The Effect of Iteration on the Design Performance of Primary School Children

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Abstract

Iteration during the design process is an essential element. Engineers optimize their design by iteration. Research of iteration in Primary Design Education is however scarce, possibly teachers believe they do not have enough time for iteration in daily classroom practices. Spontaneous playing behavior of children indicates that iteration fits in a natural way of learning. To demonstrate the importance of iteration for the design performance and understand what occurs in an optimized situation a study was conducted in a Dutch Montessori school. Four conditions were chosen to shape the design assignment; iteration, freedom of choice, collaboration and presentation. The choice for these conditions was inspired by the work of Montessori, and because of the positive effects on design performance during previous design and technology projects. This led to a concrete assignment, suitable for 6-8 years old, "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." Self correction was possible as the challenge lays in the ease to improve countable results. Clear results of iteration could be determined; an increasing sense of control and detailed insight in what to do for maximum results were found amongst the pupils. Additional literature about capability development and metacognition confirmed the value of the four conditions in relation to the observed results.

Keywords: Iteration , Collaboration , Metacognition, Montessori, Primary education, Teaching engineering design

1. Introduction

Design activities in Primary Education are not yet common practice. In some countries this kind of activity is not practiced at all, in other countries they have been applied for 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 also 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 the secondary education level more research has been done. Bamberger & Cahill (2012) describe the practice of teaching engineering design. Their strategy includes a stage of redesigning and rebuilding. Communication is also part of the strategy. The children learn from discussing the weaknesses and the strengths of the designs with each other, and gained insights are employed for redesign. At the 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 unfortunate, 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, at their own speed?

Recently, the National Research Council (2011) emphasized 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' (National Research Council, 2011, pp. 202) and Engineering is 'a systematic and often iterative approach to designing objects, processes and systems to meet human needs and wants' (National Research Council, 2011, pp. 202).

In the spontaneous playing behavior of children, there is also a lot of iteration to observe. Playing includes experimenting with 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 performance, shown in variations that are more substantial. 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 of equal importance. According to Dewey, constructive play is particularly important for developing strong senses and observation skills. Furthermore, it helps to develop 'personal responsibility' for their own learning and developing process. Games can be taught to a child, but nobody can teach play, play is a behavior.

Apart from the absence of iteration in education, all classroom activities happen sequentially 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 al, 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 Montessori's 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 their own knowledge. This kind of learning is efficient, because in the design of the learning environment and materials not much time is spent 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. With collaborating, they inform each other through sharing observations by talking, acting and playing. On top of this, they collect new knowledge themselves by observing the learning material from the perspective of the other. This new information and this new knowledge stimulate the children to go through a next cycle of learning and enlarge their knowledge furthermore.

Gurnani & Lewis (2008) wrote from the 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 for a problem.

At a Montessori school, the children are used to self-initiated iteration of the learning cycle and collaboration. This makes a Montessori classroom the perfect environment to research the effect of iteration in a design activity with ample room for collaboration. For me, as a Montessori teacher, observing the children -while playfully experimenting and learning with the designed situation- is very thought provoking, more than anything else is. Through the children, I learn new ways to come to design fruitful education situations.

Within this context, a qualitative study in a handicraft classroom was designed; to study what kind of things can occur, in an optimized situation. The situation was optimized by defining as many variables as possible to achieve bounded rationality according to 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. I, the teacher initiated some iterations in the design process. The children themselves initiated other iterations. Varied collaboration brought in different perspectives of observing. I initiated some collaboration. The children themselves initiated other collaboration.

In this paper, I present the results of the qualitative study of how an iteration loop affects 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. 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 only an experience component is not much to build an interpretation on, 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. Knowledge base used for research design

The leading pedagogic idea of Montessori is that the purpose of educating children is to teach them to respond to their call for help by doing things themselves (Montessori, 1949). Children are able to become independent by themselves. To reach this goal the child needs a coach, not a leader. Education is according to this view self-education.

Some requirements are necessary to let them reach independence 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 such 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, taking the 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 appropriately 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. Small groups of two to four children executed these assignments. 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. 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, observes different parts of the assignment than a child at the start of 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 their 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.

3. Research design

Montessori principles and knowledge about the creative thinking process have been used for shaping the research and the requirements and interventions to provide iteration and freedom of choice. The requirements 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 was 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 lay in the countable result, which was not difficult to improve. This gave an opportunity for self-improvement.
The same assignment was planned and executed three times, 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 first carrier, while cooperating and deliberating with another child, chosen by it-self. 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 the one from 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 education level of the parents is relatively high. From the research group it was known that many 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 year old children. Additional reasons for choosing these particular 41 children was the fact I was more or less familiar with them as individuals and because this age group is not often the 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.
A technical teacher and a handicraft teacher supervised the lessons.
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 whom 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 work alone.
The children were allowed to *try out* their product in a washtub *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 the explanation was complete, they put in the marbles until the “boat” sunk. The presenting children could be watched by waiting children.
Besides these four main conditions, there were some supplementary features. The assignment was performed with minimal materials and there was plenty of room for learning by experience, because several washtubs 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.
The term ‘trial and error’ is used when repeated, varied attempts are continued by the children until they have success, reach the end of phase period, or stop trying. It is a heuristic method of obtaining knowledge. The term ‘result driven’ describes a state of acting in which the presence of relevant knowledge (about how to make a well performing marble carrier) is showing. This knowledge enables the children to make a well performing carrier in an efficient and focused way. ’Slightly result driven’ describes a state of acting in which the presence of some relevant knowledge is showing. The children are acting focused, but they only succeed accidentally in making a well performing marble carrier. The focus is on experimenting with varied details to collect further knowledge about these details.
With regard to teacher behavior, the term ‘structuring’ is used to describe a method of asking questions in order to draw attention to details. ‘Confirming’ describes the acknowledgement of correct and important findings of the children. ‘Feedback’ describes critical assessment on produced carriers. This assessment is given 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’ describes a demonstration of appreciation of the children’s actions. This is used when the child is waiting for response, but when structuring and feedback are neither necessary nor appropriate.

4. Data analysis

To make sure all children had at 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. Coincidentally, 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 chose a partner, 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'. Density of a material is its mass per unit volume ($\rho = m / V$). 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. Therefore, a mandarin will float with its skin and sink without. A human will sink, but in a boat, he will float. Molding clay sinks when it is shaped like a ball, but floats when it has shaped like a bowl.

The design assignment was introduced two weeks after the experimental circuit. 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 contained fourth grade pupils from only one class, as did 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 himself or herself 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 that could hold 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. 1).

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

Fig. 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. 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 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 she had done 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 close to her, 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). After this folding, many 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 did not work, 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 ensured that every child has been given as much opportunity to improve itself, as it wanted. Many children made carrier after carrier. Some carriers were demonstrated. Other carriers did not function 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.3).When this happened and the carrier was touching the bottom of the bowl filled with water, therefore increasing amounts did not count.

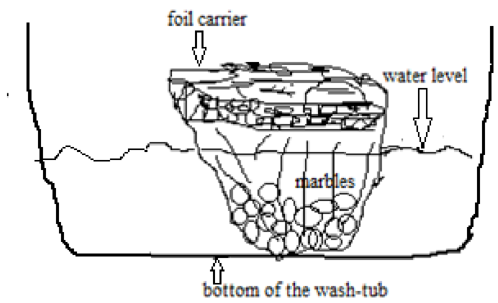

Fig. 3 Foil deformed into a sack, which touched the bottom of the washtub

At the end of the lesson, the children were gathered for an evaluation. The carriers were shown from the least to the most marbles contained. 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 base had become clear to all children, but still not every child thought this had priority. Some still thought that a solid base was more important than a large base, 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.

<u>Phase two</u>. Repeating the design assignment with a new partner. In each of the three groups, the children were linked in pairs. To make a pair, the teacher chose two children each with a different approach to the assignment the first time. This resulted often in a pair of a boy and a girl, because generally speaking boys and girls showed different approaches. By making the pairs, the teacher paid attention to how well the two children were getting on in general.
Each pair 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 unsteadily started working. They still liked experimenting and playing and they made many carriers. In the second group, many children complained about working together. They started fast to do the assignment, but made only a few carriers.
The third group (the combined group) was slightly enthusiastic and their work was 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 many children of this group took the opportunity to peek 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 working fast and made only a few 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 one 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 managed to produce 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 took turns. This team tried a third time 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 many 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 lay 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 or a boat shaped carrier, with the front and/or the back in a pointed end instead of rectangular end, arose (See fig. 4). These carriers could hold most marbles, with a maximum of 248!
The pair with ‘girl A’ in it, made the carrier that contained 248 marbles without sinking. ‘Girl A’ told on video, “This boat can float very well. I made this boat before.”

Rectangular carrier	Boat shaped carrier

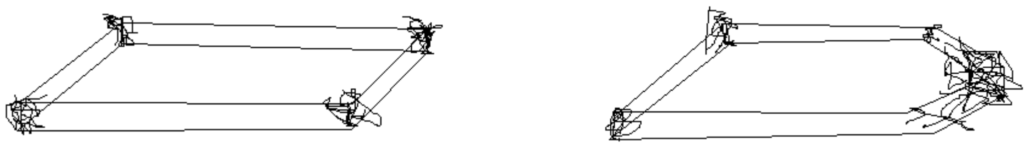

Fig. 4 Samples of carriers with sharp folds to form the edge and corners folded solid together

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 pair 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 when 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 would not say his name and nothing about the carrier. However, 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 pair molded the whole carrier, including the bottom. One clever pair used three sheets of foil together to make a firm carrier. One pair double folded the foil “to make a firm bottom” (their own words) and molded the edge. One pair of a boy and a girl called their carrier in front of the camcorder “speedboat”. One pair 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 crumpled 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 a handicraft assignment. Eighteen out of forty-one children made another marbles carrier. The complete second group of phase two did want to do a handicraft assignment instead of a design assignment. Therefore, 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 is 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 particularly effective. 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 pair 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. '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 many marbles, chose to do 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.5).
The children told about it on video. One boy said, "It has become bigger and the edges are higher." His comment for the next carrier he made was "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 pair made a carrier of double folded foil. I asked them for the reason and they said, "So it is more firm and prettier."

Fig. 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, this 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 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 pair made a carrier shaped like a speedboat. 1 x a pair 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 base of the carrier, allows it 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.

5. Interpretation of the results

The results are related to the conditions of this research. These conditions affected separately and together the design performance. In this section, I will attempt to describe the contribution of the conditions 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 additional literature.

Iteration is the first condition 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 that a carrier could hold advanced from 40 in the first stage until 149 in the last stage (see table 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 until 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 until 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. Therefore, the 'verification' stage can include 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 to develop from trial and error in the first phase, to increasingly result-driven.
Another aspect of growing perception and insight is the development of the capability to explain 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 for their age. (At 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 explaining 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 condition to observe. In the third phase the children had the most extended freedom of choice of all phases, however, in this phase only half of the children chose the design assignment, the other half chose to do the handicraft assignment. Therefore, the freedom of choice did not make all children choose the design assignment. Why? 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 subsequent carrier, e.g. '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 have freedom of choice to continue with an activity, motivation will be high and will remain high. Motivation can even become stronger still, because self-guiding is increasing. Cropley and Urban (2000), who developed a 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 condition 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 diagnoses. 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 the camcorder. In this way, all children benefit and reflect: the children presenting for the camera and the children 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 did 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 condition 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 their 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 choices available. 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 held by the carrier was improved each subsequent phase. During the third phase a maximum amount of marbles in a floating carrier was reached. In addition, the design goal was achieved all the time.

During the first phase, the children improved their design by trial and error. Gradually 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 do.

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

The design of the learning environment made the children independent in their experimenting. This, together with the verbal 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 know 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 the camcorder.

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. However, the effect of presenting and collaboration was only answered by previous experiences and not by literature known by myself 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 (2005) gives a detailed description of the development of functions of both brain hemispheres from birth to adulthood. Hannaford (2005) 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 perspective of a designer. They describe the interaction of mind and hand during designing. They model thought and action in an iterative and interactive relationship. In their view, thinking like a designer has immense potential for learning, because by iteration of the interaction between imaging and modeling inside the head and confronting reality outside the head, a 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, 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). The 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 their 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.
These 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 spontaneously and can be deliberately taught. Most of the time children of this age do not reason in a logical or a fully mathematical way, but by drawing attention to occurrences they can develop; they are close to 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 many 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 (Cropley & Urban, 2000). The importance of ample room for playing behavior, especially for this age group, is emphasized by the constructivist view of Vygotsky and Piaget & Inhelder.

7. Conclusion

Iteration, freedom of choice, collaboration and presentation are conditions that improve the children's learning process in design. The supplementary literature study shows that it is profitable to use elements of Montessori education in an assignment design, because these elements provide intrinsic motivation for redesign. Key elements are tuning to the natural ability 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 for 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, pp. 267-268).

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 teach 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 requires of 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 proven with emphasis by the metacognition research. Knowing how to get to your point and to know when you are right is important metacognitive knowledge.

The study still leaves the following questions unanswered:
- "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 lead 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?" These 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?

Recommendations

The findings of this research can be used for the optimization of design assignments 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 until 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 from each other. Let the group work for the teacher instead of merely letting the teacher work for every individual child.

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