my cuddly-toy' clearly show that engagement became possible by making use of brief, simple and objective tasks. That finding was used during a pilot study in an Arts and Crafts class with six to nine years olds, that suffered from many disengaged pupils. This pilot – that has not been described in the chapters before - showed that an intervention of brief, simple and objective tasks was helpful to decrease disengagement and to increase engagement. That finding pointed to the idea that absent engagement indicates one or more specific needs of pupils that has not been satisfied by the existing learning situation. Only at the moment that all required needs with regard to a task are satisfied, pupils are able to start the performance of a task. Their behaviour shows then engagement. The use of brief, simple and objective tasks increases the likelihood that the learner's need for competence will be satisfied. So in a situation where autonomy is the norm, both the need for autonomy and competence will then be satisfied. If there is a good atmosphere in the classroom as well, the need for relatedness will also be satisfied.

The case study ‘Observe as an artist’ is an elaborated example of the engagement that emerges as an effect of the satisfied needs of pupils. The teacher made sure that the given information was sufficient, the level of mastery of all pupils was sufficient, clarity of the task was sufficient, liberty was assured, self-determination was possible and that the task was motivating. As a result the brief, simple and objective task ‘look around until you see something unseen before’ caused a simple, challenging, not confusing view of the pupils on the task, that motivated the pupils to perform the task, resulting in engagement of all pupils in class.

This case-study also practically illustrates how teachers can create brief, simple and objective tasks. Starting point is that the teacher satisfies pupils’ need for autonomy, competence, relatedness and interest. In a classroom situation where autonomy and a good atmosphere are the norm, pupils only need a brief, simple, objective and challenging task to get engaged. When analysing a curriculum goal from the pupil's point of view, several sub-goals for brief, simple, objective and challenging tasks can be distinguished. Linking the sub-goals to tasks creates a collection of tasks. The goal of a sub-task can be seen as a sub-goal of the overarching goal.

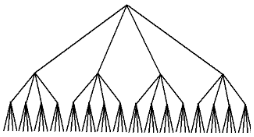
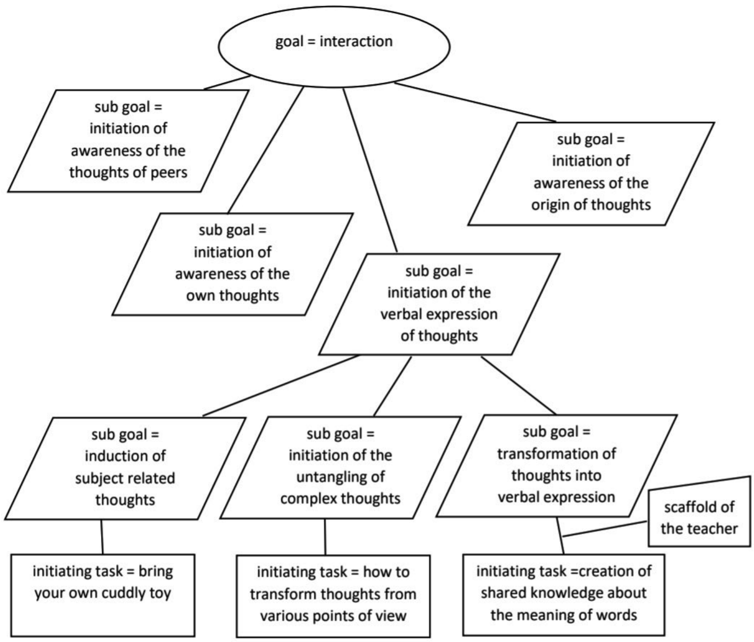


Figure 6.1 dividing an overarching learning goal in simple goals

Looking top-down (fig. 6.1), it is possible to divide each overarching goal in several concrete sub-goals. For instance, when we analyze (fig. 6.2) the overarching goal ‘interaction’ we find four sub goals. The sub goal ‘the initiation of verbal expression of thoughts’ is in the case study ‘talking about my cuddly toy’ divided in three sub-goals: ‘the induction of subject related thoughts’, ‘the untangling of complex thoughts’ and ‘the transformation of thoughts into informative verbal expressions’. The first sub-goal led to the groundwork task of bringing one's own cuddly toy from home, because topic-related thoughts are easier if the object of the thoughts is well known. The second sub-goal led to a groundwork task that created knowledge about how to transform complex thoughts into simple thoughts by means of the thinking hats of De Bono. The third sub-goal led to a groundwork task that created the shared language that could be used to verbalize a simple thought about the cuddly toy.



Figuur 6.2 dividing a goal in sub goals of tasks that are making use of the possibilities of the pupils

The shared knowledge had to be practiced to become usable. Therefore, the third groundwork task was practised in class. The knowledge of the task was applied to the own cuddly toy. The practice was supported by the teacher.

In short, a top-down approach could start from a curriculum goal and end with a sub-goal that the pupil can handle, while a bottom-up approach may start from the learner and lead to the fulfilment of a curriculum goal through sub-tasks with sub-goals. That is an important finding, because it makes it possible to fine tune tasks to the pupils, so that they can work towards curriculum goals in an engaged way.

The first three articles showed that joint presentations are a good tool for connecting sub-goals to a goal of a higher level of abstraction. The induced reflection and the sharing of gained knowledge during a joint presentation, appeared to build the starting point for a task of a higher level of abstraction.

Chapter five on Dividing a complex task in a series of well-defined tasks

We have now seen that reaching a learning goal can also be seen as taking steps. Sub-tasks that make use of the learners' abilities can bring an unattainable goal within reach for all learners. Therefore the research question of the fourth study was: *'What is the effect of dividing a complex Design and Technology assignment into well-defined tasks, combined with joint presentations?'*. The sub-questions were: *'What is the effect on the design performance of pupils aged nine to twelve years old?'*, *'What is the effect on collaboration in class?'* and *'What is the effect on the teacher?'*. Engagement is important during the Design and Technology class. Engagement is necessary to start a Design & Technology task and engagement is also a sign that the task meets the needs of the pupils. A condition for engagement during a Design & Technology task is the limitation of complexity. This condition was discovered in the first three studies. When tasks offer learners the opportunity to acquire knowledge about isolated details of the learning situation, complexity is limited and controlled. In the fourth study, complexity is limited by transforming the intended product of a complex task into ten objective sub-products of brief and simple tasks, whereby the learning goal 'Make your favorite chair' was the context for all intermediate products. This idea is explained in the interlude. When a sub goal is objective, the performance of a brief and simple task can lead to the achievement of the sub goal by all pupils. The ten tasks guided the focus of the pupils during the performance of the separate tasks from the intended product of the whole assignment 'Your favourite chair' towards an objective intermediate outcome of each of the tasks. This guidance resulted in the enabling of the use of own ways of handling. Each task was focusing on one technique at the time. The ten tasks were executed in four sessions and enabled all pupils to ongoing engagement.

Two of the four sessions of this case study ended with a joint presentation. The joint presentations led to shared knowledge and refinement of the designs of the final product, the mini chair. The sharing of processes and ideas in the joint presentations proved to be very useful in maintaining an active engagement of all students in the class, resulting in well thought-out designs and products. The sharing of processes and ideas also strengthened collaboration.

The main goal of this case-study was to engage all pupils in the process of making and discovering, especially initially disengaged pupils. In Design & Technology education it is usually not possible to engage pupils who are not engaged. In our study, however, all pupils became engaged. This was achieved by reducing firstly the complexity of the assignment. Secondly, the teacher's questioning of the reason for disengagement helped. In this dialogue, the effects of not participating on the rest of the class were discussed, complemented by the discussion of alternative ways to deal with the task. In this way, these pupils came up with their own solutions for still being able to participate. As a side effect of the discussions, teacher-pupil relations and pupil-pupil relations improved.

6.1.2. Answers to the overarching research question of this dissertation

From the four chapters can be concluded that the answer to the research question of this dissertation: '*How can we engage all pupils in class during Design and Technology activities?'* is, that pupils during Design & Technology activities in class need well-defined tasks, liberty and ample room to experiment. In addition they need joint presentations to achieve ongoing engagement, see table 1 below.

Table 6.1. *The effect of the application of the interventions*

Study/intervention	*Shared insight*	*Collaboration towards the goal*	*Ongoing engagement*	*Reduction of required instruction/correction*
1. iteration	Into the phenomenon of floating and sinking	Yes	Yes	Yes, showing in room for the teacher to observe and question pupils
2. Groundwork	Into methods of discovery, i.e. observation and feeling the power that you have to use	Yes	Yes; in subsequent everyday situations	Yes, showing in room for the teacher to observe and question pupils
3. Initiation of verbalization	Into the verbalization of complex thoughts	n.a.	n.a.	Yes, showing in the gradual decrease of the required scaffold of the teacher
4. Stepwise approach	Into the construction process of a mini chair	Yes	Yes	Yes, showing in room for the teacher to observe and question pupils

From the four studies of this dissertation, it can be learned that engagement during Design & Technology activities has two functions for the pupils; the discovery and acquisition of knowledge about a subject, and the practice of Design & Technology.

The studies show that there are different ways to focus pupils' attention. In two case studies, I used a technique, with an associated product, to provide focus for the pupils while performing the task. In the case study 'The marble boat', the focus was obtained through the technique of counting marbles and linked to the focal point of the phenomenon under investigation, the switching point between floating and sinking. In the case study 'Making a mini chair' the focus was obtained through different techniques; each task required a different technique. The aim of the subtasks was to serve the question "What is your favourite chair? Therefore, the products of the techniques had to be adapted to the intended favourite chair.

In the other studies, perception was used to provide the students with a focus during the task. The skills used were perception, sensing, and seeing an object from different perspectives. The focus of attention was linked to a concrete goal of the task: respectively, 'see a previously unseen thing', 'perceive the difference in strength required' and 'talk about your cuddly-toy from a self-chosen perspective'.

The findings of the studies show that the practiced techniques/skills of tasks require a concrete character. Further on the findings suggest that the attention of pupils can be caught in several ways.

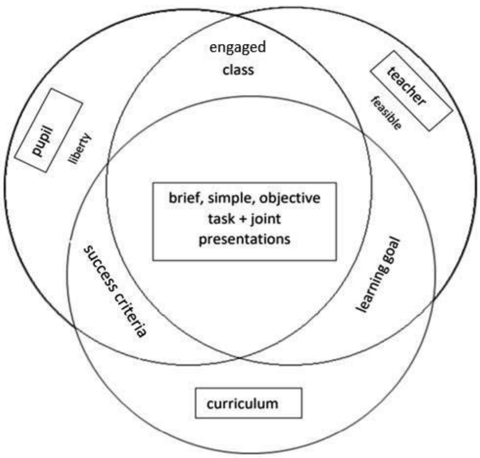


Figure 6.3. An activity can at the same time work towards curriculum goals, allow for teacher guidance, offer challenge and meet the psychological needs of all pupils in class, through well-defined tasks combined with joint presentations.

Based on the findings of the studies and the explanations found in the literature, it can be concluded that engagement can occur when the activity in question is characterised by the presence of brief, simple and objective tasks, liberty, and joint presentations. This does not prevent the achievement of curriculum goals. In this way, it is also possible to achieve all curriculum goals The presence of brief, simple and objective tasks, liberty and shared presentations make self-determination possible. By using self-determination, the activity can also have an impact on the achievement of a deep and broad knowledge growth related to the learning goal addressed (Barsalou & Wiemer-Hastings, 2005). Deep and broad knowledge growth serves personal development. In addition, self-determination makes good teacher guidance feasible.

Discussion

6.2. Discussion

The purpose of the research in this thesis was to find ways to engage all pupils during Design & Technology activities.

The goal of finding solutions for lacking engagement pushes the research in this thesis in the direction of satisfying psychological needs, complemented by the generation of interest. That is a different direction from that of most empirical educational researches. Many studies in the field of Design & Technology education have looked for an effect of one type of intervention on learning outcomes or performance success. An example of such a study, in the field of inquiry-based learning, is the meta-study of Lazonder & Harmsen (2016) on the effect of guidance on discovery learning.

The findings of this thesis have led to the assumption that a holistic approach will be needed to achieve engagement. Engagement could be seen as an expression of the fact that there is an interest and an opportunity for self-determination. The assumption that a holistic approach is needed to enable self-determination is based on the Self-Determination Theory (Deci & Ryan, 2000). It follows from this theory that the needs for autonomy, competence and relatedness all need to be satisfied in order to make self-determination possible during the performance of a task. The assumption that interest is needed in addition to self-determination in order for there to be self-determined handling, is based on Vygotsky's (1978) theory that development takes place in the zone of proximal development. A manageable challenge is located in the zone of proximal development. A manageable challenge invites the self-organisation of a task in order to meet the challenge. This process manifests itself in interest.

The first three studies looked for opportunities to achieve pupil engagement from a situation in which liberty was considered normal. This provided autonomy. Therefore, pupils also found it normal to offer liberty to their classmates. This created relatedness. Therefore, these studies only had to reflect on sufficient competence and interest. If engagement occurred, we could be sure that both competence and interest would be in order.

In the fourth study, the situation was different. The study aimed to find out how older children aged nine to twelve could be enticed into engagement. This study started from a situation in which autonomy was desired, but did not come about as a matter of course. So the aim was to find out what these pupils might need in order to experience not only competence, relatedness and interest, but also autonomy. From the first three studies, we already knew a lot about the elements that determine competence, relatedness and interest, so we used this knowledge to design the intervention of the fourth study. In this way, we could learn more about the elements that enable autonomy. We already knew from the Montessori literature that liberty is an important component. Furthermore, the starting point of this study was that it should be possible to engage these older learners, because the fact that every human being has the psychological needs for autonomy, competence and relatedness says something about the usefulness of satisfaction at any age.

For the creation of all case studies, we used elements from two approaches known at the time; one based on cognitive theories (Kirschner, Sweller & Clark, 2006) and the other based on constructivist theories (Papert & Harel, 1991). The elements of the cognitive theory focused mainly on gaining competence. The elements of the constructivist theory focused mainly on gaining autonomy. In order to achieve self-determination, the selected elements were refined on the basis of insights from the Montessori method (Gutek, 2004).

In this discussion, elements of the ‘recipe ‘approach and the ‘open design’ approach from chapter 1.2 are taken as clear examples to discuss the difference with the elements of the approach we have devised.

The aim of the detailed investigation of the effects of different elements on engagement is to find beneficial elements and blocking elements. Knowledge of the beneficial elements makes it possible to use them to gain engagement. Knowing the blocking elements allows their avoidance.

In the conclusion, the essential elements of a well-functioning approach have been formulated. Here, we discuss how this approach could enable self-determined action. In addition, we discuss what the developed insights could add to the existing body of knowledge in Design & Technology education. The successive sections of the discussion focus on the four interventions of the studies in this thesis: iteration, groundwork, initiation of verbalization, and a stepwise approach. The final section summarises the beneficial elements found and their effect on the pupil, the classroom and the teacher. The effects are explained by means of literature sources.

6.2.1. Iteration

The aim of the first case study ‘the marble boat’ described in chapter two was to engage all pupils in the iterated performance of the same task. The approach that bridges the gap between the ‘recipe’ approach and the ‘open design’ approach towards ongoing iteration, is described below.

In an ‘open design’ approach concrete focal points of attention or concrete tasks are usually not given. However, unlike this aspect of ‘open design’ approaches, in the case study ‘the marble boat’ all pupils received a concrete task (fold a sheet of aluminum foil towards a floating ‘boat’, that can hold many marbles) with a concrete focus, like in ‘recipe’ approaches. On the other hand, a ‘recipe’ to make the boat was not given, but the learning situation offered the pupils the possibility to self-construct knowledge about the relationship between buoyancy and floating area of the boat by trial and error, like in ‘open design’ approaches.

When our approach is compared in more detail to ‘open design’ approaches, three things are different. Firstly, a concrete focus of attention is given. The changeover point between floating and sinking represented the focus of self-monitoring. Secondly a concrete task is given. The task of ‘counting marbles, while watching floating/sinking’ supported the discovery of the relationship between mass and buoyancy of the boat. Thirdly, the addition of a joint presentation of arranged products – all solutions to the same task - was applied to increase insight towards more optimal solutions.

Compared to ‘recipe’ approaches our approach gave not a ‘recipe’ to the pupils of how to handle the task. Instead the pupils had to experiment. In ‘recipe’ approaches the instructed technique ‘make a boat’ would have led to a boat that floats. In the ‘marble-boat’ approach the instructed technique ‘counting marbles, while watching floating/sinking’ was leading to the evaluation of the buoyancy of the boat. The exploration of how to fold the aluminum foil resulted in a variety of marble boats.

Our approach enabled self-monitoring by including on the one hand elements of ‘recipe’ approaches, e.g. the concrete focus of attention and the concrete task ‘counting marbles, while watching floating/sinking’. On the other hand elements of ‘open design’ approaches were included, e.g. self-constructing of knowledge through the exploration of the effect of different forms of boats. Elements from the Montessori Method (Gutek, 2004) were added, e.g. liberty, the freedom to work at their own pace, and varying collaboration. The idea of facilitated play and tinkering originates from John Dewey’s ideas about play (Dewey, 1899).

Furthermore, elements that would disturb self-monitoring, were avoided, e.g. vagueness, absent capability, a focus on the product instead of on the process, and absent evaluation.

Due to the combination of adapted elements of 'open design' and 'recipe' approaches, and added elements of other sources, self-monitoring arose. The purpose of the task was to further pupils' insight into the relation between the size of the floating area and buoyancy, whereby the marbles represented the mass. Focus was accomplished by guiding pupils' attention to the changeover point from floating to sinking through counting marbles. That focus enabled the pupils to judge the buoyancy of the boat by counting the amount of marbles that the boat could hold without sinking.

The results of pupils' testing of buoyancy showed a growing knowledge about the phenomenon of floating and sinking, indicating that targeted learning took place. The variation in products and the many undertaken iterations of making and testing, indicated the self-construction of knowledge. The 'bridge' approach enabled pupils to discover the factors that are benefitting floating, the factors that have no influence on floating, and the factors that have a negative influence on floating. The formidable number of marbles, that some marble-boats could carry without sinking, indicated that insight was gained. Thus, the concrete knowledge growth, central in the 'recipe' approach, was reconciled with the self-constructed knowledge growth, central in the 'open design' approach by means of self-monitoring, an important characteristic of autonomous learning (Montessori in Gutek, 2004).

When we analyze the bridging, we can conclude that firstly the provision of a simple task (fold a sheet of aluminum foil) provided for situational autonomy.

Secondly, the sub-task that used the technique of counting marbles with a focus on floating/sinking enabled iterated self-monitoring. Where concrete goals in 'recipe' approaches represent the end of a task, the concrete goal in the case study 'the marble-boat' was to notice the floating/sinking of an aluminum sheet, folded as a boat. The goal represented the focus of attention during self-monitoring. Iterated self-monitoring was triggered by the task 'to fold a sheet of aluminum foil *that can hold as many marbles as possible*'. To achieve that goal the pupils had to find the changeover point between floating and sinking repeatedly, while counting the marbles.

Thirdly, the 'bridge' approach provided diverse opportunities to practice evaluation. Evaluation of the buoyancy took place by regarding the amount of marbles as the mass and regarding the floating area of the boat. The pupils discovered little by little that a big floating area could hold more mass without sinking than a small floating area. Diverse forms of collaboration benefitted evaluation as well. Evaluation supports, according to Zohar & Dori (2012), the development of metacognitive knowledge in science education. Although evaluation in itself is not new in the field of DBL, the combination with self-monitoring and collaboration is rather new. The presentations in front of the video and the joint arranged presentations were offering opportunities to practice evaluation in yet another way. For example, the joint arranged presentations explicitly coupled the size of the floating area with the buoyancy of the boat.

The joint presentations helped the pupils to learn to think and act like designers by addressing the 'why and how' (Van Dooren, Asselbergs, van Dorst, Boshuizen & van Merriënboer, 2020). In this way, the joint presentations delivered the anchor to continue iteration. The same effect is described by Bhattacharjee (2019). Bhattacharjee used joint presentations to start a lesson. She used in-class discussions and activities as a supplement to the review of lectures and construction videos. She found that summarizing earlier work and resuming class from that point, increased pupils' engagement, resulting in better student performance. Joint presentations have the same aim as feedback has but the effect is quite different. Schut, Klapwijk, Gielen & de Vries (2019) used feedback as another way of discussing results of learning. At the moment that the pupils were giving each other feedback, a widespread effect of resistant responses showed up. That effect can be explained by viewing feedback as criticizing what has happened and has become irreversible. Irreversible actions are not evoking a feeling of ‘I can change that’. On the other hand approaches that are just reviewing what has happened, are leading to the exploration of new possibilities. Insight will increase even more, when in addition the reviewed results are arranged from successful to less successful.

The ‘bridge’ approach improved the learning process and the learning. We found that the continued iteration resulted in perfection of the concept knowledge about the floating and sinking of an aluminum sheet. This high level of insight was not expected at the start of this research. This is an important outcome, as according to the cognitive scientists Barsalou & Weimer-Hastings (2005), insight can function as an anchor in unknown situations. Compared to ‘recipe’ approaches, the ‘bridge’ approach is improving the nature and quality of learning. Pupils who follow a ‘recipe’ towards a boat, are not exploring other options than the ‘recipe’. As a result they are not developing the comparative data, that is required to construct insight.

Compared to the ‘open design’ approach, the ‘bridge’ approach is improving the ability to participate. Pupils, who are feeling incapable, are unable to participate in learning. Feeling incapable to do a task is for instance showing in avoidance orientation. Incapable feeling pupils will remain passive until they have found sufficient information to make them feel capable. When they are not met in their incapable feelings, they will drop out (Lindfors, Heinola & Kolha, 2018). Pupils with such an orientation are present in any class and surely among the complete group of 41 fourth grade pupils (seven to nine years old) in our research.

The second improvement is shared learning, as a result of shared learning goals. When pupils follow their own interests, shared learning is minimal. When different problems are solved, the shared data is not comparable with the own data. Besides the shared data often lacks connection with own experiences. When the same problem is solved in several different approaches to the solution, the shared data can be compared to the own data and equally enriches the knowledge of every pupil (Takahashi, 2006, p.42). As this case study shows, was shared learning an important source for adjusting the personal viewpoints on the phenomenon of buoyancy towards growing insight. The pupils became inspired by the knowledge-expressions of their peers. Their interest in the work of others also stimulated collaboration and cooperation. Also joint presentations have more value when shared learning goals are central. When all pupils have the same learning goal, they have the same interest. Therefore every individual presentation during such a joint presentation is influential for the personal knowledge development with regard to the own product. Above, the knowledge in a community about the specific learning goal is more than the knowledge of one person. Concluding it can be stated that shared learning is furthered by shared learning goals. This finding is in line the argument of Gibson (2019), who writes that the combination of a shared goal and a shared value system makes it possible to collaborate and cooperate in a crafting community of practice.

As far as we know, there are no other studies available that achieve engagement of all pupils in iterative design on primary level. At secondary school level one study was found showing that iteration can be a part of a didactic strategy (Bamberger & Cahill, 2012). Teachers at middle school level included redesigning and rebuilding in their didactic strategies with a positive result. Pupils learned from discussing the weaknesses and the strengths of the designs with each other and gained insights that are employed for redesign. The findings of this case study show that also primary pupils are able to iterate under the described conditions. They appeared to achieve and optimize their design goals through iterations. This is important for design education in the foundational years, as claimed by Chusilp & Jin (2006), who state that iteration is one of the most basic features of the design process. Gurnani & Lewis (2008) indicate that discussing the weaknesses and the strengths of the various designs with each other helps engineers to gain additional knowledge. Engineers use this new knowledge subsequently to go through a next cycle of redesigning and rebuilding.

Iteration includes both evaluation and the development of new designs. For optimal iteration it is important to avoid gaps in the continuation of pupil's action. Such gaps easily result in a loss of focus. To achieve that, the learning situation was coordinated in such a way that allowed simultaneous activities. Collaborative product development was used as a strategy to accomplish this, see the case study for the various strategies used. The tightly organized learning environment enabled the pupils to playfully find their own path towards the 'product', a well-floating boat. By doing different things at the same time for the same purpose, the pupils were inspiring each other towards the improvement of their ideas.

The strategy to facilitate collaborative product development was taken from the Montessori tradition and is also found in the field of engineering (Cao, Han, Yang, Yang & Cui, 2008). The strategy allows the simultaneous occurrence of different actions. The use of the strategy resulted in the acceleration of the class proceedings. At the same time it provided room to play. Room to play arises when pressure is absent. According to the educational Philosopher John Dewey (1899) play has the potential to evoke an extensive occurrence of iteration, because an identifying aspect of play is purposelessness. Playful learning requires a learning situation with a transparent and uncluttered learning environment, and brief, simple and objective tasks. In order to achieve learning goals, pupils' attention has to be guided towards shared goals. Tasks with concrete goals support the guidance from pupils' different viewpoints towards the shared concrete goal. Such learning situations are well known in the Montessori tradition, because such situations offer pupils Montessori's (Gutek, 2004) liberty. Liberty in turn is necessary to experience Dewey's purposelessness (Dewey, 1899) and room to play and experiment. The strategy of taking account of pupils' restricted knowledge comes from the Montessori tradition, but the recognition of the phenomenon of restricted knowledge is also found in the field of policy. The economist, political scientist and cognitive psychologist Simon (1997) states that the range of possible outcomes of human actions is bounded. Rationality is bounded by the viewpoints, the knowledge and the capabilities of a person. Applied to pupils it is possible to understand that their very bounded rationality requires simplicity, transparency and unclutteredness to prevent the overwhelm that blocks play towards iteration.

A continuous renewal of the challenge is essential for iteration and was until the performance of this case study not explicitly practiced in primary design education as far as we know. According to the developmental psychologist Vygotsky (1978) renewal of the challenge can be raised by a cognitive conflict in the 'zone of proximal development' and evokes tangible mental discomfort. A cognitive conflict is the result of a confrontation with new information that contradicts prior beliefs and ideas. A renewal of the challenge stimulates the start of a next cycle of redesigning and rebuilding. The importance of the renewal of the challenge showed in the last session. The attitude of half of the pupils expressed the feeling 'I am already done'. That confirms that our strategy to offer pupils the same task over and over again, is insufficient to renew the challenge. Pupils require slightly different starting points of tasks (that imitate the process of play) to remain engaged. In the first two sessions the different formats of mandatory collaboration provided for slightly different starting points. That element was missing in the third session. Not only the organization of collaborations with peers can be used, the renewal of the challenge can be stimulated by the participation of teachers during the performance of tasks as well. When a pupil is showing disengagement the pupil can be asked what he/she can do. This way of offering a renewed challenge by means of dialogue is also applied in other case-studies, e.g. the last one. A clear description of teacher participation towards transformative learning is given by Brody (in Brody & Hill, 1991), who is an American author of Ethical and Social Issues in Professional Education.

The 'recipe' approach assumes that targeted learning requires a 'recipe' of a way towards the learning goal. This assumption is proven wrong by the findings of this case study. When the teacher avoids cognitive overload, a 'recipe' of the exact way towards a fixed outcome is not required. The enabling of self-monitoring works just as well. Cognitive overload can be avoided by taking account of pupils' restricted knowledge resulting in the employment of sub-tasks that are allowing different viewpoints, using mastered techniques and have a focus point on a mastered level of abstraction.

The 'open design' approach assumes that clearly defined goals have to be avoided to achieve the self-construction of knowledge. This assumption is proven wrong by the findings of this case study. Pupils can follow their own interest by making a broad, explorative design process important. When concrete goals and concrete tasks are given, insight can be gained in the 'why and how' of the process of discovery, designing and making. That is exactly the aim of a primary Design & Technology lesson.

The choice for many characteristics of the facilitation of iterated DBL was influenced by Montessori's idea about self-monitoring (Gutek, 2004) towards autonomous learning. The characteristics aiming on the facilitation of self-monitoring concerned:

- environment (uncluttered and transparent. Adjusted to the mastery level of the pupils),
- task (brief, simple, objective. Adjusted to the mastery level of the pupils),
- liberty (supported collaborative learning and playful experimenting),

These are in summary the newly found insights of this case study with regard to the current practice of Design and Technology Education:

- Subtasks can solve the problem of insufficient abstract thinking. Such a subtask delivers a focus of attention that helps to perceive a phenomenon on a mastered abstract thinking level. In this case study was the mastered abstract thinking level found in the technique 'counting' and perceiving floating/sinking.
- Iteration serves not only the learning of content, but also the learning of performing the process of designing and making.
- Iterated testing on primary schools can be achieved by slightly different starting points of tasks in order to imitate play.
- The optimizing of the learning situation improves efficiency and offers room to play. The optimization of the learning situation indirectly delivers opportunities for collaborative product development. Collaborative product development stimulates the rise of a community of practice. An additional profit of collaborative product development is inspiration towards the improvement of ideas.
- Joint arranged presentations renew the challenge.
- Presentation in front of the video evokes reflection. Reflection evokes abstraction and insight

6.2.2. Groundwork

The aim of the second investigation 'groundwork' in chapter three was to create a shared focus for the class. That shared focus would help to engage all pupils in the subsequent design and technology tasks. The approach for creating a shared focus of attention is described below.

In 'open design' approaches concrete focal points of attention or concrete tasks are usually not given. However, unlike this aspect of 'open design' approaches, in the 'Groundwork' case studies

'Observe as an artist' and 'Wheels at work' all pupils received a concrete task with a concrete goal ('Look around until you see something that you have not seen before', 'Find out the differences in required force', respectively) like in 'recipe' approaches. The tasks were accompanied by a demonstration to show 'how' the execution of the tasks looks like in reality.

Complementary, a 'recipe' of what to see (observe as an artist), what to do (wheels at work), respectively was not given. Instead, the learning situation offered the pupils the opportunity to determine the implementation of the task themselves. In the first case study, the task was about discovering the relationship between looking around and discovering unseen things. In the second case study, the task was about discovering the effect that a lever mechanism has on the force required to lift a weight. By performing the task in different situations, the pupils were enable to experiment in order to gain insight, as in 'open design' approaches.

Our approach created a shared focus of attention by including on the one hand elements of 'recipe' approaches, e.g. the concrete goal. On the other hand elements of 'open design' approaches were included, e.g. the construction of meaningful knowledge by means of exploration. Additional elements from the Montessori Method (Gutek, 2004) were liberty and free collaboration.

Furthermore, elements that would disturb the creation of a shared focus were avoided, e.g. vagueness, low competence, a focus on the product instead of on the process, and absent opportunities for evaluation.

A demonstration to show 'how' a task looks like in reality, to make the task concrete, that was followed by the application in other situations, was rather new in the field of Design & Technology Education. The importance of knowing 'how' of a task can be done is widely recognized. For instance Kimbell and Stables (2007) state that the interaction between the mind and hand is required to create the knowledge about the 'how' a task can be done. In addition, Montessori recommends that the acquisition of knowledge should begin with an experience. So the 'hand' is the starting point for learning. This can be explained by bearing in mind that words can only have meaning when they are linked to an experience. A word that cannot be imagined is 'empty' and useless to serve as an 'anchor' in unfamiliar situations (Barsalou & Wiemer-Hastings, 2005). Most sources, which speak of the need for self-construction of knowledge, do not provide a way to initiate the necessary grounding experience. 'Groundwork' initiates grounding by offering pupils a concrete goal (the check point) and a concrete task to make exploration usable. The strategy of initiating the explorative process by an demonstration exact to be imitated, followed by practice in other situations, is at the moment not identified as a crucial strategy in the field of Design & Technology Education. Therefore, this strategy is generally absent in Design & Technology Education studies.

Based on observations we assume that the presence of a concrete checkpoint as a focus of attention is benefitting the emergence of grounded knowledge. We made these observations during the case study 'Observe as an artist'. We observed that the task became applied in very different situations with amazing results. Although more research is necessary on the exact mental processes going on, the fact that transfer of the task to other situations took place, is a clear indication that pupils mastered the 'how' as well as understood the 'why'. Apparently, pupils need to be aware of the 'why' in order to be able to use the same task in other situations.

The importance of 'why' a task has to be done, is widely recognized. In the field of Science Education are Aalst & Sioux Truong (2011) stating that the effort for the pupil is to understand 'why' the task has to be done, instead of just performing the task. In the field of Design & Technology Education is stressing McCormick (1997) the fact that learning is a mental process, structured by the 'why', and based on context, activity, available tools and the interactions with other people. The anthropologist

Lave (1988) states that a teacher cannot simply transfer concepts to pupils. Pupils need to know "why" a concept is useful, in order to actively attempt to fit the introduced concept into their already existing knowledge.

‘Groundwork’ uses the ‘why’ as well as the ‘how’. In our view the development of the ‘why’ is preceded by explicitly showing the ‘how’. Without knowing ‘how’ to exactly do a task it is impossible to be able to perceive ‘why’ the task can be usefull.

Somewhat different from most sources in Design and Technology Education, is Mioduser’s (2009) claim that to know ‘how’ to solve technical problems (technical problem-solving, TPS), is essential. His reasoning comes near ours. Concrete knowledge about ‘how’ a machine works, accompanied by knowledge about the foci of attention (the checkpoints), delivers information about ‘why’ a machine works or not. Only then, ‘how’ to solve technical problems can follow. Thus, learning the ‘how’ of solving problems have to be preceded by exact knowledge about the ‘how’ of the working of parts of the machine.

Our approach and reasoning is similar to the idea of teaching micro competences, advocated in the European study ‘Creative little scientists’ (2012). In this study it is assumed that the identification of the ‘how’ of micro-competences, with accompanying foci of attention can lead to understanding the 'why' of a micro-competence. Then application of such micro-competences in different situations becomes possible. Our findings confirm that. For instance, the fact that transfer of the task to different situations was taking place in the case study ‘Observe as an Artist’, is a clear indication that pupils mastered the ‘how’ as well as understood the meaning, the ‘why’. The importance of the practice of ‘Observe as an Artist’ in class showed in the furthering of autonomy and relatedness. The pupils had learned to discover solutions. That made them less dependent of the opinions of others. Moreover, from then on they were able to take responsibility for their own actions. Both abilities contribute to Mercer’s larger goal; ‘It is in the interests of society that children are taught how to become effective 'inter-thinkers' by using or educating the social brain’ (Mercer, 2013, p. 164).

The importance of concrete knowledge about the focus of attention supplemented with insight in the relevance of the focus, showed in the on ‘Groundwork’ following Design & Technology tasks. The knowledge about the ‘how’ and the ‘why’ functioned as a stepping stone towards engagement. In both case studies all pupils showed engagement during the subsequent tasks. In the case study ‘Observe as an artist’, it was observed that every pupil in class undertook actions that showed insight in the principle of seeing earlier unseen things, indicating that learning was conducted by the focus (something unseen before). In the case study ‘wheels at work’ similar results were obtained, as all pupils were playfully exploring machines towards the focus (perceive differences in required force).

An important result of ‘Groundwork’ was the engagement of all pupils. The presence of a focus of attention was helping to avoid the muddling through of many ‘open design’ approaches. The amount of pupils with avoidance orientation was small and decreased to zero in both case studies during the subsequent discovery tasks. The quality of learning in the groundwork approach will generally be better than in 'recipe' approaches. As pupils gather reference knowledge (the checkpoints) about the 'how' of a discovery strategy and then use it during subsequent discovery tasks, they gain insight into the 'why'. The understanding of the 'why' enables a broad application of the 'how'.

The use of 'ground work' avoids incompetence.

When ‘Groundwork’ is combined with joint presentations, there has been found an appropriate method to prevent the often diagnosed design fixation in ‘open design’ approaches, as described by, among others, Schut et al. (2019). An exploration before the start of a design task can provide starting points to pay attention to during joint presentations of the intermediate results during the execution of the design task. The exploration should be about the point of attention during the design process and about the success criteria of the outcome of the task. This can prevent fixation during the design process. The educational philosopher Dewey (1938) states that formalized instruction does not lead to the wonder that is necessary to start exploration. However, the findings of both case studies show that also unfamiliarity with the ‘how’ of a strategy can disenable pupils to start broad wonder and exploration. So, not only a ‘recipe’, but also the absence of grounding can obstruct wonder and exploration. Learning ‘how’ to discover requires more than a ‘recipe’ of a technique, but also more than the freedom to explore whatever pupils would like. It requires insight in the use of a technique of discovery. In this way pupils are enabled to follow their own interest resulting in a satisfying result.

Additional new found insights of the case study ‘Observe as an artist’ with regard to the current practice of Design and Technology Education:

- From one of the effects of the groundwork ‘Observe as an artist’ can be learned that also boredom can be solved. Boredom often hinders pupils to make use of liberty. The boredom was cured by delivering pupils precise knowledge about ‘how to find out for yourself how to handle’. That requires liberty and competence. Competence requires insight. By giving pupils insight in how tasks that can be done in a given situation can be detected, instead of giving them these tasks, they get liberty and autonomy. They get the liberty to do the task or not and they get the autonomy to discover a challenging task themselves.

This insight is connected to newly found insights of the case study ‘wheels at work’:

- During the third episode, the pupils had to invent a lifting machine themselves. However, the pupils were restricted in their use of water and sand. Nevertheless, the pupils did not experience the limitations as a major problem. On the contrary, the limitation inspired them to look for solutions. The pupils used marbles instead of water or sand. This finding reinforces the assumption, also made during the case study 'observing like an artist', that autonomy is a natural human need, which the pupils try to satisfy. This is entirely consistent with Self Determination Theory (Deci & Ryan). The search for possible solutions, when an obstacle arises, apparently serves autonomy.

Another newly found insight of the case study ‘wheels at work’:

- A joint presentation can have distinct functions in Design & Technology education. One function can be the emergence of reflection followed by abstraction and insight. Another function can be the inspiration triggered by seeing other products and hearing their descriptions.

The classes that carried out 'wheels at work' were not followed afterwards and the transfer to other activities was therefore not studied in this case study. However, an effect was seen of the fact that in the first session there was no joint presentation of findings. This prevented the emergence of usable insights. In the third session this became clear because the students did not manage to communicate with each other about possible designs. Verbal expression of found insights is apparently crucial to the hand-mind interaction towards insight. This will be discussed in the next section.

6.2.3. Verbal expression

The aim of the third study ‘initiation of verbal expression’ in chapter four was to provide preschoolers with the tools to start interaction. Pre-schoolers have a lot of knowledge and language about activities practised at home, but they lack shared classroom experiences and a shared classroom vocabulary. In order to articulate findings during Design and Technology activities pupils need competence in the verbalization of thoughts. The approach, that could enable verbalization, is described below.

In 'open design' approaches concrete foci or concrete tasks are usually not given. However, in this case study the pupils received a concrete task with a concrete focus ('Talk about your cuddly toy, from out a view that is represented by a specific thinking hat'). The task was demonstrated and the different foci were mentioned. A 'recipe' about how to tell about the cuddly-toy was not given. Instead a focus of attention (the specific thinking hat) offered the pupils the possibility to self-determine how the concrete task , with the specific focus in mind should be performed. Our approach provided exploration of the practice of verbalization. Additional elements from the Montessori Method (Gutek, 2004) were scaffolded autonomy and liberty. The carefully tailored, individualised guidance towards autonomous verbalization is in accordance with advises of Vygotsky (1978).

Furthermore, elements that could disturb the verbalization of thoughts were avoided, e.g. overwhelming complexity and feeling incompetent.

The task execution was voluntary. The task was 'to talk about a cuddly toy'. The pupils could choose from five perspectives for the talking represented by five different colours thinking hats (De Bono, 2009). The demonstration of the teacher of 'how to talk about the cuddly toy' enabled the pupils to imitate it. The demonstration also clarified the meaning of the different perspectives. The insight in 'why' one would choose for a certain perspective became increasingly clear during practice. All pupils showed a high level of motivation to attend their peers' presentations. They also showed a growing motivation to do the task themselves. We assume that the presence of motivation of the pupils was caused by offering insight and liberty. Insight in the 'how' of verbalisation, and liberty for trying out different colours of hats. When pupils tried out a color, the accompanying perspective was getting personal meaning for them. The trial of the separate views were resulting in role-play, indicating that the self-determination actually took place. By watching the various performances of the task, the usefulness of the different perspectives became clear for all pupils.

When we analyze our approach the first finding is that the provision of a very familiar object had impact. Kangas, Seitamaa-Hakkarainen & Hakkaraine (2013) are describing a similar finding during a collaborative lamp designing process. We found that thinking about the own cuddly-toy helped the pupils to concretise and articulate ideas about their cuddly-toy. The familiar object functioned as an anchor. The thinking about the cuddly-toy turned out to be more extensive and to be easier expressed than the thinking about the class cuddly-toy.This finding is in line with the outcomes of a research in the field of social psychology. Krauss & Chiu (1998) found that in a setting based on the experiences of the pupils, the pupils are enabled to take the initiative. Such a setting takes in account the feelings of pupils and thus supports the creation of a suiting learning situation.

Secondly, the emergence of required knowledge took place. This was enabling the performance of shared instructions. The emergence of required knowledge was accomplished by offering on the one hand simple focus points (the colours of the hats) and on the other hand adequate guidance to support the existent competence. The support of the verbalization by the teacher during pupil's presentations took place through questioning and repeating the meaning of a particular color of hat. As a result many pupils dared to talk about their own cuddly-toy. After about ten presentations, the need for support decreased, showing in increasing self-confidence and role-play. This finding is in line with the findings of Rogoff, Paradise, Arauz, Correa-Chávez, & Angelillo (2003) who found that people learn by actively observing and 'listening-in' on ongoing activities when they are participating in shared endeavors.

In this case study the yet not mastered skill of verbalization was demonstrated in full. It is likely that the full demonstration played an important role in the increase of the quality of pupils' verbalization. Lazonder& Harmsen (2016) found a similar outcome of enhanced performance by explaining a yet not mastered skill in full. That positive effect on verbalization is according to the neuro psychologist Mercer (2013) the result of the teaching of rules and means of interaction.

A similar method is also used in computer gaming. At the start of a new game 'onboarding' takes place by teaching the rules and means of the game. According to Chou (2013), a game designer, helps onboarding in changing the user's attitude from being curious into feeling smart and competent.

The by Chou mentioned curiosity also showed up during our case study. All pupils were keen to attend the 'talking about your own cuddly-toy' presentations. Even if they were not sitting in the circle, but were doing something else. In that case they interrupted their activities and silently watched the presentation.

A significant part of the pupils intended to practice the task themselves. That intention showed in the amount of pupils that brought a cuddly toy from home. That the pupils were actually feeling 'smart and competent', showed in the substantial amount of pupils that really put the intention in practice.

By using a very familiar object, that induced concrete thoughts, and by supporting the transformation from overwhelming complex thoughts into unambiguous thoughts, clear verbalization emerged. This approach is hardly studied in the field of Design & Technology Education, but a comparable result is found in the study about young children by Levy and Mioduser (2007). During a 'warming up' phase a shared language was initiated. That shared language enabled the children to explain the complex behavior of a self-regulating robot.

A distinction with our case study is that they used the shared language to facilitate the discussion of tasks. In our case study it also was intended to use the shared language and use of the hats of De Bono in a later situation, but there was no occasion for that. Shortly after finishing the case study the summer break was starting. This also meant the end of the at that moment existing composition of class.

The design of our approach is influenced by Montessori's idea, that learning does not start with words, but starts with doing. Doing delivers the concrete impression, the anchor. When the teacher gives the appropriate words, the pupil is enabled to connect the concrete impression to the words.

The findings of this case study show that preschool pupils are able to express abstract thinking and to interact verbally, when they are given the means. Although developmental psychologist Piaget (1929, 1985) concluded that symbolic reasoning (abstract thinking) is absent until the age of seven, because conceptual growth needs debate and dialogue, our research and other researchers like Gopnik (2012) prove him wrong. When pre-schoolers are showing that they are able to verbalize their thoughts, they are also able to think in an abstract way.

This case-study shows that demonstration is a good way to learn 'how' to verbalise. Further on we found that giving pupils room to follow their own interest makes no sense, when pupils are feeling incompetent. When incompetent feeling pupils follow their own interest, they probably will show avoidance behaviour (Lindfors et al., 2018). Therefore pupils need an 'onboarding' to make them feel competent, as performed in this case study. Pupils need competence to be enabled to make use of liberty. Competency helps them to undertake initiatives and to follow their interest.

The importance of verbalisation for Design & Technology class is that interaction during inquiry and design processes is furthered. Interaction is not only important during the design process, but also for practising dialogue. When toddlers are able to interact, it immediately becomes a real dialogue. Toddlers possess a quality which older pupils and adults have lost: lack of bias. This makes them capable of impartial participation and of understanding the point of view of others. Once they have learned how a dialogue works, they are likely to carry it out in the same way in later life. This point contribute to Mercer's larger goal; "It is in the interests of society that children are taught how to become effective 'interthinkers' by using and educating the social brain" (Mercer, 2013, p. 164).

In summary are the newly found insights of this case study with regard to the current practice of Design and Technology Education:

- Taking in account the feelings of pupils helps to create a suiting learning situation.
- The impartial thinking from several views helps to understand the viewpoint of other people. Lack of bias is necessary to enable impartial thinking.

6.2.4. Stepwise method

The aim of the study 'Stepwise approach' in chapter five was to engage a class of nine to twelve years old pupils by giving them a series of well-defined tasks (see chapter five for a description of all tasks), complemented by joint presentations to guide the process of designing and constructing their favorite chair. The approach is described below.

In the case study 'The making of a mini-chair' all pupils received a series of concrete tasks, with a concrete focus, like in 'recipe' approaches. On the other hand the series of tasks offered the pupils the possibility to self-determine the relationship between look and comfort and solidity of the chair by trial and error, like in 'open design' approaches.

The characteristics of the assignment. Firstly, the personal idea of a favorite chair represented the success criteria of the chair. Secondly the series of concrete sub-tasks leading to sub-products supported the discovery of the relationship between look and comfort and solidity of the chair. Thirdly, a joint presentation of arranged products – all solutions to the same task - was applied to increase insight, towards optimal solutions.

The pupils had to experiment and balance the sub-products with the success criteria of the intended chair to judge the rightness of the sub-products. This is different from "recipe" approaches, in which the instructed techniques, e.g. "construct the parts of the chair", would have resulted in an unspecified chair. The various intentions about the function of the chair resulted in a variety of chairs.

Our approach made self-determination possible by providing structure on the one hand, e.g. the concrete points of attention, the concrete success criteria, the concrete subtasks. On the other hand autonomy was offered, e.g. enabling the exploration of the effect of different forms of construction. Elements from the Montessori Method (Gutek, 2004) were added, e.g. liberty to work at their own pace and liberty to redesign. An element that furthers relatedness was varying collaboration and joint presentations.

Furthermore, elements that would disturb self-determination were avoided, e.g. vagueness, absent competence, a focus on the product instead of on the process, and absent evaluation.

The findings of this case study show that pupils can create a complex product if they are given a series of well-defined subtasks. Each subtask focused pupils' attention on performing a specific technique to achieve sub-goals in the context of the final goal, the desired chair.

The idea of dividing a complex task into subtasks had arisen from the earlier case studies. These showed that well-defined tasks make engagement possible. Well-defined tasks bring about competence, whereas overly complex tasks cause overwhelm.

At the end of each subtask, pupils had to evaluate for themselves whether the result could lead to the desired mini-chair. We noticed that this evaluation promoted the involvement of all pupils in the class and encouraged them to make improvements to their sub-tasks. Sundqvist (2020), who conducted a similar study with preschoolers, explains in her research paper that using evaluation of practical activities in the context of a larger whole promotes the exploration and learning of the technological content of the practical activity.

The didactic approach in this study is rather new in Design & Technology Education, but is already being used in the field of Science Education. For example Dolin, Black, Harlen and Tiberghien (2018) are viewing learning as making sense of new experiences. To make progress, learning has to be considered as making a series of small steps. All pupils in our case study appeared to be able to make the mini-chair by making steps. During making steps they practiced different techniques in the context of the making of a mini-chair. In other words, the pupils practiced 'how to build/draw/do something for the purpose of 'make a mini-chair'.

In addition, during the case study all pupils were participating in an engaged way, indicating self-determination. The products showed insight and care, indicating that targeted learning had taken place. This case study indicates that bridging 'open design' approaches and 'recipe' approaches does not only work for young pupils, but also for nine to twelve year olds. Firstly asking pupils to make a very familiar object (a chair) appeared to be profitable. Secondly the division of the complex task into simple tasks appeared to be profitable. This was done by defining a focus point for each task on the 'how' of one specific technique. In addition a focus point for all tasks was defined on the success criteria of the overarching goal, the chair. By regarding the product of each task in the context of the overarching goal, the chair, in this way simple tasks were arisen. Thirdly, the simple tasks facilitated the support of insufficient skillfulness. Fourthly, the joint presentations provided the growth of insight for all participants.

During the joint presentations all the different used ways of handling a technique and all intermediate products were shared. The room for own ideas about the chair as a start, the clear, simple and objective tasks combined with the intermediate joint presentations, as means towards the goal, a solid chair, all supported the avoidance of design fixation (Schut et al., 2019). Meanwhile, divergent thinking took place. This showed itself in a diverse collection of chairs.

This elaboration of the 'bridge' approach not only improved the quality of learning, but also ensured that all students could experiment and continue to participate.

In summary are the newly found insights of this case study with regard to the current practice of Design and Technology Education:

- Impartial thinking is necessary during joint presentations.
- It is possible to practice impartial thinking by becoming aware of the fact that there are different interpretations possible for the same situation. If one knows how to be receptive and non-judgmental and has faith in the other, one may be able to leave bias unused. In this way, one can look for similarities and differences with one's own findings.

6.2.5. Value of self-determination for primary Design & Technology Education

We found that it is possible to promote engagement during Design & Technology activities for all pupils aged four to twelve years. This is important, because engagement means actual self-determination and self-determination is at the heart of Design & Technology activities.

We can explain this by looking at the purpose of Design & Technology education. The aim of this education is for pupils to acquire knowledge, skills and attitudes related to technology, as they will encounter it in everyday life and later in professions. The development of skills requires both knowledge and understanding. Designing is such a skill that also requires understanding. Moreover, an attitude of curiosity will also help design to succeed. Designing is a way of thinking with many aspects.

Thinking happens in one's mind and is invisible. According to Arendt (Nixon, 2020) a decision must be made before a thought can be expressed. That is why designing requires making decisions, so that the design can be expressed. Not only design requires making decisions, but also other Design & Technology activities do so. Deciding is an important subtask of designing, solving and making, which requires a lot of practice before it can be done in an informed way. So self-determination is an important aspect of Design & Technology education. As a result, the theory behind self-determination is also important. It theory states that self-determination can only occur if autonomy, competence and relatedness are present (Deci & Ryan, 2000).

By keeping in mind throughout the study that the innate psychological needs of learners for autonomy, competence and relatedness must be met, beneficial elements of Design & Technology activities could be identified. It also allowed the identification of disrupting elements.

We also found that the synergetic effect of satisfying all learner needs is engagement. If the learning situation did not sufficiently satisfy just one need, this led directly to complete disengagement.

The application of beneficial elements to achieve self-determination and the resulting engagement was done with the help of insights from the Montessori method. Montessori saw self-determined learning as the natural way of learning. She called it ‘self-education’. So she did everything possible to offer the pupils autonomy, competence and relatedness.

Montessori recognized that attention to the task was also necessary to induce the pupils to start a task of their own accord. To this end, she came up with concrete or well-known points of interest.

For autonomy, Montessori offered pupils freedom. Her pedagogical approach puts freedom first. Her conviction was that only when there is freedom can children learn for themselves. However, freedom does not take into account the freedom of others. That is why Montessori defined freedom as freedom in relatedness, liberty. Liberty allows pupils to choose whether or not to do the task and whether or not to repeat the performance. Liberty also allows pupils to perform a task at their own pace.

She created sufficient competence by adapting tasks to the level of knowledge of the pupils. For instance, young children have little competence and therefore need a concrete task with concrete success criteria and a concrete focus of attention for self-determination. In the resulting learning situation, the pupils could develop further competence.

So far, the Self-Determination Theory has been applied mainly to older pupils. Our research shows that the theory also works for younger pupils.

By satisfying innate needs, it turned out to be possible to let pupils decide how to perform a task. The only thing missing then was a way to achieve formative learning. We found a solution in the work of Arendt (Arendt, 1958/1998). Her ideas inspired us to organize joint presentations. These ensured a longer-lasting engagement.

The joint presentations had an effect not only on formative learning, but also on collaboration, cooperation and the atmosphere in the classroom. Learning to take an unprejudiced look at the ideas and products of peers not only helped during the joint presentations, but also in other classroom situations. This increased the trust in each other and therefore also the space to take an interest in the other's activities. This had a good influence on the growth of a social class atmosphere. So relatedness was also growing.

Below is a more detailed explanation of how to get a good balance of learning situation elements so that there can be engagement. There is also a detailed explanation of the effect of joint presentations on formative learning.

Balancing factors and diagnosing a cause of disengagement

Elements of the learning situation that teachers should take care of to prevent disengagement are:

- Concrete/well-known task
- Concrete/well-known focus points of attention
- Concrete/well-known success criteria
- Initiation of the 'how' of a task
- Sufficient competency to do the task
- Evaluation of the result of a task on the basis of the success criteria
- Liberty to work at the own pace
- Liberty to redesign
- Joint presentations leading to further development of the design or product

When disengagement of pupils is observed, it is an important signal for the teacher. It is then worthwhile to find ways to detect which factor of the learning situation is failing. When the failing factor is found, appropriate measures can be taken that lead to engagement.

The procedure of finding the failing factor would be explained on the basis of the case study 'the making of the mini-chair'. In this study disengagement showed up at the start of the case study and was noticed by the researcher, in the role of assistant teacher. Next, she detected the failing factor by explicitly asking disengaged pupils for the reason of their disengagement. The pupils reacted with expressing unsatisfied needs as 'I cannot do it' or 'I do not want to do it' or 'it is useless to do it'.

In this case study these questioned pupils stopped their disturbing behavior immediately after expressing their unsatisfied needs and they opened up for dialogue. That was really a surprising result. Subsequently, the teacher-assistant provided possibilities to meet the expressed needs. The disengaged pupils expressed willingness to do what they could do. In addition, these pupils suggested possible solutions. These solutions would surely meeting their unmet needs, because they proposed them themselves.

By questioning the pupils about their needs, was indicated that satisfying their needs was natural for the questioner. Apparently, the questioner and those pupils had a shared value. That helped the disengaged pupils to feel accepted. As a result the pupils opened up for a dialogue about shared goals. As Christensen (2019) arguments, dialogue between teacher and pupils is profitable for finding a shared goal.

Absence of engagement is an important signal for teachers who want to realize self-determination. The results of the case study indicate that teachers can find failing factors by moving their focus of attention from the task towards the pupils, by making pupils the center of class. This is possible by using for example a Reflect, Connect, Apply method for questioning. By Reflecting (informing the pupil concerned with the teacher's awareness of pupil's disengagement), then Connecting (ask the pupil about the failing factor), followed by Applying (reconcile idea of pupil with the idea of the teacher), failing factors can be found and remedied. The Reflect, Connect, Apply method has its roots in Kolb's experiential learning theory (Kolb, 1984) and is used in play-based learning (Lindsey & Chapman, pp 71, 2017). The Reflect-Connect-Apply steps can also be used by teachers in other situations to guide students. For example during joint presentations. Then, individual knowledge and insight must be processed in such a way that shared knowledge arises.

The importance of the balanced cooperation of all factors to achieve and sustain engagement is also evident in another episode of the case study 'making a mini chair'. Because the teacher ran out of time during the first session, the joint presentation was dropped. As a result, many pupils showed helplessness until the omission of the joint presentation was remedied. This behaviour is similar to the behaviour of the pupils during the design task that followed the groundwork task in the case study 'Wheels at Work'.

The effect of the recovery of this omission in the second session was very informative. By organizing a joint presentation of the results of the first session recovery took place. Hereafter, spontaneous cooperation and collaboration between the pupils showed up. This cooperation also helped formerly disengaged pupils to find suitable ways of handling the tasks. In addition they learned by looking around at work of other pupils. They discovered that not all sketched ideas could be realized. By asking peers and looking at peers they were enabled to find solutions for occurring problems. On the other hand, by the joint presentation pupils were discovering that peers had problems and they offered them help.

This episode from the case study shows the importance of not having counteracting factors for the emergence of engagement. It also show how teachers can 'repair' a unexpected occurring counteracting factor. In the specific episode a joint presentation of the results was helping. The joint presentation furthered redesigning, but also community in class. Community in class can complement deficiencies in the knowledge of pupils by enabling spontaneous cooperation. In other situations, other failing factors can be found, accompanied by other remedies.

Joint presentations and formative learning

The effect of joint presentations on formative learning can be explained by looking at the added value of joint presentations. The case studies are showing that joint presentations led to renewed engagement, but also to more cooperation and collaboration. This is because joint presentations are useful for sharing ideas and knowledge. The function of sharing is that it prompts reflection, because the role of the presenter is to reflect on a finding and then share the reflection by verbalization. Thus, joint presentations are resulting in reflection and sharing. When pupils are sharing their findings, a class is developing a shared knowledge base. The added value of a shared knowledge base at the start of the performance of tasks is clearly explained by Oldfather (1992). As a teacher in the field of Literacy Learning she discovered that sharing thoughts and knowledge led to 'I can think. I can know. I can have wonderful ideas.'. In this way, a shared knowledge base is facilitating the pupils in class to actively participate in further learning. This insight has been endorsed in the field of science education by Cakir (2008). However, as far as we know, attention for shared knowledge resulting from joint presentations is rather scarce in the field of Design & Technology Education.

A joint presentation is giving every pupil the chance to present findings. However, the manner in which the findings are presented and received determines the effect on pupil's engagement. Educationalist Berding (2017) describes in a clear way how a joint presentation should ideally take place. He bases his elaboration on Arendt's 'Greek solution' (Arendt, 1958/1998). The Greek solution is taking place around the table. A question is explored there by all participants. This exploration is leading to the sharing of experiences and perspectives on the subject, where the sharing of truth is more important than the making up of solutions and answers. This benefits inspiration and avoids moralizing ways of verbalization.

In a publication about lesson study is found another clear description about non-judgmental sharing. Mathematics teacher Takahashi (2006) describes in a graphic way a well-functioning way of sharing in a class. The sharing of data in class is a component of the lesson study approach, whereby teachers mutually share their set-up of a lesson towards perfection of the set-up. A different application of joint presentations is found in Bhattacharjee (2019). She uses joint presentation as groundwork. Her groundwork was reviewing the results of earlier lessons at the start of a lesson. The emphasize of all these sources is on the correct roles of the presenter and the listeners. The role of the presenter is to reflect on the own findings and to verbalize that reflection. The role of the listeners is to be receptive and non-judgmental. Sharing only actually takes place, when a listener is seeking for similarities and differences with the own findings.

The role of the teacher during sharing knowledge is multi-sided. On the one hand, the teacher can bring in new perspectives such as 'is there a difference between the construction of the chairs?', on the other hand the teacher has to be perceiving and he/she has to support pupils during the sharing. For example, it is good if the teacher notices original points of view of the pupils and then helps to explain them to other pupils using his/her knowledge of society.

The teacher, as a representative of society, can also bring in perspectives from society. For example "is this chair suitable for all ages?". The teacher collects the students' answers and contributions, and then links these to different perspectives of society, such as "so your chair is suitable if you don't have much money and want a versatile chair, and the other chair is suitable if you want a decorative chair". By rephrasing, repeating, asking for evidence etc., the teacher buils up chains of discussion. (Alexander, 2018, pp 10).

Limitations and Recommendations

6.3. Limitations and recommendations

6.3.1. Limitations

This was a small-scale, exploratory research using a case-study approach. It reveals how a specific use of interventions influenced the engagement of a specific group of children. One teacher together with a colleague determined the specific use of the different interventions. In two case studies with pre-school children, the teacher determined it alone and in the other cases, a second teacher was involved.

As a result, the outcomes are inevitably limited in generalizability. Although it is expected that the interventions will work with other teachers once they are skilled in identifying pupils' needs and applying the interventions, this has not been proven in this thesis. Also, the group of pupils must be accustomed to a self-determined way of acting in order to be able to use this way of acting immediately.

Since all cases were conducted in a Montessori context, which obviously influences the findings, the results might be different in schools with a different educational tradition. Nonetheless, the findings could be of significance to all who seek to increase self-determination and engagement in Design & Technology education.

The precise creation of the studies in this thesis was partly determined by observations during ethnographic pilots. Observation was also one of the methods to collect findings during the case-studies. Although the ethnographic character of the studies limited objectification, it deepened the insight into the meaning of the findings. When a researcher deeply understands the context, the researcher is enabled to sense what is going on during the research. Sense delivers broader information than a transcript or video's do.

6.3.2. Recommendations for further research

It is proposed to follow up the research of this thesis in a quantitative fashion, whereby the focus is on showing the effect of the application of the interventions on the engagement of the pupil in a statistical way. in an educational setting where autonomy and relatedness are already present. The interventions referred to are iteration, groundwork, interaction, joint presentation and stepwise approach.

We propose to gain insight into the degree of self-determination of the pupils by measuring the main concepts in the Self-Determination theory. Various instruments have been developed to determine this. The Centre for Self-Determination, for instance, on their website presents a whole range of instruments (https://selfdeterminationtheory.org/questionnaires/). Also there are research studies that investigate the value and limitation of such instruments (for instance, Shogren et al., 2008). A related concept that could be measured in a follow-up study is well-being (Løhre, Lydersen, Vatten, 2010; Roffey, 2008). For that, too, existing instruments can be used as a starting point. These instruments allow pupils to indicate to what extent they feel capable of being self-determining in the classroom. There are also instruments for young children. These work with pictures and smileys.

Based on these studies, it is interesting to examine the relationship between well-being during the lessons and the learning outcomes of the lessons. This could be done by having the pupils take a short test at the end of the lesson about their wellbeing during the lesson and having them write down what they learned during the lesson. An additional test of their knowledge of the subject before the lesson and after the lesson could also be a possibility. In this way, insight can be gained into the effect of wellbeing on what is learned during the lesson.

It is also suggested to determine to what extent is engagement occurring for all pupils in class. This can be determined in various ways, for example by observing in class the 'time on task' (Knight, 2007).

In the current study little attention has been paid to the teacher. Clearly, realising the interventions assumes certain attitudes and competencies with the teacher. In the first place (s)he needs to have courage to allow autonomy to pupils, thereby losing the role of the expert who transfers knowledge to learners. In the second place, the teacher needs to have competencies in guiding that autonomy so that it leads to fruitful results. One could investigate what Pedagogical Content Knowledge teachers need in order to realise interventions aiming at self-determination by pupils. As we do not know much about this yet in the context of primary Design & Technology education, a qualitative study would be an appropriate first phase for his follow-up research.

Another possibility for a follow-up study could be a qualitative study, looking for possibilities to integrate the development of different types of knowledge in one Design & Technology activity. For example, the integration of metacognitive knowledge and design skills, or the integration of knowledge about a physical phenomenon and handicraft, or the integration of interaction and exploration. A Design & Technology activity can be used to get to know about cross-curricular objectives, but also for the exercise of skills (Tuithof (red), 2018). The advantage of exploring and understanding such an innovation is that this not only creates space for working on cross-curricular goals, but also on pedagogical goals.

6.3.3. Recommendations for Design & Technology Education

During Design & Technology Education

Based on the positive results of the our approach developed in this thesis, we advise to use this approach in Design & Technology classes. Our approach, based on elements of the Montessori method (Gutek, 2004) delivers 'grip' for pupils combined with 'openness' towards circumstances that allow the use of liberty. The result is active participation, showing in engagement at a much higher level than in the recipe and open approaches currently used in Design & Technology education. A clear definition of the '*what*' pupils have to pay attention to, will deliver the 'grip' and the a free development of solutions as long as it matches the tasked *'how'* delivers the 'openness'. In this way self-determined learning becomes possible.

Our approach leads to truly Design Based Learning for all pupils in class. Design Based Learning is a form of Design & Technology education that uses self-determination. By creating a learning situation, which satisfies all innate psychological needs of the pupils and also offers a challenge, all pupils can actively engage. During Design Based Learning (DBL) pupils use and extend their science knowledge by developing a technological solution to a problem (Apedoe et al., 2008). The promotion of deeper understanding of core (science) ideas towards insight is one of the primary goals of Design Based Learning. Design Based Learning is a specific type of project-based learning in which the 'project' is an engineering design project. The intended insight is achieved by providing pupils with a rich, authentic context, in which a core (science) idea can be applied.

Design Based Learning in the way we propose is also suitable for formative learning, as Joint Presentations can be used to refine the challenge while searching for the solution.

During general Education

As we saw in the introduction of this thesis, self-determined learning is also important for general education. Therefore the second recommendation is to also use DBL for other education than Design

& Technology education. DBL is suitable to develop not only manipulative skills, but also cognitive skills, social skill, mental skills and concept-knowledge. An important element of DBL is the use of iteration. Pupils can use and extend knowledge by developing solutions to any problem. Besides, DBL can take many forms, from highly structured to completely intuitive and spontaneous and everything in between. Therefore DBL can be helpful to further the feasibility of the use of DBL for other education. The context for such use of DBL can be a Design & Technology activity, but also a very familiar environment, an outdoor environment, or a home environment. By making use of sudden opportunities occurring in and outside schools, learning has not only to take in account cognitive and manipulative conditions, but also social and affective conditions. This statements are in accordance with the recommendations of the European Creative little Scientist study (2014).

This broadening of the use of DBL can be accomplished by adapting a path to a learning goal to the pupils. When teachers want to achieve a learning goal they first have to determine the desired outcome of the first step towards the learning goal. Then it is possible to identify the required skills, techniques and knowledge for the achievement of the desired outcome of that step. Next teachers have to check the presence of the required skills, techniques and knowledge among their pupils. When the check yields absent ability or knowledge, there are two options. The first option is adaptation to the pupils as described in 'the marble boat' or support as described in 'talking about the own cuddly-toy. The second option is groundwork as described in 'Observe as an artist', but also in dividing complexity towards grip as described in 'talking about the own cuddly-toy' and 'the making of a mini-chair'.

In this way DBL can contribute to virtually all learning goals of the primary curriculum (see fig. 6.1 and 6.2). As Williams (2000) stated with regard to Design & Technology education: 'Students must be taught, and then given the opportunities to practice specific skills and techniques before expecting them to incorporate them into a process of technology.' Translated to DBL in other education: gaining new knowledge can be put central during a DBL activity, but also the application of already gained knowledge can be put central. The DBL activity is then the means to achieve or apply knowledge about the learning goal.

Furthermore, our research shows that the coupling of informal and non-formal learning to formal school learning is beneficial for grounding formal school learning. We used the coupling of formal school learning with home-situations in the first four case-studies with young pupils. For instance, the case-study 'Observe as an artist' used an at school initiated thinking skill and practiced the skill in everyday life. The opposite approach was used during the case-study 'talking about the own cuddly-toy'. An in everyday life frequently used object was used in school as an object to practice verbalization with. Informal and non-formal learning can not only be practiced at home, at after-school care, at leisure clubs and at school, but also during teacher education. This approach also proved its quality during an assignment for the pre-service teacher training of the Thomas More University of Applied Science. The students had to use the 'Observe as an artist' or the 'talking about the own cuddly-toy' approach during applications in their primary class. Afterwards, the students reported a lot of engagement among all pupils of their training class. They also reported remarkable results. It also appeared from their reports that the assignment delivered the students new insights in the learning process of their pupils.

Towards connection of learning goals resulting in a network

Concluding it is recommended to use DBL activities during Design & Technology Education, but also to develop broad ability and knowledge. That succeeds by using the 'approach developed in this thesis. An additional profit of DBL is that it can connect learning goals of different subjects towards a network to achieve 'whole child education' (NIVOZ foundation, 2018).

Use joint presentations to support ongoing engagement and communities of practice

In our research, joint presentations appeared to offer opportunities for ongoing engagement and growing community in the classroom. It is therefore recommended that joint presentations are used in the classroom. The use of joint presentations makes the use of self-determination in classroom teaching more feasible.

How does a joint presentation do that? Joint presentations make use of the principle of Reflect-Connect-Apply (RCA). The principle of RCA has its roots in Kolb's experiential learning theory (1984). RCA is used in play-based learning approaches (Lindsey & Chapman, pp 71, 2017). The play-based learning approaches are internationally used with the mission: protect, educate and empower children to rise above adversity using the power of play (https://www.righttoplay.nl/nl/). RCA changes games into lessons.

Joint presentations are preceded by tasks that are performed in a self-determined way, as in Design Based Learning. During the joint presentation, the pupils must have the liberty to decide for themselves how they want to talk and what they want to say about their product or idea. It is not the intention that their expressions be criticized. It is good, however, if their expressions are questioned. The joint presentation is about learning to understand the other person's expressions.

Reflection is the learning principle of presentation. Reflection results in a higher level of abstraction of the knowledge acquired. Reflection on what has been learnt can be induced by a test, but also by having the learnt presented. Therefore, another important advantage of joint presentations is that they further disclosure of flaws in the knowledge constructions of pupils (Takahashi, 2006, p.42) without testing. In this way joint presentations can also reduce disadvantages of classroom teaching, just as testing does. The disclosure of flaws is necessary, because classroom tasks are never exactly suitable for each individual pupil.

Classes can use joint presentations to create shared knowledge, but also to create community towards collaboration and cooperation. The function of joint presentations is the sharing of knowledge in the gathered class. Sharing leads to community, because the sharing leads to involvement, joint understanding and collaboration. The collaboration available between pupils is also useful for solving problems during the lesson. A joint presentation also enables the use of feedforward tasks. Such a task builds on the presented strengths and leads to insight into the presented weaknesses. Such a task can be created by raising questions, thus renewing the challenge. Thus, feedforward supports formative learning (Black & Wiliam, 2009).

6.3.4. Recommendations for teacher professionalization

An important advice for teachers is to experiment with creating well-defined tasks for the pupils and with adapting their own attitude to the pupils. The findings of the studies in this thesis show that experimenting helps teachers to create feasible and valuable class-centered education and that the profit is an improved atmosphere in class for both pupils and teacher. By choosing simple experiments (e.g. 'observe as an artist') experiment is accessible. In analogy to pupils who use experimenting to develop dexterity in everyday life and to gather insights, teachers can experiment with tasks and attitude in the same way.

It is recommended for school leaders to recognize the importance of experimenting by teachers. Through experimenting and tinkering teachers are able to gain dexterity in approaching pupils with a non-judgmental, participating attitude. In this way teachers are also enabled to find out more about pupils' needs in relation to a planned lesson. They can do that by taking in account the principle of Reflect-Connect-Apply (see the 'paragraph 'Joint presentations in this section). Reflection encourages pupils to examine their experiences, relate those experiences to what they already know (connect), and apply that learning to their daily lives.

The application of reflection can be done in different ways. A joint presentation of reflections can take place before the lesson starts and will help the teacher to fine-tune the tasks. Individual reflection can take place during the lesson. Pupil's presentation of their reflections to the teacher will help the teacher to support the pupils in connecting to the task. Joint reflection can take place at the end of the lesson and will help the teacher to create a suiting next lesson (apply). During the lesson the teacher can observe the progress of the lesson, whereby a video recorder could function as an extra eye

Another recommendation is to apply participating coaching in class. During the case-study 'the making of a mini-chair' the successful collaboration with the Arts and Crafts teacher resulted in a changed attitude of that teacher. In class, both coach and the coached teacher will meet the same problems, but may have different interpretations. When in class the occurrences of inability or occasions for collaboration are pointed out to the coached teacher. The occurrences will evoke a cognitive conflict in the coached teacher, that can be discussed later. Differing interpretations can facilitate the dialogue towards possible solutions for disengagement. Teachers can, for instance, through this coaching start to see the absence of abilities or the absence of manageable expectations of their pupils. As a result new possibilities to handle pupil's expectations and inabilities can arise. Coaching in class can help teachers in their professionalization, because the view of an extra eye can enable inner discussion. The coaching can be done by an expert colleague or another expert teacher, similar to the approach used in the last case-study.

6.3.5. Recommendations for teacher education

The recommendation to use participating coaching in class also applies to pre-service teacher education. A guidance counselor can observe the practice of a pre-service teacher with an assessing eye, but also with a coaching eye. A non-judgmental discussion afterwards can help to see the absence of liberty and/or room to experiment in class.

Final remarks

Last but not least, based on the findings of this study, it is recommended that more use be made in primary education of the possibilities offered by Design & Technology education to practice the thinking processes that go hand in hand with self-determination. A far-reaching integration of Design & Technology activities in the educational system can ensure this.

Autonomy, competence and relatedness are essential in realizing the full potential of design based learning. Design and technology educators and researchers should make more use of the principles and interventions that have been developed in the context of Montessori education. Not only does Montessori's method give indications on how well-defined tasks can be created, but it has also dealt extensively with the integration of subjects.

Chapter 7

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Summary

This thesis is searching for ways to engage all pupils in class in an ongoing way during primary Design & Technology lessons, so that all pupils are able to profit from the lessons.

The aim of Design & Technology education is that pupils acquire knowledge, skills and attitudes related to technology as they encounter it in daily life and later in professions. Some of those skills can be instructed, but others need to be taught until understanding emerges, for instance designing.

Designing is a way of thinking with many aspects. Creativity is one of them. Design can be seen as the imagination of ideas in reality. Thinking happens in one's mind and is invisible. That is why designing requires making decisions, so that the design can be expressed. Not only design requires making decisions, but also other Design & Technology activities do so. Deciding is an important subtask of designing, solving and making, which requires a lot of practice before it can be done in an informed way. Therefore, Design & Technology education must provide pupils with opportunities to practise decision making broadly. When pupils have learned how to make their own decisions, and they have the freedom to do so, every pupil can make their own decisions, anytime, anywhere.

Design can have many functions. Design can be used to do research and construct knowledge, to think out solutions and make them, or to re-create reality to someone's personal taste. In turn technology is an important means to experiment with the design in reality to fine-tune the knowledge or idea.

Children go to school to prepare for their future lives. So personal development should be an important goal of learning. Then tasks are needed that focus on this. The exercise of deciding for themselves how to approach design and technology is useful for personal development. Design & Technology education can offer such exercises. In this way, children can discover that it is enjoyable to be able to decide for themselves. By being allowed to decide for themselves how they learn, pupils can make use of their strengths and work on their weaknesses. They can also discover that it is useful to be able to decide for themselves. Through the discoveries made during exercises in deciding for themselves, their personal development grows. The result, a well-matured personal development, will manifest itself in social behaviour, flexibility and creativity.

Although Design & Technology activities have a huge potential, many teachers experience that children are not always engaged in these activities. That is a problem because without engagement, learning is impeded.

The starting point of this thesis is the assumption that children should learn to make their own decisions. In order to do so, it is necessary that they can practice with tasks that require self-determination. According to the Self Determination Theory (Deci & Ryan, 2000), this requires that innate psychological needs are met. These needs are autonomy, competence and relatedness. According to Montessori (Gutek, 2004), the pupils must also be triggered to become curious about the outcome of tasks. The occurrence of self-determination becomes visible in engagement.

Pupils' engagement shows in an active attitude. Existing theories of learning as the cognitivist and the constructivist theory both have their advantages and disadvantages with regard to the occurrence of engagement. The cognitivist theory circumvents the use of self-determination. The constructivist theory does not take sufficient account of pupils' needs. Therefore, they are both unsuitable to evoke engagement for all pupils.

The Montessori method (Gutek, 2004) offers pupils the opportunity to use and expand their knowledge by developing solutions to a precisely specified problem. Montessori realizes self-determination by offering

pupils liberty, supplemented by the circumstances that make the use of liberty possible. The circumstances are formed by two factors. The first factor is a clear definition of the 'what' to pay attention to while performing the task. The second factor is the success criterion of the task in order to know whether the task was performed correctly or incorrectly. Furthermore, Montessori motivates her pupils by making them curious about ways to achieve the outcome of the task. Curiosity allows them to use their liberty to try out different solutions to a task. This creates self-determination. I applied these principles to existing Design & Technology lessons with a 'recipe' or an 'open design' approach, which resulted in the engagement of all pupils in the class.

This thesis is devoted to the study of finding the elements of the learning situation that enable ongoing engagement of all pupils during Design & Technology activities. Engagement points to feelings as '*I can do the task*', '*I want to do the task*'.

The purpose led to the main research question 'How can we engage all pupils in class during Design & Technology activities?*'.* In an organic way the main question led to four sub-questions.

1. *'What is the effect on the design performance when the same task is presented multiple times to 6-8 years old pupils?'*
2. *How to shape groundwork in design and technology education for children aged 4-8 year?'* and *'What are the effects of groundwork on the subsequent process of exploration and learning?'*
3. '*How can a teacher initiate verbal expression in young children in Design and Technology education?'* and *'Can we scaffold the existing expertise of 4-6 years olds?'*
4. *'What is the effect of dividing a complex Design and Technology assignment into well-defined tasks, combined with joint presentations?'* and *What is the effect on the design performance of pupils aged nine to twelve years old?', 'What is the effect on collaboration in class?' and 'What is the effect on the teacher?'*

Outcomes ordered by chapter

Chapter two, which is about the case-study 'the marble-boat', investigated by means of observation the effect of diverse factors of the learning situation on iteration of the design performance of six to eight years old pupils.

The learning situation was introduced by a demonstration and an associated task; 'Fold a piece of aluminum foil so it can hold the weight of marbles when it lies on the water. The more marbles it can hold the better.'. The effect of additional interventions on the amount and quality of iterations was also researched. The interventions were the offering of joint arranged presentations, mandatory and free collaboration, and presenting the performance of the task in front of the camera. Liberty was an important characteristic of the learning situation. The liberty applied to thinking out ways to do the task, and to finding out the effect of the thought out ways. Further on a focus of attention was offered; the changeover point from floating to sinking. The technique, that was used to define the mass of the marbles at the changeover point, was counting the marbles.

The general effect was engagement of all pupils. Special effects were observing/ 'listening-in' and consulting each other during the performance in front of the camera. The pupils exposed a striking pleasure in presenting the boat in front of the video recorder. The joint arranged presentations led to redesign and further exploration in the next session. In this way the task was iterated until really perfect solutions were discovered.

The combination of all interventions, provided space to meet the limitations of young children with little knowledge and little skill. The limitations were addressed by the concrete, achievable task; 'Fold the aluminium foil'. The effect of placing a piece of unfolded aluminium foil on the water, followed by placing a marble on the foil, was demonstrated. The effect was that the marble rolled in the water. The task description was completed with the addition of a clear expectation; 'the more marbles the boat can hold without sinking, the better'. This expectation led to the technique of counting, which was used because pupils of this age had mastered the technique of counting. Later, it turned out that the distribution of the marbles over the floating area was also important. The combination of interventions and the learning situation allowed for a focus on the relationship between the floating surface of the boat and the mass of the marbles in relation to floating/sinking. This focus increased the importance of understanding the phenomenon and decreased the importance of making the boat, making the task achievable for all pupils in the class.

Chapter three, which is about two case-studies, 'observe as an artist' and 'wheels at work', investigated the accomplishment of groundwork. The age of the pupils was four to six years old, seven to nine years old, respectively. Through groundwork, a class can gather knowledge and expertise needed to start a task for which existing knowledge is insufficient. The knowledge and expertise, which after groundwork is also shared by all pupils in the class, makes it easy to create a starting point for a Design & Technology task. It also makes it easier to talk about the findings of the Design & Technology task.

Groundwork can take many forms. In our study, both groundworks were introduced by a demonstration. In the case study 'observing like an artist' it was a demonstration of a way that led to discovery, in the case study 'wheels at work' it was a demonstration of the phenomenon of the lever. The demonstration was followed by the exploration in both cases. In the case study 'observing like an artist', it was exploration in class by all the pupils at the same time. In the case study 'wheels at work', it was individual exploration.

The effect of demonstration on engagement during groundwork was investigated. The learning situation was characterized by liberty, a focus of attention and success criteria. Liberty applied to determining one's own ways of performing the task. Another characteristic of the learning situation was a focus of attention; respectively 'seeing a previously unseen thing' and 'perceiving a difference in the force required'. The techniques demonstrated to determine the outcome of the task were, respectively, observing and lifting. The success criteria were, respectively, 'previously unseen' and 'which method of lifting requires me to apply more force?'

In the case-study 'observe as an artist' the group wise exploration in class led to the verbalization and sharing of individual ideas. In the case-study 'wheels at work' joint verbalization was absent. The only sharing of findings took place by collaboration, observing/ 'listening-in' and consulting each other during performance.

The implementation of the design and technology activities, which followed the groundwork, was informative. It told something about the effectiveness of the groundwork. In the case study 'observing like an artist', the pupils showed self-determined performances. In the case study 'wheels at work', the execution stopped when the pupils had to design a machine themselves. The absence of a joint presentation of ideas had led to the absence of reflection. The absence of reflection led to an absence of insight. The absence of insight led to incapacity during the design task.

Chapter four, which is about the case-study 'Talking about your own cuddly-toy' investigated the possibilities to initiate verbal expression in young children. The interest in the verbal expression of young pupils was inspired by the effects of joint verbalization and sharing of ideas and findings in the previous studies. The age of the pupils studied was four to six years. At this age, children have little knowledge and few words at their disposal. In addition, the words and knowledge at this age come from home and not from learning at school. If it were possible to initiate verbal expression, this would make more interaction possible. A successful outcome would enable an increase of interaction. The task 'Talk about your cuddly toy' is in itself a vague one, which does not create a clear expectation about what is to be said. Therefore, De Bono's thinking hats were used as a tool to clarify expectations. The introduction to the task consisted of a demonstration of the thinking hats. The demonstration was accompanied by words to express the views on the object, the cuddly toy, associated with the hat. The same words were always used in the following exercise. Whenever a student forgot the right words, the teacher supported the expression by listing the possible words to be used.

These interventions allowed the pupils to make use of their freedom to decide for themselves how to carry out the task. The focal points (five colours of the thinking hats) helped them to create thoughts that matched the object (the cuddly toy) and the chosen focus.

The case study revealed several important effects. All pupils enjoyed the activity. When not participating themselves, they made sure to observe and listen in, which they did in silence. Furthermore, the importance of familiarity of the object became clear. Compared to the own hug, the classroom hug led to less expression and even to fear of expressing oneself. The own cuddly toy aroused enthusiasm and role-playing. Especially the black hat generated a lot of fun. The pupils apparently enjoyed talking about their beloved cuddly toy in disgust.

Chapter five, which is about the case-study 'the making of a mini-chair' investigated the relationship between activities tailored to pupils aged nine to twelve and their engagement. If self-determined learning is the natural human way of learning, it should also be possible for this age group by meeting their needs. The assignment was 'Make your favorite mini-chair'. The assignment was divided into ten well-defined tasks, in which hands-on techniques were used to produce partial products. During joint presentations, each pupil was able to report on his/her working method and show his/her product. Questions like 'what do we know and what don't we know yet?' and 'what still needs to be done?' had to make the pupils share knowledge with each other. The joint presentations provided feedforward. After the past had been expressed (I did this task in this way), so much understanding had developed in the present (can the result of this subtask lead to the desired chair?), that the desired future (the desired chair) could be shaped further. In this way, pupils did not have to defend the product of a subtask. That would have blocked their sense of wonder that is necessary for any improvement. Wonder is what pupils need in order to decide for themselves how to carry out a task.

These interventions enabled the pupils to self-determine ways to do the subtasks, whereby the instructed technique would be used and the focus of attention (the favorite mini-chair) was kept in mind.

Because of the growing of shared knowledge through the joint presentations, also collaboration increased. The effect was that the teacher was able to scaffold remaining inabilities of pupils. De class atmosphere changed from chaotic to structured and engaged.

The end-result was a collection of diverse, nice mini-chairs.

Interpretation of the findings

Several factors have to be taken in account to realize a successful Design & Technology lesson. A topic has to serve an educational goal and to suit the pupils. Thus, the educational goal has to be converted into an identifiable and doable task. A task is doable, when there is clarity about 'how' to do something and what to pay attention to while doing it. Furthermore, the success criteria of the task must be clear in order to know whether the task has been performed correctly or incorrectly. In addition, the task should challenge the pupil to do it. A motivational task evokes feelings of '*I can do that*' and feelings of '*I want to do that*' and results in active participation. In other words, engagement shows up when a task is identifiable, doable and motivational. Joint presentations are also needed to achieve iteration. Presenting evokes reflection and listening to and observing other pupils' presentations increases understanding and provides inspiration.

The case studies of this thesis show that it is possible to engage all pupils in class during a Design & Technology activity. Every teacher can create the circumstances, in which engagement can flourish. The use of self-determination during Design & Technology leads to insight, but also to practicing making one's own decisions.

The conditions that allowed self-determination to flourish in this thesis were the liberty to self-determine one's own ways of performing a task and to experience the consequences of those ways. Furthermore, the liberty to perform or not perform a task, sufficient knowledge to be able to oversee the task, sufficient skill to perform the task, success criteria, and a concrete picture of what needed to be observed while performing the task (point of attention), ensured engagement. The joint presentations, in which each pupil showed his/her product, shared his/her findings and talked about the process used, followed by the joint formulation of the next goal, helped to obtain ongoing engagement.

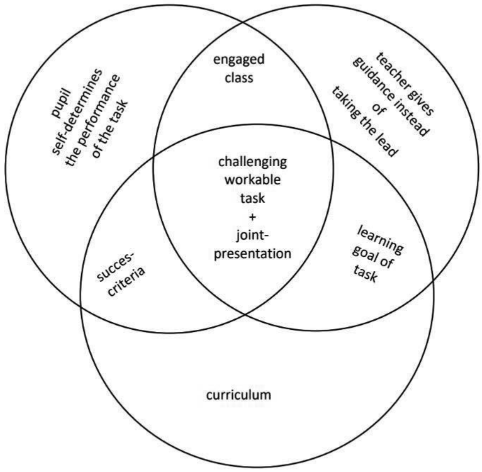


Figure summary 1. An activity can at the same time work towards curriculum goals, allow for teacher guidance, offer challenge and meet the psychological needs of all pupils in class, through well-defined tasks combined with joint presentations.

Looking differently at the factors that create the conditions for engagement, it is possible to see that disengaged learners experience feelings that disengage them. A learner needs feelings of 'I can do that', 'I am allowed to do that' and 'I am interested in the effect of a thought-out method' (challenging), and 'I want to know more' (shared presentations) in order to be engaged for a long term.

Limitations

Although this research was done on a relatively small scale (about 130 pupils were involved) in Montessori schools, it clearly shows how interventions can influence the engagement of a group of children. It is likely that the interventions will also work for other primary school pupils, if they are used to being given the freedom to self-determine.

Recommendations

Allowing pupils to decide how a task is done proved to be the heart of Design & Technology education during the research for this thesis. I also discovered that the design process can take many forms, from highly structured to completely intuitive and unplanned, and everything in between. Non-formal and informal learning are by nature characterised by 'figuring it out'. In everyday life, people are constantly designing solutions. Whenever they try to close a gap between an existing and a desired state, they design solutions. The combined use of formal, informal and non-formal learning could also take place at school, by using the reality of the pupils as a starting point for the Design & Technology lessons.

Design-based learning is not only useful during Design & Technology lessons, but also during thinking tasks, which are separate from Design & Technology education. For example, in the case study 'Observe as an artist', a thinking skill initiated at school was used and the skill was practised in everyday life.

Design-based learning can be achieved by adapting a path to a learning goal to the learners. This can be done through a step-by-step or project approach, but also by first organising a preparatory activity, so that the planned activity starts to fit in with the pupils' knowledge.

However, schools must take into account that adapting the lessons to the pupils requires a lot of time and attention from the teacher. For example, teachers need to be given room to experiment and discuss the results of experiments, with regard to offering tasks that invite pupils to 'find out for themselves'. They must also be given room to experiment with meeting the innate psychological needs of autonomy, competence and relatedness of pupils.

In order for all pupils in a class to be able to decide for themselves how to carry out an assignment, teachers must make it possible for them. For this they need more than knowledge; they need insight and skill. This can be achieved by experimenting with creating well-defined tasks for the pupils and by adapting their own attitudes to the pupils.

In our research, joint presentations appeared to offer opportunities for the continuation of engagement and for a growing community in the classroom. It is therefore recommended that joint presentations are used in the classroom. The use of joint presentations makes the use of self-determined learning by all pupils more feasible.

Final remarks

Last but not least, based on the findings of this study, it is recommended that more use be made in primary education of the possibilities offered by Design & Technology education to practice the thinking processes that go hand in hand with self-determination. A far-reaching integration of Design & Technology activities in the educational system can ensure this.

Autonomy, competence and relatedness are essential in realizing the full potential of design based learning. Design and technology educators and researchers should make more use of the principles and interventions that have been developed in the context of Montessori education. Not only does Montessori's method give indications on how well-defined tasks can be created, but it has also dealt extensively with the integration of subjects.

Samenvatting

In dit proefschrift wordt gezocht naar manieren om elke basisschool leerling actief te betrekken bij Design & Technology lessen, zodat ze allemaal kunnen profiteren van deze lessen.

Het doel van Design & Technology onderwijs is om leerlingen kennis, vaardigheden en attitudes te laten verwerven met betrekking tot de technologie, zoals ze die in het dagelijks leven tegenkomen en zoals ze die later in hun werkzame leven kunnen tegenkomen. Sommige van deze vaardigheden kunnen worden aangeleerd, maar andere moeten worden onderwezen totdat er inzicht ontstaat in het effect van handelingen en in de toepassingsmogelijkheden. Ontwerpen is een voorbeeld van zo'n vaardigheid.

Ontwerpen is een manier van denken, waarvan creativiteit een belangrijk aspect is. Ontwerpen kan worden gezien als de verbeelding van ideeën in de werkelijkheid. Omdat denken in iemands hoofd gebeurt en onzichtbaar is, moet er iets gebeuren voordat het idee verwerkelijkt kan worden. Dit vereist het nemen van een beslissing over de manier van verwerkelijken. Niet alleen ontwerpen vereist het nemen van beslissingen over de manier waarop het moet gebeuren, maar ook andere Design & Technology activiteiten doen dat. Beslissen is dus een belangrijke deeltaak van ontwerpen. Het kunnen nemen van bewuste, doordachte beslissingen vraagt veel oefening. Daarom moet het onderwijs in Design & Technology de leerlingen mogelijkheden bieden om beslissen vaak te oefenen. Als leerlingen hebben geleerd hoe ze tot hun eigen beslissingen kunnen komen, kunnen ze dit ook toepassen in andere situaties.

Ontwerpen kan vele functies hebben. Het kan worden gebruikt om onderzoek te doen en kennis op te bouwen, om oplossingen te bedenken en te maken, of om de werkelijkheid te herscheppen naar eigen inzicht en smaak. Technologie is niet alleen het middel om het ontwerp te verwezenlijken, maar ook om er in de werkelijkheid mee te experimenteren. Zo kan verworven kennis of een ontworpen idee verfijnen.

Kinderen gaan naar school om zich voor te bereiden op hun verdere leven. Deze voorbereiding vraagt om de ontwikkeling van hun denken, hun manier van communiceren en om hun manier van omgaan met hun omgeving. Ook moeten ze zich bewust worden van de invloed van hun handelen op de wereld. Deze voorbereiding moet daarom een belangrijk doel van het leren zijn. Dan zijn er taken nodig die daarop gericht zijn. De oefening om op een verantwoorde manier zelf te beslissen hoe taken worden aangepakt is daarom nuttig voor hun persoonlijke ontwikkeling. Design & Technology-onderwijs kan zulke oefeningen bieden. Zo kunnen kinderen ontdekken dat het fijn is om zelf de regie te hebben bij het nemen van een beslissing. Een extra voordeel is dat kinderen, door zelf te bepalen hoe ze een taak aanpakken, gebruik zullen maken van hun sterke kanten en werken aan hun zwakke kanten. Door in de gelegenheid te zijn om vaak zelf te beslissen zullen kinderen het nut ontdekken van zelf de regie te hebben en daar zelf om gaan vragen. Zij ontwikkelen zo zelfvertrouwen. Het resultaat zal zich uiten in sociaal gedrag, flexibiliteit en creativiteit.

Hoewel er goede resultaten worden behaald binnen Design en Technology onderwijs, is er nog geen aanpak beschikbaar waarmee een actieve betrokkenheid bij alle leerlingen wordt bereikt.

Het uitgangspunt in dit proefschrift is de aanname dat betrokkenheid van de hele klas mogelijk is, als elk kind zelf kan beslissen hoe het iets gaat doen. Volgens de zelf-determinatie theorie (Deci & Ryan, 2000) vraagt dit om de bevrediging van drie aangeboren psychologische behoeften. Mensen hebben een gevoel van autonomie, competentie en verbondenheid nodig om in staat te zijn hun eigen beslissingen te bedenken en uit te voeren. Volgens Montessori (Gutek, 2004) is het bovendien nodig dat er nieuwsgierigheid is naar de uitkomst van de handeling die volgt op de beslissing. Dan pas zal een leerling nadenken over mogelijke uitvoeringen van de handeling. Als de zelf-determinatie van een uitvoering van een handeling werkelijk plaatsvindt, is dat zichtbaar; in betrokkenheid.

Betrokkenheid leidt tot actie. Bestaande leertheorieën, zoals de cognitieve en de constructivistische theorie, hebben allebei hun voordelen en nadelen met betrekking tot het mogelijk maken van betrokkenheid. De cognitieve theorie omzeilt het gebruik van zelf-determinatie, waardoor leerlingen niet zelf de regie krijgen over de uitvoering van opdrachten. De constructivistische theorie houdt onvoldoende rekening met de aangeboren behoeften aan competentie, waardoor ook autonomie en verbondenheid niet tot hun recht komen. Hierdoor zijn zij beiden niet geschikt alle leerlingen in een klas te actief te laten meedoen.

De Montessori methode (Gutek, 2004) biedt leerlingen de gelegenheid om de kennis die ze hebben te gebruiken en uit te breiden door ze oplossingen voor een heel precies gedefinieerd probleem te laten ontwikkelen. Montessori's methode maakt het mogelijk dat ze dat op een zelfbepaalde manier doen door ze 'liberty' (vrijheid met verantwoordelijkheid voor verbondenheid) te bieden, aangevuld met omstandigheden waardoor de 'liberty' ook werkelijk gebruikt kan worden. De omstandigheden worden bepaald door twee factoren. De eerste factor is een heldere definitie van waar op gelet moet worden tijdens de uitvoering van de taak. De tweede factor is een heldere definitie van een juiste uitkomst van de taak. Verder motiveert Montessori's methode leerlingen door ze nieuwsgierig te maken naar hoe ze de gewenste uitkomst kunnen bereiken. De nieuwsgierigheid zorgt ervoor dat zij hun 'liberty' gebruiken om verschillende oplossingen uit te proberen. Dit zorgt voor het gebruik van zelf-determinatie. Ik gebruikte deze principes om bestaande Design & Technology lessen aan te passen. Zo werden in mijn klassen alle leerlingen actief betrokken bij de opdrachten.

Het doel van het onderzoek in dit proefschrift was het vinden van de elementen die het langdurig betrekken van alle leerlingen bij Design & Technology activiteiten mogelijk maken. Betrokken gedrag wijst op gevoelens van *'ik kan de taak doen'* en '*ik wil de taak doen*'.

Dit doel leidde tot de volgende hoofdvraag voor mijn onderzoek: 'Hoe kunnen we alle leerlingen van een klas activeren tijdens een Design & Technology activiteit?'. Deze hoofdvraag leidde op een organische manier naar vier deelvragen:

1. *'Wat is het effect op de uitvoering van het ontwerpproces als dezelfde opdracht verschillende keren wordt gegeven aan zes tot acht jaar oude leerlingen?'*
2. *'Hoe kunnen we vier tot achtjarige leerlingen voorbereiden op Design & Technology activiteiten?'* en *'Wat zijn de effecten van de voorbereiding op het daarop volgende ontdek- en leerproces?'*
3. *'Hoe kan een leraar ervoor zorgen dat jonge kinderen zich verbaal kunnen uiten?'* en *'Hoe kunnen leraren de kennis die 4-6 jarigen hebben zo ondersteunen dat ze zich kunnen uiten?'*
4. *'Wat is het effect van het verdelen van een complexe Design & Technology opdracht in simpele, concrete taken, gecombineerd met tussentijdse presentaties van de individuele werkwijzen en producten door alle leerlingen?'* en *'Wat is het effect op de uitvoering van het ontwerpproces bij leerlingen van negen tot twaalf jaar oud?'*, *'Wat is het effect op de samenwerking in de klas?'* en *'Wat is het effect op de leraar?'*

Bevindingen per hoofdstuk

In ***hoofdstuk twee,*** dat de case-study 'De knikkerboot' behandelt, wordt het effect van diverse factoren van de leersituatie op het herhalen van de uitvoering van eenzelfde opdracht onderzocht met behulp van observatie.

De leersituatie werd ingeleid door een demonstratie en een bijbehorende opdracht; 'Vorm een vel aluminium zo, dat het –op het water gelegd- knikkers kan dragen zonder te zinken. Hoe meer knikkers gedragen worden, hoe beter.'

Verder werden er interventies toegevoegd om de gewenste leersituatie te bereiken. De interventies waren: vrijheid om zelf manieren te bedenken om het aluminium te vormen, vrijheid om dit uit te voeren, het bieden van een focus (het omslagpunt tussen drijven en zinken) om zelf te kunnen bepalen hoe de opdracht werd uitgevoerd en een succes criterium om te kunnen bepalen of het resultaat gewenst was of niet. De leerlingen konden zelf bepalen of het resultaat gewenst was door de knikkers te tellen die ze in de boot legden. Het aantal dat op het moment dat de boot ging zinken in de boot lag, bepaalde het resultaat. Verder werd er door de leerlingen samen gewerkt (verplicht en zelfgekozen), mochten ze het uitproberen van het drijfvermogen van hun boot op laten nemen op video, werden er aan het einde van een les groepspresentaties van alle bedachte 'boten', georganiseerd. De boten werden tijdens deze presentatie geordend aan de hand van het aantal knikkers dat gedragen werd zonder te zinken.

Het algemene effect was dat alle leerlingen betrokken aan de slag gingen. Extra effecten waren dat kinderen bij elkaar keken. Ook vroegen ze elkaar om uitleg over *'waarom'* een boot was vormgegeven op een specifieke manier. De kinderen bleken het erg leuk te vinden om het drijfvermogen van hun boot voor de video uit te proberen. Verder gaven de aan het einde van elke les georganiseerde groepspresentaties aanleiding om nieuwe oplossingen uit te proberen in een volgende les. Zo werd de uitvoering van de opdracht herhaald met als gevolg dat er echt perfecte oplossingen werden gevonden.

De combinatie van alle interventies bleek ruimte te bieden om tegemoet te komen aan de beperkingen die jonge kinderen hebben door geringe kennis en geringe handvaardigheid. Deze beperkingen veroorzaken een behoefte aan concrete aanwijzingen en een behoefte aan een makkelijk uitvoerbare opdracht. De concrete aanwijzingen bestonden uit de demonstratie van hoe een vel aluminium op het water drijft en hoe een knikker eraf rolt als die er op gelegd wordt. Verder bestond de concrete aanwijzing uit het uitspreken van de verwachting; 'Hoe meer knikkers je 'boot' draagt zonder te zinken, hoe beter'. Hierdoor werd de aandacht gevestigd op het tellen van de knikkers tijdens het in de 'boot' leggen. Daar alle leerlingen op die leeftijd het tellen goed beheersen, werd deze techniek ingezet om het gewicht van de knikkers te bepalen. Gaandeweg werd ook de aandacht gevestigd op het netjes verdeeld in de 'boot' leggen van de knikkers. Het waarnemen van de relatie tussen de grootte van het drijvend oppervlak en het drijfvermogen werd hierdoor belangrijker gemaakt dan het maken van de boot.

In ***hoofdstuk drie*** worden twee case-studies besproken, 'kijken als een kunstenaar' en 'wielen (ver)draaid handig'. De leeftijd van de leerlingen was respectievelijk vier tot zes jaar oud, en zeven tot negen jaar oud. Beide case-studies onderzochten of voorbereidende activiteiten konden zorgen voor een dusdanige leersituatie, dat alle leerlingen in staat zouden zijn om een daarop volgende Design & Technology activiteit uit te voeren. Een Design & Technology activiteit is bovendien gebaat bij gedeelde kennis. Door gedeelde kennis bij de start van een nieuwe opdracht kan de klas makkelijker met elkaar praten over de opdracht. Het maakt het ook makkelijker om tijdens de uitvoering over de bevindingen te praten.

Zo'n voorbereiding, waardoor een gedeeld startpunt bereikt wordt, kan op verschillende manieren worden vormgegeven. In ons onderzoek had het als overeenkomst dat het een klassikale activiteit was. In beide case-studies werd de uitvoering van de opdracht gedemonstreerd. In de case-study 'Kijken als een kunstenaar' werd het observeren van de demonstratie gevolgd door klassikaal uitproberen en vertellen van de bevindingen. In de case-study 'Wielen, (ver)draaid handig' werd het observeren van de demonstratie gevolgd door individuele exploratie van oplossingen.

Het effect van de demonstratie op de betrokkenheid tijdens de uitvoering van het uitproberen werd onderzocht. De leersituatie bevatte de volgende factoren; vrijheid om zelf manieren te bedenken om respectievelijk 'iets nieuws te ontdekken', 'verschillen in uit te oefenen kracht te voelen', en vrijheid om dit uit te voeren. Verder werd een focus geboden om zelf te kunnen bepalen wat het resultaat is van de uitvoering van de taak en of dat een gewenst resultaat was. Ook samenwerken was mogelijk.

Door de gezamenlijke exploratie bij de case-study 'kijken als een kunstenaar' werden individuele ideeën direct verwoord en gedeeld. Dit ontbrak bij de case-study 'Wielen, (ver)draaid handig'. Het individueel verwoorden van 'Wat weten we nu?' bleef achterwege. Ook bleef tijdens de op de voorbereiding volgende Design & Technology activiteit het gezamenlijk formuleren van 'Wat weten we nog niet' achterwege. Het delen van bevindingen gebeurde wel tijdens de les, doordat leerlingen bij elkaar gingen kijken.

De effecten waren in het eerste case-study dat leerlingen het inzicht gingen toepassen. Dat gebeurde in de klas, maar later ook buiten de klas en thuis. Deze voorbereiding was dus goed geslaagd.

In de tweede case-study was het goede effect van de demonstratie te zien tijdens het uitproberen. Echter, tijdens de laatste les, waarin de leerlingen gevraagd werd om zelf een machine te ontwerpen, bleek het effect van de afwezigheid van reflectie op wat geleerd was tijdens het uitproberen. De leerlingen kwamen niet of moeilijk tot ontwerpen en niet langer waren alle leerlingen betrokken. Aan de behoefte van voldoende inzicht om een duidelijke verwachting te kunnen ontwikkelen over de uitkomst, was niet voldaan. Deze voorbereiding schoot dus tekort.

Vanwege de duidelijke effecten van een groepsgewijs verwoorden en delen van individuele ideeën werd de in ***hoofdstuk vier*** besproken case-study 'Praten over je eigen knuffel' gestart. Met vier tot zesjarige leerlingen werden knuffels besproken. Omdat dit een opdracht is met een op zichzelf vage verwachting, werd met behulp van de denkhoeden van De Bono (2009) geprobeerd de verwachting helderder te maken. Ook werd er rekening gehouden met het feit dat er op deze leeftijd nog erg weinig gedeelde kennis is. Ook gedeelde woorden die passen bij ideeën en gevoelens zijn er op die leeftijd nog niet veel, omdat de kennis, die de leerlingen hebben, van thuis komt en niet van school. Daarom werd geprobeerd om de behoefte aan voldoende kennis te bevredigen door in een voorbereidende activiteit met de leerlingen woorden af te spreken, die iedereen zou gebruiken. Leerlingen die toch niet op goede woorden konden komen, werden geholpen door de leraar die de woorden nog een keer herhaalde en hen vervolgens liet kiezen uit deze woorden.

Hierdoor kregen de leerlingen de vrijheid om zelf manieren te bedenken om iets te vertellen over hun knuffel, en de vrijheid om dit al dan niet uit te voeren. De denkhoeden boden de keuze uit vijf heldere perspectieven om te bepalen hoe ze ideeën zouden delen.

De case-study onthulde verschillende belangrijke effecten. Alle kinderen vonden de activiteit erg leuk. Als ze niet meededen, zorgden ze er voor dat ze de activiteit goed konden volgen. Daarbij waren ze heel stil. Kennelijk waren ze actief aan het luisteren en waarnemen. Verder had de mate van vertrouwdheid van de knuffel een duidelijk effect. De redelijk bekende klasse-knuffel zorgde voor weinig uitingen en zelfs vrees om te uiten. De eigen knuffel zorgde voor enthousiasme en veel uitingen. De leerlingen pakten de eigen knuffel beet en speelden ermee tijdens het vertellen. Dat deden ze niet met de klasse-knuffel.

Het bespreken van de eigen knuffel op duidelijk onderscheiden manieren (bepaald door de denkhoeden) bleek het uiten makkelijker te maken voor de leerlingen. Sterker nog, de vertellende leerling nam zichtbaar de rol van de denkhoed op zich. Vooral de zwarte hoed gaf veel plezier. Leerlingen vonden het blijkbaar heel vermakelijk om vol afschuw over hun lievelingsknuffel te vertellen.

In ***hoofdstuk vijf*** werd de case-study ‘het maken van je favoriete mini-stoel’ besproken. Deze case-study onderzocht de relatie tussen het aanpassen van opdrachten, aan de kennis en vaardigheden die leerlingen bezitten, en hun betrokkenheid. De in de vorige hoofdstukken gevonden factoren werden toegepast om te onderzoeken of deze factoren ook leerlingen in de leeftijd van negen tot twaalf jaar. Deze oudere leerlingen zijn meer dan jonge leerlingen gewend aan formeel leren. Echter als de aanname dat de bevrediging van psychologische behoeften nodig is op alle leeftijden om de zelfbepaling, van hoe een opdracht wordt uitgevoerd mogelijk te maken, zouden ook oudere leerlingen betrokken gedrag moeten kunnen vertonen als ze een geschikte opdracht krijgen. Het project was ‘Maak je favoriete mini-stoel’. Het project werd verdeeld in tien eenvoudige en duidelijke taken, waarbij steeds een andere techniek de aandacht vasthield. Het resultaat van elke taak moest worden bezien in het kader van het einddoel van het project. Er werden regelmatig groepspresentaties georganiseerd, waarbij elke leerling vertelde over zijn werkwijze en zijn stoel. Zo’n presentatie zorgt voor reflectie. Door leerlingen te bevragen; ’wat kunnen we leren van de gevonden resultaten?’ en ‘wat weten we nog niet/wat hebben we nog niet bereikt?’ konden leraar en leerlingen erachter komen wat er nog niet werd beheerst. Een groepspresentatie kan leiden tot “feed-forward” en zorgt ervoor dat nieuwsgierigheid niet verdwijnt, maar wordt aangewakkerd. Nadat over het verleden verteld is (ik had dit plan en heb het zo uitgevoerd), ontstaat er een dusdanig inzicht in het heden (dit is het resultaat), dat de gewenste toekomst (de gewenste stoel) verder kan worden vorm gegeven.

Deze interventies zorgden ervoor dat de leerlingen zelf konden bepalen hoe ze de deeltaken gingen uitvoeren. Ook het samenwerken nam toe. Door deze twee factoren kwam er ruimte voor de leraar om leerlingen te ondersteunen bij vaardigheden waar ze nog niet zo goed in waren. De sfeer in de klas veranderde geleidelijk aan van chaotisch naar gestructureerd en betrokken. De duidelijke verwachtingen, de gedeelde kennis en de geboden hulp door de leraar leidden kennelijk tot groepsbetrokkenheid.

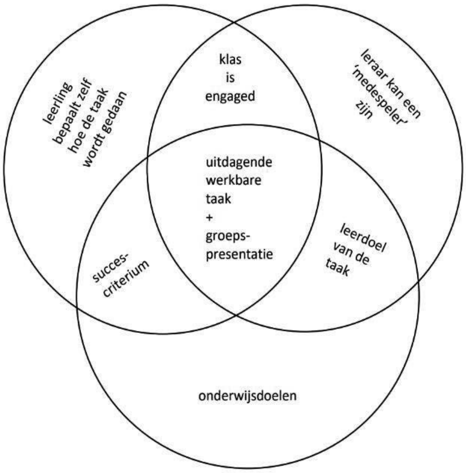
Het eindresultaat was een collectie van heel verschillende, mooi uitgevoerde stoeltjes.

Interpretatie van de bevindingen

Om een succesvolle Design & Technology les te realiseren moet er met verschillende factoren rekening gehouden worden. Een goed gekozen onderwerp dient én een onderwijsdoel én de leerling. Dus het onderwijsdoel moet vertaald worden naar een werkbare taak met een herkenbaar onderwerp. Een taak is werkbaar als het duidelijk is '*hoe*' die moet worden gedaan en op '*wat'* gelet moet worden, (het aandachtspunt) om te weten of het doel behaald is of niet. Verder moet een succes criterium duidelijk maken of de uitkomst van de taak goed is of (nog) niet. Als de taak bovendien prikkelend is, raken leerlingen gemotiveerd om de taak te doen. Zo krijgen leerlingen het gevoel *'dat ze de taak kunnen doen'.* en het gevoel krijgen '*dat ze de taak willen doen*'. Leerlingen hebben dus een uitdaging nodig om de taak te doen. Pas als de taak herkenbaar, uitdagend en werkbaar is, kunnen alle leerlingen betrokken raken. Om de leerlingen een aanleiding te geven voor iteratie, zijn groep-presentaties nuttig. Als iedere leerling zijn idee/product presenteert zorgt dit voor de reflectie (door presenteren) van iedere leerling en voor inspiratie voor hun klasgenoten.

De deelstudies uit dit proefschrift laten zien dat het mogelijk is om alle leerlingen in de klas te betrekken bij een Design & Technology activiteit, als we omstandigheden scheppen, waaronder de leerling zelf kan bepalen hoe deze de taak doet. Dit leidt tot inzicht in de uitkomst van de taak. Bovendien wordt zo het nemen van bewuste, doordachte beslissingen als vaardigheid geoefend.

De omstandigheden, die zelfbepaling in deze dissertatie mogelijk maakten waren de vrijheid om zelf te bepalen hoe men een taak uitvoert en om daarmee te experimenteren. Verder zorgden de vrijheid om een taak wel of niet uit te voeren, voldoende kennis om de taak te kunnen overzien, voldoende vaardigheid om de taak uit te voeren, succescriteria, en een concreet beeld van wat er tijdens het uitvoeren van de taak moest worden waargenomen (aandachtspunt), voor betrokkenheid. De groeps-presentaties, waarbij elke leerling zijn product liet zien, zijn bevindingen deelde en over het gebruikte proces sprak, gevolgd door het gezamenlijk formuleren van het volgende doel, hielpen bij het verkrijgen van langer durende betrokkenheid



Figuur samenvatting 1. De eigenschappen van een situatie die het mogelijk maakt dat een opdracht motiverend is voor de hele klas, de leerling vrijheid biedt om te experimenteren, de leraar de ruimte geeft om mee te doen én toewerkt naar het bereiken van onderwijsdoelen.

Anders kijkend naar de factoren die de omstandigheden scheppen voor betrokkenheid, zien we dat als leerlingen niet actief en betrokken zijn, zij blijkbaar bepaalde gevoelens ervaren die hen tegenhouden. Zo moet een leerling het gevoel hebben van 'Dat kan ik wel', 'Ik mag het doen', 'Ik ben nieuwsgierig naar hoe het werkt' (uitdagend), en 'Ik wil nog meer weten!' (groeps-presentatie) om echt langdurig actief te worden.

Beperkingen

Hoewel dit onderzoek gebeurde op relatief kleine schaal (er waren ca. 130 leerlingen bij betrokken), op Montessori scholen, laat het duidelijk zien hoe interventies de engagement van een groep kinderen kan beïnvloeden. Waarschijnlijk werken de interventies, die zorgen voor voldoende competentie, ook voor andere basisschoolleerlingen, die gewend zijn om de vrijheid te krijgen om zelfbepalend te werken.

Aanbevelingen

Leerlingen zelf laten bepalen hoe een taak wordt uitgevoerd bleek tijdens het onderzoek voor deze dissertatie een actieve uitvoering van Design & Technology activiteiten te dienen. Ik ontdekte ook dat het ontwerpproces vele vormen kan aannemen, van zeer gestructureerd tot volledig intuïtief en ongepland, en alles daar tussenin. Niet-formeel en informeel leren worden van nature gekenmerkt door 'zelf uitzoeken'. In het dagelijks leven zijn mensen voortdurend bezig met oplossingen te ontwerpen. Telkens wanneer zij een kloof proberen te dichten tussen een bestaande en een gewenste toestand, ontwerpen zij oplossingen. Het gecombineerde gebruik van formeel, informeel en niet-formeel leren zou op school ook kunnen plaatsvinden, door de realiteit van de leerlingen als uitgangspunt te nemen voor de lessen Design & Technology.

Ontwerpend leren is niet alleen nuttig tijdens de lessen Design & Technologie, maar ook tijdens denktaken, die los staan van Design & Technology onderwijs. Zo werd in de casestudy 'Kijken als een kunstenaar' gebruik gemaakt van een op school geïnitieerde denkvaardigheid en werd de vaardigheid in het dagelijks leven geoefend.

Ontwerpend leren kan worden bereikt door een pad naar een leerdoel aan te passen aan de leerlingen. Dit kan door een stapsgewijze aanpak of project-aanpak, maar ook door eerst een voorbereidende activiteit te organiseren, zodat de geplande activiteit gaat aansluiten op de kennis van de leerlingen.

Scholen moeten er echter rekening mee houden dat het aanpassen van de lessen aan de leerlingen veel tijd en aandacht van de leerkracht vraagt. Zo moeten leraren de ruimte krijgen om te experimenteren en de resultaten van experimenten met elkaar te bespreken, met betrekking tot het aanbieden van taken die leerlingen uitnodigen om 'zelf uit te zoeken hoe het zit'. Ook moeten ze de ruimte krijgen om te experimenteren met het tegemoet komen aan de aangeboren psychologische behoeften van autonomie, competentie en verbondenheid van de leerlingen.

Om alle leerlingen in een klas in staat te stellen zelf te bepalen hoe ze een opdracht uitvoeren, moeten leraren het mogelijk maken voor hen. Daarvoor hebben ze meer nodig dan kennis; ze hebben inzicht en vaardigheid nodig. Dit kan worden bereikt door te experimenteren met het creëren van goed omschreven taken voor de leerlingen en door hun eigen houding aan te passen aan de leerlingen.

In ons onderzoek bleken gezamenlijke presentaties te leiden tot langdurig actief en betrokken gedrag tot een gewenst leereffect bereikt was. Ook maakten ze een groeiende gemeenschap in de klas mogelijk. Het is daarom aan te bevelen om groeps-presentaties in de klas te gaan gebruiken.

Slotopmerkingen

Last but not least wordt op grond van de bevindingen van dit onderzoek aanbevolen om in het basisonderwijs meer gebruik te maken van de mogelijkheden die Design & Technology onderwijs biedt om de denkprocessen te oefenen die nodig zijn voor zelfbepaling. Een verregaande integratie van Design & Technology activiteiten in het onderwijssysteem kan hiervoor zorgen.

Autonomie, competentie en verbondenheid zijn essentieel om meer gebruik te kunnen maken van het potentieel van ontwerpend leren. De principes en interventies die zijn ontwikkeld in de context van Montessori onderwijs zouden kunnen helpen om dat voor elkaar te krijgen. Niet alleen geeft Montessori's methode aanwijzingen over hoe opdrachten kunnen worden gecreëerd die rekening houden met autonomie, competentie, verbondenheid en uitdagen, maar Montessori heeft zich ook uitvoerig beziggehouden met de integratie van vakken.

Dankwoord

Dit proefschrift is mede tot stand gekomen dankzij de steun van velen. Alle mensen die elk op hun eigen manier dit mogelijk voor mij hebben gemaakt wil ik hierbij dan ook bedanken.

Als eerste wil ik graag de belangrijke rol van mijn promotor Marc de Vries benoemen in de totstandkoming van dit proefschrift. Hoewel wij het van meet af aan eens waren over de strekking van het proefschrift (Design & Technology onderwijs geschikt maken voor elke basisschool-leerling), had ik geen idee over de vormgeving van het promotie-proces. Marc's vertrouwen in de goede afloop stelde mij gerust. Hij doceerde de vormgeving van het hele proces in voor mij haalbare stapjes, waarbij hij steeds ons gedeelde idee 'engagement verkrijgen' als uitgangspunt (succescriterium) nam. Door zijn onderwijstalent ervaarde ik het promotie-proces als aantrekkelijk en als iets dat binnen mijn bereik lag. Belangrijk voor een praktisch lerend persoon, zoals ik ben.

Mijn copromotor Remke Klapwijk speelde een heel andere rol in het promotie-proces. Zij was belangrijk in de vormgeving van de onderzoeken die ik deed en de beschrijving daarvan. Waar ik dacht vanuit de leerlingen en hun mogelijkheden, dacht zij vanuit de methodiek en de technische hulpmiddelen. Samen kwamen we tot herkenbare onderzoeksresultaten voor Design & Technology onderwijs. Remke was ook degene die voor de uitleg van de gevonden resultaten een in onderwijskringen algemeen bekend perspectief aandroeg als focus. Door dit focus werd de discussieparagraaf makkelijker te lezen. Ik heb bewondering voor de onuitputtelijke hoeveelheid tijd en energie die zij gestoken heeft in het helpen omzetten van mijn uitingen in communiceerbare, wetenschappelijke teksten.

Ook een onafhankelijk lid van mijn promotiecommissie, Perry den Brok, heeft een belangrijke bijdrage geleverd aan het verhogen van de begrijpelijkheid van mijn proefschrift. Door te opperen de uitleg te koppelen aan de zelf determinatie theorie werd het mogelijk om de werking van de door mij gevonden elementen van een activerende Design & Technology activiteit helder te beschrijven.

Aan de inzichten die ten grondslag liggen aan de inhoud van dit proefschrift zijn hebben verschillende personen bijgedragen. Mijn eerste juf, juffrouw Buize, op de dorpsschool in Pijnacker was er één van. Samen met mijn vriendinnen haalden wij haar op van huis en dan liepen we gearmd naar school. Haar participerende rol was mijn voorbeeld toen ik zelf leerkracht werd. Mijn moeder, ook onderwijzeres, heeft mij zelfredzaamheid geleerd. Samen lazen wij Simone de Beauvoir (in het Frans!). Zo legde mijn moeder de kiem voor mijn waardering van autonomie. Na het overlijden van mijn moeder leerde ik van mijn stiefmoeder, professor Aafje Vos, dat autonomie en rekening houden met anderen samen kunnen gaan en dan juist identiteit versterken. Door de leiding te nemen over jezelf en daarover duidelijk te zijn, heeft zij haar hele leven veel bereikt op uiteenlopende gebieden. Als echter de macht over jezelf je ontnomen wordt, is het moeilijk om jezelf te zijn. Mijn vriendin Simone en ik bespreken regelmatig uitgebreid zulke situaties. Heerlijk bevrijdend is dat en heel leerzaam. Van deze vrouwen komt mijn inzicht vandaan dat zelfs kinderen de leiding over zichzelf kunnen nemen, als ze dat toegestaan en mogelijk gemaakt word. Dat is goed voor hun zelfstandigheidsontwikkeling. Aan volwassenen is dan de taak te zorgen dat zij dat zonder gevaar kunnen doen.

Als praktisch lerend persoon heb ik veel kunnen leren in de verschillende banen die ik gehad heb. Ik heb het vaak getroffen met mijn leidinggevenden. Ik ben hen veel dank verschuldigd voor de uitdagende taken die zij mij gaven. Ik hoefde geen controlelijstjes af te werken, maar mocht zelf beslissen hoe ik iets aanpakte. Zij schiepen eenvoudigweg de omstandigheden, waarbinnen het voldoen aan eisen en veiligheid gewaarborgd was. Dat begon op de afdeling Klinische Neurofysiologie van Ursula Kliniek in Wassenaar, waar ik o.a. de praktische uitvoering van wetenschappelijk onderzoeken deed, waarbij een arts de leiding had. Bij het team Vroegtijdige Onderkenning van Ontwikkelingsstoornissen van Jeugdgezondheidszorg Den

Haag werd ik betrokken bij de werkzaamheden van de diverse teamleden. Met Jan van der Hoeven en Lia de Gier heb ik heel fijn samengewerkt. Met Petra Steuteknuel, jeugdarts, heb ik nog steeds contact. Zij is altijd heel geïnteresseerd in mijn onderzoek en brengt mij zo op nieuwe gedachten. Het hoofd van de afdeling Jeugdgezondheidszorg, jeugdarts Mariet Monné, heeft mij vervolgens gestimuleerd om verder te gaan studeren. Uit praktische overwegingen werd het geen Orthopedagogiek, maar de PABO. De directeur van de Montessori basisschool waar ik vervolgens ging werken, Peter Soonius, gaf mij de geweldige opdracht om het techniekonderwijs vorm te geven op onze school. We bespraken regelmatig de aanpak en de mogelijkheden, waarbij hij sprak vanuit zijn interesse in (spoor)techniek en ik vanuit mijn interesse in maak-onderwijs. Met Leny van Willige, de handvaardigheidslerares en adjunct-directeur, voerde ik twee onderzoeken met vierde-groepers uit (beschreven in deze thesis). Gedrieën gingen we naar de landelijke Techniektoernooien en hadden veel plezier.

In deze tijd kwam ik tijdens een techniekevenement in contact met Eveline Holla, destijds projectleider Verbreding Techniek Basisonderwijs Haaglanden. Wij hadden gemeen dat wij allebei vonden dat techniekonderwijs geschikt zou moeten zijn voor zowel jongens als meisjes. Ook waren we in tegenstelling tot vele anderen van mening dat techniekonderwijs in de onderbouw heel goed mogelijk en zeer waardevol kan zijn. Toen zij overstapte naar het Wetenschapsknooppunt van de TU Delft, nodigde ze me uit om met de vier kleuterklassen van mijn school deel te nemen aan het project 'Nieuwsgierig? Graag!'. In het project 'Nieuwsgierig? Graag!' werden TU Delft-studenten en PABO studenten gekoppeld aan de deelnemende leerkrachten en samen gaven wij vorm aan projecten in de klas, in een zelfgekozen thema. Bij ons op school werd dat 'Riolering', een thema dat we vanuit allerlei invalshoeken hebben benaderd en enorm leefde in de klassen. Amber Nissen, een bouwkunde student van de TU Delft werd samen met Sandhia Bansi, een PABO student van de HHS aan onze school gekoppeld om de lessen vorm te geven en de leerlingen mede te begeleiden. In dit project was ook Remke Klapwijk als onderzoeker betrokken, mijn huidige co-promotor, met wie ik sindsdien tot op heden samenwerk.

Nog steeds is Eveline voor mij de schakel tussen de universiteit en de praktijk. Ik ben haar heel dankbaar dat ze ondanks haar drukke werkzaamheden regelmatig de tijd neemt om mij te betrekken bij het Wetenschapsknooppunt. De laatste tijd praten we ook samen over mijn proefschrift, waarbij zij een adviserende rol heeft. Haar gezichtspunt zorgt voor nieuwe invalshoeken om bevindingen te beschrijven.

Leon Dirks, een andere collega van Eveline, hielp mij ook, op weer een andere manier, om mijn ideeën in de praktijk te brengen. Zo mocht ik samen met hem een workshop uitproberen op een studiedag van een basisschool. Omdat hij, als expert, op dat moment uitging van de door mij bedachte ideeën, leerde ik meer over de uitwerking van mijn ideeën op de leerkrachten. De manier waarop hij dat deed, maakte het voor mij een prettige en leerzame dag. Leon, dank je wel.

Verder wil ik graag de directie van Casa Tweetalige Montessorischool in Pijnacker, met name Karin Keizer, bedanken voor het vertrouwen dat zij in mij stelde en voor de toestemming om mijn laatste case study hier uit te voeren. Ricarda Zielonka, dank je wel voor het delen van je kennis over 'Arts' onderwijs tijdens de pilot die ik tijdens jouw lessen deed. Annekat van Velzen, dank je wel voor het delen van je expertise en je open houding tijdens de gezamenlijke uitvoering van de laatste case study. Zo kon ik veel informatie verzamelen.

Ik wil Paul Mos, bestuurder van de stichting Montessori Zuid-Holland, waaronder de basisschool waar ik indertijd werkte viel, speciaal bedanken. Door hem voelde ik mij gesteund in mijn ideeën over techniekonderwijs. Hij was de enige van heel MZH die waardering uitsprak voor de publicatie van mijn eerste wetenschappelijke artikel. Later heeft hij een concept van een ander artikel van mij nagelezen op het gebruik van de Engelse taal en gecorrigeerd. Pas nog heeft hij een concept van de introductie van mijn proefschrift becommentarieerd qua leesbaarheid en een concept van mijn lekenpraatje aangehoord.

De hoofdredacteur van het Montessori Magazine, Bob Molier, was de eerste die mij stimuleerde om in de Montessori wereld te publiceren over mijn onderzoek. Hij gaf op een zelfvertrouwen versterkende manier aanwijzingen hoe ik dat het beste kon doen. Hij hielp mij om op een passende manier mijzelf te presenteren. Ik zie dit als een praktische uitwerking van 'iemand helpen om het zelf te doen' waar ik hem zeer dankbaar voor ben. Later hielp de moderator van Montessori-net, Jelle Beijer, mij heel fijn om op een passende manier online te communiceren op dit platform. Zo kwam ik ook terecht bij Jaap de Brouwer, onderzoeker bij het lectoraat Vernieuwingsonderwijs van de Saxion Hogeschool. Hij geeft leiding aan de Nederlandse Montessori Onderzoeksgroep en vroeg mij om deel te nemen aan de groep. Een recente opdracht van Jaap voor mij was om Montessori literatuuronderzoek te doen m.b.t. de rol en de ontwikkeling van de zintuigen. De goed geformuleerde onderzoeksvragen van Jaap leidde mij naar een onderzoek dat mijn kennis over de werking van de zintuigen verder heeft verdiept. De relatie tussen de 'hand' en de 'mind' werd daardoor voor mij nog duidelijker.

Ik wil de collega's van SEC bedanken voor het delen van hun kennis tijdens de interessante 'SECond opinion' presentaties. Ikzelf heb twee keer een presentatie mogen geven; een leerzame reflectie-oefening! Verder heb ik aan de AKOTO'O bijeenkomsten met Hannah, Miros, Alice, Sathyam, Ebrahim en Tessa goede herinneringen. Deze bijeenkomsten waren gezellig en leverden veel bruikbare ideeën op.

De voormalige secretaresses van de afdeling Science Education and Communication van de TU Delft, Leonie de Kluijs en Jose van Leeuwen wil ik ook apart bedanken, omdat ik bij hen altijd met al mijn vragen terecht kon, waarna zij mij heel prettig en persoonlijk hielpen. Zij zorgden - wat mij betreft - voor een gevoel van welkom op de afdeling.

Verreweg het meeste heb ik geleerd van kinderen; eerst van mijn patiëntjes van de Ursula Kliniek, daarna van mijn eigen kinderen en weer later van de leerlingen in mijn klas. Van mijn zonen Wytze en Felix, kon ik veel handige maniertjes afkijken hoe ik het beste met kinderen kon communiceren zonder hen autonomie te ontnemen. Bijvoorbeeld door een kind op Wytze's wijze te vragen "wat dòe je?" kon ik veel te weten komen. Door thuis samen met Felix 'proefjes' uit te proberen, kwam ik tot uitvoerbare 'proefjes' voor in de klas. Deze heb ik veel gebruikt. Daarom ben ik blij dat jullie mijn paranimfen willen zijn.

Zonder Marten, mijn echtgenoot, was mijn hele leven heel anders gelopen. De jaren waarin wij samen de deeltijd HTS-opleiding tot programmeur deden, waren de meest onbezorgde jaren van mijn leven en vormden een stevige basis voor onze jaren samen, die gelukkig nog steeds voortduren. Zonder jou, Marten, was ik nooit aangeland bij de realisatie van dit proefschrift. Dank je wel voor je acceptatie, ook al zag je het nut van mijn onderzoeken niet altijd in. Je gunde mij mijn plezier.

Curriculum Vitae

Annemarie Looijenga was born on 17 April 1956 in Leiden, the Netherlands.

During her first job as a Clinical Neurophysiological Lab Technician (1977-1985) she developed an exploratory attitude.

During her training as a programmer (1988-1991), she learned to structure problem-solving processes so that simple problems arose, for which simple and effective solutions could be found.

During her work as a Montessori teacher (2002 to the present), she applied the previously learned competences and programming techniques in the classroom. In this way, she was able to structure the complex system of learning objectives, relieving the workload caused by having to work towards them. She discovered that teaching methods usually do not offer solutions to this work pressure, because they do not offer an overview. They only offer a way through the complexity.

By adapting existent Design & Technology education to Montessori Education she discovered that Design Based Learning is really the heart of all learning and began to regret that this was not seen in Dutch primary education.

During her scientific studies (2012 to the present) at Delft University, she discovered that a guiding goal not only helps primary school pupils to gain an overview in complexity. It can also help adults. Montessori elaborates on this in her 'method'. Following Montessori, she therefore changed her guiding principle from teaching children to educating children. Educating is in the service of children's needs and abilities, while teaching is in the service of achieving learning goals. The transformation of teaching into learning led to the transformation of curriculum objectives into sub-objectives appropriate for children. This had good consequences not only for her as a teacher but also for all the pupils in her classes. It opened the way for every child to self-determined 'design based' learning and development.