A better understanding of 21st century skills in mathematics education and a view on these skills in current practice

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Abstract

The intention of this explorative study, which combines qualitative and quantitative methods, was to investigate how to implement several 21st century skills in mathematics education. Within this study the following hypothesis is tested: there is more potential to further develop 21st century skills in mathematics with a problem based learning setting compared to a traditional educational setting. The study was carried out with three different classes at two different schools, with in total eighteen groups of four students. Each class was observed during a regular mathematics lesson and during a lesson where the students made a problem based task which is designed by researchers of the Mascil project. Based on literature, an observation framework was developed that was used for both observing the ways the teacher and the task elicits several specific skills and observing the ways students use these skills. The focus of the observations was on the skills creativity, critical thinking, communication and collaboration. The audio and video documents were transcribed, coded and analysed on the number of observed skills. In all three classes, the number of skill observation were respectively higher within the problem based lesson. From the analysis, it can be concluded that 21st century skills are positively promoted with problem based tasks in mathematics education. We recommend enrichment of the mathematics education with problem based tasks to address the 21st century skills in daily practice.

Introduction

Due to globalization and the growing importance of Information and Communication Technology (ICT) and sharing knowledge, the content of education is changing (Voogt & Roblin, 2010; Trilling & Fadel, 2009). In order to cope with the changes, knowledge and skills have become an essential part in an economy where people embody, create, improve and apply knowledge. This creates new demands in the labour market (DeSeCo Symposium, 2003; Voogt, Erstad, Dede , & Mishra, 2013). It is getting more important for job seekers to be competent in knowledge construction, working together, solving problems, be able to work with ICT and develop their creativity. These are examples of competencies that are also called *21st century competencies* (van den Oetelaar & Lamers, 2012; Riordan & Rosas, 2002). According to Riordan and Rosas (2002), a competence is: a combination of knowledge, skills and attitudes that are acquired at different stages in life, starting from basic education, move into initial training and continuing throughout adult working life (p.91). Especially the skills needed to succeed in the workplace, have changed significantly over the past three decades. These skills are not completely new but it is the extent to which these skills imply success what creates the need for more explicit attention (Rotherham & Willingham, 2010). Our focus will be on this so-called 21st century skills. A good mastery of these 21st century skills apply citizens with better opportunities to secure a job and retain employment. When employers are asked what competencies job applicants are missing, they mention the following skills the most frequently according to Riordan and Rosas (2002): the ability to learn how to learn (planning); the competence in reading, writing and computing (basic-skills); be effective in listening and oral communication (communication / collaboration); adaptability through creative thinking and problem solving; personal management; interpersonal skills; ability to work with other people; basic technology skills (ICT literacy) and leadership (decision

making). A major task is to reduce the gap between education and work by decreasing the level difference of the skills (Riordan & Rosas, 2002).

The Dutch Government stated that it would be an enrichment of the curriculum when there is more attention for the 21st century skills (Onderwijsraad NL, 2014). For a good connection between school and a future professional job, it is important that teachers are aware of the important role these skills play. The major changes in the requirements of education result in a need to change what has to be learned and how this is instructed and learned. Implementation requires a school-wide awareness on the importance of the implementation process and thereby, collaboration with other schools and partners. It is important that there is strong leadership and a good adoption of ICT (Voogt, Erstad, Dede , & Mishra, 2013). In this study, the focus lies on implications for the school subject mathematics. It is expected that the implementation of 21st century skills in mathematics is a challenge because, currently, mathematics education is mainly orientated on acquiring low-level cognitive processes, asks for students to work alone and in silence and does not stimulate students to develop deeper understanding in mathematics (Silver, Mesa, Morris, Star, & Benken, 2009). Therefore, it is important to gain insight in the possibilities to implement these 21st century skills in mathematics education.

The European Union promotes the implementation of 21st century skills by funding different projects that support the implementation of 21st century skills. The Mascil project is one of these projects. The goal of the Mascil project is to connect inquiry based learning (IBL) with aspects of the work field (Doorman, Fechner, Jonker, & Wijers, 2014). This project is experimenting with self-designed tasks, according to pre-defined guidelines, in the second grade at some schools in the Netherlands. Simulating a real-world environment where a skill or specific knowledge is normally used, also called an authentic context, increases the change that a lesson will be remembered (Trilling & Fadel, 2009). Besides, it could have a

major influence on the ability to learn science, because the students are exposed to parallel tasks as the work of practicing scientists (Capps, Crawford, & Constas, 2012).

It is our expectation that the tasks within this project will show more potential in emphasizing 21st century skills compared to regular mathematics classes because IBL tasks are meant to give a good practical view in the work field. The aim of this study is to improve the implementation of 21st century skills in mathematics by understanding how 21st century skills can be elicited in mathematics and thereby, improve the preparation of students to the future world where they need to use the 21st century skills in practice.

Theoretical background

Views on 21st century skills

It is a major goal of education to prepare students for their role as a self-reliant lifelong learning citizen (Trilling & Fadel, 2009). Globalization has resulted in a worldwide working field. Therefore, collaboration is an important skill in this century. In order to collaborate, it is necessary to be able to communicate. This means in the 21st century that you need to express, listen, hear, document, convey, argue and analyse using various communication tools (DeSeCo Symposium, 2003). Communication is embedded in digital literacy. Digital literacy consists of three concepts; information literacy, media literacy and ICT literacy (Trilling & Fadel, 2009). The students should be able to access, evaluate, use and manage information, analyse media, create media products and apply technology effectively (Trilling & Fadel, 2009). Problem solving and critical thinking are considered as the new basic skills by many (Trilling & Fadel, 2009). Students should be able to reason effectively, use system thinking, make judgements and decisions and solve problems. In order to develop these skills, it is important to stimulate creative thinking and productivity.

In 2010, Voogt and Roblin wrote a review study commissioned by Kennisnet (Voogt & Roblin, 2010). Their goal was to provide information about the current status of 21st century skills concerning definitions, implementation and evaluation. They incorporated the available frameworks which included Partnership for 21st century skills (p21, now called partnership for 21st century learning), EnGauge, Assessment and Teaching of 21st century skills (ATCS), National Educational Technology Standards (NETS/ISTE) and National Assessment for Educational Progress (NAEP). Besides, there are some additions from research and recommendations of the European Union (EU), the OESO and UNESCO. p21, ATCS and the recommendations from the EU were the only frameworks that discussed 21st century skills within the current curriculum. It is our goal to implement the 21st century skills in the mathematics curriculum. Furthermore, p21 and ACTS refer to mathematics as a core subject. Therefore, our focus could be on the skills described by p21 or ATCS.

The different frameworks consider ICT as the core of 21st century learning. This means that ICT is considered as both an argument for implementing the 21st century skills and as an instrument that supports the development and assessment of 21st century skills.

It is decided that p21 will have our focus because, besides the arguments written above, it focusses on creating a framework for the conceptualization of 21st century skills while the other frameworks focus on the assessment of 21st century skills. It is our intention to get more inside in the current status of 21st century skills in mathematics and therefore, p21 is a fitted framework to focus on. Their argument for the implementation of 21st century skills is that there still is a gap between what students learn and what students need to learn in order to succeed in the work field (http://www.p21.org). Within this study, it is expected that students who work with Mascil tasks are more stimulated to work on mastering their 21st century skills and p21 also claims that the acquisition of 21st century skills can be supported the best by

didactical methods such as problem based learning.

The framework of p21 consists of four major elements: life and career skills, learning and innovation skills, information, media and technology skills and core subjects and 21st century themes. Learning and innovation skills are said to be the skills that separate the students who are prepared for life in the 21st century, with increasingly complexity, from those who are not. This part of the framework consists of the so-called 4 C's. Critical thinking & problem solving, creativity and innovation, communication and collaboration.

In order to elicit creativity, critical thinking, communication and collaboration, it is important to create a safe learning environment. A safe learning environment is created when the students dare to speak up their creative or critical opinion to other students and / or the teacher.

The first element of the learning and innovation skills is the skill to use creativity in order to be innovative, *creativity and innovation.* The definition of creativity which is used for this study is: 'the intentions and motivation to transform the objective world into original interpretations, coupled with the ability to decide when this is useful and when it is not (p.4)' (Runco, 1996). Creativity is understood as the fact that students take part of the process of creating new ideas by elaborate, refine, analyse and evaluate their own ideas. Thereby, they learn to use a range of different techniques. It is also necessary that students learn how to communicate (parts of) new ideas to others effectively and to be open and responsive to new and diverse perspectives. According to Collard (Gain time, 2014): "Creative skills aren't just about good ideas, they are about having the skills to make good ideas happen." He claims that creative skills should include 5 major areas: imagination, being self-disciplined, resiliency, collaboration and giving responsibility.

The second element of the learning and innovation skills is the skill to think critically and to effectively solving a problem, *critical thinking & problem solving*. This is understood as the fact that students make judgements, decisions and solve different kinds of (non-) familiar problems wherein different types of reasoning are effectively used (Soland, Hamilton, & Stecher, 2013). Students need to analyse how all of the different parts of a problem interact as a whole by analysing and evaluating evidence, arguments, claims, beliefs and alternative views. They need to interpret information, make solid connections between different types of information and draw a conclusion out of the information (Partnership for 21st century learning, 2011). The ability to understand academic content deeply is also supported by this skill (Soland et al., 2013).

The third element is *communication.* This is understood as the fact that students learn how to articulate their thoughts and ideas by using different types of communication, such as oral, written or nonverbal communication, for a wide range of purposes in diverse teams and environments. Thereby, they need to listen effectively. Communication forms the basis when it comes to empathy, the ability to trust, solving conflicts and negotiation (Solande et al., 2013). The value of being able to communicate mathematics should be given more prominence as this is essential in employment because of the need of mathematics in solving problems in the work field.

The fourth and last element of the learning and innovation skills is *collaboration.* ICT is changing collaboration into a worldwide event. According to Dede (2009): Collaboration is worthy of inclusion as a 21st century skill because the importance of cooperative interpersonal capabilities is higher and the skills involved are more sophisticated than in the prior era (p.2). Collaboration is understood as the fact that students need to demonstrate the ability to work within diverse teams on an effective and respectful manner. In order to do this, they need to

be flexible and willing to be helpful. It is necessary to provide shared responsibility for collaborative work and thereby valuing each individual team member.

As a summary of this section, we acknowledge that the important 21st century skills in science education are creativity, critical thinking, communication and collaboration. The next step is to look at the different aspects of these skills which could be observed and/or elicited.

Observing 21st century skills in mathematics

Creativity can be divided in three subcategories; the fluency and flexibility of ideas came up by students (Balka, 1974), originality / novelty (Mann, 2005; Sriraman, Manuel, & Kajander, 2014) and elaboration (Mann, 2005). The level of fluency, flexibility and originality of students is an indication of the extent to which the student is participating and the attempts tried to find a fitted approach. The combination of these three can create new interpretations of the task. The third category refers to attempts to improve interpretations from other students or the newly created interpretations.

Critical thinking can roughly be divided in three subcategories; questioning the task, questioning the process and reflection. Questioning the task refers to a student who asks questions and states arguments with or about a mathematical problem and provides clarification for his or her choices (Ennis, 2011) and to a student that takes the source reliability into account (Ennis, 2011; Aizikovitsh-Udi & Cheng, 2015). Questioning the process refers to a student that explicitly describes and checks inferences (Ennis, 2011) and a student that analyses connections between mathematical information related to the problem and evaluates the big picture. Reflection refers to evaluation of the thinking process both for the own process as well as the groups process. It is necessary that students rethink the thoughts about solving the problem in order to describe good argumentation.

Communication can be divided in two subcategories; oral and written communication. The act of talking and responding can help students develop improved understanding (Franke, et al., 2009).

Collaboration can be divided in three subcategories; providing and receiving feedback, making decisions together and committed participation and shared responsibilities (Marinez-Mayona, 2006). Feedback is a way to improve individual performance that can ultimately lead to improvement of collaboration but it requires committed participation and different roles within the group.

In Figure 1, this previous section is summarized in an observation framework.

Aspect	**What is observed?**
1. General	
2. Creativity	
1a. Be fluent and flexible	
1b. Be original / novel	
1c. Be elaborate	
3. Critical thinking	
2a. Posing questions and arguments with or about a (mathematical) problem that can lead to solving the problem and provide clarification for their choices or limiting conditions.	

2b. Check source reliability	
2c. Explicitly describe and check inferences	
2d. Analyse connections between mathematical information related to the problem and evaluate the big picture	
2e. Evaluate (own) thinking	
4. Communication	
3a. Clear oral communication	
3b. Clear written communication	
5. Collaboration	
4a. Provide and receive feedback	
4b. Make decisions together	
4c. Committed participation and shared responsibilities	

Figure 1. Observation framework for the 4 C's in mathematics education

Eliciting 21st century skills in mathematics

Besides observing the different 21st century skills, it is also interesting to look at the eliciting of these skills. Inquiry-based learning (IBL) is a learning strategy that could elicit these skills. IBL is defined as student-centred and the tasks are created with a focus on creativity and collaboration with the purpose to enhance the interest and motivation of the students (Doorman, et al., 2013) (Capps, Crawford, & Constas, 2012). These elements can be compared with aspects of 21st century skills like a collaborative classroom culture, exploring problems and engaging in solving these problems. One of the projects which is promoted by the European Union is called *Mascil project*. The Mascil project is a collaboration between different universities around Europe. They give attention for and development of competencies related to activities from the workplace by using inquiry based tasks.

Research questions

The focus of this study lies on the improvement of the implementation of 21st century skills in mathematics. To start with this, the first step will be gaining insight in the current situation of mathematics education. It follows the following hypothesis: *there is more potential to further develop 21st century skills in mathematics with a problem based learning setting compared to a regular educational setting.*

To investigate this hypothesis, there are two questions:

1. To what extent can 21st century skills be observed in the daily practice of mathematics education?
2. How can the 21st century skills be elicited in the daily practice of mathematics education?

Methods

Literature study

In order to provide an answer to the first question, a literature study is carried out. Different databases were used such as google.com and google scholar. The references were found using the following starting points: the review study of Voogt (2010), the Mascil guideline document and searching terms that refer to either 21st century skills in general or 21st century skills within mathematics education. The study of Voogt refers to different existing frameworks that describe 21st century skills in general from different angles. One of the existing framework is used for further development of an observation framework.

Within the second part of the literature study, the references were used to investigate the selected 21st century skills within mathematics. This was used as a basis for the development of the observation framework.

Instrument development

An observation framework was put together with aspects of the literature study and own additions from the researcher, the supervisor and the Mascil expert team. For each of the four selected 21st century skills a word web was created with the different aspects that link each of the skills to an aspect of mathematics education. In order to reduce the number of observation aspects, the word webs were submitted to an expert team of the Mascil project consisting of different Mascil project researchers who worked with and/or on the different tasks used for the current study. After the meeting with the experts, the word webs were reduced to approximately 2, 3 or 5 subcategories which were further analysed. Before the use

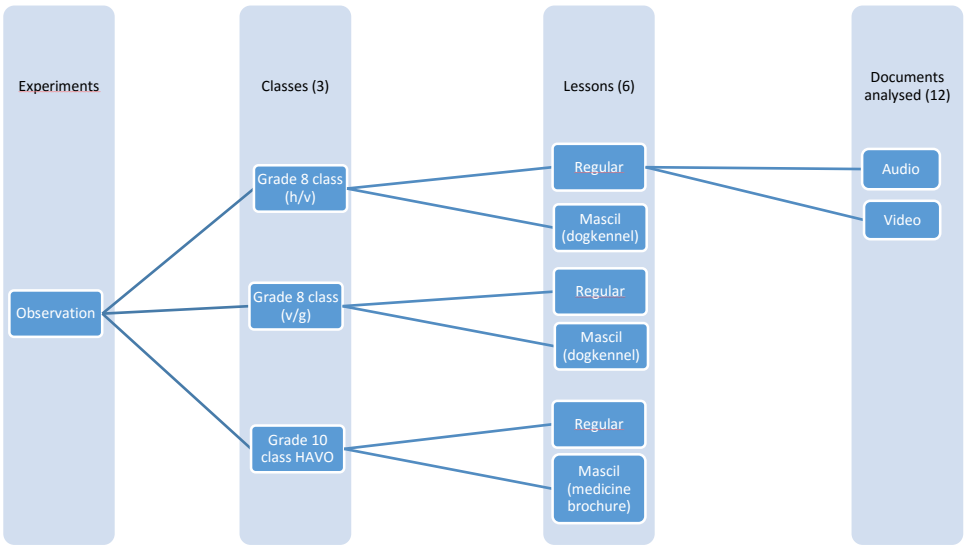

Figure 2. An overview of the observations and the generated documents. The observations were carried out in three different classes. Both a regular and a problem based lesson were observed. Within the problem based lesson, the teacher tested a re-designed Mascil task. Each lesson is both audio and video recorded and each document is analysed and scored using the observation framework.

of the observation framework for the experiments, the observation framework was tested multiple times. Firstly, we tested the utility of the framework for live observation with a pre-recorded video file from April 2015. Secondly, the framework was tested multiple times with the video and audio files from the experiments and with transcribed documents of the experiments. Short interviews were carried out with the aim to underpin the level of knowledge and consciousness of 21st century skills. Both the two teachers and three groups of students (figure 2), that were randomly selected, were interviewed.

Exploratory phase

The observation framework is used to score the different aspects of creativity, critical thinking, collaboration and communication that can be observed in a classroom environment. Both the students and the teacher were observed with the framework. The lessons were audio and video recorded in order to analyse it afterwards. The live observation was focused on the different attempts from the teacher to elicit 21st century skills.

The reliability of the framework was tested multiple times during this study. First directly from the video file, later with transcribed documents without scoring marks and at the end with transcribed documents with scoring marks.

Two schools were selected in different areas in the Netherlands. Both schools have a regional character and are not situated in a big city. Three groups of students with different experienced teachers, both more than 20 years of teaching, are selected for this observation. Two different eighth classes HAVO/VWO, with both 24 participants, and one tenth HAVO class, with 22 participants were observed during both a regular mathematics lesson and a lesson with a selected Mascil task that fitted in their curriculum (Figure 2. An overview of the observations and the generated documents. The observations were carried out in three different classes. Both a regular and a problem based lesson were observed. Within the problem based lesson, the teacher tested a re-designed Mascil task. Each lesson is both audio and video recorded and each document is analysed and scored using the observation framework.). For the lessons of the tenth HAVO class, only the audio files were scored because one of the video files was missing. There was permission to record the conversations.

Within this study, two Mascil tasks are used. In the first task students needed to create a dog kennel for different types and sizes of dogs where they also need to think about the costs (appendix). The second task that is used is the drug concentration guide, in which students need to create a medicine brochure for a self-chosen medicine where they need to think about different medicine concentrations and the corresponding side effects. Both tasks address a problem where students need to create a product which can be used by a customer or client, which is in lines with one of the two principles of the nature of scientific inquiry called stable enquiry (Capps, Crawford, & Constas, 2012). This means that students need to work on a problem by using scientific principles (Capps, Crawford, & Constas, 2012)

Data analysis

The data were aimed to provide understanding of the status of 21st century skills in the school subject mathematics and the enabling benefits of project-based learning. All of the video and audio recordings were transcribed. In total there were eleven documents since the last lesson of the fourth HAVO class is only audio recorded. The quotes of the students were scored on the expressions about the different aspects within the framework and the quotes of the teachers were scored on attempts to elicit the different aspects. Each group of three or four students created an end product within the Mascil lesson which was analysed on the different aspects of the observation framework.

Results

Overview of the 21st century skills during the observations

Class 1 and 2, both eighth HAVO classes, consisted both of 24 students. Within their regular lesson, they worked on surface and content calculations and in their Mascil lesson, they worked on the dog kennel assignment. In total, six different groups in each class created a dog kennel. Class 3, a tenth HAVO class, consisted of 24 students. Within their regular lesson, they worked on practice assignments for their upcoming exam and in their Mascil lessen, they worked on the medicine brochure. In total, six different groups created a brochure. Within each lesson, one group was recorded on video and another group was recorded with audio (see Figure 2).

With the observation instrument, we were able to identify moments during the lesson in which 21st century skills were addressed or needed. During the tasks, the students worked in groups of two students in the regular lessons and in groups of four students in the problem based lessons (Figure 3). The conversations between the students were analysed according to the number of critical, creative, collaborative or communicative comments made about the task by the students. For example, in one of the regular lessons a student said: 'If you fold this figure, it is not closed right'. The student recognizes that the cube is not complete which indicates critical thinking by this student. In a problem based lesson, one of the students said: 'That is not quite right. Do you know why?' This student provides his group member with clear feedback and he is willing to help him understand why it was wrong, which indicates collaboration.

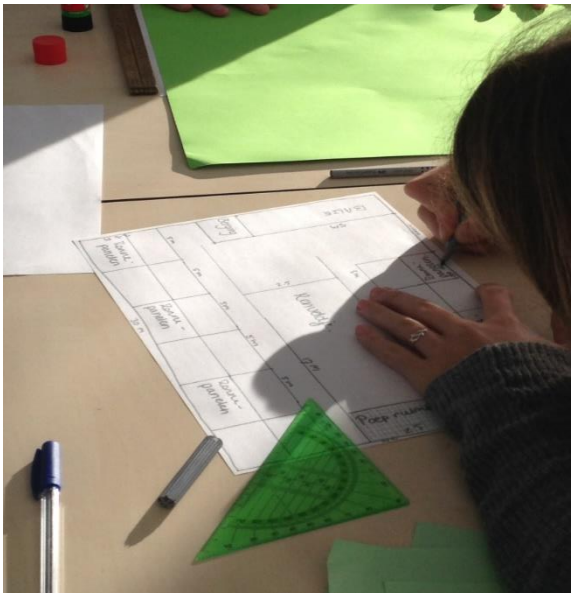

Figure 3. One of the students of a group draws the different doghouses in the dogkennel which are calculated by other members of the group

The observation framework was also used to score comments made by the teacher that could elicit the use of 21st century skills. For example, the teacher said during a regular lesson: 'Why is this not a cube?' The teacher asks the students to rethink their argumentation which could elicit critical thinking.

Table 1, 2 and 3 show the number of observations of students that made such a comment. Table 1 and 2 refer to two eighth classes which made the dog kennel task and table 3 refers to the tenth class which made the drug concentration task.

Table 1
 # 21st century skill observations during a regular and a problem based (Mascil) lesson in class 1 (eighth class)

	Regular lesson			Problem based (Mascil) lesson		
	Student	**Teacher**	**Total**	**Student**	**Teacher**	**Total**
Creativity	0	0	**0**	8	3	**11**
Critical thinking	5	12	**17**	15	1	**16**
Communication	0	2	**2**	6	3	**9**
Collaboration	1	1	**2**	13	1	**14**
Total	**6**	**15**	**21**	**42**	**8**	**50**

Table 1 shows that the total number of observed aspects of 21st century skills in this eighth class is higher within the problem based lesson compared to the total number of aspects in the regular lesson. It also shows that, although the total number of critical thinking observations within both lessons is almost the same, the teacher is responsible for eliciting critical thinking in the regular lesson and the students show almost no response. While in the problem based lesson critical thinking was immediately initiated by the students which could have been elicited by the task or by them working together on a task.

Table 2. The number of 21st century skill observations in class 2

Table 2

 # 21st century skill observations during a regular and a problem based (Mascil) lesson in class 2 (eighth class)

	Regular lesson			Problem based (Mascil) lesson		
	Student	**Teacher**	**Total**	**Student**	**Teacher**	**Total**
Creativity	0	0	**0**	12	0	**12**
Critical thinking	7	1	**8**	16	2	**18**
Communication	1	0	**1**	7	5	**12**
Collaboration	2	3	**5**	9	4	**13**
Total	**10**	**4**	**14**	**44**	**11**	**55**

Table 2 shows the same difference in the total number of observed aspects of 21st century skills between the two lessons as seen in table 1. The main difference is that in both lessons of this class, the students showed more use of 21st century skills in contrast to the previous mentioned class. The table also shows that creativity was initiated by the students which could be elicited by the task or by them working together on a task.

Table 3. The number of 21st century skill observations in class 3

Table 3

 # 21st century skill observations during a regular and a problem based (Mascil) lesson in class 3 (tenth class)

	Regular lesson			Problem based (Mascil) lesson		
	Student	**Teacher**	**Total**	**Student**	**Teacher**	**Total**
Creativity	0	0	**0**	3	0	**3**
Critical thinking	2	7	**9**	15	4	**19**
Communication	0	0	**0**	0	2	**2**
Collaboration	1	0	**1**	4	2	**6**
Total	**3**	**7**	**10**	**22**	**8**	**30**

Table 3 shows a similar difference in the total number of observation aspects of 21st century skills between the two lessons as seen in the two eighth classes. The lower total number of aspects compared to the two eighth classes can be explained by only scoring the audio files. Within these lessons, it is seen that the students showed more use of 21st century skills in the problem based lesson compared to the regular lesson. Within all three classes, critical thinking is the most observed 21st century skills.

Multiple students indicated, during the interviews, that the tasks did not look like mathematics but more like craft work. This could indicate that students are aware of the creative input for this tasks and its difference with regular mathematical textbook tasks that do not emphasize free design or product development.

21st century skills elicited

It is the responsibility of the teacher to create a safe learning environment and to check whether the task is fairly distributed, both essential conditions in order to create an environment where 21st century skills could be improved. The teacher only guided the students during the task which is important in student-centered education (Capps, Crawford, & Constas, 2012). However, because the teacher chose to be more on the background not all students in each group worked as hard. It was expected that the groups would divide different aspects of the task so that each student had his or her own responsibility and inquiry-based teaching should have possibilities of engaging all students (Capps, Crawford, & Constas, 2012), but this was not seen during this observations. It could depend on the level of experience of the teacher with the inquiry-based tasks. One of the teachers also said she would change the level of openness of the task the next time she would use it.

The observations showed that the teacher elicits critical thinking by asking questions and then keeps asking further in order to start the thinking process. In order to elicit creative behaviour, the teacher asks the students to create a winning design. The design that stands out will win a price. Communication can be elicited by asking for a presentation or a report.

It is important that the task is an open task where students get the space to give their own twist to the task. For example, the students are asked to formulate a solution to a problem or create an innovative product. To stimulate creativity, the task can ask for different representations because information can sometimes be represented in different suitable ways. It is also possible that the task asks for various ways to solve the problem. Another aspect of stimulating the four C's is the need to take risks. For example, this can be elicited when there is not one right solution but the students need to choose a path.

Conclusion and discussion

The present study was aimed to test the following hypothesis: *there is more potential to further develop 21st century skills in mathematics with a problem based learning setting compared to a regular educational setting.* The results suggest that the problem based tasks indeed show more use of the 21st century skills compared with the regular tasks. Both the teacher and the task play a role in the creation of space for students to express the use of the different 21st century skills. Tasks in which students need to collaborate have a potential to develop 21st century skills, also seen by Bell (2010). As Bell said, many of the 21st century skills cannot be measured with standardized tests. Besides, within this study it is shown that with authentic tasks the students express more use of the 21st century skills. In agreement with Silver (1997), it was found that teachers can assist students with strategic fluency and flexibility to develop their creativity.

However, this study shows a few limitations. The regular lesson within class 2, the second eighth class, and class 3, the tenth class, were relatively shorter and different from the regular lesson in class 1, the other eighth class. This could influence the scoring rate because the scoring rate is based on the number of observations with in a particular lesson time. It would be interesting to see the difference in rate between more comparable lessons. The different levels of the classes, two eighth and one tenth class, should not have an influence on the results because the tasks were suitable for the different levels.

The observation framework proved to be too complex because it was not possible to score reliably with the current framework. The following aspects could be improved: the scoring of multiple lines within one category which is now highly depending on the opinion of the scorer, the description of the subcategories which need to be more specific in order to score them reliably, scoring of a negative effect (for example, a student that gives feedback with no / little respect) on the skills which is now not scored but which could have an

influence, an observation which fits multiple categories which is now scored in both categories but it could be more reliable to have guidelines for this and last, distinction between non-mathematical and mathematical creative and critical thinking.

The video files were only useful for the underpinning of the audio files. The interactions of the students gave a valuable addition to the audio files but the conversations for the video files could not be used for the analysis. As a recommendation, it would be better to have at least two audio files with an underpinning video file.

Further research should be executed on a bigger scale and more systematically in order to underpin the current findings. The current observation framework is designed according to research which refers to mathematics education but it would be interesting to investigate whether the framework can be adapted for use by other (science) subjects.

Finally, based on these findings, we recommend the implementation of more problem based tasks in the mathematics educational practices, because they have the potential to elicit 21st century skills.

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Appendix

Een vakantie kennel voor honden

Veel mensen met een hond vinden het lastig dat hun hond niet mee kan op vakantie. Gelukkig zijn er tijdens de zomervakantie verschillende hondenkennels waar je je hond kunt brengen. Deze kennels moeten zich houden aan bepaalde regels over de ruimte die nodig is voor bepaalde aantallen van verschillende soorten honden. Het is aan jou om een fantastische plek te maken voor de honden. Wat heeft een hondenhuisje in de kennel eigenlijk nodig?

In de onderstaande tabel staat de minimale grootte van de ruimte van een hondenhuisje in de kennel en het aantal honden bij een bepaalde hoogte van de hond.

Aantal honden	*Hoogte van de schouders van de hond*					
	Kleiner dan 25 cm	Kleiner dan 30 cm	Kleiner dan 40 cm	Kleiner dan 60 cm	Kleiner dam 75 cm	Kleiner dan 85 cm
1	1	1,5	2	3	5	7
2	1,5	2	2,5	4	7	10
3	2	2,5	3	6	10	12
4	2,5	3	4	8	12	18
5	3	4	5	12	20	24
6	4	5	6	18	25	40
7	5	6	7	25	42	50
8	6	8	12	30	50	65
9	8	10	15	34	60	80
10	10	12	20	38	70	95

1. Vraag 1
    a. Wat is de minimale ruimte voor een hondenhuisje met vier honden met een hoogte tussen de 40 cm en de 60 cm?
    b. In de tabel kun je vijf keer het getal 10 herkennen. Omcirkel deze getallen. Verwijst elke 10 naar een gelijkwaardig grootte van een huisje? Ja / Nee, Omdat
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2. Vraag 2
    a. De getallen in de rijen van de tabel nemen toe in waarde van links naar rechts. Leg uit hoe dit komt?

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3. Vraag 3, <u>ontwerp een hondenkennel en beargumenteer je ontwerp.</u>
   Meneer en mevrouw poedel hebben een grote tuin van 10 m x 30 m vlak bij het bos. Ze willen een hondenkennel starten. De vraag is hoe ze de verschillende huisjes voor de verschillende honden het beste kunnen rangschikken.
   Ontwerp een plan voor deze hondenkennel en laat zien hoeveel honden van elke grootte er maximaal in de kennel passen.

Credits: RekenGroen. Rekenen voor vmbo-groen en mbo-groen. Leerlingentekst versie 1.0
Auteurs: Mieke Abels, Monica Wijers, Elise van Vliet, Vincent Jonker

Medicijn concentratie

In deze opdracht ga je samen met een aantal klasgenoten een folder ontwerpen voor een bepaald medicijn. De groepjes zijn vooraf opgesteld.

De volgende aspecten zijn bekend over dit medicijn:

- Gemiddeld 25 procent van het medicijn verlaat het lichaam na één dag.
- Sla geen dag over!
- Het is onverstandig om een vergeten dosis te vervangen door een dubbele dosis de volgende dag.
- Bij een hoeveelheid van 3000 mg of hoger kunnen gevaarlijke bijwerkingen ontstaan.

Let op: dit is een simplistische weergave.

<u>Onderzoek</u>

- Gebruik berekeningen om te onderzoeken hoe de concentratie van het medicijn veranderd in één week wanneer iemand begint met een dagelijkse dosis van 1500 mg door driemaal daags 500 mg in te nemen.
- Beschrijf het verloop van de hoeveelheid medicatie in het lichaam voor minimaal drie verschillende doses zodat de folder voor een breed publiek toegankelijk is.
- Zijn de consequenties, wanneer iemand een dag overslaat en / of een dubbele dosis inneemt, echt zo dramatisch?
- Welke dosis zorgt ervoor dat iemand minstens een week het medicijn kan gebruiken zonder bijwerkingen?

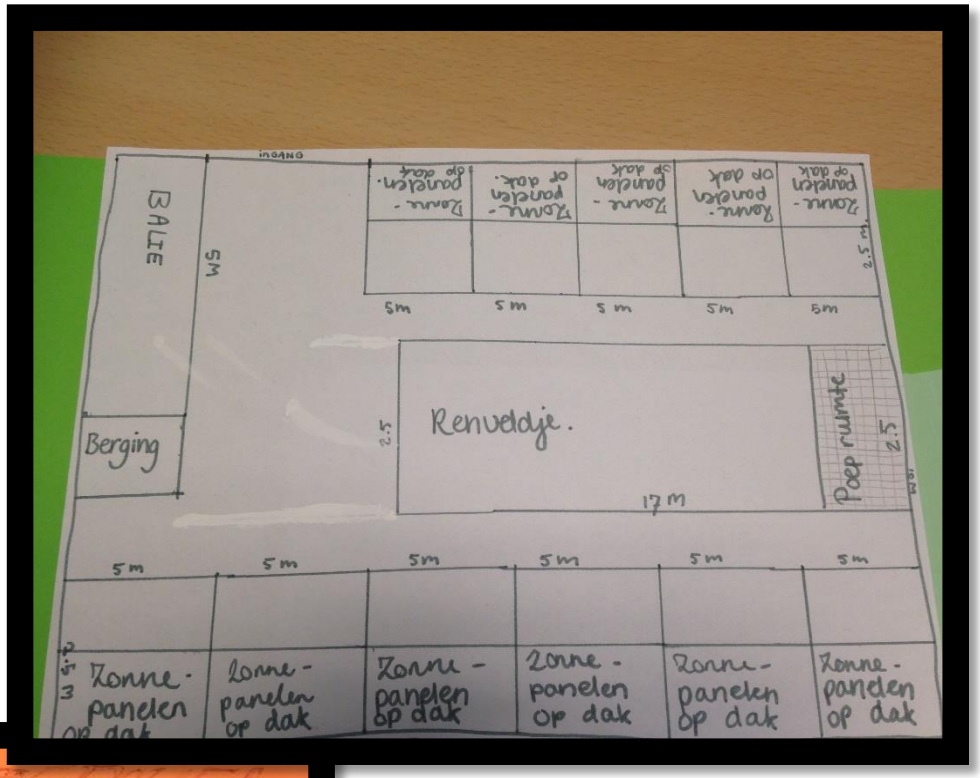
<u>Product Design</u>
Ontwerp een folder waarin patiënten informatie krijgen over het gebruik van het medicijn met argumenten vanuit het eigen onderzoek. Je mag het doel en de naam van het medicijn zelf bedenken. In de folder staat op z'n minst een grafiek en een tabel.

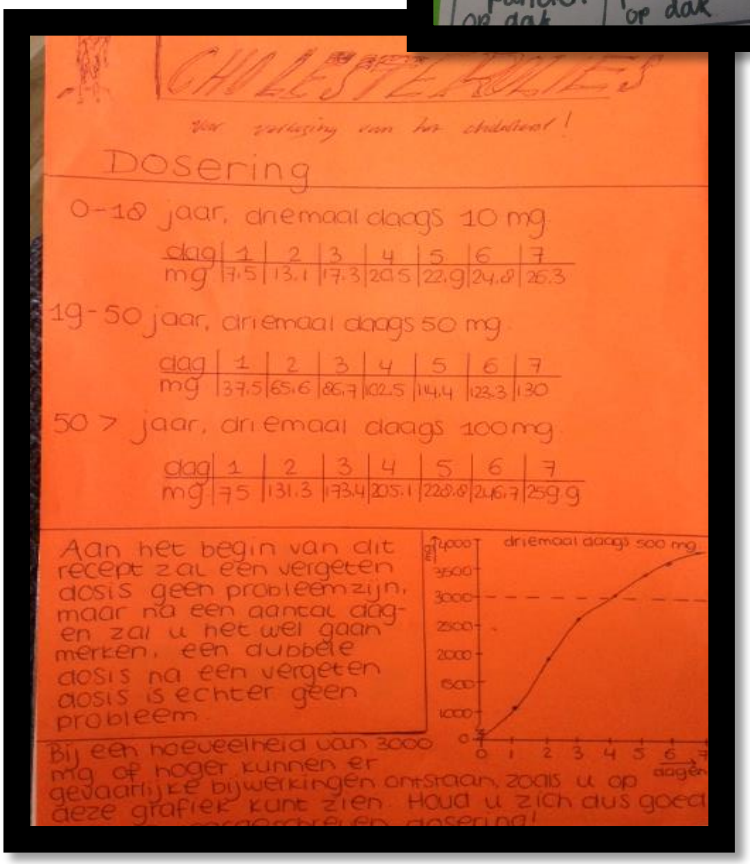
Probeer de berekeningen af te krijgen tijdens de les. Het werk aan het eind van deze les wordt gefotografeerd voor onderzoek. Jullie krijgen een week om de folder verder af te ronden. Volgende week vrijdag (11 december) moeten jullie de folder inleveren in het begin van de les.

Bron: www.mascil.eu

Voorbeelden van uitwerkingen

Hondenkennel
In de afbeelding hiernaast is een voorbeeld te zien van een uitwerking van de hondenkennel opdracht. Hier is te zien dat de leerlingen hondenhokken maken van verschillende grootte verdeeld over een gegeven oppervlakte. Daarnaast hebben de leerlingen de vrijheid om andere (innovatieve) aspecten toe te voegen aan hun kennel. Ook hebben ze een reclamefolder moeten maken voor de promotie van hun kennel.





Medicijnfolder
Hiernaast is een uitwerking te zien van de medicijnfolder opdracht. De leerlingen hadden de vrijheid om een zelfbedacht medicijn te kiezen. Ze hebben daarbij verschillende berekeningen moeten uitvoeren om uiteindelijk een folder te maken die voor meerdere patiënten te gebruiken was. De (meeste) leerlingen hebben gebruik gemaakt van zowel tabellen als grafieken.