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ENHANCING CREATIVE PROBLEM SOLVING IN AN INTEGRATED VISUAL ART AND GEOMETRY PROGRAM: A PILOT STUDY

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Abstract. *This article describes a new pedagogical method, an integrated visual art and geometry program, which has the aim to increase primary school students' creative problem solving and geometrical ability. This paper presents the rationale for integrating visual art and geometry education. Furthermore the MathArt pedagogy and program is described and it is explained how the MathArt program intends to increase students' creative thinking and geometrical ability. Additionally initial results of the pilot study are presented, which investigates the effects of the MathArt program.*

Key words: creative problem solving; visual art; geometry; primary school

INTRODUCTION

In current primary mathematics education, there is little room for creative problem solving. Teaching materials in primary math education often focus on solving word problems in which students need to select and perform mathematical operations (e.g. Jansen, Van der Schoot & Hemker, 2005). Students learn to solve routine problems (exercises), but often do not learn to solve mathematical (non-routine) problems, which requires creative thinking because the student has no learned solution to solve the problem (Leikin & Pitta-Pantazi, 2013). Furthermore, teachers are often not used to teach for creativity. To change current math educational practices in primary schools, the MathArt project was started. It is a practice-based research project, in which researchers, primary school teachers and teacher trainers collaborate to develop a MathArt program for primary schools.

Aims of the MathArt program

The MathArt program has the aim to increase students' creative problem solving skills in geometry and visual art and to increase students' geometrical ability in the upper grades primary school. To achieve these goals on a student level a teaching sequence for fourth, fifth and sixth grade students was designed in which geometry and visual art are integrated. Since it was expected that Dutch teachers were not sufficiently equipped to support students' creative problem solving in geometry, a professional development (PD) program for teachers was designed. This study has the aim to evaluate the effects of the teaching sequence and the PD program. In this paper the preliminary results of the pilot study will be presented.

THE RATIONALE FOR INTEGRATING VISUAL ART AND GEOMETRY EDUCATION

The MathArt program focuses on geometry education, which is a good context to enhance student's creative problem solving, since it is never fully based on algorithmic procedures and therefore involves heuristic reasoning (Levav-Waynberg & Leikin, 2012). In this program geometry education is integrated with visual art education. Currently visual art

and mathematics are taught in fixed disciplines and to solve a geometry or visual art problem, students might only rely on subject-related knowledge and are less able to 'break out' their thinking rut. We assume that integrating both mathematics and visual art, might help students to think in a more flexible and non-fixed way, and thus can enhance their creative thinking. Furthermore, the integrated context might also help the teacher to break out of their fixed idea of teaching math education in a separate discipline; it could show them that geometry education can also be taught in relation to other contexts instead of teaching geometry only from a math teaching method.

Creative problem solving plays both a role in mathematics and in visual arts. Several subprocesses can be distinguished that are important for the process of creative problem solving. Although diverse models of creative problem solving in general (e.g. Treffinger & Isaksen, 2005) or problem solving in mathematics (e.g. Schoenfeld, 1985) or visual art (e.g. Cawelti et al., 1992) exist, most models consist of several similar or overlapping subprocesses or stages. It is expected that subprocesses important in visual art might also help creative problem solving in geometry. An example is the role of orientation (defining the problem and recalling (pre-requisite) information related to this problem; e.g. Getzels & Csikszentmihalyi, 1975). Orientation seems to be important for creative problem solving, because if the problem and its related concepts are clear, it will be easier to produce a new and meaningful solution. Although the subprocess of orientation is also important in math education (SLO, 2008), it might play a bigger and more significant role in visual art (Getzels & Csikszentmihalyi, 1976) and visual art education (SLO, 2015). Within the Dutch visual art pedagogy, students need to learn to give meaning to a problem by reacting on it with association and memories; it is important that students sense (see, hear, feel) and talk about the theme and assignment from several perspectives during visual art education (SLO, 2015). In math it often seems to be more related to framing the problem, but not to recalling information necessary to understand the problem situation (SLO, 2008). A greater focus on the subprocess of orientation might also help geometry education. This is one example of how visual art might give an impulse to geometry education.

THE MATH-ART PROJECT – A BRIEF DESCRIPTION

The MathArt program consist of a teaching sequence for fourth, fifth and sixth grade students and a PD program for their teachers (see Figure 1), in which both the disciplines of visual art and mathematics are both equally covered and honored.

PD program

The PD program for teachers consist of 5 sessions (each 2,5 hours), given by experts in the field of mathematics and visual art. After each session, teachers have to give one or two lessons of the MathArt teaching sequence. The aims of the professional development program are to learn teacher how to stimulate students' creative thinking in this integrated visual art and mathematics program, to create a positive attitude of the teachers towards geometry, visual art education and the integration of both and to increase teachers' geometrical knowledge and their pedagogical content knowledge of teaching geometry and visual art.

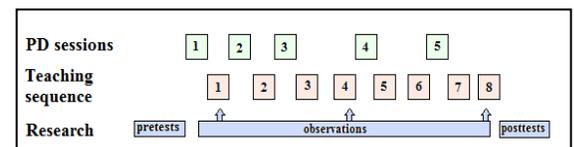


Figure 1. The MathArt research project

The teaching sequence

The teaching sequence consist of eight lessons; 4 lessons related to the theme 'space' and 4 lessons related to the theme 'patterns'. Each lesson takes about 60 minutes and starts with an introduction on class level which takes between 15- 25 minutes. This is followed by an individual or group assignment that takes 25-30 minutes. A lessons ends with a reflection on class level which takes about 10 minutes. Aims of the teaching sequence are to enhance students' ability in geometry and visual arts and to enhance their creative problem solving skills.

THE MATH-ART PEDAGOGY

In this section we will shortly report on the MathArt program, by describing the most important features of the pedagogy. Each lesson starts with **visual art reception**, with a groupwise discussion to activate children's prior knowledge and to develop students' visual perception and spatial reasoning. This part of the lesson is also meant to orient on the subject and the problem used in the lesson.

Within the program **open problems** and multiple solution tasks are used, because these can enhance students' creative thinking (e.g. Leikin & Pitta-Pantazi, 2013) and learning in geometry and visual art. The open problems are related to themes of both geometry and visual art, like perspective or symmetry and the open problem follows visual art production (Rouches-Levano Kerr, 1995). In this way students will learn to visualize their experiences, which is an aim of art education, but at the same time also learn to order and organize these spatial situations (geometry education). Furthermore, during visual art production, students work with materials and form visuospatial and sensorimotor representations of their personal experiences, which can help them in thinking and reasoning about geometry (Nunez et al., 1999).

During the lessons, students are engaged in a process of creative problem solving by producing visual art. Several subprocesses are expected to play a role when they creatively solve problems related to both geometry and visual art, namely **orientation, idea generation, idea evaluation and execution**. These subprocesses are interactive, do not occur in a certain sequence and can have a cyclic character (Leikin, Koichu, & Berman, 2009). So although some of these subprocesses are more implicit, it can help to make them explicit to enhance students' creative problem solving. Except for orientation, not all subprocesses need to become explicit in every lesson. Within the sequence of lessons there is varied explicit attention for each of these subprocesses. Orientation plays a role in every lesson, since it is important in art reception. Furthermore, during the execution of the assignment, the teachers evaluate the process and the products of the students so far, which enables the students to make a new product, or to adjust or improve it.

Interaction with peers is important for students to compare their ideas, see ideas from other points of view which can enhance creative thinking (e.g. Beghetto & Kaufman, 2010). It also increase students' learning since they have to explain their thinking, get feedback, and get other points of view. Interaction evokes reflection, which enables students to reach a higher level of understanding. Within the MathArt lessons students are stimulated to discuss, exchange and communicate ideas with peers, since research suggests that it can enhance students' creative thinking and geometry learning.

Reflection is very important within this integrated pedagogy, since it can help students to make explicit what knowledge and skills they have obtained regarding geometry and visual art. Reflection on the followed process and final product together with the teacher and peers at the end of the lesson, can help students to make explicit their implicit knowledge and skills obtained during creative problem solving. Reflection could extend and modify the existing knowledge, since students have to clarify what was going on and what they have learned. Furthermore it could help students to get more insight into creative problem solving strategies and how they could be reapplied (e.g. Chi, De Leeuw, Chiu, & Lavancher, 1994).

An example of one of these lessons is “playing with perspective”. Teachers start with an introduction in which they discuss a few visual artworks. The teacher discusses six artworks in which artists have played with perspective and viewpoints. Two examples are the artwork of Escher (see Figure 2) and a photo (see Figure 3). Questions that teacher could ask during this introduction are ‘What's happening in this picture?’, ‘What do you see that makes you say that?’, ‘What more can we find?’, ‘How did the artist create this effect?’, ‘Can you tell something about the viewpoint of the artist and what could be the reason for this?’ and ‘How would the photo look like when they would have used another point of view?’. After the introduction, students have to make photos in which they create illusions by playing with perspective and point of view in groups of 3/4 students. After 15-20 minutes, students need to select their two best photos. Figure 4 shows one of the photos that students created. At the end of the lesson the selected photos and their process of making the photos is discussed. Questions that the teacher can ask are for example: ‘What



Figure 2. M.C. Escher (1947) Another world



Figure 3. A photo in which is played with perspective



Figure 4. One of the photos created by the students in MathArt pilot study

effect did you want to create?’, ‘What did the students do to create this effect?’, ‘What perspective did they use?’ and ‘Where would they stand if we draw a map?’. Furthermore students need to reflect on what they have learned.

In the pedagogy of our PD program active learning is

important. Therefore interactive methods are used in the sessions. Teachers for example have to experience the MathArt lessons themselves, watch film fragments of other teachers and have to make a hypothetical learning trajectory. Afterwards, teachers always have to discuss and reflect on these activities. The content of the PD program is related to the classroom practice. Furthermore reflection on and experimentation with the MathArt lessons is important; it can support on-going learning and encourages change.

THE RESEARCH PROJECT

In a pilot study we evaluated the goals of the MathArt teaching sequence and the PD program. Fourteen teachers from grade 4, 5 and 6 in four schools in Rotterdam, the Netherlands and their students participated in the MathArt program from September 2016 – January 2017. To quantitatively evaluate students’ creative thinking and geometrical ability several pre- and post-measures were administered, like a geometrical ability test, a

geometrical creativity test and more general measure of creative thinking (TCT-DP). To evaluate the PD program a pre- and post-survey was administered and teachers were observed during lesson 1, 4 and 8.

EVALUATION AND FINDINGS

In this paper we will present some initial findings of the pilot study. More systematic evaluations are scheduled and the results will be presented during the conference in April.

One of the aims of the MathArt program is foster students' creative problem solving skills. Unstructured observations of the lesson "Playing with perspective" suggest that students are able to create photos in which they show illusions. Although some examples of photos with illusions were presented during the introduction, students came up with new ideas. Furthermore, one student also indicated that making the picture was very difficult. So although they might have an idea of how to create such a photo, actually making the photo requires different skills. By thinking of ideas, trying out and evaluating the picture (did it create an illusion?), students practiced their creating problem solving skills. Observations also showed the role of the environment for creative problem solving. Students also seemed to inspire each other; one group came up with the idea to try to touch the roof by standing on the ground, and another group continued on this idea in a slightly different way.

Another aim of the MathArt program is to increase students' geometrical knowledge by using creative problem solving activities. Although we cannot yet present results of quantitative data, qualitative data suggests students' improvement of geometrical knowledge. During the observation of one of the lessons, teachers asked their students after the lesson what they have learned. Students answers indicated: "to find the right position for the camera and the position of the students to create these effects", "that other students have to stand at a very precisely place, otherwise you do not get the effect" and "every viewpoint creates a different effect". Furthermore, unstructured observations suggested that students started to use the new words they have learned during the presentation of their photo's; they used words like perspective, bird's-eye perspective, frog perspective, position/viewpoint and optical effect while they were reflecting on their process and product. However, learning gains of students might differ between classes. Differences might be caused by the geometrical vocabulary introduced and used by the teachers and the kind of questions asked by teachers to help students during the process of creative problem solving and to help them explain geometrical phenomena.

Our observations in the first and fourth lesson of the teaching sequence showed the significant role of the teacher for stimulating students' creative thinking and their learning in geometry. Although we presented the fourteen teachers with the same lesson description, the way teachers enhanced students' creative thinking and geometrical learning varied a lot. For example, it is important that a teacher behaves like a facilitator; generate open ended questions that can extend students' explorations and thinking during the process of creative problem solving (e.g. Begehtto & Kaufman, 2010). However, during the observation of the first MathArt lesson, we saw large differences between teachers: some were getting coffee and walked away during the assignment, other teachers sat behind their desk and observed their students now and then, while others walked around through the class, asked questions to students about what they were doing and asked them questions about how they could improve their product. During the observation of the

fourth lesson this point of observation already improved; more teachers behaved like a facilitator.

The implications that emerge from this pilot study are that this study can give more information about the effects of creative problem solving in a classroom and also on how creative problem solving emerges in a primary school classroom setting. Furthermore, the study also sheds light on practical issues and challenges related to (the implementation of) enhancing creative problem solving in current primary school education.

Acknowledgement

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