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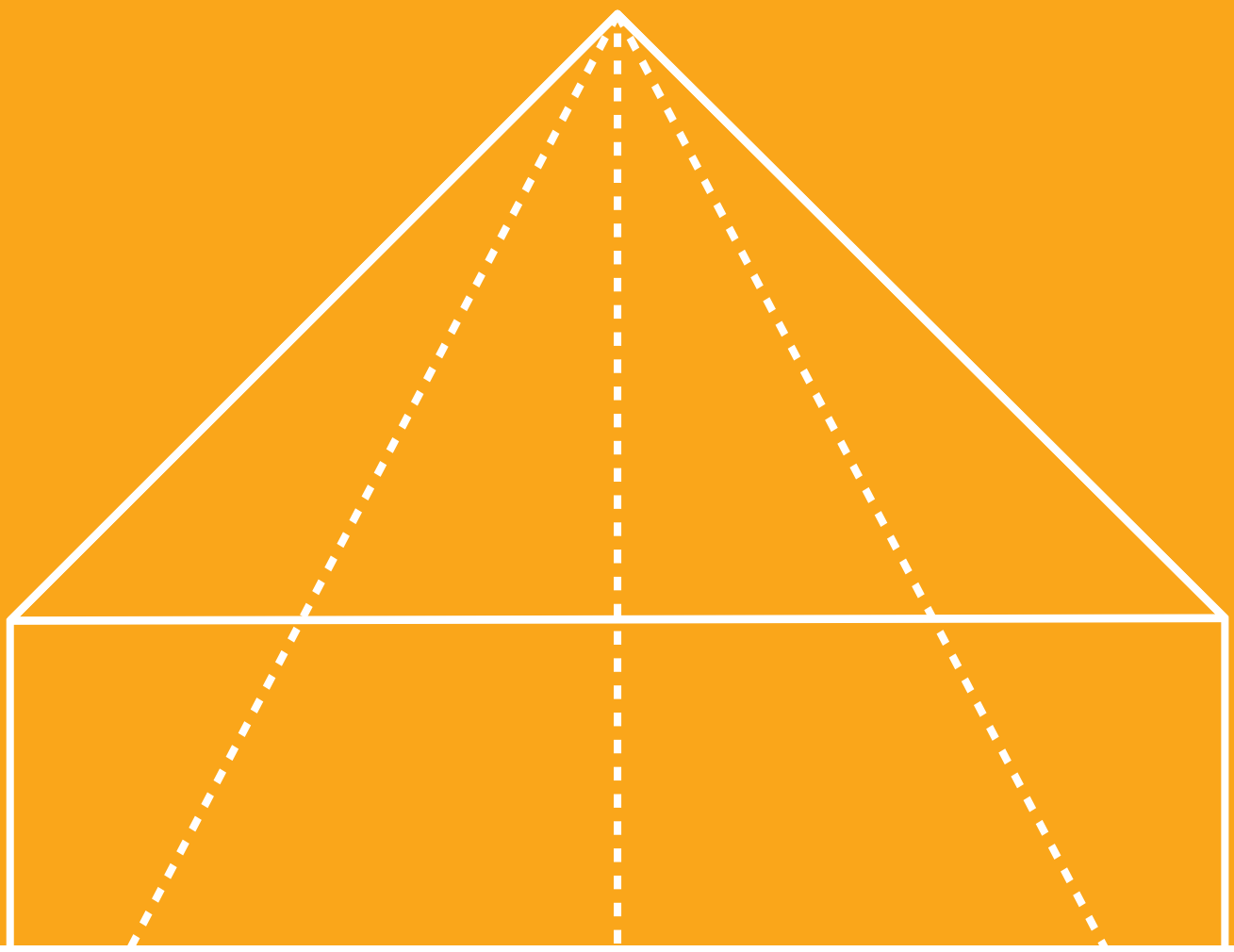
Maker education in the Netherlands – state of play and lessons for the future



maker education
leren door te maken

Maker Faire Eindhoven

Introduction

FabLearn Netherlands invited submissions to the first FabLearn conference in the Netherlands that was held September 28, 2018, preceding Maker Faire Eindhoven September 29 and 30. This publication contains the accepted papers that were presented at the conference.

FabLearn Netherlands brought together national and international researchers, educators, designers, and makers to discuss and explore designing and making in educational contexts, digital fabrication in education, and hands-on learning for the 21st Century.

Some of the main guiding principles of the FabLearn community are the democratization of maker education, its implementation in public education systems, and a focus on constructionist learning. Submissions from both maker education and design and technology education were received.

The FabLearn Netherlands call for papers was organised jointly by MakerEducation.nl, Rotterdam University of Applied Sciences, TU Delft and Waag. FabLearn the Netherlands is a sister conference to the global FabLearn conference that has been held over the past five years at Stanford University, USA.

Adapting Maker Education to pupil's abilities: How clear bordered tasks can lead to discovery behaviour

Annemarie Looijenga
Delft University of Technology, Delft.
The Netherlands
A.Roel-Looijenga@tudelft.nl

Remke Klapwijk
Delft University of Technology, Delft.
The Netherlands

ABSTRACT

Maker education uses the concept of learning through interaction of the hand and the mind and is therefore a good instrument for Design and Technology education. However it appears to be difficult to engage all pupils in a class. Still, it is in all pupils' interest that all pupils are enabled to engage, because only then a strong community of makers can emerge.

Engagement can be hindered by the absence of abilities, needed to accomplish a task. When this leads to passiveness or frustration, it may disturb the group process of collaboration.

In earlier research we found out that adjusting simple challenges to pupils' abilities and adding clear success criteria to create a manageable 'cognitive conflict' is a way to border a task. Within these borders there is room for freedom. This freedom can result in ongoing discovery behaviour. A joint evaluation of the various results of the task will lead to joint development of knowledge, leading to a next level of familiarity. This joint knowledge together with the by discovery behaviour expanded abilities, outlines the base of a next task.

When for some pupils the devised borders fail, diagnosis of the failing border will be simple; is it a failing adjustment to pupil's abilities, or is it a too complex challenge, or is it a vague success criterium or is it a failing joint evaluation? After diagnosis offering proper support is easy.

In this study we researched the actual effect of a series of clear bordered tasks on the discovery behaviour of the pupils. In the tradition of lesson-study [11] we focused on if and how this approach was useful to get disruptive pupils active in discovery through making.

The results showed that the tasks turned out to be useful in changing the observed pupils' behaviour towards active making and discovery. As a result of the improved discovery behaviour the teacher-pupil relationships and the pupil-pupil relationships improved as well.

KEYWORDS

Attitude, task structure, ability, inability, collaboration

1 INTRODUCTION

Maker education is recognised as a good instrument for Design and Technology education, because it uses the concept of learning through the interaction of the hand and the mind [1]. The importance of knowledge gained by experience as an anchor for abstract thinking is recently confirmed by Hayes & Kraemer [2]. Sennett [3] arguments that doing a job properly takes the time it takes. While we are making, submerged processes of thought and feeling are in progress. Making also suits pupil's natural learning process through hypothesis testing [4]. When a pupil finds out that a self thought out solution turns out to be not working, this perception subsequently naturally leads to seeking to improve.

What are the competences conveyed by maker education, and how are those competences acquired? Especially in the context of a school class is this an issue of interest. Sennett [3] points out the significance of specific abilities within a task. To start discovery behaviour competence in several skills is needed. Not only practical skills, but also skills, utilised in virtually every aspect of our lives - how we work, do, play, socialize and learn, are required. Which abilities are needed to evoke active discovery behaviour during the performance of a task and which inabilities prevent pupils from active discovery behaviour? Such inabilities can be seen as calls for avoidance or support. Awareness of pupil's needs during maker education can help a teacher to create doable tasks.

However, the importance of such awareness of needs is generally hardly recognised. As a result, frustration for a minor percentage of the pupils is just around the corner. Unfamiliarity with specific competences, needed to accomplish the task, can lead to frustration and passiveness. It is precisely these frustrated pupils, who should require maker education to get rid of frustration resulting from inability. If their frustration is not solved, they can later on disturb the group process of collaboration. It is in all pupils' interest that all pupils are enabled to join maker education lessons. This enables the emergence of a strong community of makers, comprising the whole class of pupils. In a strong group, pupils are in a positive way aware of both their weaknesses and their strengths. They can variable take the expert or the novice role, depending on their skill level in a situation, important issues during collaboration.

1.1 Theoretical framework

The importance of awareness of abilities and inabities for the creation of an effective educational task is in line with the ideas of Vygotsky [5], who argues that the function of an educational task is to create a bounded "cognitive conflict" in the pupils (Table 1, Nr. a) and is in the zone of proximal development. A bounded cognitive conflict initiates reconsideration of ideas (Table 1, Nr. b, leading to discovery behaviour and finally to knowledge development.

A task with an unbounded cognitive conflict, will be perceived as a concern and can result in passiveness or frustration; the task is in the zone of ontological discomfort (Table 1, Nr. c). According to Dewey [6], such a task is useless with regard to discovery behaviour and knowledge development (Table 1, Nr. d).

The absence of a cognitive conflict is also not helpful for discovery behaviour. A task in the zone of actual development is perceived as not challenging and cannot hold pupil's attention (Table 1, Nr. e), because there are no ideas to be reconsidered. Such a task can eventually function as a test or check of the actual development, but will not lead to new knowledge development.

Table 1: Relation between behaviour and task

Nr	pupil's behaviour	task characteristic
a	attentive	fascinating subject
b	active	challenging
c	unwilling	frustrating
d	passive	unfamiliar
e	bored	not challenging
f	ongoing active	clear and familiar expectations
g	undirected active	absent directing expectations
h	decreased active	absent directing expectations

For this reason we developed in a former research paper, through a series of case-studies [7] a task structure ensuring a bounded cognitive conflict showing in discovery behaviour (Fig. 2).

Such a task is based on:

- Clarity of the situation for the whole class, because of familiarity of the context and of all the required skills
- Simplicity of the challenge

And defined by (Table 1, Nr. f):

- Simplicity of the criteria for a successful performance of the task (absence leads to Table 1, Nr. g)
- Clarity of the results for the whole class through joint evaluation (absence leads to Table 1, Nr. h)

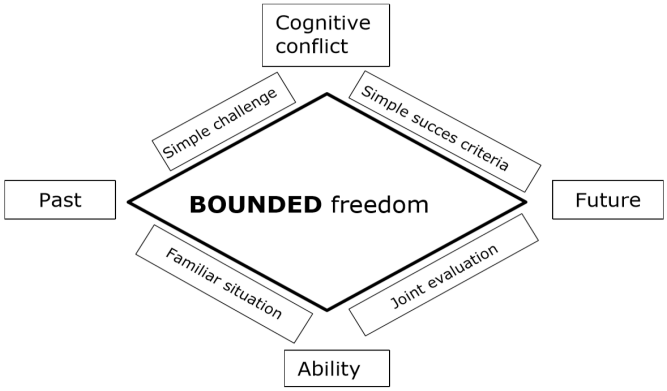


Figure 2: Task-structure supporting discovery behaviour

This model on task structure can help to adapt the task at hand to the pupils.

This model can be used in the tradition of Science, Technology and Mathematics education leading to a structured acquisition of skills. An example of this tradition is STEAM education. This educational approach to learning uses Science, Technology, Engineering, the Arts, and Mathematics as access points for guiding student inquiry, dialogue, and critical thinking. The end results are students who can take thoughtful risks, engage in experiential learning, persist in problem-solving, embrace collaboration, and work through the creative process [8]. When a thoughtful program of STEAM assignments is planned, teachers can be ensured of the familiarity of a wide range of skills amongst their pupils.

The model (Fig. 2) can be helpful to create tasks, enabling pupils to build on existing knowledge and experience [9]. Through adaptation of the learning situation it is possible to build on pupil's experiences as well as to promote positive skills and dispositions [10].

When pupils fail to show discovery behaviour, adapting the task to the pupils by means of clear borders as shown in the model (Fig. 2) can help to create room for freedom in order to start ongoing discovery behaviour.

2 CASE STUDY

In this paper, we focus during Design and Make Education in a microscopic way on the connection between pupil's discovery behaviour and a succession of to the pupils adapted bordered tasks. Do right adapted clear bordered tasks help to initiate discovery behaviour? We investigated through observation and action research the behaviour of about forty-nine to twelve years olds on a Montessori school. The reason for this study was the fact that the researcher noticed specific problematic behaviour during a former experience - while working as an out-of-school-care teacher- with some pupils on this school. A small, but dominant group of children then regularly showed rebellious and defensive behaviour. Six months later, these same children continued to disrupt lessons, in particular the Arts and Crafts lessons. The management was looking for the origin of the failing Arts and Crafts lessons. The researcher just completed a three months pilot study of about sixty six- to nine-years-olds, together with another Arts and Crafts teacher. The study was on the relationship of task elements and discovery behaviour and had resulted in increased discovery behaviour for all pupils. Because of that result the management asked the researcher to study the origin of the failing lessons in the older group of pupils.

The researcher started the study with an orientation period, in which the researcher assisted the Arts and Crafts teacher in order to get acquainted with her approach. Additionally, the researcher informed herself about other possible origins of the disrupting behaviour during Arts and Crafts, for instance raised by class supervisors or daily class practice. During these lessons the researcher noticed the problematic behaviour all the time. By behaving like this tis small group of pupils serious disturbed the lessons. The question from the class supervisors was "Is it the teacher, who triggers this behaviour?" Because of the experienced improvement of behaviour during the first pilot study in the six to nine years olds classes, the researcher changed the research question in "Is it the lesson, that triggers this behaviour?".

To answer this question the Arts-and-Crafts teacher and the researcher together started a case-study, whereby the researcher assisted the Arts-and-Crafts teacher during class and coached her on the fly to notice the relationship between task elements and the appearance/disappearance of discovery behaviour. During the first pilot study one important characteristic of the challenge in a task emerged; simplicity. Other characteristics appeared to be ability (as a result of familiarity) and simple success criteria. Through joint evaluation of all the results of the task, clarity and familiarity for the whole class was acquired (fig. 2).

The teacher and the researcher planned a series of bordered tasks and put these central during the lesson-sessions, one at the time. In the tradition of lesson-study [11] the researcher especially wanted to know if this approach to the tasks could help the pupils, who were known for their rebellious and defensive behaviour in Arts-and-Craft classes, to overcome frustration and to realise ongoing discovery behaviour.

Therefore, the central research question of this case study was: "Does the transformation of a design and making assignment into a collection of clear bordered tasks affect pupil's discovery behaviour?"

2.1 Methodology

The researcher observed pupil's behaviour on three days, during assisting the lessons. She also video recorded all sessions from a fixed place, with

Nr	Task	Joint evaluation [10]
1	draw a chair on a piece of paper	sharing and evaluating all models
2	draw the components of the chair on paper	
3	cut out the components with scissors	
4	assemble the components with glue	sharing and evaluating all models
5	If necessary; re-design	
6	draw the components on cardboard e	
7	cut out the components with a knife	sharing and evaluating individual progress
8	assemble the components with glue	sharing and evaluating individual progress
9	If necessary; solve construction problems	
10	colour and finish your chair	sharing and evaluating all models

Table 2: Tasks succession in case-study "Make a mini-chair"

the objective to have an extra, impartial eye to review the sessions. At the fourth day of the sessions the researcher was absent, but the teacher reported her after the lesson by phone. The series of lessons were given three times a day, to a group of eight to thirteen pupils aged nine to twelve years old. At the school were two school classes for the nine- to twelve-year-olds. The composition of the groups was done by the two class supervisors. Each group comprised pupils of the two school classes.

Each day and on the fly the researcher shared what she witnessed with the teacher. She shared witnessed behaviour of the pupils and of the teacher in relation to task characteristics, in order to feed her awareness of the relationship.
The STEAM assignment "Make a mini chair" [12] suited the succession of simple tasks. The tasks were adjusted (Table 2) to the model (fig. 2). The proceedings during the appliance of this assignment are described for all three groups in the next paragraphs.

2.2 Sessions

2.2.1 The first session.

After a PowerPoint introduction about the function of a chair and the purpose of the assignment, in short, all tasks were identified. All pupils started with the first task, drawing a chair on a piece of paper. When finished, they could start with the second task, drawing the components of the chair on paper. After, they were allowed to continue with cutting out the components with scissors and then to assemble the components with glue (Fig. 3). Dependent on pupil's contentment with their paper model, they could re-design or start to draw the components on cardboard. At the end of the first session the pupils were working on various stadia of the assignment, depending on their progress. Where a single pupil was already getting around with cutting the cardboard components, was one third of the pupils still in the "draw components on paper" phase. A few pupils did not get past the "draw a chair on paper" phase. At the end of the first session it was intended to share all chair models and evaluate the process of transforming the 2D model into 3D parts, but the teacher and the researcher forgot to do this in all three groups.

Figure 3: First session. Working with paper

2.2.2 The second session.

In the first group it showed that a rather large number of the pupils did not manage to transform the 2D model into 3D parts. After evaluating this process, all pupils managed to make a 3D paper model of a chair and most of them managed to start cut out the components with a knife. Therefore, we started in the other two groups with evaluating the transformation of 2D into 3D. In all groups some pupils already managed to assemble the components with glue. A short sharing of products and applied procedures ended this session. The focus of attention during the main part of this session was –besides the transformation from 2D to 3D- on the handling of the knife.

2.2.3 The third session.

During the third session all pupils were working hard on cutting and assembling. A significant number of pupils could already colour and finish the chair (Fig. 1). During solving construction problems some children got brilliant and simple ideas about a new model or about fixing stability problems (Fig. 4).

Figure 4: Third session. Working with card board

2.2.4 The fourth session.

During the fourth session, most pupils finished their chair. The teacher made a small exposition in the central hall. The teacher told the researcher, that the atmosphere was really good; pupils enjoyed the working. One third of the pupils finished the assignment during the fourth session and worked on a self-chosen job.

2.3 Discovery behaviour of the pupils

During the first session, many pupils were distracted by the video camera. After explaining the function of the camera (an extra, independent watching eye) most pupils stopped paying that much attention to the camera. However, some children were so much distracted by the camera, that they could not control themselves enough to concentrate on the assignment. They liked watching themselves on camera more than working on the assignment. In the third group (14 pupils) it was not so much the camera, that disturbed the lesson. The bad mood for arts-and-crafts lessons of six dominant boys disturbed the lesson and the atmosphere. In this group not much work was accomplished; neither by the uncooperative pupils, nor by the cooperative pupils.

The second session was planned to be about cutting. The teacher instructed the drawing of chair parts on the cardboard and the handling of the knife during cutting out the parts. During this session, the researcher diagnosed in the first group an inability of a major part of the pupils to think in 3D about their 2D chair creation. As a result, the pupils got stuck and the general behaviour was unfocused. The researcher suggested the teacher to pause the lesson for a short explanation and later on the researcher scaffolded the transformation from 2D to 3D for some pupils. More support was not required, because the pupils looked at each other and helped each other.

In the second and third group the teacher started with asking attention for 3D thinking followed by instruction about holding the knife during cutting.

The second group was directly working enthusiastic and focused.

In the third group only four of the six pupils, who showed disturbing behaviour during the first session, still showed disturbing behaviour. The researcher suggested the teacher to instruct and guide the willing pupils. At the same time the researcher discussed the why of their rebellious and defensive behaviour with the unwilling boys and offered them help for whatever which problem they would meet. This resulted in motivated working by two boys. The other two boys were still defensive, but started, while guided through a step by step demonstration, scaffolded working. The two boys' 3D drawing followed by the construction of a paper chair was going well. New problems showed up during cutting the cardboard. They appeared to be clumsy regarding handling the knife, but this time they were open for help and they started trial and were active in making.

Interpreting the second session we can say, that during session two, attentive ongoing discovery behaviour was achieved for all pupils in all three groups. The former disruptive pupils were still a bit defensive, but they gradually relaxed more and more.

At the end of the session, during joint evaluation, every pupil showed his/her work and reported shortly about the process followed and plans for the next session.

The third session was intended to be about constructing and finishing, but a lot of pupils were still busy with cutting. The teacher instructed the construction of the cardboard chairs and the use of the special glue. A specimen of a chair, made by the researcher was showed to illustrate some possibilities for solving construction problems, like instability.

The groups were differently composed this time, because of testing in the classes. The moment a pupil could go to Arts-and-Crafts depended on the moment of testing in class.

The first thing the researcher noticed in all groups was the joy the pupils showed during making. There was certainly no unfocused behaviour. There was a delivery of varied chairs at a fast pace.

Pupil's behaviour was easy to handle this time for the arts-and-crafts teacher and the researcher. The six during the first session disruptive behaviour

showing pupils were present in an unobtrusive, somewhat clumsy way. Some of the pupils, who in the second session showed inability to think in 3D about their 2D creation appeared to have changed their chair design dramatically. This time, they were actually the ones with big plans to make the same chair at home.

The fourth session was added to allow all pupils to finish their chair. The arts-and-crafts teacher reported that the pupils were easy to handle and proud of their product.

2.4 Analysis

Borders have a limiting function. In the case of a task, borders limit the amount of possible needs of the pupils by eliminating foreseeable inabilities. They also limit the amount of possible needs of the pupils by focusing on only one challenge, in this case the practice of one technical skill. The third border offers a clear and simple expectation about the outcome of the practice; an intermediate product that has to lead to a well-defined end-product. In this case the end-product was a nice, solid and comfortable chair. The last border is created at the end of the task, by joint evaluation, and forms also the first border of the next task. In this case, these borders delivered us transparency, resulting in readily understood needs of the pupils (not foreseen inabilities and an unexpected low level of the technical skill). These readily understood needs made it possible to offer suitable help to compensate pupils for technical and other inabilities. In this way all pupils were enabled to perform the tasks. Experiencing ability during performance resulted in further development towards ongoing discovery behaviour.

The borders also make it possible for the teacher to offer pupils freedom. The borders will provide for bounded freedom. Together with transparency of needs, as another consequence of borders, the manageability of the lesson will be preserved.

This specific assignment comprised a succession of clear bordered tasks. The borders were as follows: Because every pupil knows that a chair has to serve sitting, the situation seemed to be familiar and the success criteria seemed to be clear and simple. The challenge of each task was found in the application of technical skills. The challenges were simple, because each task was focusing on only one technical skill. The bounded freedom was in the possible variety of chairs from which the pupils could choose. They could choose to make a chair for resting, reading, studying, working at a computer or watching a movie. Every activity has his own demands with respect to the position of the sitting and with respect to solidity. This bounded freedom enriched the joint evaluations. Through these rich joint evaluations every pupil gained more knowledge than they would have gained in the case of absent freedom of choice.

This was also true for the pupils with signaled rebellious and defensive behaviour. It mitigated after the researcher and the teacher, during dialogue, had showed recognition and had offered appropriate support. Apparently, this dialogue restored these pupils' secure feelings.

At the end of the first session, immediate recognition of needs was hindered, because the evaluation-phase was omitted. The significance of the forgotten evaluation showed up in de second session. In the first group a rather large number of the pupils did not manage to transform the 2D model into 3D parts. This lastly made the teacher and the researcher together reflect on the first session. Through this reflection they became aware of earlier not recognised needs of the pupils. After the insertion of a joint evaluation of the transformation of the 2D thinking into the 3D thinking in the first part of the second session, pupil's needs decreased, which enabled the teacher and the researcher to adequate support the remaining needs. After this support, the pupils further on looked at each other and helped each other. Subsequently all pupils managed to make a 3D paper model of a chair and most of them managed to start to cut out the components with a knife. This inserted joint evaluation resulted in improved discovery behaviour in all groups.

3 CONCLUSIONS AND DISCUSSION

3.1 Conclusions

In summary; the pupils made nice and diverse chairs (Fig. 1). In the process they discovered much about chair construction. By using the model (fig. 2) for the creation of the tasks within the assignment, the pupils met many simple challenges, which triggered them to a lot of design and redesign, making, and problem-solving activity.

Through joint formative evaluation at the end of each session the pupils discovered impossibilities. Some of these discoveries resulted in a need for redesign. For instance, the discovery that the cardboard was not the right material to make a favourite chair of.

Joint formative evaluation took place at the end of task 1, 4, 7, 8 and 10. At the end of task 1 the pupils encountered eventual problems with the conversion from 2D to 3D. At the end of task 4, they encountered eventual construction problems with respect to solidity. At the end of task 7 and 8 they were confronted with construction problems regarding stability and at the end of task 10 they could reflect on the relationship between appearance of the chair and the design features.

The simplicity of the encountered problems created clear and solvable challenges. For instance, the transformation from a 2D chair to a 3D chair, the handling of the knife, problem solving in the construction-phase. This resulted in active ongoing

behaviour even when problems had to be solved. Therefore, the beauty of the assignment was the logic of the successive simple tasks.

It was nice to see that all pupils' behaviour by offering adequate support was improving over time. At the start a small, but dominant percentage of the pupils was behaving rebellious and defensive. Mid-term their behaviour was changed into asking for help and trial.

Insufficient scope for pupils to follow their own interests and using their strengths is often mentioned as a disadvantage of closed assignments. This was not the case for this closed assignment, composed of clear bordered tasks. The clear bordered tasks offered the pupils a lot of bounded freedom and in addition a chance to collaborate and cooperate.

Of course, could a succession of clear bordered tasks also take place in the case of an open assignment, but the additional benefit of natural collaboration and cooperation as a result of generally experiencing the same possibilities and impossibilities will be absent. By this absence, the practice of several much-needed skills, utilised in collaboration and cooperation, such as awareness of other pupil's needs, dialogue, practical assisting, problem solving, explaining will reduce. Furthermore, joint evaluation is impossible, because each pupil is making something different. Therefore, it is more difficult to make discovery behaviour flourish for all pupils during open assignments, because they miss -besides a structured accomplishment of knowledge through joint evaluation- knowledge development through learning from each other and through helping each other.

3.2 Limitations

This case-study covers the proceedings of a Design and Technology assignment in a Montessori school class, guided by an Arts-and-Crafts teacher together with the researcher as assistant. The abilities and inabilities of the pupils in this context can be different from the abilities and inabilities in regular school classes, because pupils in a Montessori tradition are considered to be enabled to operate autonomously.

3.3 Implications

The results implicate that a stepwise assignment, composed from clear bordered tasks suits discovery behaviour during Design and Maker education in school classes. This task structure is not only provokes ongoing discovery behaviour, but it also enables teachers to become aware of pupil's abilities and inabilities. This knowledge can be used by teachers to build next tasks and challenges on [13]. Awareness among pupils of each other's abilities and inabilities allows cooperative behaviour and collaboration.

Teachers working in traditional education often mention passive or passive aggressive behaviour as problematic behaviour. An explanation for that can be that, when pupils are used to teachers taking the lead, they are not used to operating autonomously. In case of inability they seize activity.

By contrast teachers working in a Montessori tradition more often mention defensive or rebellious behaviour as problematic behaviour. An explanation of that can be that autonomous behaviour and inability are incompatible. An autonomous answer to inability is avoiding the inability and choosing for another, mastered activity. This will lead to rebellion when the teacher disputes their choice.

Now, we have found the described results on pupil's behaviour in a Montessori tradition, it would be interesting to research the effects of a succession of simple tasks on pupil's behaviour in a traditional school. What are the similarities and what are the differences with our findings?

Another interesting item for further research would be reproducibility. Although we looked in a pre-trial into the practice of another teacher with a different age-group, this study only deals with one researcher, one school, one Arts and Crafts teacher and one age-group of pupils. Other researchers and other teachers can help to fine-tune the characteristics of a clear bordered task. They also can help to find alternative ways of supporting and of applying bordered tasks.

Furthermore, it would be most interesting to search for new ways to facilitate teachers to enable practical self-discovery of the virtues of clear bordered tasks in relation to the abilities and inabilities of their pupils. By practical discovery teachers could learn to apply the model and start to see possibilities to handle pupil's abilities and inabilities themselves and become enabled to create clear bordered tasks themselves.

4 FINAL REMARKS

We can conclude that the closed, stepwise assignment, through the manageable acquisition of skills, benefitted cooperative and collaborative behaviour. For instance, during the second session, after a short scaffolding of 2D to 3D thinking, the pupils further on looked at each other and helped each other. The simplicity of the encountered problems created clear and solvable challenges, leading to a lot of active design and redesign. Through cooperation and collaboration pupils helped each other and learned from each other [14].

After the development of cooperative and collaborative skills during closed assignments, cooperation and collaboration between pupils and pupils and teacher can also make the successful proceeding of open assignments feasible. Thus, a closed assignment can pave the path for an open assignment.

In turn an open assignment can function as an opportunity to exercise certain skills. Then, the assignment is free, but the method is prescribed.

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Colophon

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