MASTER'S THESIS

An Investigation of the Effect of a Pedagogical Agent on Achievement Motivation, Affect and Learning for Primary School Students.

Gorter, Margareta

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Een Onderzoek naar het Effect van een Pedagogisch Agent op Doelgerichte Motivatie, Emotie en Leren voor leerlingen op Nederlandse Basisscholen.

An Investigation of the Effect of a Pedagogical Agent on Achievement Motivation, Affect and Learning for Primary School Students

Margareta Gorter

Master Onderwijswetenschappen
Open Universiteit

Cursusnaam en cursuscode: OM9906
Naam begeleider: Kate Xu
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Inhoud

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Title

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Samenvatting

Uit eerder onderzoek blijkt dat leren met een pedagogisch agent een voordeel geeft bij het leren in een virtuele omgeving (Schroeder & Adesope, 2015). Pedagogisch agenten zijn virtuele figuren die een student begeleiden door deze virtuele leeromgevingen (Heidig & Clarebout, 2011; Schroeder, Adesope, & Gilbert, 2013). Desondanks heeft eerder onderzoek meestal het effect van het karakter en de eigenschappen van deze pedagogisch agenten op retentie en transfer gemeten en niet louter het effect van het gebruik van een pedagogisch agent of niet in een virtuele leeromgeving. Daarnaast bestaat er maar beperkt onderzoek naar de motivationele en emotionele voordelen van leren met een pedagogisch agent (Heidig & Clarebout, 2011). De meeste onderzoeken zijn gedaan met studenten uit het hoger onderwijs en maar een paar met leerlingen uit het primair onderwijs (Heidig & Clarebout, 2011).

De huidige studie wil het effect van werken met een pedagogisch agent op emotie motivatie en leerresultaten onderzoeken bij leerlingen in het primair onderwijs.

In dit experiment zijn 132 leerlingen van groep 7 en 8 uit het primair onderwijs geworven op drie basisscholen in Nederland door een brief van de onderzoeker die is gedistribueerd door de leerkracht. De deelnemers zijn ad random toegewezen aan de experimentele conditie (n = 63) en de controle conditie (n = 58). Voor het experiment is de geheugen capaciteit gemeten door de digit span test van Cowan (Cowan et al., 2005) en voorkennis is gemeten door het oplossen van kansberekenings-problemen.

Tijdens het experiment keken alle leerlingen naar een instructievideo over het oplossen van kansberekeningsproblemen. In de experimentele groep was er een pedagogisch agent aan de video toegevoegd. In de controle groep was er alleen een stem die de instructie gaf. Na de instructie video hebben de leerlingen geoefend met het oplossen van kansberekenings-problemen. Na het oplossen van deze problemen, kregen de leerlingen questionnaires over self-efficacy, motivatie, emotie, cognitief load en social presence. Aan het eind van het experiment moesten de leerlingen acht kansberekeningsproblemen oplossen en deze testten retentie en transfer.

De sleutel variabelen zijn gemeten door Patterns of Adaptive Learning Scales (Midgley et al., 2000), Situational Interest Scale (Linnenbrink-Garcia et al., 2010), Positive And Negative Affect Schedule (Watson, Clark, & Tellegen, 1988), Achievement Emotion Questionnaire (Pekrun, Goetz, Frenzel, Barchfeld, & Perry, 2011), CLI scale (Leppink, Paas, Van der Vleuten, Van Gog, & Van

Merriënboer, 2013), CL scale (Klepsch, Schmitz, & Seufert, 2017), Social Presence (Kreijns, Weidlich, & Rajagopal, 2018).

De experimentele groep had een klein beetje hogere leerresultaten op retentie, transfer, motivatie en cognitief load, maar geen van deze resultaten was statistisch significant. De uitkomsten van social presence waren significant hoger in de experimentele groep dan in de controle groep.

De huidige studie bevestigt niet dat leren met een virtueel pedagogisch agent de motivatie, positieve emoties en leeruitkomsten verhoogt. Dit zou kunnen komen door de moeilijkheidsgraad van de kansberekeningsproblemen of de wijze van instructie geven. Leren met een pedagogisch agent verlaagt ook niet de cognitief load. De huidige studie bevestigt dat leren met een pedagogisch agent de social presence verhoogt. Aanvullend onderzoek is nodig om te onderzoeken hoe een pedagogisch agent een voordeel kan hebben bij het leren.

Keywords: Pedagogisch agent, Self-efficacy, Motivatie, Emotie, Social Presence, Cognitive Load, Primair onderwijs

Summary

Previous research showed that learning with a pedagogical agent is beneficial for increasing learning outcomes in virtual learning environments (Schroeder & Adesope, 2015). Pedagogical agents are virtual characters who will guide the students in these environments (Heidig & Clarebout, 2011; Schroeder et al., 2013). Nevertheless, previous research had examined mostly the character and qualities of these pedagogical agents demonstrating the direct effect on learning retention and transfer. They did not demonstrate the effect of just using a pedagogical agent in a virtual learning environment. Beside this, only limited research showed the motivational and emotional benefits of learning with a pedagogical agent (Heidig & Clarebout, 2011). Most of the studies are done with college students and very few research is done for pupils of primary schools (Heidig & Clarebout, 2011).

The present study aims to investigate the effect of working with a pedagogical agent on emotion, achievement motivation and learning outcomes of pupils at primary schools.

In this experiment a total of 132 pupils of grade 7 and 8 of primary schools were recruited from three primary schools in the Netherlands by a letter from the experimenter and distributed by their teacher. The participants were randomly assigned to either the experimental condition (n = 63) or the control condition (n = 58). Before the experiment memory capacity was measured by the digit span test of Cowan (Cowan et al., 2005) and prior knowledge by solving probability problems. During the experiment all the pupils watched an instructional video about solving probability problems. In the experimental group a pedagogical agent was added in the instructional video. In the video of the control group instruction was just with a voice. After the instructional video pupils did practice to solve probability problems. Next to solving the problems, pupils got questionnaires about self-

efficacy, motivation, emotion, cognitive load and social presence. At the end the pupils did solve eight probability problems testing retention and transfer.

The key variables are measured by Patterns of Adaptive Learning Scales (Midgley et al., 2000), Situational Interest Scale (Linnenbrink-Garcia et al., 2010), Positive And Negative Affect Schedule (Watson et al., 1988), Achievement Emotion Questionnaire (Pekrun et al., 2011), CLI scale (Leppink et al., 2013), CL scale (Klepsch et al., 2017), Social Presence (Kreijns et al., 2018).

The experimental group reported just a slight higher learning outcome on retention and transfer, emotion, motivation and cognitive load than the control group. But none of the results were statistically significant. The outcome on social presence was significant higher at the experimental group than the outcome of the control group.

The current study did not confirm that working with a virtual pedagogical agent will increase motivation, positive emotions on learning and learning outcome. This could be due to the difficulty of the task or the instructional design. Working with a pedagogical agent did not decrease cognitive load. The current study did confirm that working with a pedagogical agent did increase social presence. Additional research is required to investigate how a pedagogical agent can be a benefit for learning.

Keywords: Pedagogical Agent, Self-efficacy, Motivation, Emotion, Social Presence, Cognitive load, Primary School Pupils

1. Introduction

In OECD reports a decreasing trend of motivation of Dutch secondary school students is shown (OECD, 2019). Dutch students are among the least motivated when compared to other developed countries. An aim in Dutch education is to increase the motivation of Dutch students (OECD, 2019).

Although many ways of instruction and learning are accessible for teachers and students the development of computer based learning environments are very interesting, especially for increasing achievement motivation (Atkinson & Atkinson, 2002; Yanghee Kim & Baylor, 2016). A lot of formal instruction that normally took place face to face can be replaced by computer technology through the development of computer techniques (Hoogerheide, Loyens, & van Gog, 2016). In the computer-based learning environment a Pedagogical Agent (PA) can be used. A PA is a virtual character embedded in a learning environment and it can act in various roles, for example, as an instructor who guide the learner through the lessons (Baylor, 2009; Baylor & Kim, 2004a; Mayer & DaPra, 2012).

PA's should guide the students in the curriculum, they act like a tutor or a peer and they instruct and help the students with learning. They can motivate and stimulate learning of students (Baylor &

Kim, 2004b; Chen, Kalyuga, & Sweller, 2017; Heidig & Clarebout, 2011; Mayer, 2014a; Schroeder et al., 2013). Researchers are beginning to understand the conditions in which a PA can promote learning and achievement motivation by students, but many questions still remain (Baylor, 2009). Mixed results are found in research about learning with a PA (Heidig & Clarebout, 2011; Schroeder et al., 2013). One of the reasons is a lot of research is done about specific characteristics of a PA and not at working with or without a PA in general (Schroeder et al., 2013).

Most of the research on learning with a PA is related to samples based on students in higher education, less is done based on samples from younger learners (Heidig & Clarebout, 2011). It is interesting to study if a PA can promote achievement motivation and affect among learners at a primary school. The present study aims to research if a PA can motivate achievement and affect learning. Research was done among primary school children with an experimental condition with PA and a control condition without PA.

1.1 Theoretical frame

1.1.1 What are pedagogical agents?

In virtual learning environment the learners can be guided by text, just a voice or an animated PA with a voice. A PA is a virtual character in a computer-based learning environment who helps students learn the material. They are mostly presented as an animated image with a voice. The PA can instruct and guide learners through learning material. These characters talk to the students, give instructions, explain the task or give explanations how to solve problems (Atkinson, 2002; Roxana Moreno, Mayer, Spires, & Lester, 2001; Park, 2015; Schroeder & Adesope, 2015).

The focus of designing the first PA's was initially to build an intelligent agent in a virtual learning environment, with the expectation of some achievement motivational benefit through visual presence. Achievement motivation compares to competence beliefs, performance and reactions on failures of children (Wigfield et al., 2015). The PA was an expert for the learners with just an instructional role (Yanghee Kim & Baylor, 2016). Nowadays the PA is not only a guide, the PA is designed to serve more functions in the learning environment: achievement motivation, information processing, storing and retrieving, transfer of information and monitoring and redirecting (Heidig & Clarebout, 2011).

Although the best way for learning is to have a relation with a real life tutor (Atkinson, 2002), in the virtual learning environment a learner can build a relation with the PA. This social relation can have an important role during the learning process for the learner (Mayer, 2014b; R Moreno, 2005). A PA can support learning and motivation by simulating social interaction with the learner (Atkinson, 2002; Y. Kim, Baylor, & Shen, 2007; Schroeder, Romine, & Craig, 2017). The social relation between a learner and a PA can have different roles. A PA can be a social role model or a peer companion (Y. Kim et al., 2007; Mayer, 2014a; Roxana Moreno et al., 2001). This simulated social interaction can

offer a unique instructional opportunity (Y. Kim et al., 2007). Another benefit of the PA is the character is always available for the students as part of the instructional environment (Baylor, 2009). The technical improvement of computer technology will help improve the PA's and they can act more like human beings and start up a relationship with the learner (Lin & Atkinson, 2011).

1.1.2 Theoretical background of the role of pedagogical agents in learning

There are several theories on learning and instruction that have been proposed to incorporate the possible effects of a PA in instructional design practice and research. The current section reviews these relevant theories.

1.1.2.1 Social-cognitive theory

In social cognitive theory the acquisition of knowledge is related to observing other people within social interaction and experiences (Bandura, Adams, Hardy, & Howells, 1980). In order to acquire a specific behaviour, learners need to see how that behaviour is performed by other people. Observing behaviour can also engage learners in behaviour they already learned (Bandura et al., 1980). Teachers will act as social role models, they are not just instructors. They have a relationship with the learners which can lead to motivational and affective features (Atkinson & Atkinson, 2002).

Many computer-based learning systems ignore the benefits of human teachers (Atkinson, 2002). Recent research in social cognition seems to support the need to include social context in computer-based learning (van der Meij, van der Meij, & Harmsen, 2015). The PA can be a social role model for the learner when he gives an example of behaviour and social attitude to the learner (Baylor, 2009).

The more similarities between the model and the observer, the higher the rate of imitating that behaviour will be (Yilmaz & Kiliç-Çakmak, 2012). The learner feels comfortable when a PA looks like the human he aspires to be (Mayer & DaPra, 2012). For younger children the PA can be seen as a partner and member of the group if he PA dresses and acts in the same way as the children do. In this role the PA will be very motivating, he has a social role in the group and the children will be the same as him and copy his behaviour (Baylor, 2009). In the research of Johnson et al. (2013) a sample of 223 primary school children indicated a preference for young realistic looking, casual clothing with a fun personality. Findings on the specific preferences are: A preference of 85% with χ^2 (1, N = 223) = 110.5 and p = <.001, realistic looking 61% with χ^2 (1, N = 223) = 11,7 and p = <.001, casual clothing 70% with χ^2 (1, N = 223) = 37.1 and p = <.001, fun personality 78% with χ^2 (1, N = 223) = 67.8 and p = <.001 (A. M. Johnson, Didonato, & Reisslein, 2013). This compares to the *persona effect* which shows the presence of life like characters in a learning environment can have a positive effect on students' perception of their learning environment (Mayer & DaPra, 2012)

1.1.2.2 Self-efficacy

According to social cognitive theory, a direct motivational benefit of a PA is the self-efficacy of learners. Self-efficacy is the way humans have their own belief in their capacities to solve a problem or to learn a task (Bandura et al., 1980). Self-efficacy can decrease the fear of complex tasks and increase the achievement motivation for the task (Bandura & Adams, 1977). The learners can develop a social bond with the PA, resulting in more interest and enjoyment in learning and increased value and decreased pressure (Y. Kim et al., 2007).

The influence of motivational messages and emotional support from a PA on self-efficacy is examined by Baylor, Shen and Warren (2004) among college students. The students in the experimental group got positive feedback (e.g. "So far you're doing great") and emotional support (e.g. "Just keep on trying, you can do it") from a PA. In the control group no achievement motivational support was given by the PA. The students scored significant better on self-efficacy when they received achievement motivational expressions and achievement motivating messages with $p <$ .001 and affect size $d = .82$ or higher. This research is confirmed by the experiment studying the benefits on self-efficacy of working with or without a PA among 49 students at a Dutch primary school by van der Meij (2013). The students who studied with a PA had a higher self-efficacy outcome ($M = 6.27$) than the control group who studied without a PA ($M = 5.84$) with an increase of self-efficacy $F(1,55) = 29.71$, $p = < .001$, $d = 0.51$.

1.1.2.3 Cognitive load theory

According to Cognitive Load Theory (CLT) the process of learning is when new information successfully transfers from the working memory to the long-term memory also called schema (Sweller, 1988). CLT provides a theoretical foundation for developing instructional designs that take into account the limited space in the working memory, and gives opportunities for the most effective learning strategies (Chen, Kalyuga, Sweller, & Sweller, 2015; Mayer, 2014a; Mousavi, Low, & Sweller, 1995; Sweller, Van Merrienboer, & Paas, 1998). The working memory holds limited information in a temporarily accessible state in service of cognition (Cowan et al., 2005). This memory span differs for individuals and changes with age. Retrieval is related to the memory span and depends on a profile of processing rates in the brain (Cowan et al., 1998).

The last twenty years the CLT is has been extended and the most recent framework proposes three types of cognitive loads *intrinsic load , germane cognitive load ,* and *extraneous cognitive load* (Leppink et al., 2013; Sweller, 2010a). The *intrinsic load* depends on the task. The natural complexity of the task must be understood and learned. A task with a low complexity can be learned with not too much prior knowledge. A high complexity task needs more prior knowledge and is more complex for the learner (Leppink et al., 2013). A PA must adapt to the prior knowledge. The *germane cognitive load* is the way information comes into the brain, this will affect the short term memory and is

responsible for effective learning. This is about how the new information can connect with the existing knowledge (Sweller, 2010a). The task a PA provides must not be too big or too complex especially when the learners are learning new subjects.

The *extraneous cognitive load* is about the way the information is presented to the learner. In designs with a lot of extra information around the topic of the lesson, learners will be distracted from the main subject of the lesson. Information will not be learned because the learners focus on other subjects. Designers should try to minimize the *extraneous load* by paying attention to how learning can be optimized through effective design (Mayer, 2014a). When learners get too much information, students can't make a difference between the important and less important information. With too much information learners have to split their attention between the numerous visual elements (gestures, facial expressions) and other information in a multi-media learning environment (Schroeder et al., 2017).

Concerns are made by the influence of a PA on the cognitive load, especially extraneous cognitive load (Mayer, 2014a). Research proves that non-task messages made by a pedagogical agent distracted learners away from the main learning content (Liew, Mat Zin, & Sahari, 2017; Schroeder et al., 2017). But when learners work more often with a PA in a virtual learning environment the split-attention principle will not have harmful effects on learning (Roxana Moreno et al., 2001). Because, when students work more often with the pedagogical agent, they will recognize the agent and the agent is not taking up resources in the working-memory anymore (Schroeder et al., 2017).

1.1.2.4 Cognitive Theory of Multimedia Learning

Within the framework of Cognitive Theory of Multimedia Learning, Mayer proposed the *social agency theory* (Mayer, 2014b) in which social cues are hypothesized to be important factors facilitating motivation and affect which contribute to better learning outcomes.

The PA is critical for fostering cognitive engagement during learning, which depends on the feeling of interacting with another social being. This is the perception of *social presence* (Kreijns, Kirschner, & Vermeulen, 2013). Social cues prime a feeling of *social presence* , a feeling of interacting with another social being (Roxana Moreno et al., 2001). While working with a computer, people are easily induced to accept computers as social partners and can respond socially to a virtual tutor (Ophir, Nass, & Wagner, 2009; Reeves & Nass, 1996). This line of research suggests that social presence related subtle cues such as a speaker's voice or conversational style can encourage learners to respond socially to an online tutor (Mayer, 2014b). Thus social cues of a PA may prime social responses in learners that lead to deeper cognitive processing during learning and hence better test performance (Mayer, 2014b).

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The Social Agency Theory has in particular suggested that the effects of PA are mediated through motivational and affective processes (Mayer, 2014a). In the past, these aspects have been examined in relation to situational interest (Park, 2015) and positive emotions (Liew, Tan, & Ismail, 2017). Below brief introductions on these aspects are presented.

1.1.2.5 Emotional benefits of Pedagogical Agents

In line with social cognitive theory, the hypothesized positive effect of a PA on learning has also been proposed to be mediated through positive emotions and achievement motivations (Baylor, 2009; Heidig & Clarebout, 2011). Learning environments contain a lot of emotions such as enjoyment of learning, hope, pride or anger (Pekrun, Elliot, & Maier, 2006). Emotions are suggested to influence the learning process, such as attention, achievement motivation and use of learning strategies as well as the learning outcomes (Pekrun et al., 2011).

The general experienced emotions are stated as good or bad, energized or enervated. This is called the *core affect* and it influences the perception, cognition and behaviour. The *core affect* is defined as a "neurophysiological state that is consciously accessible as a simple, nonreflective feeling" (Russell, 2003). These feelings are influenced by internal and external causes like a PA and people are not necessarily aware of the relation between these feelings and the internal and external causes (Russell, 2003). In research there are direct links between positive emotions and increasing learning outcomes (Mayer & DaPra, 2012). For example a positive mood causes the brain to relax and be more perceptive to curiosity, creativity and affective learning, while a negative mood causes the mind to focus narrowly on the problem (Liew, Mat Zin, et al., 2017). The presence of an instructor or a learning companion might play a role in influencing the affective and cognitive characteristics of a learner.

The role model of a PA can be extended for influence on the achievement motivation of a learner because achievement motivation emotions play a critical role for the students (Pekrun et al., 2011) and the PA has been hypothesised to increase positive feelings and motivate learners (Baylor, 2009; Yanghee Kim & Baylor, 2016). The learners can feel supported by the social cues of a PA, or even hurt by its criticism like they should experience of a human being (Heidig & Clarebout, 2011).

1.1.2.6 Motivational benefits of Pedagogical Agents

There are very few studies which have taken measures on motivation other than self-efficacy and there are mixed findings (Heidig & Clarebout, 2011). This was partly because most of the studies were about the design of a PA rather than whether it was comparing learning with or without a PA. One of the studies which did research achievement motivation with or without a PA was in a sample of 98 Chinese college students. Four experimental groups were formed. Two conditions with or without a PA and two conditions had a PA with a conversational style versus a PA with a formal style.

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The analysis used a 2x2 between subject design based on 12 questions and resulted in the significant effect on interest (measured by intrinsic motivation using the McAuley et al. questionnaire; (McAuley, Duncan, & Tammen, 1989) in the agent conditions $F(1,92) = 4.25$, $p = .04$ (Lin, Ginns, Wang, & Zhang, 2020a).

1.1.2.7 Situational interest

Situational interest is another form of achievement motivation outcome that could be a result of a PA. Interest of the learner is a form of intrinsic motivation. Situational Interest (SI) and situational factors are critical in the development of individual interest. The SI gives an attentional and affective reaction of the learner on the situation (Linnenbrink-Garcia et al., 2010). The PA can influence the SI, because it is part of the learning environment. The *triggered* SI is about how to grab individuals' interest, the influence of a PA can be positive or negative on the *triggered* SI. The *maintained* SI is a more involved and deeper form of SI. Learning environments with a PA as a role model can promote or decrease maintained SI (Linnenbrink-Garcia et al., 2010).

Two types of maintained SI are described. The first type are the feeling related components of *maintained* SI, like the joy of working with a PA and the affective experiences (positive or negative) of working with a PA. The second type are the value related components of working with a PA. This refers to when the learners believe that a domain of education is meaningful (Linnenbrink-Garcia et al., 2010). The maintained SI is considered as a deeper form of interest compared to triggered SI, and both forms are important for the development of the more stable form of individual interest (Ann Renninger & Hidi, 2016). In the context of PA research, since the learners have not experienced the novel concept taught in the lesson, and that PA constitutes as part of the learning environment which may grab the attention and trigger initial interest of the learner, it is possible that the effect of the PA presence is likely contributing most mostly to *triggered* SI.

1.1.2.8 The effect of PA on learning retention and transfer

The PA has shown to promote the learning outcomes in terms of retention and transfer of the learner (Mayer, 1999). Retention contributes to the direct recall of the examples learned and transfer contributes to performance capacity in different contexts with changes in the task condition. Meaningful learning outcomes include transfer test performance in which a learner must use knowledge to solve a new problem (C. I. Johnson & Mayer, 2009). Transfer tests are widely recognized as superior measures of the learner's understanding of a lesson (Mayer, 1999). In both the Lin & Ginns (Lin et al., 2020a) and van der Meij (van der Meij et al., 2015) studies, learning with PA increased learning gains on retention performance, learning outcomes including both transfer and retention were shown to be improved in the conditions. The transfer performance did not show difference in the university student sample (Lin et al., 2020a). The van der Meij (van der Meij et al.,

2015) on the other hand, did not measure transfer performance specifically. Thus, more research is necessary in order to determine the effect of PA on learning performance both for transfer and retention.

1.1.2.9 Prior knowledge and working memory capacity as covariates

Prior knowledge is used as a covariate, because of its relevance in cognitive load perceptions and learning performance (Chen et al., 2017). Including relevant covariates can reduce the unexplained variance in the outcome variables, thus increase statistical power (Kahan, Jairath, Doré, & Morris, 2014).

Working memory capacity is the fundamental basis of the cognitive load construct proposed in CLT (Sweller, Van Merriënboer, & Paas, n.d.) and an important basis for learning (Bichler et al., 2019). It has been suggested to be an important measure to control (Anmarkrud, Andresen, & Bråten, 2019) for examining cognitive load and learning in multimedia environment.

1.1.3 Present investigation

In sum, research found conflicting results on the benefit of a PA. Meta-analytic research has not always reported consistent beneficial effects on computer based learning (Heidig & Clarebout, 2011; Schroeder et al., 2013). In particular, there are some indications that working with a PA was more beneficial for K-12 students than for post-secondary students (Schroeder et al., 2013), but most of the previous studies are done in older samples such as college students. Furthermore, most of the studies on PA's investigated different features of agents and did research on many different characteristics of agents. They did not compare these characteristics with a control group without a PA (Heidig & Clarebout, 2011; Schroeder et al., 2017). Studies mostly did not research if it was worth implementing an agent in general (Heidig & Clarebout, 2011). There is not much research on whether the PA is effective in terms of achievement motivation for learning (Heidig & Clarebout, 2011). In this study the lesson of probability is chosen because this is a new topic for the primary school pupils, thus enables us to better control level of prior knowledge. Learning probabilities is abstract and difficult to understand. A PA can be helpful to visualise the problem and guide the learners to the steps of solving the problem. And furthermore, this topic has already been used to study the effect of PA (Wouters, Paas, & van Merriënboer, 2008) thus is a suitable topic for the present study. Hence the aim of this study is to examine how a PA can be useful to motivate and affect the learners when learning a novel math topic on probability.

1.2 Questions and hypotheses

The aim of the present study is to investigate what the achievement motivational and affective benefits are of the presence of a pedagogical agent in a computer-based learning environment, in primary school children. The following research question and hypotheses are made on the relationship of these variables described in the research review.

Does a pedagogical agent increase the achievement motivation and affect of pupils of a primary school on learning a new math task?

The following hypotheses are made;

1. learners have higher achievement motivation in terms of triggered situational interest after instruction with the presence of a pedagogical agent than after instruction of just a voice. There will not be an effect regarding maintained interest-value nor maintained interest – feeling.
2. learners have higher self-efficacy after instruction with the presence of a pedagogical agent than after instruction of just a voice.
3. learners feel more positive emotions after instruction with the presence of a pedagogical agent than after instruction of just a voice.
4. learners receiving instruction with a pedagogical agent will experience higher extraneous load, but the intrinsic load will not differ from the control group since the instructional content is the same across both conditions.
5. learners perform better on retention and transfer tests after learning under instruction with the presence of a pedagogical agent than instruction with just a voice.
6. learners receiving instruction with a pedagogical agent have a higher feeling of social presence than after instruction with just a voice.
7. learners with higher prior knowledge (covariate) will perform better on retention and transfer.
8. learners with higher memory capacity (covariate) will perform better on retention and transfer.

An overview of the measurements can be seen in Figure 1.

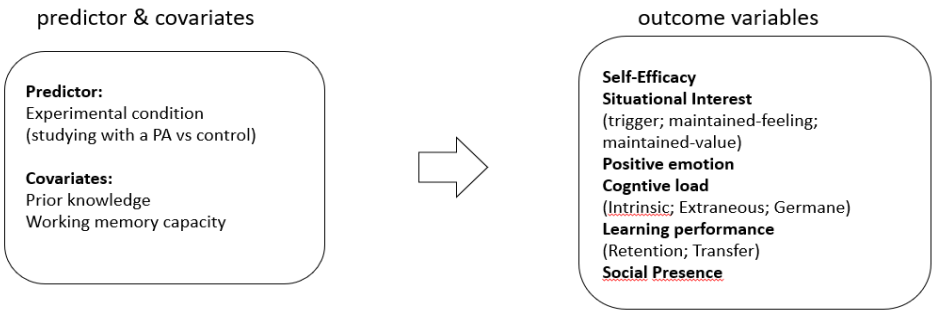

Figure 1

The factors measured in the research.

2. Method

2.1 Design

In this 'between-subject' design experiment, the participants are randomly assigned to either the experimental condition or the active control condition to answer the research hypothesis. The experimental condition was treated as the predictor. The achievement motivation, emotion, cognitive load perceptions and the learning outcomes were treated as the outcomes of this experimental study. Additionally prior knowledge and working memory capacity were measured, and included as covariates in the analysis. The internal consistence of the items is measured by Cronbach's α. A α below .5 is not acceptable, an α between 0.5 and 0.7 is acceptable and an α of 0.7 and higher is good (Field, 2013).

2.2 Participants

Participants were Dutch pupils of the 7th and 8th grade recruited of 3 Primary schools located in the North Western part of the Netherlands. Out of the 163 students who were approached, 132 gave consent and attended the experimented. The age of the pupils was M = 10.6 years with SD = 0.6. Minimum age was 9 years and maximum age was 12 years. The participants consists 36% in grade 7 of primary school and 64% in grade 8. The pupils were randomly assigned in the experimental group (with PA) , 48% (n = 63), and 52% of the pupils (n = 69) was randomly assigned in the control group.

Power analysis indicated a total of 128 participants is needed to have a moderate effect size (d=0.50), based on a power level of 80% and 5% Type I error rate. Additional power analysis with two covariates does not change resulting statistical power. This sample size is also sufficient compared to previous research in PA that was conducted in primary school children (van der Meij, van der Meij, & Harmsen, 2015). The primary school teachers of the participants were asked to verify that probabilities were not part of the curriculum before the test

2.3 Materials and Measures

During the experiment two instructional videos were used to deliver a short instructional message on probability, audio digits recordings for a memory test, and paper and pen based materials to record participants' response on constructs measured in the present investigation. All the materials are included in the Appendix A to M at the end of the thesis. The materials used before and after the experiment also contained an information letter, a consent form for the students and parents, a consent form for the schools, and a debriefing letter.

2.3.1 Instructional video and design of the pedagogical agent

The experimental conditions were based on two animated videos with the same instructional message but only in the experimental condition there was a PA present. For both conditions the same instructional material was used on a learning environment of four power point slides with a duration of 2 minutes and 53 seconds.

In the experimental condition a PA was embedded into each power point slide and the PA did appear as a teacher to instruct the participants (see Figure 2). In the control group, just the voice was used to instruct the participants (see Figure 3). The PA is a young female and a fairly realistically looking human. A human PA was chosen because better learning effects have been found with a realistic agent (Baylor & Kim, 2004). The choice of a young individual was based on results from research in primary school pupils who often show a preference for young, realistic looking and casually dressed agents (A. M. Johnson, Didonato, & Reisslein, 2013). The choice of female was because the primary care taker of children this age is often female (e.g. mother, teacher), thus is more likely to receive more beneficial modelling effects based on social cognitive theory (Bandura & Adams, 1977).

The PA was created using CrazyTalk© version 7 and exported into video files, which were inserted into PowerPoint (see Figures 2 and 3). Lip synchronization are incorporated with audio narration. For the experiments, the video was transferred to USB stick as mp4 recording. To avoid possible confounding, the facial expressions were kept neutral so that no expressions are expressed by the PA (Baylor & Kim, 2004; Liew, Mat Zin, & Sahari, 2017). For the same reason it had only slight natural body movement without any gesturing or signalling (Mayer & DaPra, 2012). The voice of the audio narrations were identical in both conditions.

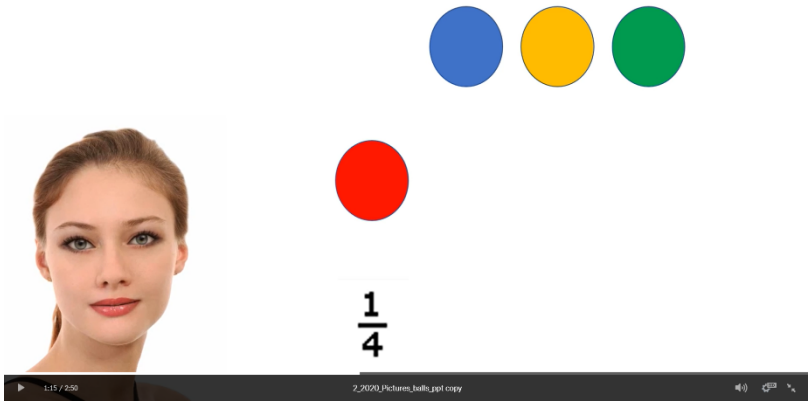

Figure 2

Slide of video with a PA

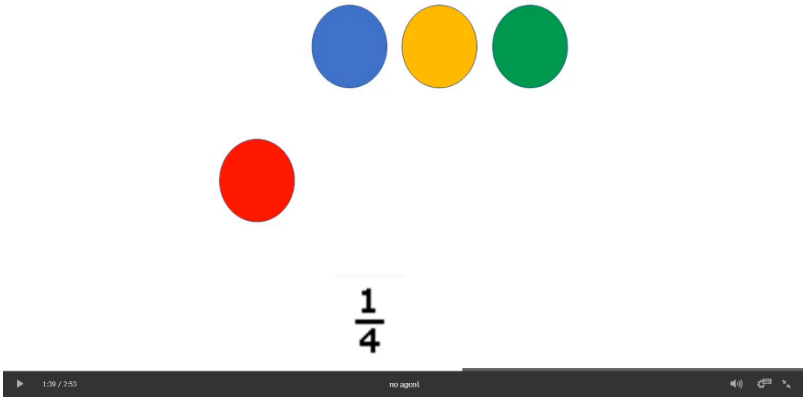

Figure 3

Slide of video without a PA

2.3.2 Probability Instruction

The short video lesson presented the concept for solving a probability calculation problem. This problem was without replacement, the balls picked out will not be back in the bowl again. The problem-state of the example is presented in the video as: “The scouting staff brings four coloured balls for the club scouts to play with. There is a red ball, a blue ball, a yellow ball, and a green ball. The club scouts get to choose a ball one by one and they prefer every colour equally. What is the chance that the red ball gets picked first and the green ball second?”. The video explained step by step how to solve this problem. At the start of the problem, four coloured balls were in the middle of the slide. In the second slide, the red ball is a distant from the other balls and the fraction of 1/ 4 was shown under the red ball. On the third slide the green ball was also aside the other balls. The fraction of 1/3 was shown under the green ball. In/on the last slide the red ball and the green ball were aside the other balls and the complete calculation, 1/ 4 x 1/3 = 1/12, was shown under the balls. In the video is a sample of solving probabilities without replacement. The instruction in the video explains also what should be done if the problem was an example of probability calculation with replacement. The instructional message and the accompanying probability problems for the math task in this experiment were based on the materials used in a previous study (Hoogerheide, Loyens, & van Gog, 2014), which was already in the same language as the participants in the current study.

2.3.3 Probability problem items

Three sets of comparable probability test items were used during the experiment to access the prior knowledge, to practise with the instructional videos during the learning phase, and to test the knowledge acquisition afterwards. The first set measured prior knowledge. This measured how much the students already knew about solving probability problems. The second set was for the participants to practise solving the probability problems during the learning phase. The pupils were allowed to watch the video as many times as they needed while they tried to solve these practical problems. The third set was for testing if the pupils had learned how to solve probability problems.

The last set of probability problems was used to test the main experimental effect of having a PA versus without a PA in the learning environment in terms of retention and transfer. Retention contributes to the direct recall of the examples learned. Transfer contributes to performance capacity in different contexts with changes in the task condition. The statistical concept taught in the lesson was probability without placement. And the retention test problems were designed to be similar to what was taught in the lesson as well. The probability problems with transfer contained probability problems in which probability *with* replacement is required in the problem solving.

For every problem the participants could score a maximum of 2 points. One point for giving the right final answer (e.g. "1/12") and 1 point for using the correct method (e.g. "1/4 x 1/3=").

2.3.4 Prior knowledge problems

Four probability problems are given in the pre-test phase for measuring prior knowledge (Cronbach's $\alpha = .89$). These problems are similar to those measuring retention.

2.3.5 Practise problems

Four probability problems are given in the practise phase, in order to examine the effect of PA on the process of learning (Cronbach's $\alpha = .87$). Two problems measure retention and two problems measure transfer.

2.3.6 Performance problems

Eight probability problems are used to measure performance on solving probability problems, of which four measures retention and four measures transfer. The tasks of retention and transfer are presented in alternating order. Cronbach's α was .88 for retention and .88 for transfer.

2.3.7 Memory capacity test

The memory capacity test is based on an adapted version of the digit span test used in Cowan (Cowan, 2005) and contains two tasks of twelve sets of digits and every set has two trials. In the first

task participants will be asked to write the digit in the same order as they heard the digits. In the second tasks participants will be asked to write the digits in the backwards order. For every correct answer the participants get one point.

The test was recorded as audio files. This was played out with a speaker during the experiment. After every set of digits a pause of two seconds was on the audio then a sign was heard and the participants could start writing. The participants wrote the answers on the testing paper. The internal reliability of the memory test was doubtful, Cronbach's $\alpha = .55$. However, this was expected, because the pupils were in a small classroom with 30 pupils. During the experiment it was not possible to make an exact control on not writing before the signal was heard.

2.3.8 Questionnaires

Participants are asked to fill in questionnaires in order to measure variables in achievement motivation, emotion and cognitive load.

2.3.8.1 Self-efficacy

The items were adapted based on the Patterns of Adaptive Learning scales (PALS) (Midgley et al., 2000). The questions referred to participants' perceptions of their competence to solve the pre-test probability problems (e.g. "I'm certain I can master the skills for calculating probability" and "I'm certain I can figure out how to do the most difficult probability problem."). The items were on a ten point likert-scale from 1 (*strongly disagree*) to 10 (*strongly agree*). Furthermore, after each pre-test items, we also additionally asked the participants to rate on a single item based on scale of 1 to 10 how confident they were in solving the problem presented to them. The pre-test problems and the items on self-efficacy were then repeated again after the practise phase, in order to measure whether there will have been an increase in self-efficacy afterwards. The internal reliability of this scale was high Cronbach's $\alpha = .95$.

2.3.8.2 Situational Interest

The questionnaire was based on the SI scale (Linnenbrink-Garcia et al., 2010) for measuring motivation. The SI scale contains three questions for measuring triggered interest (T), four questions about maintained interest feeling (MT) and four questions about maintained interest value (MV). The questions were about learning solving probabilities, (e.g. "I like what we are learning in the probability video." and "I find the math in the probability video interesting."). The items were on a ten point likert scale ranging from 1 (*not at all true*) to 10 (*very true*). The internal consistency reliabilities were high for triggered-SI, Cronbach's $\alpha = .79$, maintained-SI-feeling, Cronbach's $\alpha = .88$ and for maintained-SI-value, Cronbach's $\alpha = .85$.

2.3.8.3 Emotion for situation

Emotion for situation was assessed by the positive and negative affect schedule (PANAS) questionnaire (Watson, Clark, & Tellegen, 1988). This measures the intent of how a participant felt during solving the probability problems on twenty items (e.g. "interested, scared and proud") on a ten point likert scale from 1 (*very slightly or not at all*) to 10 (*extremely*). The internal consistency reliability of this scale was high, Cronbach's $\alpha = .95$.

2.3.8.4 Positive emotion for learning

Positive emotion about learning the lesson was based on the Achievement Emotion Questionnaire AEQ (Pekrun, Goetz, Frenzel, Barchfeld, & Perry, 2011) of enjoyment. This measures the enjoyment a pupil felt during solving the probability problems (e.g. "I enjoy acquiring new knowledge in this lesson." and "I enjoy dealing with the material in this lesson."). Items were on a ten point likert scale from 1(*strongly disagree*) to 10 (*strongly agree*). All questions are translated in Dutch. Emotions specific to interest and enjoyment were also assessed for each probability problem during the practise phase (e.g. "How curious you were to know the answer to this problem?" and "How much did you enjoy solving this problem?"). The items were on a ten point likert scale from 1 (*very slightly or not at all*) to 10 (*extremely*). The internal reliability of the AEQ scale was high, Cronbach's $\alpha = .95$.

2.3.8.5 Cognitive load

The questionnaire about cognitive load was based on the CLI scale (Leppink, Paas, Van der Vleuten, Van Gog, & Van Merriënboer, 2013). This scale contains ten questions about how pupils experienced the cognitive load during the task (e.g. "The activity covered concepts and definitions that I perceived as very complex "and "The activity really enhanced my understanding of the topic(s) covered"). Items were based on intrinsic cognitive load (IL), extraneous cognitive load (EL) and germane cognitive load (ML). The answers were on a ten point likert scale from 1 (*not at all*) to 10 (*completely the case*). Since there were relatively low number of items in each dimension of the CLI scale, we additionally assessed a scale developed by Klepsch (Klepsch, Schmitz, & Seufert, 2017) Global cognitive loads specific to mental effort and task difficulty were also assessed for each probability problems during the practise phase on a ten point likert scale from 1 (*very slightly or not at all*) to 10 (*extremely*). The Klepsch scale had a low reliability (Cronbach's $\alpha = .58$), for extraneous cognitive load Cronbach's $\alpha = .48$ was low, for intrinsic cognitive load Cronbach's $\alpha = .70$ and germane cognitive load Cronbach's $\alpha = .74$ internal reliability was medium. At the conclusions we did not use this scale in the analysis because of the low reliability. At the questionnaires based on Leppink internal reliability of intrinsic cognitive load scale was high, Cronbach's $\alpha = .92$, the internal

reliability of extraneous cognitive load and germane cognitive load was medium, Cronbach's α = .80 and Cronbach's α = .88. The analysis of the results was thus based on the Leppink scale.

2.3.8.6 Social presence

According to Mayer (Mayer, 2014b), the presence of a PA can facilitate a sense of social presence which can promote better learning. Five items (e.g. "It feels like the probability teacher in the video is a real person" and "It feels like the probability teacher is in the same room") were adapted from a scale measuring social presence (Kreijns, Weidlich, & Rajagopal, 2018). The scores of social presence were examined as supplementary analysis to examine whether the presence of a PA during instruction increases the feeling of social presence. The internal reliability of social presence was high, Cronbach's α = .94.

All scales used in the present study were translated into Dutch language, with necessary adaption for children in primary school age. The translation was examined by two bilingual speakers of Dutch and English languages.

2.4 Procedure

Three schools and their teachers in grade 7 and 8 were recruited by email to participate. The participants were invited by a letter with the consent form given by their school teacher two weeks before the experiment. The letter contains information about the experiment and a form for permission for being part of the experiment. Because the participants were minors, the parents had to fill the form and give permission.. For thanking the participants every participant did receive a pencil. The experiment took place in the own classroom of the participants. All participants had a laptop computer of the school.

At the start of the experiment all the participants got one envelope with papers labelled with an ID number, a USB stick with the instructional video, and a pencil. Two versions of the videos were on the USB-stick. One with a pedagogical agent (experimental group) and one without the pedagogical agent (control group). These envelopes were randomly distributed at the start of the experiment. Thus the pupils are randomly assigned to the experimental group or the control group. The ID number did not contain any student information and was only used to keep track of the experimental conditions.

The experiment had four phases which were timed by the experimenter. The participants were told only work on material from the envelope for a particular phase. The pupils could start each phase after a sign of the experimenter. The pupils did work silently and only focused on their own papers and computer. No questions were allowed until the experimental session was completed.

The first phase took 10 minutes, and contained the memory span test and the pre-test. The second phase did take 15 minutes and the participants watched the videos with probability instruction and solved the probability problems of the practise phase. The third phase took 15 minutes and pupils

filled the questionnaires. The fourth phase did take 15 minutes and pupils did solve probability problems. At the end of phase four all USB sticks and papers were collected.

The whole procedure did take 50 minutes. After the experiment the participants and their parents got a debriefing letter on paper to deliver to their parents after the test. In this letter more information about the purpose of the experiment was given.

2.5 Data-Analysis

One-way Univariate analyses of Covariance (ANCOVA) was used to analyse the effect of instruction with or without a PA on performance retention or transfer, self-efficacy, situational interest, positive emotion about learning, cognitive load and social presence.

Partial η^2 was used as an effect size, representing the proportion of variance explained by a specific predictor, which was not explained by other independent variables. A partial η^2 of .01 is considered to have a small effect, a partial η^2 .06 is considered to have a medium effect, and a partial η^2 bigger than .14 indicates a large effect (Richardson, 2011).

3 Results

In the current study, a sample of 132 7th and 8th grade students was randomly assigned to the experimental condition (n = 59) and the control condition (n = 63) to examine the effect of instruction of solving probabilities with a PA on motivation, emotion, social presence, cognitive load and performance retention and transfer. Sample means and standard deviations as well as Cronbach's α (reliability) of the demographic variables regarding both the experimental and the control group, are displayed in Table 1, for the variables of the questionnaires in Table 2 and for performance, retention and transfer in Table 3.

Table 1 *Number of participants, Cronbach's α, mean and standard deviation of all demographic variables and prior knowledge.*

Variables		N	α	Mean	Std. Deviation
Age	all	132	x	10,55	0,66
	0 without PA	69		10,61	0,71
	1 with PA	63		10,49	0,59
Grade		133	X	7,64	0,48
	0 without PA	69		7,64	0,48
	1 with PA	63		7,63	0,49
Gender	all	132	X	0,55	0,50
	0 without PA	69		0,58	0,50
	1 with PA	63		0,51	0,50
Prior Knowledge	all	132	0.89	1,56	2,78
	0 without PA	69		1,57	2,89
	1 with PA	63		1,54	2,66

Table 2

Number of participants, Cronbach's α, mean and standard deviation of all questionnaire variables.

Variables		N	α	Mean	Std. Deviation
Situational Interest	all	128	0,92	4.72	2.08
	0 without PA	66		4,56	2,20
	1 with PA	62		4,90	1,95
Situational Interest trigger	all	128	0,79	4,24	2,18
	0 without PA	66		4,22	2,23
	1 with PA	62		4,16	1,98
Situational Interest value	all	128	0,88	4,47	2,35
	0 without PA	66		4,25	2,36
	1 with PA	62		4,70	2,34
Stuational Interest Ifeel	all	128	0,85	5,78	2,52
	0 without PA	66		5,44	2,75
	1 with PA	62		6,14	2,21
Positive Emotion	all	128	0,95	5,30	2,40
	0 without PA	66		5,19	2,53
	1 with PA	62		5,41	2,28
Extraneous Cognitive Load	all	124	0,80	4,99	2,32
	0 without PA	65		5,22	2,48
	1 with PA	59		4,73	2,13
Intrinsic Cognitive Load	all	124	0,92	5,38	2,94
	0 without PA	65		5,43	3,06
	1 with PA	59		5,33	2,84
Germane Cognitive Load	all	123	0,88	5,72	2,43
	0 without PA	64		5,59	2,53
	1 with PA	59		5,87	2,32
Social Presence	all	129	0,94	5.71	3.08
	0 without PA	67		4,81	3,17
	1 with PA	62		6,51	2,72

Table 3

Number of participants, Cronbach's α, mean and standard deviation of all performance variables.

Variables		N	α	Mean	Std. Deviation
Retention	all	122	0,88	1,68	1,56
	0 without PA	64		1,68	1,57
	1 with PA	59		1,69	1,56
Transfer	all	121	0,88	1.91	1.58
	0 without PA	64		1,88	1,58
	1 with PA	59		1,95	1,72

Randomisation check

An independent t-test made at the geographic information of the pupils consists 36% in grade 7 and 64% in grade 8. They were equally randomised in the experimental group M = 7.64 and the control group M = 7.64. The mean age of the pupils was M = 10,55 (SD = 0.66). In the experimental group mean age was M = 10.49 (SD = 0.59) and in the control group mean age was M = 10.61 (SD = 0.71). A chi-square test made at the experimental group (n = 58) consisted of 51 % boys and 49% girls. The control group (n = 60) consisted of 58% boys and 42% girls. There was no significant difference between the two groups of prior knowledge of solving probability problems with M = 1.54 (SD = 2.66) for the experimental group and a M = 1.57 (SD = 2.89) for the control group, $F(1,116) = 0.003$, p = .958, partial η^2 = .005. The memory capacity of the experimental group M = 6.49, was a bit higher than the memory capacity of the control group M = 5.75., $F(1, 121) = 0.027$, p = 0,027, partial η^2 = 0,002. In sum, the descriptive statistics regarding grade, age, gender, prior knowledge and memory capacity were distributed equally across the experimental and control group, indicating a successful randomisation of the two groups.

In Table 4 are set all variables as well as ANCOVA results of group comparisons of the questionnaires and performance, retention and transfer with prior knowledge as covariate. In Table 5 are set all variables as well as ANCOVA results of group comparisons of retention and transfer with memory capacity as covariate.

Table 4

Variables as well as ANCOVA Results of Group Comparisons

ANCOVA*						
			t-test for Equality of Means			
	sample size					
	no PA	PA	F	df	Sig. (2-tailed)	partial eta
Situational Interest	66	62	0,807	1,126	0,371	0,080
SI_trigger	66	62	0,028	1,126	0,868	0,015
SI_value	66	62	2,503	1,126	0,116	0,140
SI_feel	66	62	1,160	1,126	0,284	0,095
Self-efficay_instruction	60	55	1,420	1,113	0,236	0,111
Positive emotion	59	57	0,062	1,114	0,804	0,023
CLI_Leppink	65	59	0,005	1,122	0,946	0,006
CLI_ECL	65	59	1,392	1,122	0,240	0,106
CLI_ICL	65	59	0,034	1,122	0,857	0,017
CLI_GCL	64	59	0,428	1,121	0,514	0,059
Social Presence	67	62	9,556	1,127	0,002	0,265
Performance	63	59	0,113	1,120	0,740	0,031
Retention	60	57	0,003	1, 115	0,957	0,005
Transfer	63	58	0,059	1,119	0,809	0,022

**Note*. ANCOVA analyses included prior knowledge as a covariate.

Table 5.

ANCOVA results of Group comparisions

ANCOVA**						
			t-test for Equality of Means			
	sample size					
	no PA	PA	F	df	Sig. (2-tailed)	partial eta
Retention	60	57	0,035	1,115	0,853	0,061
Transfer	63	58	0,017	1,119	0,896	0,063

** *Note*. ANCOVA analyses included memory capacity as covariate

Achievement motivation and triggered situational interest *(Hypothesis I)*

There was no difference in terms of triggered situational interest after instruction with a pedagogical agent than after instruction with just a voice. The experimental group did report slightly higher triggered situational interest (*M* = 4.16, *SD* = 1.98) than the control group (*M* = 4.22, *SD* = 2.23), but the difference was not significant *F* (1,126) = 0.03, *p* = 0.87, partial η^2 = .015.

Self-efficacy *(Hypothesis II)*

The experimental group did report slightlyhigher self-efficacy after instruction (*M* = 6.18, *SD* = 2.50) than the control group (*M* = 5.60, *SD* = 2.74). The difference was not significant *F*(1,113) = 1.42, *p* = .24, partial η^2 = 0.111. Learners had no significant higher self-efficacy after instruction with the presence of a pedagogical agent than after instruction with just a voice.

Positive emotions *(Hypothesis III)*

In the experimental group were higher positive emotions after instruction with a pedagogical agent (*M* = 5.07, *SD* = 2.39) than in the control group (*M* = 4.81, *SD* = 2.65), but the difference was not significant *F*(1,126) = 0.28, *p* = .598, partial η^2 = 0.047.

Extraneous cognitive load and intrinsic cognitive load *(Hypothesis IV)*

The experimental group with instruction with a pedagogical agent had a lower extraneous cognitive load (*M* = 4.89, *SD* = 1.79) than the control group with instruction with just a voice (*M* = 5.07, *SD* = 2.04). This difference was not significant *F*(1,122) = 0.12, *p* = .730, partial η^2 = 0.031. No difference was seen at the intrinsic load of the experimental group (*M* = 5.34, *SD* = 2.89) and the control group (*M* = 5.40, *SD* = 6.08). This was not significant with *F*(1,122) = 0.37, *p* = .534, partial η^2 = 0.000.

Retention and transfer *(Hypothesis V)*

Learners in the experimental group did not perform better on retention tests (*M* = 2.40, *SD* = 2.23) after instruction with a pedagogical agent than the learners in the control group (*M* = 2.40, *SD* = 2,18) with instruction with just a voice. A very slightly higher mean was found for the experimental group in transfer tests after instruction with a pedagogical agent (*M* = 1,94, *SD* = 1,71) comparing with the results of the transfer test after instruction with the control group (*M* = 1.89, *SD* = 1.58) who had instruction with just a voice.

Social presence *(Hypothesis VI)*

Learners in the experimental group (*M*= 6.51, *SD*= 2.72) had a higher feeling of social presence of the PA than the learners in the control group (*M* = 4.81 , *SD* = 3.170) , *F*(1,127) = 9,56, *p* = 0.002 and partial η^2= 0,265

Prior knowledge as covariate *(Hypothesis VII)*

Controlling the influence of prior knowledge on retention and transfer, the one-way ANCOVA did not show a relation between prior knowledge on performance on retention $F(1,115) = 0.012$, $p = .912$, partial $\eta^2 = 0.000$ and transfer $F(1,119) = 0.128$, $p = 0.722$, partial $\eta^2 = 0.001$ (Table 4).

Memory capacity as covariate *(Hypothesis VII)*

Controlling the influence of memory capacity on performance of retention and transfer, one-way ANCOVA did not show a relation between memory capacity and the performance on retention $F(1,115) = 0.525$, $p = .470$, partial $\eta^2 = 0.005$ and transfer $F(1,119) = 0.269$, $p = .605$ and partial $\eta^2 = 0.002$ (Table 5).

4 Discussion and conclusion

According the theoretical framework , less research is done on working with or without a pedagogical agent (PA) at learners at primary schools. While meta analyses have conflicting conclusions it is worth to measure the benefit of working with a PA in a virtual learning environment (Heidig & Clarebout, 2011; Schroeder, Adesope, & Gilbert, 2013). Therefore the primary purpose of this experiment was to examine the influence of a PA on positive emotions, motivation, social presence, cognitive load, retention and transfer at instruction on solving probability problems. The current research did not confirm a positive influence of the PA on positive emotions, motivation, cognitive load, retention and transfer, except for that feelings of social presence were higher after learning with a PA than after learning without a PA. These results indicate that just using a PA for instruction in a virtual learning environment does not have an influence on motivation, cognitive load and learning outcomes.

The effect of a PA on situational interest, self-efficacy, and positive emotion

In opposite of hypothesis 1, 2 and 3 no higher achievement motivation in terms of triggered situational interest (SI), self-efficacy and positive emotions were found at the pupils learning with a PA than pupils learning without a PA. Virtual learning environments with a PA can promote or decrease maintained SI (Linnenbrink-Garcia et al., 2010), in this study we had expected the PA should increase the maintained SI.

In the experiment , the probability problems were made narrative. It could be the stories of the probability problems were not valuable enough for the learners. For further investigation a critical sight on the stories is necessary.

During the experiment no feedback was given to the learners. Feedback will influence the motivation of learners (J. Li, Wong, Yang, & Bell, 2020). When learners get feedback and know if they succeed at the task, they will be motivated to solve more problems (Kirschner, Sweller, & Clark, 2006). In further research feedback should be given after the practise phase. Motivation in online education depends on self-efficacy, if learners have positive feedback, self-efficacy will increase (Hartnett, 2016).

The effect of a PA on social presence

As predicted in hypothesis 6 learners who learned solving probability with a PA felt more social presence of the PA than learners who learned solving probability problems without a PA. Cognitive engagement in virtual learning environment depends on the feeling of interacting with another social being (Kreijns, Kirschner, & Vermeulen, 2013). The learners in the experimental group felt more presence of a teacher than learners in the control group. When learners develop a social bond with the PA, this can result in better learning outcomes (Kim, Baylor, & Shen, 2007). In this experiment were no better learning outcomes for working with a virtual PA. Just one moment of instruction in one hour could be too short for developing a bond with the PA. During further investigation the effect of more moments of instructions with the same PA can be explored. If a PA feels like a real person it be could strengthened. A PA talking a conversational style will increase the feeling of social presence (Moreno, Mayer, Spires, & Lester, 2001). The outcomes of transfer with a personalised PA talking in a conversational style were higher than the pesonalised PA talking in a formal style.

The effect of a PA on cognitive load

As predicted in hypothesis 4, a higher extraneous load (M = 5.22) is seen at the pupils who learned without the PA than at pupils who learned with the PA (M = 4.73). But this was a very small difference and this was not significant (p = .80). There is no evidence from the present investigation to support the notion that working with a PA should reduce extraneous cognitive load for primary school pupils when working in a virtual learning environment. When learners are getting used of working with a PA on regular base, they will recognize the agent and is not taking resources of in the working memory anymore (Schroeder, Romine, & Craig, 2017). The study contented just one task. Learners need rehearsal to learn a new task before fitting in the long term memory (Sweller, Kirschner, & Clark, 2007). Further research testing the effect of more lessons with or without a PA in a longer period will be needed.

The task was a high complexity task for the pupils and high complexity tasks need more prior knowledge from the learner (Leppink et al., 2013). A positive effect of a PA may be more detectable when the task complexity is kept at appropriate level.

The participants in the present experiment were only just taught basic fraction calculation involving dividing pizza's and cakes.thus their level of prior knowledge is low. Due to the high level of novel information, the learning task was likely to have negatively impacted on the learner's cognitive load

. (Sweller, 2011).

The topic of solving probability problems t did not fit in the curriculum of grade 7 at this moment of the year. To avoid the negative effect of high complexity tasks and reduce extraneous cognitive load small steps in the curriculum should be made (Rosenshine, 2010; Sweller, 2010). With an effective design it is possible to reduce cognitive load (Moreno et al., 2001), The best effect made when a problem is rehearsed, then chunks of knowledge will be made and more space is left in the working memory (Wouters, Paas, & van Merriënboer, 2009) To reduce cognitive load a subject closer to the curriculum should be found, then the pupils will have more prior knowledge of the math they needfor learning probabilities.

The effect of a PA on retention and transfer

In opposite of hypothesis 5 no difference in learning outcomes are found on retention at the students learning with or without a PA. We expected higher outcomes in the experimental group, pupils learning with a PA in prior studies of Lin & Ginns (Lin, Ginns, Wang, & Zhang, 2020) and van der Meij (van der Meij et al., 2015) learning with a PA improved learning outcomes both on retention and transfer were shown to in the experimental conditions. In the current experiment neither for retention nor transfer was a significant increased learning outcome. In transfer test performance a pupil must use knowledge to solve a new problem (C. I. Johnson & Mayer, 2009), in the current experiment pupils who learned with a PA had slightly better learning outcomes on transfer, but this was not significant. In the video just one sentence was mentioned on solving probability without or with a PA.

Recommendations for further study

In spite of practical and theoretical implications, there are some limitations that ought to be addressed in future research. While the sample for this study (n = 139) exceeded the needed number of 128, the fact that the participants were drawn from only three schools may be limit the generalizability of the results. Thus it is of theoretical and policy relevance to replicate these results in other samples and contextual factors to further investigate what works best for whom and under what circumstances.

The focus of this investigation was the effect of learning with or without a PA. In the experiment motivation, social presence, cognitive load, retention and transfer were measured after an instruction. The instruction was simple and without interaction between the tutor and the student. The interaction between the learner and the teacher can improve learning (Kreijns et al., 2013; W. Li, Wang, Mayer, & Liu, 2019) Simple cues like a human voice, talking in a conversational style and small gestures can increase the feelings of social presence (Moreno et al., 2001). In a further study the effect of some small human cues on the PA can be investigated.

In this study it is proposed that learning with a PA has a positive effect on social presence. When learners get used to the presence of the PA and this will not use space in the short time memory (Sweller, 2011) They also feel like they are in a real environment in stead of working in a computer based environment (Mayer, 2014a). In future research can be investigated the effect of new instructions when children learn with a familiair PA.

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Bijlagen

Appendix A

Working memory test. General description audio memory span test

The participants will hear an increasing sequence of single-digit numerals ranging from 0 to 9 spoken in a male voice. The test starts with 3 digits and increases to 8 digits. Each digit lasts for about 700 ms. and is then followed by a 700 ms. pause. After each sequence is a tone that serves as a response signal. The participants are not allowed to write the digits before the signal. The participants are asked to recall 12 sequences of digits in the same way as they are read.

After a trial the following 12 sequences will be tested:

Trial
Trial1. 2 1 8
Trial2. 6 2 9

Digit Span Test

Start 9 7 2
Next 7 1 5
Next 1 3 6 7
Next 9 4 2 0
Next 3 4 2 1 6
Next 8 6 5 9 3
Next 1 9 5 8 7 2
Next 6 8 4 6 0 3
Next 1 4 8 9 6 2 5
Next 8 4 5 2 9 4 6
Next 1 9 2 6 4 7 8 3
Next 7 4 9 2 0 6 8 3

Appendix B

Prior knowledge probability problems. All probability problems in the experiment are based on the probability problems used in the investigation of Hoogerheide (Hoogerheide et al., 2014).

1)Op een koude zondag vangen vissers alle één voor één uit een meertje. Er zwemmen 4 vissen in het meer, één baars, één snoek, één brasem en één paling. Wat is de kans dat de brasem als eerste wordt gevangen en de snoek als tweede wordt gevangen?

2) Op een zondag rennen paarden de jaarlijkse paarden race. De paarden willen de finish zo snel mogelijk bereiken. In totaal zijn er 6 paarden die in de race rennen, hun namen zijn: Bas, Niels, Anne, Jan, Martine en Kim. Je hebt geen informatie over welk paard het snelste kan rennen. Wat is de kans dat Bas als eerste over de streep gaat en Martine als tweede?

3) Op een zaterdag bestaat een heel voetbalteam uit 11 spelers waaronder Ricardo en Jay. Na de wedstrijd gaan de spelers een voor een op het doel schieten. De coach bepaalt wie er mag schieten. Hoe groot is de kans dat Ricardo als eerste mag schieten en Jay als tweede?

4) Er zijn 14 apen in een grote kooi in een dierentuin. Deze apen worden één voor één gewassen door de verzorgers. Jij mag voorspellen welke aap er als eerste wordt gewassen en welke aap als tweede wordt gewassen. Hoe groot is de kans dat je voorspelling goed is?

Appendix C
Self-efficacy questionnaire, PALS

Zet een rondje om het goede cijfer. Van 1= *helemaal niet mee eens* tot 10=*helemaal mee eens*		
12.	Ik ben er van overtuigd dat ik de vaardigheden kan leren die ik nodig heb voor het oplossen van kansberekeningsproblemen.	1 2 3 4 5 6 7 8 9 10
13.	Ik ben er van overtuigd dat ik de moeilijkste kansberekeningsproblemen kan leren oplossen.	1 2 3 4 5 6 7 8 9 10
14.	Ik kan bijna alle kansberekeningsproblemen maken als ik niet op geef.	1 2 3 4 5 6 7 8 9 10
15.	Ook al is het oplossen van kansberekings problemen moeilijk, ik kan het leren.	1 2 3 4 5 6 7 8 9 10
16.	Ik kan zelfs de moeilijkste kansberekenings problemen oplossen als ik het probeer.	1 2 3 4 5 6 7 8 9 10

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Appendix D

Practical phase probability problems

1) Vijf honden doen mee met een schoonheidswedstrijd. Het eerste deel vindt op maandag plaats en het tweede deel op dinsdag. De organisatie heeft vijf linten en elk lint heeft een andere kleur (geel, rood, blauw, groen en oranje). De organisatie deelt de linten willekeurig uit aan elke hond aan het begin van de wedstrijd. Wat is de kans dat een hond op de eerste dag het gele lint krijgt en op de tweede het blauwe lint?

2) Op Koningsdag pakken kinderen alle Pokémonkaarten een voor een uit een grabbelton. Er zijn 4 Pokémonkaarten in de grabbelton: een Pikachu kaart, een Squirtle kaart, een Balbusaur kaart en een Snorlax kaart. Hoe groot is de kans dat de Squirlte kaart als eerste wordt gepakt en de Snorlax kaart als tweede wordt gepakt?

3) Een weddenschap is gewonnen als een speler een bepaalde combinatie van getallen gooit met een gewone dobbelsteen (een met 1 tot 6 zijden). Om te winnen moet de speler eerst een 6 gooien en dan een 2. Hoe groot is de kans dat de speler eerst een 6 gooit en dan een 2?

4) Een kind gooit 6 steentjes op het schoolplein. Deze steentjes zijn allemaal even groot en even mooi. Wat is de kans dat je precies voorspelt welk steentje als eerste wordt gepakt en welk steentje als tweede wordt gepakt en welk steentje als derde wordt gepakt?

Appendix E

Social Presence questionnaire

In de kansberekeningsvideo…….. Zet een rondje om het goede cijfer. Van 1=*helemaal waar* tot 10= *helemaal niet waar*		
51.	voelt het alsof ik te maken heb met een echte leraar en niet met een denkbeeldige rekenleraar in de video.	1 2 3 4 5 6 7 8 9 10
52.	voelt het alsof de denkbeeldige rekenleraar in de video een echt persoon is.	1 2 3 4 5 6 7 8 9 10
53.	voelt het alsof de denkbeeldige rekenleraar van de video in dezelfde kamer is.	1 2 3 4 5 6 7 8 9 10
54.	voelt het alsof de denkbeeldige rekenleraar uit de video in de buurt is.	1 2 3 4 5 6 7 8 9 10
55.	voelt het of ik een goede heen en weer contact heb met de denkbeeldige rekenleraar in de video.	1 2 3 4 5 6 7 8 9 10

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Appendix F

Situational Interest questionnaire

Zet een rondje om het goede cijfer. Van 1=*helemaal niet waar* tot 10=*helemaal waar*		
58.	De kansberekeningsproblemen in de video zijn heel erg leuk.	1 2 3 4 5 6 7 8 9 10
59.	In de kansberekeningsvideo, legt de leraar dingen uit die mij interesseren.	1 2 3 4 5 6 7 8 9 10
60.	De kansberekeningsvideo is leuk om naar te kijken.	1 2 3 4 5 6 7 8 9 10
61.	De kansberekeningsproblemen zijn zo leuk dat het makkelijk is om je aandacht er bij te houden.	1 2 3 4 5 6 7 8 9 10
62.	Wat we leren in de kansberekeningsvideo fascineert me.	1 2 3 4 5 6 7 8 9 10
63.	Ik vind het geweldig wat we leren in de kansberekeningsvideo.	1 2 3 4 5 6 7 8 9 10
64.	Ik vind het leuk wat we leren in de kansberekeningsvideo.	1 2 3 4 5 6 7 8 9 10
65.	Ik vind het rekenen in de kansberekeningsvideo interessant.	1 2 3 4 5 6 7 8 9 10
66.	Wat we leren in de kansberekeningsvideo is nuttig om te weten voor mij.	1 2 3 4 5 6 7 8 9 10
67.	De dingen die we leren in de kansberekeningsvideo zijn nuttig om te leren voor mijn doelen in de toekomst.	1 2 3 4 5 6 7 8 9 10
68.	Wat we leren in de kansberekenings video kan je toepassen in het echte leven.	1 2 3 4 5 6 7 8 9 10

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Appendix G

Emotion questionnaire, PANAS

Hoe voelde jij je tijdens het maken van de kansberekeningsproblemen? Zet een rondje om het goede cijfer. Van 1=*een heel klein beetje of helemaal niet* tot 10=*helemaal wel*		
69.	Geïnteresseerd	1 2 3 4 5 6 7 8 9 10
70.	Geweldig	1 2 3 4 5 6 7 8 9 10
71.	Sterk	1 2 3 4 5 6 7 8 9 10
72.	Enthousiast	1 2 3 4 5 6 7 8 9 10
73.	Trots	1 2 3 4 5 6 7 8 9 10
74.	Alert	1 2 3 4 5 6 7 8 9 10
75.	Geïnspireerd	1 2 3 4 5 6 7 8 9 10
76.	Vastbesloten	1 2 3 4 5 6 7 8 9 10
77.	Aandachtig	1 2 3 4 5 6 7 8 9 10
78.	Actief	1 2 3 4 5 6 7 8 9 10

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: the PANAS scales. Journal of personality and social psychology, 54(6), 1063.

Appendix H

Cognitive load questionnaire based on Klepsch

Zet een rondje om het goede cijfer. Van 1=*absoluut fout* tot 10= *absoluut waar*		
79.	Bij deze kansberekeningsproblemen moet je veel dingen tegelijk onthouden.	1 2 3 4 5 6 7 8 9 10
80.	Deze kansberekeningsproblemen zijn erg ingewikkeld.	1 2 3 4 5 6 7 8 9 10

Zet een rondje om het goede cijfer. Van 1=*absoluut fout* tot 10= *absoluut waar*		
81.	Ik moest een inspanning leveren om het hele probleem te begrijpen.	1 2 3 4 5 6 7 8 9 10
82.	Ik vond het moeilijk om deze kansberekeningsproblemen goed te begrijpen.	1 2 3 4 5 6 7 8 9 10

Zet een rondje om het goede cijfer. Van 1=*absoluut fout* tot 10= *absoluut waar*		
83.	Tijdens de taak was het vermoeiend om belangrijke informatie bij deze kansberekeningsproblemen te vinden.	1 2 3 4 5 6 7 8 9 10
84.	Het ontwerp van deze kansberekeningsproblemen was erg onhandig voor leren.	1 2 3 4 5 6 7 8 9 10
85.	Bij het oplossen van deze kansberekenings problemen was het erg moeilijk om de belangrijke informatie te vinden.	1 2 3 4 5 6 7 8 9 10

Klepsch, M., Schmitz, F., & Seufert, T. (2017). Development and validation of two instruments measuring intrinsic, extraneous, and germane cognitive load. *Frontiers in Psychology*, *8*, 1997.

Appendix I

Cognitive load questionnaire based on Leppink

Zet een rondje om het goede cijfer. Van 1=*helemaal niet het geval* tot 10= *helemaal het geval*		
86.	Het onderwerp van de kansberekeningsvideo was erg ingewikkeld.	1 2 3 4 5 6 7 8 9 10
87.	Ik ervaar de kansberekeningsvideo als erg ingewikkeld.	1 2 3 4 5 6 7 8 9 10
88.	De oplossingsmethode in de kansberekeningsvideo heb ik als erg ingewikkeld ervaren.	1 2 3 4 5 6 7 8 9 10
89.	De instructie en/of uitleg tijdens de kansberekeningsvideo waren….. Van 1= *heel duidelijk* tot 10= *heel onduidelijk*	1 2 3 4 5 6 7 8 9 10
90.	De instructies en /of de uitleg in de kansberekeningsvideo waren voor het leren ….. Van 1=*heel bruikbaar* tot 10= *helemaal niet bruikbaar*	1 2 3 4 5 6 7 8 9 10
91.	De taal die gebruikt werd bij de instructie en uitleg in de kansberekeningsvideo was…… Van 1=*heel duidelijk* tot 10=*heel onduidelijk*	1 2 3 4 5 6 7 8 9 10
92.	Ik begreep de oplossingsmethode van de kansberekeningsvideo volledig.	1 2 3 4 5 6 7 8 9 10
93.	Ik begreep de meeste lesstof die in de kansberekeningsvideo werden uitgelegd.	1 2 3 4 5 6 7 8 9 10
94.	Ik begreep hoe alle onderdelen van de kansberekeningsvideo met elkaar te maken hadden.	1 2 3 4 5 6 7 8 9 10
95.	Ik kon de nieuwe dingen die ik in de kansberekeningsvideo heb geleerd samenvoegen met wat ik al wist over rekenen.	1 2 3 4 5 6 7 8 9 10

Leppink, J., Paas, F., Van der Vleuten, C. P. M., Van Gog, T., & Van Merriënboer, J. J. G. (2013). Development of an instrument for measuring different types of cognitive load. *Behavior Research Methods*, *45*(4), 1058–1072. https://doi.org/10.3758/s13428-013-0334-1

Appendix J

Emotion and enjoyment questionnaire

Zet een rondje om het goede cijfer. Van 1=*helemaal niet mee eens* tot 10=*helemaal mee eens*		
96.	Ik vind de uitdaging van dit leermateriaal leuk.	1 2 3 4 5 6 7 8 9 10
97.	Ik vind het leuk om nieuwe kennis te krijgen in deze les.	1 2 3 4 5 6 7 8 9 10
98.	Ik vind het leuk om met nieuw lesmateriaal om te gaan.	1 2 3 4 5 6 7 8 9 10
99.	Ik zal meer tijd besteden dan nodig is aan leren van de kansberekeningsproblemen omdat ik het zo leuk vind.	1 2 3 4 5 6 7 8 9 10
100.	Ik kijk er naar uit om meer te leren over kansberekenings problemen.	1 2 3 4 5 6 7 8 9 10
101.	Reflecteren op mijn vooruitgang bij kansberekeningsproblemen maakt me blij.	1 2 3 4 5 6 7 8 9 10
102.	Ik ben zo blij met de vooruitgang die ik boek bij het maken van kansberekenings problemen dat ik gemotiveerd ben om er meer over te leren.	1 2 3 4 5 6 7 8 9 10
103.	Sommige onderdelen van kansberekenings problemen zijn zo leuk dat ik er meer over wil leren.	1 2 3 4 5 6 7 8 9 10

Watson, D., Clark, L. A., & Tellegen, A. (1988). Development and validation of brief measures of positive and negative affect: The PANAS scales. *Journal of Personality and Social Psychology*, *54*(6), 1063–1070. https://doi.org/10.1037/0022-3514.54.6.1063

Appendix K

Probability problems of the test phase

1) Op dierendag springen sprinkhanen zo ver als ze kunnen tijdens een wedstrijd. In totaal zijn er 6 sprinkhanen die mee springen en hun namen zijn: Jaap, Eva, Sofie, Tamara, Fred en Remy. Je hebt geen informatie over welke sprinkhaan het verst kan springen. Hoe groot is de kans dat Eva eerste wordt en Fred als tweede eindigt?

2) In de finale van de Voice of Holland, strijden 8 zangers om een platen contract. Ze zijn allemaal even goed. Hoe groot is de kans dat je goed voorspelt wie op de eerste plek eindigt, wie op de tweede plek, wie op de derde plek en wie op de vierde plek

3) Tijdens de kerstviering, mogen 11 basisschool kinderen, waaronder Hans en Iris, aan de klas een kerstverhaal vertellen tijden het diner. De leraar bepaalt de volgorde waarin de kinderen mogen vertellen. Wat is de kans dat Hans als eerste mag vertellen en Iris als tweede?

4) Bij ganzenbord, een speelster kan alleen winnen als zij een bepaalde combinatie gooit met een gewone dobbelsteen (1 tot 6 op de zijden). Om te winnen moet ze eerst een 4 gooien voor een veilige plek en daarna een 1. Hoe groot is de kans dat ze eerst een 4 gooit en daarna een 1?

5) Er zijn 14 kinderen op een verjaardagsfeestje. Alle kinderen krijgen om de beurt een versierde cupcake. Je voorspelt welke cupcake als eerste wordt uitgedeeld en welke als tweede wordt uitgedeeld. Wat is de kans dat je voorspelling goed is?

6) Er zijn 6 honden over in een asiel en zij zoeken een nieuw baasje. Alle 6 de honden zijn even leuk. Hoe groot is de kans dat je precies voorspelt welke hond als eerste een nieuw baasje vindt, welke hond als tweede en welke hond als derde?

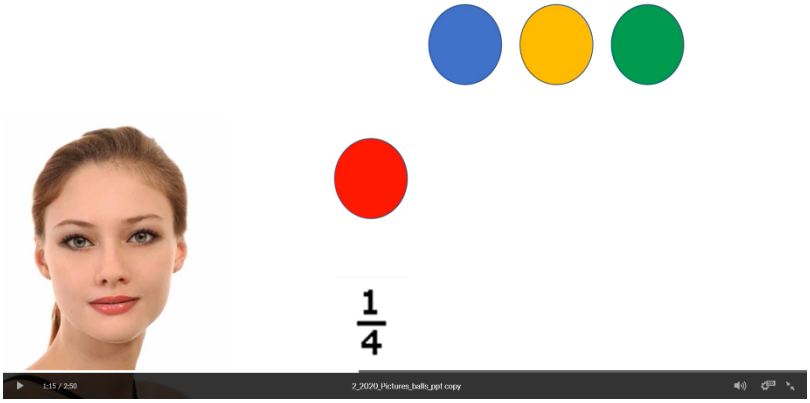
7) Vijf kinderen doen mee aan een wielerwedstrijd, het eerste deel vindt plaats op zaterdag en het tweede deel op zondag. De organisatie heeft 5 helmen en elke helm heeft een andere kleur (groen, blauw, geel, rood en oranje). De organisatie deelt de helmen willekeurig uit bij de start op beide dagen. Hoe groot is de kans dat een fietser de eerste dag een rode helm krijgt en op de tweede dag een blauwe helm.

8) In de finale van Boer Zoekt Vrouw zijn er 8 vrouwen die strijden om de liefde van een boer. Ze zijn alle 8 even leuk. Wat is de kans dat je goed voorspelt welke vrouw de wedstrijd wint, welke vrouw als tweede eindigt, welke vrouw als derde en welke rouw als vierde?

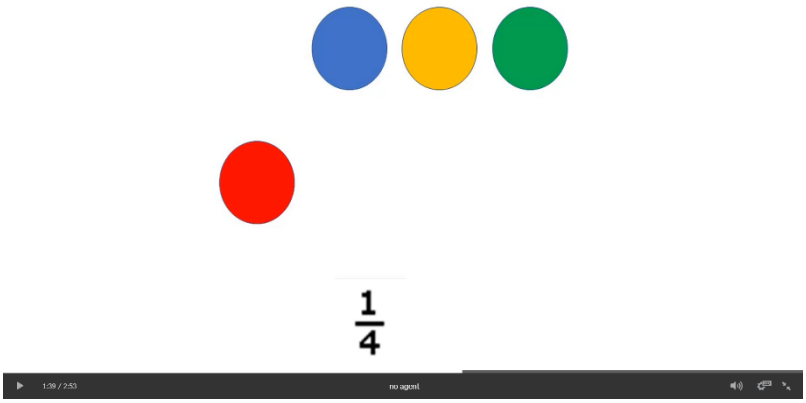
Appendix L

Pictures of video on the USB stick.

Video with PA.



Video without PA.



Appendix M

The video script:

De scouting heeft voor de deelnemers aan een spel gekleurde ballen meegenomen.
Er is een rode bal, een blauwe bal, een gele bal en een groene bal.
De kinderen mogen om de beurt een kleur bal kiezen en vinden alle kleuren even mooi.
Wat is de kans dat de rode bal als eerste gekozen wordt en de groene bal als tweede gekozen wordt?
Dit is een kansrekeningsprobleem waarbij de volgorde belangrijk is.
Want het gaat eerst om de rode bal en dan de groene bal.
Het is ook een probleem zonder teruglegging.
Want als de rode bal al gekozen is, kan die niet nog een keer gekozen worden.
Om de kans te berekenen op de eerste gebeurtenis, dat de rode bal als eerste gekozen wordt, is het nodig om te bepalen wat het aantal goede opties is en wat het aantal mogelijke opties is.
Het aantal goede opties is 1, omdat alleen de rode bal juist is.
Het aantal mogelijke opties is 4 omdat er 4 gekleurde ballen zijn.
Het aantal goede opties, 1, moet gedeeld worden door het aantal mogelijke opties, 4.
Dus de kans dat de rode bal als eerste gekozen wordt is ¼.
Om de kans te berekenen op de tweede gebeurtenis, dat de groene bal als tweede gekozen wordt, is het opnieuw nodig om te bepalen wat het aantal goede opties is en het aantal mogelijke opties.
Het aantal goede opties is nog steeds 1 omdat alleen de groene bal juist is.
Het aantal mogelijke opties is omlaag gegaan naar 3, omdat we de rode bal al uitgedeeld hebben en dit een voorbeeld zonder teruglegging is.
Stel dat de rode bal wel terug was gelegd, dan zou het aantal mogelijke opties nog steeds 4 gekleurde ballen zijn.
Maar omdat de rode bal al door het eerste kind werd gebruikt, zijn er slechts 3 mogelijke opties over.
Het aantal goede opties, 1, moet gedeeld worden door het aantal mogelijke opties, 3.
Dus de kans dat de groene bal als tweede gekozen wordt is 1/3.
De kans dat de rode bal als eerste gekozen wordt en de groene bal als tweede gekozen wordt, kun je nu berekenen door de kans op de twee gebeurtenissen te vermenigvuldigen.
1/4 x 1/3 = 1/12

End.