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Effects of Anxiety-Reducing Strategies in an Online Math Lesson for Primary School Children

MASTER'S THESIS

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Abstract

Math anxiety is a widely acknowledged problem with many negative consequences, especially for performance and well-being of students. Online learning environments in particular offer little support for learners with such psychological characteristics. Therefore, this study explored the use of anxiety-reducing strategies within the context of an online math lesson for Dutch primary school children of grade 5 (age 10-11). The primary goal was to investigate the effects on state anxiety, self-efficacy, student engagement, and task performance. A secondary goal was to investigate if these constructs, including math anxiety, were related. A total of 80 children were randomly and equally divided over three groups (two experimental and one control group) based on their math anxiety levels. All groups had to make the same online math lesson about the metric system. For the experimental groups, this lesson was enhanced with problem-focused coping messages (problem group) or emotion-focused coping messages (emotion group) provided by an animated pedagogical agent. Overall, no effects for the anxiety-reducing strategies were found. However, the present study demonstrated intertwined and reciprocal relationships among the variables math anxiety, state anxiety, self-efficacy, and task performance. Moreover, math anxiety and self-efficacy were found to be sequential mediators of the relationship between state anxiety and task performance. The results underscore the importance of reducing math anxiety and enhancing self-efficacy to increase math performance of students.

Keywords: anxiety, coping, self-efficacy, math performance, multimedia learning

Effects of Anxiety-reducing Strategies in an Online Math Lesson for Primary School Children

During the Covid-19 (Coronavirus disease 2019) pandemic, over 90 percent of the global enrolled learners had to stay home and attend online education due to temporary school closures to control the spread of the virus (UNESCO, 2020). As a result, virtual classrooms were set up all over the world at an exceptional speed and online learning platforms were overrun by visitors (Hijink, 2020). This phenomenon shows the importance of online learning opportunities in today's education. In recent years, online education already has been gaining ground and has increasingly become the norm for today's students (see for a review Henrie, Halverson, & Graham 2015). It offers opportunities in distance learning situations, but is also a valuable addition to traditional instruction, for example in blended-learning courses (Allen & Seaman, 2005; Simonson, Zvacek, & Smaldino, 2019). Some researchers identify online learning as a more recent or improved version of distance education (See for a review Moore, Dickson-Deane, & Galyen, 2011). Online learning environments offer students the opportunity to control their learning pace and to learn at any place and anytime. This way of learning offers students more autonomy, while their progress is monitored to assess their achievements (Rhode, 2009).

However, learning with an online lesson is a complex process which involves cognitive and affective processes (Huang & Mayer, 2016). Although there is a substantial body of research that can guide the instructional design of online instruction in terms of cognitive processes, much less is known about affective processes in online instruction (Clark & Mayer, 2016; Huang & Mayer, 2016; Mayer, 2014). As in traditional education, users of online education have diverse backgrounds, characteristics and learning needs, which require support (Simonson et al., 2019). Accordingly, the OECD (2020, March 18) strongly suggested that educational solutions must be designed to prevent greater educational and social inequalities in online education. This means that in addition to academic aspects, psychological aspects should also be addressed in instruction (Holmberg, 2005; Jegede & Kirkwood, 1994; Simonson et al., 2019).

A prominent learner characteristic that should be considered when designing online education is math anxiety, a widely acknowledged problem with many negative consequences. Online learning of mathematics is particularly prone to elicit learner anxiety that tends to interfere with learning (Maloney & Beilock, 2012). Math anxiety can hamper the development of mathematical skills and impede well-being of students (Beilock & Maloney, 2015). Moreover, math anxiety is an important reason why not all students achieve an optimal mathematical level (Ashcraft & Moore, 2009; Justicia-Galiano, Martín-Puga, Linares, & Pelegrina, 2017; Maloney, Risko, Ansari, & Fugelsang, 2010).

Looking at the Netherlands in international comparisons, a downward trend in math performance has been observed between 2003 and 2015. In 2018 the mathematical performance was at the same level as that in 2015. (Gubbels, Van Langen, Maassen, & Meelissen, 2019). Although the worldwide average also fell during that period, the level of mathematics in the Netherlands has deteriorated more sharply. This is problematic, as adequate arithmetic skills are essential for participation in society and appeared to be crucial predictors of life success (Maloney, et al, 2010; Reyna & Brainerd, 2007). Mathematics is therefore worldwide a core subject and was given priority in Dutch online education during the Covid-19 pandemic (SLO, 2020, April 23).

Given the important role of mathematical skills in today's society and the negative consequences of math anxiety, it is of great importance to improve students' mathematical performance and perceptions. Recent insights and protocols emphasise that learning to do mathematics is not just a technical matter, and thus cannot be separated from psychological factors that determine how a learner experiences mathematics. These experiences include the behaviour, thoughts, and feelings of students with regard to mathematics (Van der Beek, Toll, & Van Luit, 2017). However, according to Donolato, Toffalini, Giofrè, Caviola, and Mammarella (2020), it is still not clear to which degree math anxiety affects mathematics achievement, once any other forms of anxiety (such as state anxiety) and other personal assets (such as self-efficacy) have been taken into account. Research indicates that high math anxiety is not only associated with low performance, but also with high state anxiety, low self-efficacy, and low student engagement.

The central goal of this study is to examine the effects of anxiety-reducing strategies on state anxiety, self-efficacy, student engagement, and task performance within the context of an online math lesson for primary school children. A secondary goal is to investigate if these constructs, including math anxiety, are related. All constructs can be measured at school, course, or activity level. As the current study entails one online lesson, the constructs are measured at the activity level, a learning activity occurring within a course.

Theoretical framework

Anxiety

During learning situations, students may experience difficulties or even failure. When this happens, negative emotions, stress, and especially anxiety can arise (Dowker et al., 2016; Goetz, Keltner, & Simon-Thomas, 2010; Skaalvik, 2018). Folkman and Lazarus (1984) defined anxiety as: “A vague, uncomfortable feeling exacerbated by prolonged stress and the presence of multiple stressors.” (p. 4). It is a common human experience characterised by a variety of symptoms, including worrisome thoughts, physiological arousal, and strategic avoidance behaviours (Barlow, 2002). Anxiety is an ambiguous concept because it has been defined in many ways: as a trait, a state, a stimulus, a response, a drive and as a motive (Endler & Kocovski, 2001).

This study will follow Spielberger's (1966) Trait-State Anxiety Theory, which distinguishes two types of anxiety: trait and state anxiety. Trait anxiety refers to anxiety that is chronic and pervasive across situations and is not triggered by specific events (Spielberger, 1972). State anxiety refers to anxiety that occurs in specific situations and usually has a clear trigger (Huberty, 2009). The same distinction is made in mathematics: a general tendency to feel anxiety during arithmetic (trait) versus the experience of anxiety within a specific mathematical situation (state; Goetz, Bieg, Lüdtke, Pekrun, & Hall, 2013). However, levels of state anxiety depend on both the person (trait anxiety) and the stressful situation (Endler & Kocovski, 2001). Accordingly, later studies confirmed that the multidimensionality of state and trait anxiety should be considered in both theory and assessment (Endler & Kocovski, 2001; Zuckerman & Spielberger, 2015), which will be done in the current study.

Math anxiety

In educational situations, anxiety can have harmful consequences for students. This relates to negative feelings in specific situations, such as exams, but also to general learning and even to lifelong academic and professional development. A severe reaction to these situations can indicate specific forms of test and performance anxiety related to a knowledge domain. The most prominent of these is math anxiety (Luttenberger, Wimmer, & Paechter, 2018), which is considered as trait-level anxiety and can be distinguished from both test anxiety (Kazelskis et al., 2001) and state anxiety (Hembree, 1990).

Math anxiety refers to feelings of anxiety, tension, and fear that many people experience when they are engaged in mathematics (Ashcraft, 2002). Tension and fear are symptoms that can hamper the ability to solve mathematical problems in different situations. This concerns not only academic learning situations, such as opening a math textbook or even entering a math classroom. It also concerns situations in daily life. Activities such as reading a cash register receipt can cause people with math anxiety to panic (Ashcraft & Moore, 2009; Maloney & Beilock, 2012).

Math anxiety impacts all ages and it has many negative consequences: It is worldwide related to decreased math achievement (Ashcraft & Moore, 2009; OECD, 2013; Wang et al., 2015) and negative attitudes about math (see for a review Ramirez, Shaw, & Maloney, 2018). In the short term, math problems can lead to the avoidance of math tasks. In the long term, math problems can affect children's school careers and daily lives (Maloney, et al, 2010; Passolunghi, 2011; Reyna & Brainerd, 2007). To conclude, math anxiety is considered as a trait which represents a fairly stable characteristic. Therefore, this construct will be included in the current study as a personal characteristic of students, which influences how a person perceives and evaluates specific situations.

State anxiety

Math-related situations, especially in stressful ones, are such specific situations in which math anxious persons generally experience more anxiety (Paechter, Macher, Martskvishvili, Wimmer, & Papousek, 2017), which is known as state anxiety. State anxiety refers to anxiety that occurs in specific situations and usually has a clear trigger (Huberty, 2009). It is conceptualised as the emotional state of an individual in response to a particular situation or moment which varies in intensity and fluctuates over time (Spielberger, 1972). When it comes to mathematics, this involves levels of momentary anxiety in specific academical or real-life mathematical situations (Bieg, Goetz, Wolter, & Hall, 2015). State anxiety includes symptoms of apprehension, tension, and activation of the autonomic nervous system, and can include tremors, sweating, or increased heart rate and blood pressure (Moscaritolo, 2009).

As earlier stated, the person (trait anxiety) and the situation are important in determining levels of state anxiety (Endler & Kocovski, 2001). Like math (trait) anxiety, state anxiety leads to outcomes such as decreases in achievement (Luttenberger et al., 2018). The basic expectation is that state anxiety should be more predictive of task performance than trait anxiety because trait anxiety is pervasive across situations (Eysenck, 1979). Therefore, this study will focus on the manipulation of state anxiety because the focus is on students' anxiety in response to a math lesson.

Dimensions. In order to manipulate state anxiety, it must be considered that it is a multidimensional construct that consists of worry and emotionality (Endler & Kocovski, 2001; Eysenck, 1979). Worry refers to the cognitive concerns about the consequences of failure. It is regarded as the cognitive component of anxiety, involving concern about one's level of performance, negative task expectations, and negative self-evaluation (Liebert & Morris, 1967). It is activated in stressful situations, especially in test, evaluation, or competition situations (Eysenck, Derakshan, Santos, & Calvo, 2007). Highly worrying individuals can become overwhelmed by concerns in various domains (Power & Dalgleish, 2015). Worry distracts attention away from the task and can impair performance. Thus, high levels of worry are often associated with low levels of performance (Eysenck et al., 2007; Sarason, 1988).

Emotionality refers to nervousness, tension, and arousal reactions of the autonomic nervous system in evaluative situations (Liebert & Morris, 1967). It is regarded as the affective component of anxiety, which involves physiological reactions such as sweating and increased heartrate. It further involves accompanied feelings of uneasiness, tension, and nervousness (Eysenck, 1979; Liebert & Morris, 1967). In this study, both worry and emotionality will be manipulated, with the aim of reducing state anxiety.

Self-efficacy

In addition to performance, students' anxiety can impact self-efficacy. Students' self-efficacy is known as the belief in one's capabilities to perform particular academic tasks and successfully produce the desirable outcomes (Bandura, 1986; Bandura, 1997). Bandura (1997) considers anxiety as a physiological or affective source of self-efficacy. Increased anxiety is associated with lower levels of one's self-efficacy (Scholz, Doña, Sud, & Schwarzer, 2002).

In general, self-efficacy has been extensively researched and it has been shown that is has an important influence on academic outcomes such as task performance and the amount of persistence and effort that students are willing to put in when they encounter difficulties (Bandura 1997; Hodges, 2008). Low levels of self-efficacy often lead to several undesirable consequences, such as poor performance and the avoidance of more advanced courses or career choices that require skills in the specific academic field (Bandura, 1997;

Schunk & DiBenedetto, 2016). The importance of self-efficacy has been consistent over a period of several decades, through all levels of the educational process, with different student populations, and in diverse learning domains (Hodges, 2008).

Mathematics has received special attention in self-efficacy research because it has a valuable place in the academic curriculum (Pajares & Graham, 1999). Math anxiety, math self-efficacy, and math self-concept are often mentioned in research. After various discussions whether they are too closely related or not, they were eventually found to be separate constructs (Lee, 2009). Prior research has demonstrated medium to large negative correlations between math anxiety and math self-efficacy (Betz & Hackett, 1983, Cooper & Robinson, 1991; Hackett, 1985, Lee, 2009; Lent, Lopez, & Bieschke, 1991). Furthermore, math self-efficacy is found to be among the most significant predictors of mathematics achievement (Bandura, 1986; Spence & Usher, 2007), better than math self-concept (Lee, 2009). Also, self-efficacy was found to be a mediator between anxiety and performance (e.g. Bandura, 1997). An explanation is that, regardless of ability level, students with high self-efficacy are more accurate in their mathematical calculations and show more perseverance in difficult calculation tasks than students with low self-efficacy (Collins, 1982). According to Spence and Usher (2007), that is why teachers must remain aware of the power of self-efficacy, both for the engagement of their students in the course material and for their eventual academic success.

Student engagement

Both anxiety and self-efficacy can influence the perseverance of students in math. Math anxiety is one of the main reasons for students to avoid mathematics (Ashcraft, 2002). When students do not have confidence in themselves to master the content of the course, their motivation decreases, and they are less likely to make further attempts to understand new learning materials (Keller & Suzuki, 2004). This perseverance is also known as student engagement. Student engagement has been defined in various ways across research, from broad to narrow, without a clear consensus yet (See for a review Henrie et al., 2015). This study follows Cole and Chan's definition (1994), which has been well reviewed (Henrie et al., 2015) and fits within the current study: Student engagement is “the extent of students’ involvement and active participation in learning activities” (p. 259). Where engagement can include both learning inside and outside the academic setting, student engagement focuses only on the academic setting (Henrie et al., 2015). Therefore, this study uses student engagement, as online learning modules fall within the scope of the academic setting.

Student engagement is seen as a meta-construct with various indicators: features that are part of the construct (Henrie et al., 2015; Skinner, Furrer, Marchand, & Kindermann, 2008). These indicators are translated into widely accepted and used sub-constructs of student engagement: behavioural, emotional, and cognitive engagement (Fredricks, Blumenfeld, & Paris, 2004; Henrie et al., 2015). According to Fredricks et al. (2004) behavioural engagement involves observable behaviour essential to academic success, such as attention, participation, and homework completion. Emotional engagement includes students' feelings about their learning experiences, such as being happy or anxious, expressing interest, or reaction to failure and challenge. Cognitive engagement is the focussed effort students make to effectively understand what is being taught. It includes beliefs about the value of education and future aspirations, cognitive strategy use, self-regulation, or metacognitive behaviour, and doing extra work and going beyond the requirements of school.

Various studies have linked student engagement to important educational outcomes. Engaged students invest more in their performance, participate more in school activities, develop better self-regulation of their learning process, have greater satisfaction and self-reliance and have less performance problems (Assunção et al., 2020; Coetzee & Oosthuizen, 2012; Elmore & Huebner, 2010; Fredricks et al., 2004; Gilardi & Guglielmetti, 2011; Reschly & Christenson, 2012). Nowadays, determining the best ways to help students to engage in meaningful and effective learning experiences is an important issue for research in instructional technology (Henrie et al., 2015). Student engagement can be seen as a malleable concept that evolves over time. It can therefore be influenced by interventions that improve positive performance and prevent potential dropouts (Appleton, Christenson, & Furlong, 2008). Student engagement, in particular behavioural engagement, can provide a useful indication of how well students are on track to achieve the desired outcomes. Technology affords us with new methods to measure student engagement in ways both scalable and minimally disruptive to learning, such as using computer-generated data of user activity within a learning system (Henrie et al., 2015). Therefore, the current study will focus on behavioural engagement, as the experiment consists of an online math lesson. Cognitive and emotional engagement are often measured with self-report, which is more intrusive.

Besides indicators and outcomes, student engagement also involves facilitators: causal factors outside the construct that are expected to influence engagement, such as self-efficacy and anxiety (Skinner et al., 2008). High levels of anxiety and low levels of self-efficacy are negative related to student engagement (Keller & Suzuki, 2004; Maloney, et al, 2010; Passolunghi, 2011; Reyna & Brainerd, 2007; Spence & Usher, 2007). Students with math anxiety often finish the math tasks carelessly and quickly to stop the stressful situation as soon as possible (Faust, Ashcraft, & Fleck 1996). Therefore, the current study will both measure behavioural engagement during the online math lesson and investigate its relationship to state anxiety, self-efficacy, and task performance. This is in line with prior research that measured student engagement to evaluate whether a technology-based learning intervention positively impacted student engagement, and to understand its relationship with other theoretical constructs in technology-based learning (See for a review Henrie et al., 2015).

In sum, during challenges in mathematical learning situations, students may experience difficulties and even failure, which can cause stress (Skaalvik, 2018). These stressors can exacerbate students' math anxiety, which in turn can lead to higher state anxiety, lower self-efficacy, lower student engagement (such as avoidance), and ultimately lower math performance. Therefore, it is important to look for ways to decrease students' anxiety, especially in online courses.

Coping as an intervention

Whether and to what extent the discussed consequences of stress occur, depends on the various coping strategies students use: the thoughts and behaviours of students in order to deal with the demands of the learning situation that is experienced as stressful (Billings & Moos, 1981; Carver & Connor-Smith, 2010; Endler & Parker, 1994; Folkman & Lazarus, 1980, 1988; Folkman & Moskowitz, 2004). Some students use adaptive coping strategies, which are focused on performing as well as possible by hard work, trying to understand the study material and finding solutions to problems (Skaalvik, 2004). These strategies are seen as effective because they have a stabilising effect that supports better psychological adjustment during stressful periods, and are associated with a greater sense of well-being (Aldao, Nolen-Hoeksema, & Schweizer, 2010; Carver et al., 1993; Moos & Holahan, 2003). In addition, adaptive coping strategies appear to be positively related to math performance (Ader & Erktin, 2012; Huang & Mayer, 2019) and can thus increase students' learning and their chances of doing better in following attempts (Skaalvik, 2018). By contrast, other students use maladaptive coping strategies, which are usually self-protective strategies, such as avoidance, procrastination and concealing their own work and grades (Skaalvik, 2004). These strategies are seen as ineffective and should be counterbalanced by more adaptive strategies, otherwise they may lead to negative feelings and weaker school performance (Folkman & Lazarus, 1988; Skaalvik, 2018). Students' choice of coping strategies is therefore crucial for learning (Skaalvik, 2018).

Accordingly, an important starting point for interventions in math education is to stimulate or further develop adaptive strategies used by students and at the same time unlearn or reduce maladaptive strategies (Van der Beek et al., 2017). Likewise, Ramirez et al. (2018) concluded in their review that interventions designed to change the students' mindsets and give them a distanced perspective in order to better evaluate stressful math situations can have lasting effects in reducing math anxiety and enhancing self-efficacy. They suggest that educators must show in their interactions with students that math material can be learned by everyone and that failure is normal and often optimal for improving. In this way, students learn to realistically attribute success and failure to their abilities and effort, believe in their abilities instead of doubting them, focus on past successes rather than failures, and in doing so built a positive but realistic self-concept (Luttenberger et al., 2018).

Agent-delivered coping messages

In a digital learning environment, as in the present study, such a mastery climate can be established by sending adaptive coping messages to the student. These messages can encourage students to use adaptive coping strategies to minimize or deal with their own math anxiety (Iossi, 2007). Further, it has been found that, in an attempt to develop students' growth mindset, coping messages effectively enhance college students' self-efficacy in mathematics (Friedel, Cortina, Turner, & Midgley, 2007; Huang & Mayer, 2019). Online learning environments are ideal for showing these messages to students in an adaptive way, such as based on students' behaviour or scores. However, multimedia environments themselves lack social support, while this is important for supporting a growth mindset (Shen, 2009). The feeling of support, for instance from the teacher, can enable students to face a stressful situation that might otherwise seem overwhelming (Moos & Holahan, 2003) and contributes to the development of self-efficacy (Ahmed, Minnaert, Van der Werf, & Kuyper, 2010; Kordes, Bolsinova, Limpens, & Stolwijk, 2013; Moos & Holahan, 2003; Sakiz, Pape, & Hoy, 2012). Also, the appraisals and coping efforts that students adopt may be heavily shaped by their social environments, because social resources can provide information and guidance to help assess the threat and plan coping responses (Moos & Holahan, 2003; Ramirez et al., 2018).

To solve this shortcoming, social support can be provided by animated pedagogical agents (Shen, 2009). Pedagogical agents are animated lifelike characters that can support learning in a computer-based learning environment (Johnson, Rickel, & Lester, 2000). By appearing welcoming and friendly, pedagogical agents can reduce anxiety and frustration in learners (Shen, 2009; Wei, 2010). Also, agents can support the emotional state of pupils by exhibiting empathy and building and maintaining relationships with pupils (Veletsianos & Russell, 2014). Such motivational agents can increase learners' self-efficacy (Baylor & Kim, 2005) and, in specific, coping-type models are likely to promote learners' interest and motivation (Ebbers, 2007). Therefore, the interventions of the current study are aimed at helping students to have adaptive coping behaviour by sending coping messages through an animated pedagogical agent.

Types of coping messages and related constructs

In the present study, the adaptive coping messages are grouped into problem-focused coping (manage or solve the problem by removing or circumventing the stressor) and emotion-focused coping (regulate, reduce or eliminate the emotional arousal associated with the stressful situation), a widely accepted distinction by Folkman and Lazarus (1984). These dimensions correspond to the two tasks that individuals face in stressful situations: solving the problem and regulating their emotions (Lazarus and Folkman, 1984). Problem- and emotion-focused coping messages may directly address the earlier discussed worry and emotionality components of anxiety (Huang & Mayer, 2016). Accordingly, Folkman and Lazarus (1988) reported for their younger sample that both problem-focused (e.g. planful problem-solving) and emotion-focused (e.g. positive reappraisal) forms of coping were associated with increased positive emotions (pleasure, happiness, and confidence) and decreased worry, fear, disgust and anger. Likewise, in a study with a similar population to the current study (Dutch children aged 9 to 11), it was found that positive reappraisal (emotion-focused coping) was strongly related to lower worry (Garnefski, Rieffe, Jellesma, Terwogt, & Kraaij, 2007). Also, the more problem-focused and emotion-focused coping strategies were used, the fewer depressive symptoms were found. These negative relationships suggest a protective value of adaptive problem- and emotion-focused coping (Garnefski et al., 2007).

Research that has developed problem- and emotion-focused coping messages, although limited, has shown promising results of the effectiveness of these strategies in achieving anxiety coping toward learning mathematical content and reducing math anxiety (Huang & Mayer, 2016; Shen, 2009; Wei, 2010). All three studies based the coping messages on elements of the Coping Orientation to Problem Experience (COPE) inventory, which consists of 15 ways in which people cope with stress (Carver, Scheier, & Weintraub, 1989). In this study, the adaptive underlying strategies of the problem- and emotion-focused coping categories (as identified by Zeidner, 1995) have been used to construct the coping messages. The used strategies and their relationships with other useful variables for this study are discussed in detail below.

Adaptive problem-focused coping. Problem-focused coping is regarded as a task-focused coping strategy (Endler & Parker, 1999). This way of coping includes strategies that are directly aimed at changing the stress factor in a situation, such as solving the problem or attempting to change the situation itself (Stanisławski, 2019). In this study, adaptive problem-focused coping includes three coping strategies of the COPE inventory: Active coping, planning, and suppression of competing activities (Zeidner, 1995). Active coping is the process of taking direct action to do something about or to get around the problem, one step at a time. Planning is thinking about how to cope with a stressor. Planning involves coming up with action strategies about what to do, thinking about what steps to take and how best to handle the problem. Suppression of competing activities means putting other activities aside and keeping oneself from distracted by other thoughts, even letting other things slide, if necessary, in order to concentrate on the problem (Carver et al., 1989).

Adaptive problem-focused coping can help to reduce or regulate worries that often guide students' negative appraisals about their level of performance, negative task expectations, negative self-evaluation, or the consequences of failure (Liebert & Morris, 1967). Accordingly, it was shown that problem-focused coping was negatively correlated to anxiety and depression (Cohan, Jang, & Stein, 2006). In specific, it was shown that the use of 'active coping' and 'planning' as coping strategies were positively related to optimism, the feeling of being generally able to do something about stressful situations, and self-esteem and negatively related to anxiety (Carver et al., 1989; Scheier, Carver, & Bridges, 1994).

Adaptive emotion-focused coping. Emotion-focused coping is regarded as an affective coping strategy. In contrast to problem-focused coping, this coping strategy is aimed at managing distress emotions rather than at dealing with the stressor itself (Carver & Connor-Smith, 2010). Positive emotional coping means being kind and understanding to oneself when trying to solve a problem, regardless of success. This way of coping includes strategies as positive self-determination, relativization, and reframing of the problem in such a way that it regulates or does not evoke negative emotions and less stress (Endler & Kocovski, 2001; Hampel & Petermann, 2005). Similarly, in this study, adaptive emotion-focused coping includes the positive reinterpretation and growth strategy of the COPE inventory (Zeidner, 1995). Positive reinterpretation and growth is about looking for something good in what is happening, trying to see it in different light to make it more positive, learning something from the experience, and trying to grow as a person as a result of the experience (Carver et al., 1989).

Positive reappraisal is an essential part of cognitive behavioural therapy and has been demonstrated to reduce negative emotions (Samson & Gross, 2012; Van Beveren, Harding, Beyers, & Braet, 2018), and to increase positive affect and adaptive emotional regulation (Tugade & Fredrickson, 2007). In specific, the use 'positive reappraisal and growth' as coping strategy was positively related to optimism, control, and self-esteem, and negatively related to anxiety (Carver et al., 1989; Scheier et al., 1994; Solberg Nes & Segerstrom, 2006). Moreover, positive reappraisal of the stress experienced by high math anxious students led to improved performance (Jamieson, Peters, Greenwood, & Altose, 2016). In line with these findings, for mathematics in computer-based learning environments in particular, promising effects have been found for emotion-focused coping messages on reducing anxiety and improving performance (Huang & Mayer, 2016; Im, 2012; Shen, 2009).

The Present Study

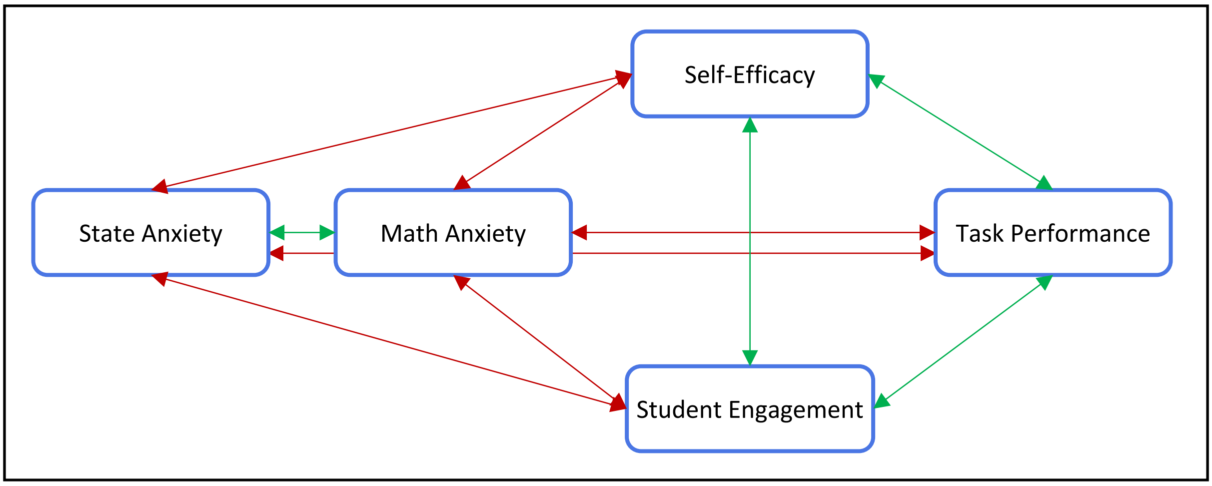
The central goal of the present study is to examine the effects of anxiety-reducing strategies on state anxiety, self-efficacy, student engagement, and task performance within the context of an online math lesson for primary school children. A secondary goal is to investigate if these constructs, including math anxiety, are related. This is a unique integrated approach, especially within the context of online math education for 10-11-year olds, based on the links among these constructs that have been shown by the previously discussed research (see Figure 1).

The overall research question of the study is as follows: What is the effect of adding anxiety reducing strategies to an online math lesson on state anxiety, self-efficacy, student engagement, and task performance? Based on the discussed literature, it is expected that adding anxiety reducing strategies will result in decreased state anxiety (hypothesis 1), in increased self-efficacy (hypothesis 2), in increased student engagement (hypothesis 3), and in increased task performance (hypothesis 4).

The secondary research question of the study is as follows: What are the relations among math anxiety, student engagement, the outcome variable of state anxiety, and the outcome variable of self-efficacy? Based on the discussed literature, it is expected that there are intertwined relations among the variables math anxiety, student engagement, state anxiety, self-efficacy, and task performance (hypothesis 5). Further, it was predicted that there are mediating roles of the outcome variables, with at least self-efficacy serving a mediating role between (math and state) anxiety and performance (hypothesis 6).

Figure 1.

Conceptual model of the predicted relations among the variables math anxiety, state anxiety, self-efficacy, student engagement, and task performance



Note. Red lines represent negative relations, and green lines represent positive relations.

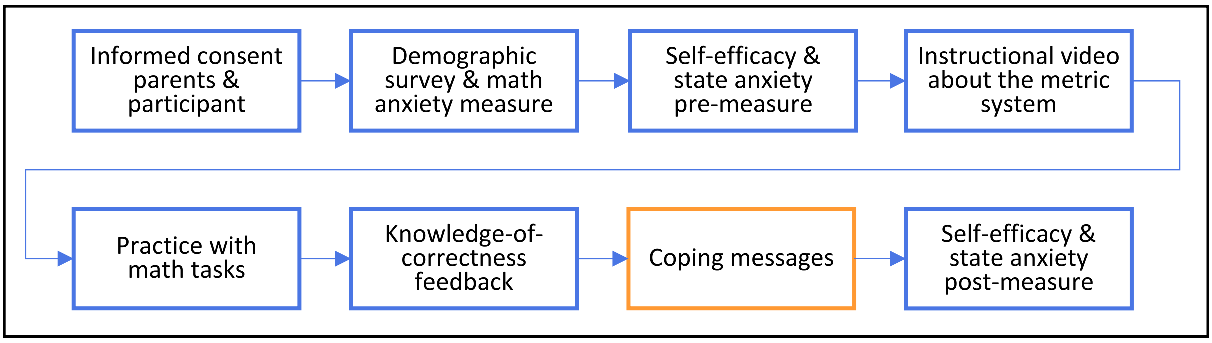
Methods

Design

This quantitative study used a classical experimental design to assess the effect of adding anxiety reducing strategies to an online math lesson about the metric system on state anxiety, self-efficacy, student engagement, and task performance. The experiment consisted of one control group, that received no anxiety coping messages, and two experimental groups, one group received problem-focused coping messages (problem group) and the other received emotion-focused coping messages (emotion group). As shown in Figure 2, for all versions, the experiment consisted of the following sections in a sequence: (a) demographic survey and math anxiety questionnaire, (b) pre-test through self-report questionnaires on self-efficacy and state anxiety, (c) instructional video about the math topic, (d) practise with seven math tasks, (e) post-test through self-report questionnaires on self-efficacy and state anxiety. The control version and the treatment versions were identical except for the feedback. The feedback in the treatment versions was enhanced with either problem-focused or emotion-focused coping messages to lower participants' anxiety and boost participants' confidence in performing the math task. All versions were designed and delivered via a specially designed website on Qualtrics that also recorded learner responses and time on task to measure student engagement. The independent variables of the study were math anxiety, and the premeasures of state anxiety and self-efficacy. The dependent variables were the post measures of state anxiety and self-efficacy, student engagement, and task performance.

Figure 2.

Overview of the content organisation of the online lesson



Note. Anxiety coping information in the orange box was presented to the treatment groups only.

Participants

A total of 106 children participated. The inclusion criterion was that participants had completed the entire study (75% of the participants). Altogether 8 children were excluded for not completing the initial measures, and 18 children for not completing the post measures. The final sample consisted of 80 children (mean age = 10.72, *SD* = .64; females = 39, males = 41).

The participants were selected with convenience sampling at seven primary schools in the regions Utrecht, Overijssel, and Flevoland of the Netherlands. Only pupils of grade 5 (in Dutch: *groep 7*) were selected to participate in the study, because math anxiety tends to increase during development, and to peak in high school years (Hembree, 1990). This causes early adolescence to be a key time to investigate this internalizing behaviour's effects on mathematics and to implement interventions (Lukowski et al., 2019). The teachers and legal representatives of all participants were fully informed about the study and its purpose beforehand. The teachers of the participating classes have informed the school principals and received permission if necessary and parents were asked to actively sign an informed consent to allow their child to the study. The Ethics Committee of the BMS department approved of the procedures.

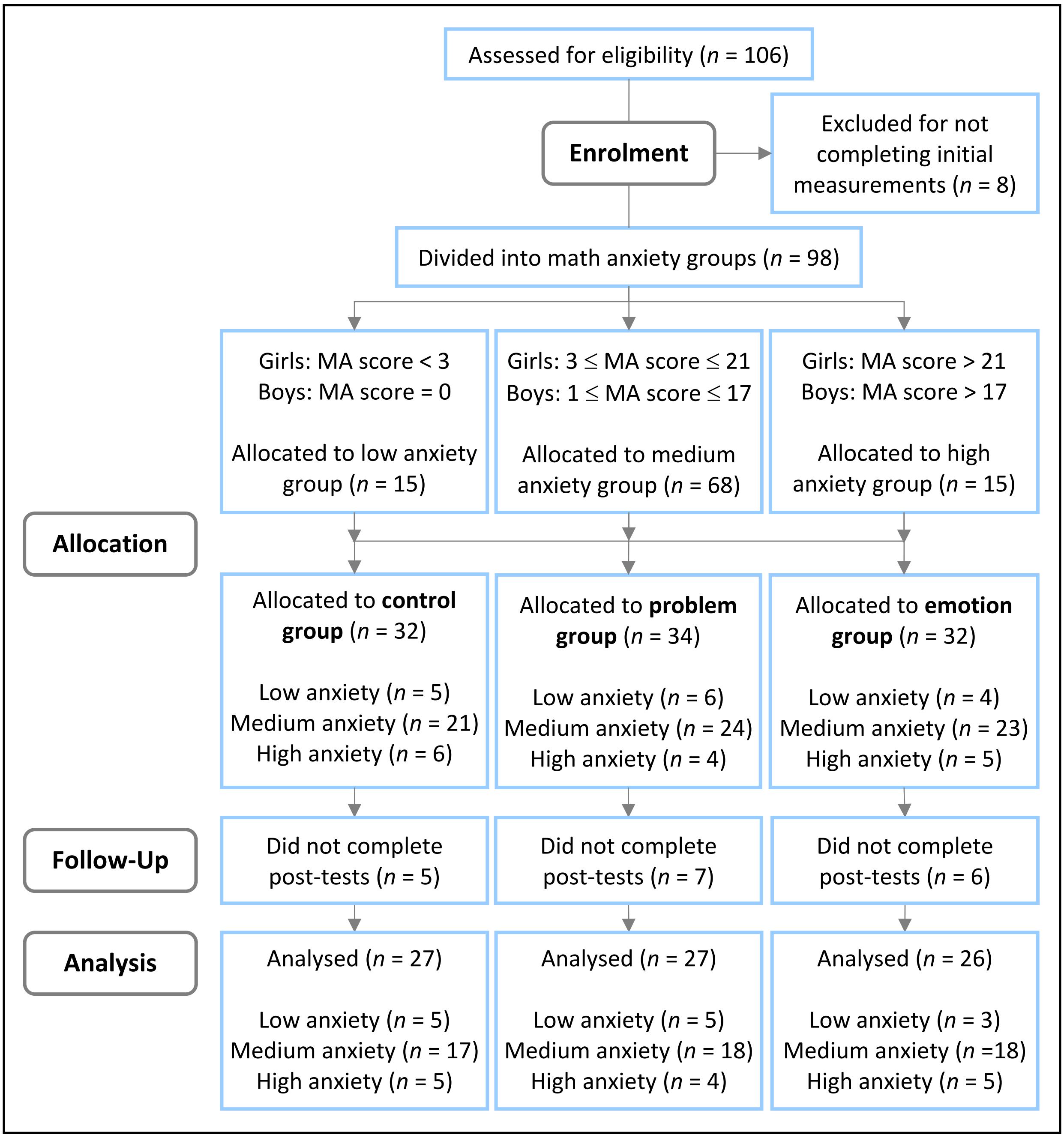
With the aim to create equal groups, participants were randomly and automatically divided over conditions, corrected for math anxiety levels by the web-based system Qualtrics (see Figure 3). This means that participants were automatically labelled with low, medium, and high math anxiety based on their math anxiety scores. Then, these three anxiety groups were randomly and equally divided to one of the three conditions, with 27 participants in the control condition (mean age = 10.81, *SD* = .74; females = 14, males = 13), 27 participants in the problem condition (mean age = 10.63, *SD* = .57; females = 13, males = 14), and 26 participants in the emotion condition (mean age = 10.73, *SD* = .60; females = 12, males = 14). See Figure 3 for the participants flow.

It was decided to do so, because as earlier stated, math anxiety is considered as a trait which represents a fairly stable personal characteristic of pupils (Eysenck, 1979), and it is predicted that math anxiety is related to the other variables of this study. It was decided not to divide gender equally, because the math anxiety scores have been corrected according the norms of the Math Experience Questionnaire (Van der Beek et al., 2017).

Moreover, previous studies report no gender differences in math state anxiety (Bieg et al., 2015; Goetz et al., 2013).

Figure 3.

Sampling and Flow of Participants



Note. MA score = Math Anxiety total score of the Math Experience Questionnaire, based on which participants were divided into low, medium, and high anxiety groups. Each anxiety group was randomly and equally divided over the three conditions. The flow was automatically regulated by the pre-programmed Qualtrics system.

Instrumentation

Online lesson. The math lesson consisted of an instruction about the metric system and exercises including feedback. Attention, involvement, and motivation should be standards when creating e-learning environments for children (Huffaker & Calvert, 2003; Tung & Deng, 2006). This is because e-learning self-paced, which makes class management is an issue. For instance, students could play games, use social networking sites, or just waste their classroom time (Ali, 2013). This is also the case in the present study. Therefore, Kim and Frick (2011) identified eight design principles to reach sustained learner motivation during online learning, which have been incorporated into the design of the current study. For an overview of the application of the principles in this study, see Table 1. Also, other evidence-based design principles have been used, such as Mayer's (2014) multimedia principles (see for an overview the yellow boxes in Appendix A).

Table 1

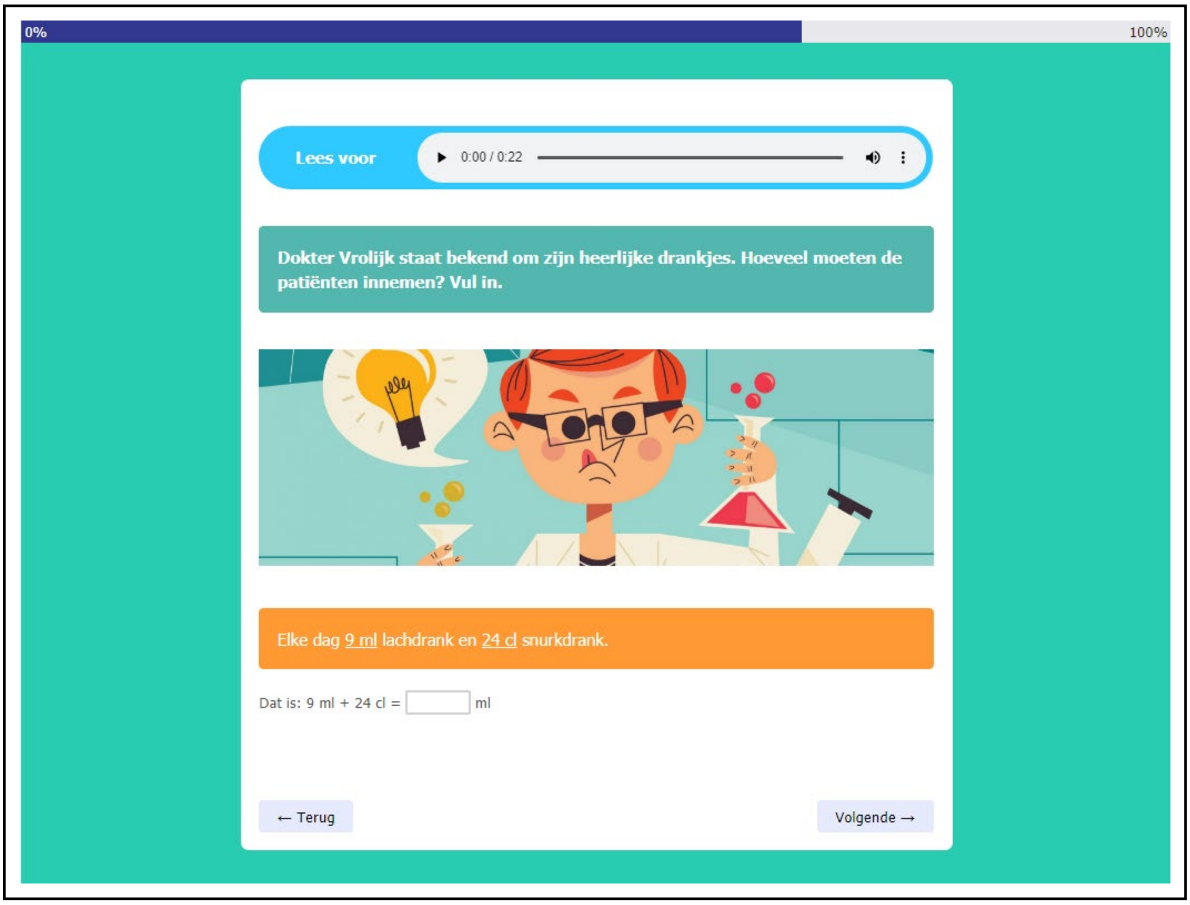
Summary of the Applied Motivation Principles by Kim and Frick (2011)

Design Principles	Design Application
Design the website so that it is easy for learners to navigate.	A user-friendly interface of the lesson with a simple and constant design.
Provide learners with content that is relevant and useful to them.	The topic choice was based on a needs analysis with teachers from the field and fits within the curriculum. The instruction started directly with explaining why the learning is important and worth doing using real-world examples.
Incorporate multimedia presentations that stimulate learner interest.	The instruction was provided through an instructional video and images were added to the math tasks.
Provide learners with feedback on their performance.	In each condition, participants received score feedback (e.g. you received x out of y points) and the correct answers.
If possible, incorporate some social interaction in the learning process (e.g., with an instructor, technical support staff, or an animated pedagogical agent).	An animated pedagogical agent was included to guide the students through the lesson and to provide the anxiety-coping messages.
Provide learners with hands-on activities that engage them in learning.	Math tasks were integrated into the online lesson directly after instruction.
Provide content at a difficulty level which is in a learner's zone of proximal development.	The tasks were selected by the teachers from the participating schools from their math method books and on the basis of the learning needs of their class.
Include learning activities that simulate real-world situations.	Realistic contexts for the math tasks were animals, a candy store, a laboratory, and a schoolyard.

User interface. A user-friendly interface of the lesson was coded within Qualtrics. The lesson consisted of multiple screens to organize content into small, manageable chunks of information (Mayer & Fiorella, 2014; Xu, Reid, & Steckelberg, 2002). The layout of the screens was constant with a simple design (See Figure 4), which allowed learners to open a webpage and immediately start learning without having to guess what to do next (Morrison, Ross, Kalman, & Kemp, 2013). For instance, there was always a progress bar at the top to display the progress of the lesson. Also, a read-aloud tool was integrated into each screen to help poor readers with reading comprehension (Wood, Moxley, Tighe, & Wagner, 2018). Further, colour boxes have been used to highlight important information (for instance, a question) and to distinguish information from each other (Mayer & Fiorella, 2014). Finally, to prevent errors in answers of students, error messages appeared when required answers or actions were missing (Tristán-López & Ylizaliturri-Salcedo, 2014).

Figure 4.

Example Screen of the Interface of the Online Lesson



Subject and learning content. The subject of the lesson is “the metric system” and fits within the curriculum of the last period of grade 5. The learning content of the lesson was based on key objective 33 and its guidelines for mathematics drawn up by the Dutch government (TULE SLO, 2006): “The pupils learn to measure and learn to calculate with units and measures, such as time, money, length, circumference, surface area, capacity, weight, speed and temperature.” The topic choice was based on a needs analysis through interviews with teachers from the field (see Appendix B & C), who identified the metric system as a generally difficult topic for their students. The topic therefore required more instruction and practise. As there was a high pressure on the curriculum due to school closures during the coronavirus pandemic, it was determined which topic was most needed and which fitted best into the curriculum of that (data collection) period.

Instructional video. The instruction was provided through an instructional video with a duration of 4.12 minutes (see Appendix A screen 18), which was made with the programmes Animaker and Davinci Resolve. The video was about ‘the metric staircase’, a common way to visualize the relationship among the different units within the metric system. This was in line with the guideline of key objective 33, which states that the measures of length, weight and capacity should be organised in one coherent system (TULE SLO, 2006).

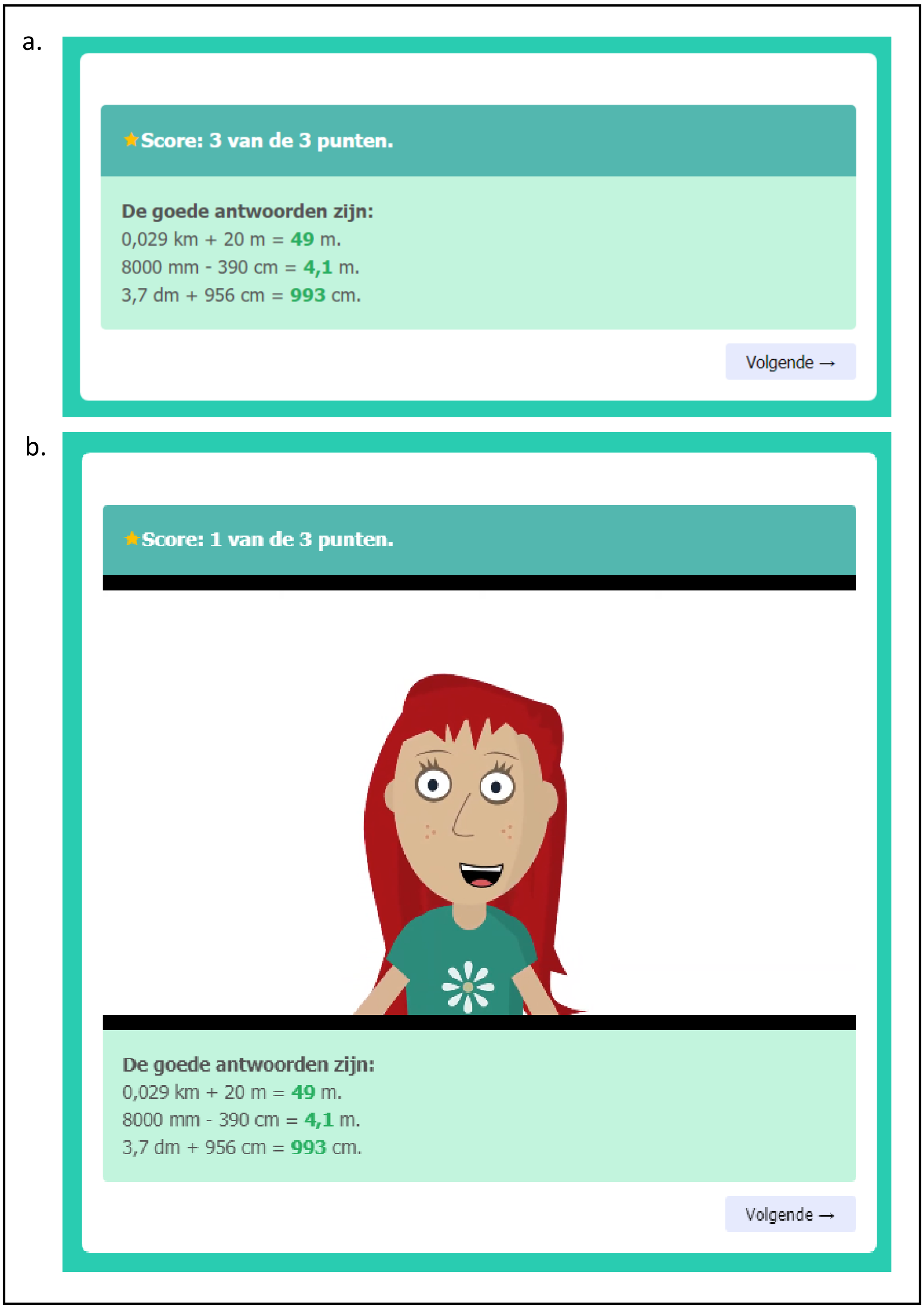
In order to show students the value of the metric system, the instruction started directly with explaining why the learning is important and worth doing using real-world examples. This enables learners to connect the learning content with their everyday lives, which enhances meaningfulness and encourages personal involvement (Hartnett, 2015; Kim & Frick, 2011). Hereafter, the learning goal was presented: “The goal of the lesson is that you have an idea of the different weights and measures and that you can convert them, for example from kilometre to meter, from gram to kilogram.” Subsequently, students’ prior knowledge was activated by encouraging students to think about what they already knew about the topic, by asking questions and repeating the basis of the metric staircase through an animated instruction. This way, students can better incorporate new information into existing schedules and better understand and remember them (De Grave et al., 2001). Also, animations activate the prior knowledge of students who know little about a subject better than static pictures (Kalyuga, 2008).

The instruction became gradually more complex by expanding the metric system and eventually integrating it into a single model that students could more easily memorise and apply when converting measurements (Freudenthal, 1991; Van den Heuvel-Panhuizen, 1998). Furthermore, each unit of measurement was supported by an image of an everyday example. This helped to put the unit in a realistic context and to make a unit of measurement imaginable for the student (Mayer, 2014; Van den Heuvel-Panhuizen, 1998). Finally, A worked example was added to illustrate how to convert between metric units by presenting each individual step that leads to the final solution (Renkl, 2014). In this way, students learn more and deeper than when just the problem and the final solution step are presented or when they immediately have to carry out a task independently (Atkinson, Derry, Renkl, & Wortham, 2000; Chen, Kalyuga, & Sweller, 2015; Renkl, 2014).

Feedback and coping messages. In each condition, participants received score feedback (e.g. you received x out of y points) after each math task (seven times) and the correct answers. In the experimental conditions, this feedback was enhanced with integrated anxiety coping messages (See Figure 5). A total of 28 messages were created, as the messages were adapted to the participants' scores and were designed in such a way that participants would not receive the same feedback twice. If participants had the majority of questions right, they received a compliment and were told how they could improve themselves to perform even better. If they had the majority of questions wrong, they were reassured and motivated to continue. One experimental group (the problem group) received adaptive problem-focused coping messages. An example is “Don't give up, if you first think about what you already know, you will also understand the more difficult parts step by step”. Likewise, to the other experimental group (the emotion group) received adaptive emotion-focused coping messages. An example is: “Don't give up, making mistakes is part of learning and practicing. As a result, we learn more and become more confident”. See for the complete transcript of the messages Appendix A, from screen 22. The messages of both groups were based on the Multidimensional Coping Inventories (COPE) scale (Carver, Schreier, & Weintraub, 1989), as discussed earlier, and the Math Experience Questionnaire (MEQ; Van der Beek et al., 2017). Also, some of these messages were based on the task-analysis with teachers from the field (see Appendix C).

Figure 5.

Feedback Pages by Condition



Note. (a) Example of the feedback page in the control condition. (b) example of the feedback page in the treatment conditions. Both treatment conditions look the same but consist of different messages. The problem-focused coping message was here: "Making mistakes is not a bad thing, use your scrap paper well to make resolving the sum clearer for you". The emotion-focused coping message was here: "Don't give up, making mistakes is part of learning and practising. That's how we learn more and become more self-confident".

Pedagogical agent. The anxiety-coping messages were delivered by an animated pedagogical agent in video format. The duration of the anxiety-coping message videos was 6 to 11 seconds and each video played automatically when the feedback page was displayed. Controls such as replay were available. The agent of the current study represented a young female primary school teacher who had a calming tone. The narrations were recorded in a human (researcher's) voice rather than a machine voice (Clark & Mayer, 2016), in first person and conversational style (Van der Meij, 2013). Also, the pedagogical agent has human gestures (Mayer, 2014). This has been done by using Adobe Character Animator 2020 that uses the presenter's facial expressions and movements to animate characters in real time: From lip synchronisation to eye, head, and arm movements. In this way, the pedagogical agent was able to provide social cues, which contributes to a more enjoyable experience (Shen, 2009).

The same animated pedagogical agent was implemented in the study as a research leader to guide participants through each step of the study and to help improve participants' motivation (Baylor & Kim, 2005; Gulz, 2005; Kim, Keller, & Baylor, 2007; Shen, 2009). These instructions consisted of three videos of 39, 18, and 13 seconds (see Appendix A screens 4, 6, and 41). This contributed to the quality of the experiment, because the agent provided each participant with the exact same instructions and the amount of reading material was limited for the participants.

Outcome measurements. To measure math anxiety, state anxiety, self-efficacy, student engagement, and task performance, several measurements have been included. A demographic survey was also included in the study (three items), asking for gender, age, and grade (inclusion check; see Appendix A screen 5).

Math tasks. To measure the learning outcomes of the lesson, math tasks were integrated directly after instruction. The performance measurement consisted of seven math tasks (24 items) from which two parts can be distinguished: one part concerns estimating measures of animals and the other converting units of measurement (See Appendix A screens 20-38). Several studies have shown that a high level of variation between learning tasks results in a stronger transfer (Quilici & Mayer, 1996; Paas & Van Merriënboer, 1994; Corbalan, Kester, & Van Merriënboer, 2009). The tasks are based on the guidelines of key objective 33: Awareness of which unit is most appropriate in which context and, if desired, make conversions in the process. Also, explore and practise simple conversions in a context (TULE SLO, 2006).

The following realistic contexts were used for the math tasks: animals, a candy store, a laboratory, and a schoolyard. ‘Realistic’ does not necessarily refer to a connection with the real world, but the situation should be imaginable for the student. These contexts help students to formulate mathematical concepts and strategies and to learn to apply them (Freudenthal, 1991; Van den Heuvel-Panhuizen, 1998). The tasks belong to the category 'problem solving' of the math domain in Dutch primary education: they require productive thinking. In principle, these are new to the pupil, even though the insights, knowledge and skills needed to solve the problem are present. In general, these are tasks that require more than two steps to reach a solution (SLO, 2017).

The tasks were selected by the teachers from the participating schools from their math method books and on the basis of the learning needs of their class (see needs analysis Appendix C). Accordingly, the tasks have been obtained from the method books Wereld in Getallen (Van Grootheest, Huitema, & De Jong, 2009) and Stenvertbloks Rekenmakkers Eind Groep 7 (Van der Borgh et al., 2002). Twenty pilot participants which were representative of the target population (pupils of Grade 5) were asked to complete a first version of the whole study. As a result, the vast majority of pupils scored high on the tasks. Therefore, the math tasks have been made more difficult for the actual study, to be challenging enough. Cronbach’s alpha for the math tasks (24 items) was .75, which can be considered acceptable for research purposes. Although this can be considered adequate for research purposes, a closer examination of the item-total statistics indicated that item 4 had a relative weak negative correlation with the sum of the other items. The alpha would increase to .77 if item 4 were removed. After removal of item 4, item 14 showed also a relative weak negative item-total correlation. The alpha would increase to .78 if item 14 were removed. Consequently, these items were dropped, and all subsequent analyses are based on the remaining 22 items.

Math anxiety. Math anxiety was measured using the Math Experience Questionnaire (MEQ; Van der Beek et al., 2017, see Appendix A screens 7-9). The questionnaire consists of four scales: adaptive coping strategies, maladaptive coping strategies, math self-concept, and math anxiety. In this study, only the math anxiety scale was used (15 items), in which the participants have to indicate on a 4-point Likert scale to what extent they agree with the statement ranging from 0 (totally disagree) to 3 (totally agree). An example of an item is: “I get nervous when solving math sums”. Total scores range from 0 to 45 points. In order to be able to interpret and compare the scores of the participants the scale scores were converted to T scores, which are standardised scores (Van der Beek et al., 2017). Math anxiety is a continuous construct, so there is no clear cut-off point on any measure that divides anxious individuals from non-anxious individuals (Ramirez et al., 2018). However, the math anxiety scores can be classified into below average (T score < 40), average (40 ≤ T score ≤ 60) and above average (T score > 60) using the available normative data (Van der Beek et al., 2017). The reliability and validity of the questionnaire and its separate scales were assessed in a Dutch population of children primary education and in secondary education. The reliability ranged from .82 to .94. Also, the individual scales have been assessed as reliable and valid (COTAN, 2019; Van der Beek et al., 2017). In this study, Cronbach’s α coefficients for the 15-item Math anxiety measure was .93, which can be considered excellent for research purposes. All items were relatively high correlated with each other and with the total score. No items needed to be rewritten or removed.

Self-efficacy. Self-efficacy was measured by a 10-point Likert scale (4 items), ranging from 0 (“Not confident at all”); through intermediate degrees of assurance, 5 (“Moderately confident”); to complete assurance, 10 (“Completely confident”), as recommended by Bandura (2006). Participants were asked how confident they were on successfully completing four math tasks about the metric system (see Appendix A screens 10-13). The four tasks were used to assess the level of math self-efficacy, are similar to those presented in the practise part of the study. To be able to interpret the scores, average self-efficacy scores were calculated by dividing the total score (ranging from 0 to 40) by four (the number of items). Such a specific scale for self-efficacy was chosen because children perceive their competence in different domains differently (Jansen et al., 2013). Furthermore, Multon, Brown and Lent (1991) found in their meta-analysis of the self-efficacy beliefs that researchers who used specific measures for self-efficacy in combination with corresponding performance measures found the strongest effects.

Twenty pilot participants (primary school pupils of grade 5) were asked to complete a first version of the whole study. It turned out that the vast majority of respondents checked high or the maximum efficacy category (8, 9, or 10). According to Bandura (2006), this means that these items lack sufficient difficulty, challenge, or impediments to distinguish levels of efficacy among respondents. After analysis of the subsequent math task scores, it turned out to be a lack of sufficient difficulty, because many of the children scored high on the math tasks (as already discussed under math tasks above). Therefore, similar to the math practice tasks, the tasks of the self-efficacy scale have been made more difficult for the actual study. In this study, a Cronbach's α coefficients of .88 was obtained for the 4-item Self-Efficacy premeasure, which can be considered good for research purposes. For the post measure, a Cronbach's α coefficients of .92 was obtained, which can be considered excellent. All items were relatively high correlated with each other and with the total score. No items needed to be rewritten or removed.

State anxiety. The Dutch translated version (ZBV-K; Bakker, Van Wieringen, Van der Ploeg, & Spielberger, 1989) of the State-Trait Anxiety Inventory for Children of 8 to 15 years old (STAIC; Spielberger & Edwards, 1973) was used to measure state anxiety, which consists of a 'state' and a 'trait' version. Only the state anxiety scale was included to examine the effects of the anxiety-reducing strategies (see Appendix A, screens 14-17), because state anxiety measures provide a valid indication of change in anxiety in response to real-life stress (Spielberger, 1985). This scale consists of 20 statements describing various emotional states (e.g., calm, upset, nervous). Each statement began with the phrase "I feel…" followed by three choices (e.g., very calm, calm, not calm; score 1, 2 or 3 respectively). Participants were asked to select the option that best described how they felt at the present moment. Scores range from 20 to 60 (the sum of items scores). High total scores indicate a high level of state anxiety. The reliability of the STAIC was assessed in four Dutch populations of children aged 8–16, Cronbach's α coefficients ranged from 0.81 to 0.88 (Bakker et al., 1989). In the current study, the Cronbach's α coefficients of the 20-item STAIC was .89 for the premeasure and .92 for the post measure. This can be considered good and excellent for research purposes, respectively. All items were relatively high correlated with each other and with the total score. No items needed to be rewritten or removed.

Student engagement. To measure student behavioural engagement, behavioural observation through user data has been used, because digital learning environments provide the unique opportunity to observe behaviour through (real-time) data on student interactions with the system (Henrie et al., 2015). The specially designed website on Qualtrics recorded learner responses and time on task to measure student engagement, which is called event tracking. Log data records were obtained by adding a timing question to each page of the online lesson, which is a hidden question that tracks the time a respondent spends on a particular page. For each task, one variable was created using this data: time spent on the task page. Subsequently, these variables were added up to produce the total time on the math tasks. It is possible that a page was open, but students were not active on the page. Although this is not a precise measure of actual time spent on a page, it does provide a meaningful starting point for capturing data on student engagement according to Henrie, Bodily, Larsen, & Graham (2018).

Procedure

The study was conducted mid-June to early-July 2020 and consisted of one session (the online math lesson) that would take about 20 to 45 minutes. However, no maximum time was set as this was a self-paced online lesson. The average time for participants to complete the self-paced study was about 31 minutes. The researcher was not present because of Covid-19 restrictions. Therefore, the teachers were carefully instructed beforehand about the procedure and a digital animated character was present as the research leader in the online lesson to guide the participants through each step.

The study took place in the classroom where each participant individually participated with a Chromebook and headphones. The teachers provided them an anonymous link to the self-paced online learning environment (Qualtrics) and instructed them to access this website and follow the instructions there to complete the study. Also, the participants had to remain silent. Participants were automatically and randomly assigned to one of the three conditions.

After starting the lesson, the participants were informed by the pedagogical agent about the study. They were told that the lesson was designed to see how the online lessons can be improved. They were also instructed to follow the steps of the lesson (pretests, instruction, practice with math tasks and posttest) at their own pace to complete the lesson. If participants were twelve years or older, they were automatically asked for their consent within the online learning environment Qualtrics before they could proceed with the study. Then the demographic survey, the math anxiety pretest, the self-efficacy pretest, and the state anxiety pretest took place. At the end of the study the participants were debriefed about the full purpose of the study.

Data analysis

IBM SPSS Statistics 26 was used to conduct the analyses. First, a One-Way Between Groups ANOVA was conducted to determine if the treatment groups and the control group were equivalent in terms of math anxiety level, and the initial self-efficacy and state anxiety level before learning the lesson. Before conducting the analyses, Shapiro-Wilk and Levene's test statistics were used to test the assumptions of normality and homogeneity of variance. The Shapiro-Wilk statistics indicated that the assumption of normality was violated for one group of math anxiety, two groups of state anxiety, and one group of self-efficacy. Multiple outliers were identified and were removed for both state anxiety and self-efficacy, whereafter only one of the three groups (for both state anxiety and self-efficacy) was still not normally distributed according to the Shapiro-Wilk. However, the departure of normality was small, and this test has a reputation of being over-sensitive (see Tabachnick & Fidell, 2007). Also, the inspection of the skewness and kurtosis indicated that the concerning groups were approximately normal. Overall, this has been considered sufficient. Levene's statistic was non-significant for math anxiety, F (2, 77) = .17, p = .842, and state anxiety, F (2, 73) = .39, p = .682, but significant for self-efficacy, F (2, 74) = 10.01, p < .001, and thus the assumption of homogeneity of variance was not fully supported (not for self-efficacy). Considering this assumption, ANOVA is not sensitive to violations when the samples are moderately to large approximately equal sized (Field, 2013), which applies to the current samples. Overall, it was decided to proceed with the One-Way Between Groups ANOVA, and for self-efficacy Welch statistics were used to deal with homogeneity of variance.

Second, a Mixed Model ANOVA was conducted to examine the effectiveness of the interventions on state-anxiety and self-efficacy, respectively. Again, Shapiro-Wilk, F_{max} and Levene's test statistics were used to test the assumptions of normality and homogeneity of variance. The very same choices as described above were made. It was decided to proceed with the mixed model ANOVA.

Third, a One-Way Between Groups ANOVA was conducted to investigate whether there is a difference in engagement and task performance between the groups. Inspection of the skewness, kurtosis and Shapiro-Wilk statistics indicated that the assumption of normality was supported for each of the three conditions of task performance but was violated for engagement. Multiple outliers were identified and were removed, the assumption of normality was now supported for each of the three conditions of engagement. Removal is justified, because the researcher had observed that some participants took a break from the online lesson, which resulted in a high duration time of their participation. Levene's statistic was non-significant for both engagement, F (2, 69) = 2.25, p = .113, and task performance, F (2, 77) = 2.21, p = .117, and thus the assumption of homogeneity of variance was supported.

Fourth, a Spearman's Rho Correlations, a mediation analysis using PROCESS (model 4; Hayes, 2013), and a serial multiple mediator model using PROCESS (model 6; Hayes, 2013) were conducted to examine how math anxiety, state anxiety, self-efficacy, engagement, and task performance relate to each other. Participant math anxiety, the total performance scores on the mask tasks, engagement during the math tasks, and self-efficacy and state anxiety after practicing the math tasks of the total group of participants were used in the analyses of this section.

To assess the size and direction of the linear relationships of the aforementioned variables, bivariate correlation coefficients were calculated. Inspection of the scatterplots indicated that the assumption of linearity and homoscedasticity was met. However, the assumption of normality was violated, which is partly due to outliers. Therefore, Spearman's rho was used as non-parametric alternative to a bivariate Pearson's product-moment correlation coefficient (Field, 2013). Moreover, bootstrapping was performed with 5000 samples to compute robust confidence intervals for which the distribution is not a concern.

To further analyse the relationships found in the previous section, mediation (path) analyses were conducted to examine if the found relations involve mediation of another variable. Inspection of the scatterplots indicated that the assumption of linearity was met. However, the assumption of normality was violated. Multiple outliers were identified for the variables state anxiety and self-efficacy, which were removed because regression is sensitive to outliers. Hereafter, the assumption of normality was met, and it has led to minimal or no changes in the results. Moreover, bootstrapping was performed with 5000 samples, which is robust to the sources of bias and is a preferred method to interpret the indirect effects of the mediation models (Efron & Tibshirani, 1993; Field, 2013). These choices apply to all mediation analyses in this article.

Results

Group equivalence

First, a One-Way Between Groups ANOVA and post hoc analyses with Tukey's HSD (using an α of .05) were conducted to determine if the treatment groups and the control group were equivalent in terms of math anxiety level, and the initial self-efficacy and state anxiety level before learning the lesson (dependent variables). The analyses confirmed that the three groups did not differ significantly on math anxiety level ($M_{\text{control group}}$ = 49.67, *SD* = 10.24, $M_{\text{problem group}}$ = 48.56, *SD* = 8.69, $M_{\text{emotion group}}$ = 52.15, *SD* = 9.92, *F* (2, 77) = .97, *p* = .386, η^2 = .02). Likewise, the same analyses showed no significant difference on initial state anxiety ($M_{\text{control group}}$ = 28.42, *SD* = 4.64, $M_{\text{problem group}}$ = 27.56, *SD* = 4.12, $M_{\text{emotion group}}$ = 28.36, *SD* = 3.87, *F* (2, 73) = .34, *p* = .712, η^2 = .05) and initial self-efficacy with Welch statistics ($M_{\text{control group}}$ = 6.57, *SD* = 2.58, $M_{\text{problem group}}$ = 7.18, *SD* = 1.07, $M_{\text{emotion group}}$ = 6.60, *SD* = 1.57, *F* (2, 46.53) = 1.47, *p* = .241. To conclude, all three groups were equivalent in their initial measures for math anxiety, initial self-efficacy, and initial state anxiety.

Did the inclusion of anxiety-reducing strategies reduce state anxiety?

The major prediction of this study is that inclusion of anxiety-reducing strategies in an online math lesson would reduce learners' level of state anxiety. A 3 (Condition: control vs. problem vs. emotion) x 2 (Time: premeasure vs. post measure) mixed model ANOVA was used to investigate the impact of adding anxiety-reducing strategies on state anxiety after learning. No significant main effect for time was found, *F* (1, 72) = 2.87, *p* = .095, partial η^2 = .04 with state anxiety levels after the lesson (*M* = 28.76, *SD* = 5.08) being not significantly lower than before the lesson (*M* = 28.11, *SD* = 4.20), as shown in Table 2. Also, no significant main effect for condition was found, *F* (2, 72) 0.56, *p* = .573, partial η^2 = .02. Finally, no significant interaction between time and condition was reported, *F* (2, 72) = 0.35, *p* = .706, partial η^2 = .01. The anxiety levels of all groups are relatively moderate and are a little lower compared to the Dutch norm groups consisting of a girl group, *M* = 30.40, *SD* = 4.63, *N* = 323, and a boy group, *M* = 29.70, *SD* = 4.81, *N* = 320, for 7 to 12-year-olds (Bakker et al., 1989). However, it should be noted that the norm groups are outdated (COTAN, 1992), but these are not further used, because state anxiety is measured as a continuous construct. To take a closer look at the effects, math anxiety (low vs. medium vs. high) was added as an extra factor to the analysis described above. However, no significant effects were identified either.

Table 2

Descriptive Statistics for All Measures by Condition

		Control group		Problem group		Emotion group		Total	
Measure	Range of scores	*M*	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Math anxiety	37–73	49.67	10.24	48.56	8.69	52.15	9.92	50.10	9.63
State anxiety									
Premeasure	20–39	28.42	4.64	27.56	4.12	28.42	3.94	28.11	4.20
Post measure	20–40	28.92	5.17	27.93	5.48	29.54	4.55	28.76	5.08
Self-efficacy									
Premeasure	0–10	6.57	2.58	7.18	1.07	6.72	1.46	6.81	1.85
Post measure	2–10	7.33	2.18	7.40	1.11	6.90	1.58	7.21	1.69
Engagement	211.92–1526.82	645.63	228.91	561.40	264.61	694.21	349.48	634.41	284.53
Task performance	1–20	10.56	4.37	9.00	3.51	9.19	4.90	9.59	4.29

Note. The potential minimum and maximum for math anxiety is 37–80, for both state anxiety measures 20-60, for both self-efficacy measures 0–10, for engagement the boundaries were set on 180–1800, and for task performance 0–22. For all measures applies: a higher score indicates a higher level of math anxiety, state anxiety, self-efficacy, engagement, or task performance.

Did the inclusion of anxiety-reducing strategies enhance perceived self-efficacy?

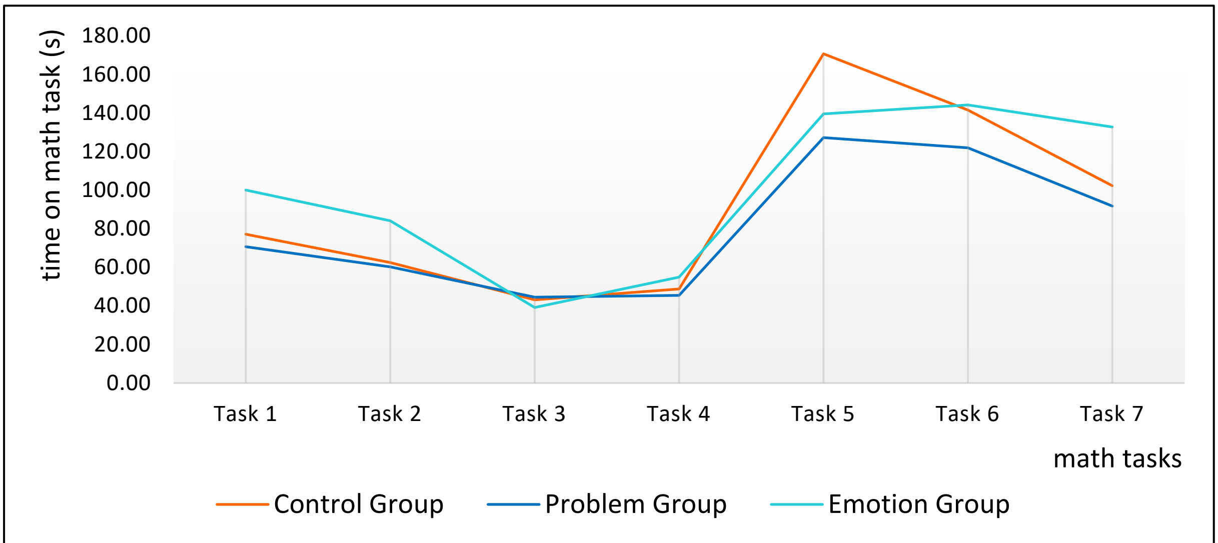
The second prediction of this study is that adding anxiety-reducing strategies to an online math lesson would increase learners' self-reported self-efficacy after learning. Again, a 3 x 2 mixed model ANOVA was used to investigate the impact of adding anxiety-reducing strategies on perceived self-efficacy after learning. A significant main effect for time (pre vs. post) was found, F (1, 73) = 4.98, p = .029, partial η^2 = .06 with self-efficacy levels after the lesson (M = 7.21, SD = 1.70) being significantly higher than before the lesson (M = 6.81, SD = 1.85). No significant main effect for condition was found, F (2, 73) = .56, p = .574, partial η^2 = .02. No significant interaction between time and condition was reported, F (2, 73) = 1.21, p = .304, partial η^2 = .03. Examination of the means indicated that although there was a large change in self-efficacy levels of participants of the control condition before the lesson (M = 6.57, SD = 2.59) compared to after the lesson (M = 7.33, SD = 2.18), the lesson did not produce a large change in the self-efficacy levels of participants of the problem group (pre-test M = 7.18, SD = 1.07; post-test M = 7.40, SD = 1.11) and the emotion group (pre-test M = 6.72, SD = 1.46; post-test M = 6.90, SD = 1.58), as shown in Table 2. Also, no effects were identified either when math anxiety (low vs. medium vs. high) was added as an extra factor.

Did the inclusion of anxiety-reducing strategies enhance student engagement?

The third prediction of this study is that adding anxiety-reducing strategies to an online math lesson would increase learners' engagement during learning. A One-Way Between Groups ANOVA was used to investigate the impact that the anxiety-reducing strategies had on the engagement of students during the math tasks. The ANOVA was statistically not significant, indicating that students' engagement (total time spent on the math task pages) during the math tasks was not influenced by the anxiety-reducing strategies, F (2, 69) = 1.31, p = .278, η^2 = .04. The emotion group showed the highest average engagement score (M = 694.21, SD = 349.48) followed by the control group (M = 645.63, SD = 228.91), with at last the problem group (M = 561.40, SD = 264.61), as shown in Table 2. Also, no clear trends were found in engagement scores during the tasks, after each intervention, and between conditions (see Figure 6).

Figure 6.

Engagement scores (total time spent on the math tasks in seconds) by condition.



Note. Between the tasks all participants were shown their intermediate score and for the experimental groups (problem and emotion) the intervention (coping messages) took place. Tasks 1, 2, 3 and 4 are about estimating measures and tasks 5, 6, and 7 about converting units of measurements.

Did the inclusion of anxiety-reducing strategies enhance task performance?

The fourth prediction of this study is that adding anxiety-reducing strategies to an online math lesson would increase learners' task performance. A One-Way Between Groups ANOVA was used to investigate the impact that the anxiety-reducing strategies had on the total scores of students on the math tasks. The ANOVA was statistically not significant, indicating that students' task performance on the math tasks was not influenced by the anxiety-reducing strategies, F (2, 77) = 1.02, p = .354, η^2 = .03, as shown in Table 2.

How did math anxiety, state anxiety, self-efficacy, engagement, and task performance relate to each other?

Another goal was to examine the relations among the variables included in the study for the total group of participants. To assess the size and direction of the linear relationships of the variables, bivariate correlation coefficients were calculated. Table 3 presents the Spearman's rho correlations among the aforementioned variables with N = 72, two-tailed p-values and bootstrapped 95% confidence intervals. Spearman's rho indicated a small positive correlation between math anxiety and state anxiety, r_s = .47, p < .001. A moderate negative correlation was found between math anxiety and self-efficacy, r_s = -.57, p < .001. There was a small negative correlation between math anxiety and task performance, r_s = -.35, p = .002. Engagement had no significant correlations with math anxiety, r_s = -.03, p = .798, state anxiety, r_s = .06, p = .593, self-efficacy, r_s = .04, p = .755, and task performance, r_s = .16, p = .178. A small negative correlation was found between state anxiety and self-efficacy, r_s = -.44, p < .001. There was a small negative correlation between state anxiety and task performance, r_s = -.28, p = .016. Finally, a small positive correlation was found between self-efficacy and task performance, r_s = .43, p < .001.

Table 3

Spearman's rho correlations Between Math Anxiety, State Anxiety, Self-Efficacy, Engagement, and Task Performance

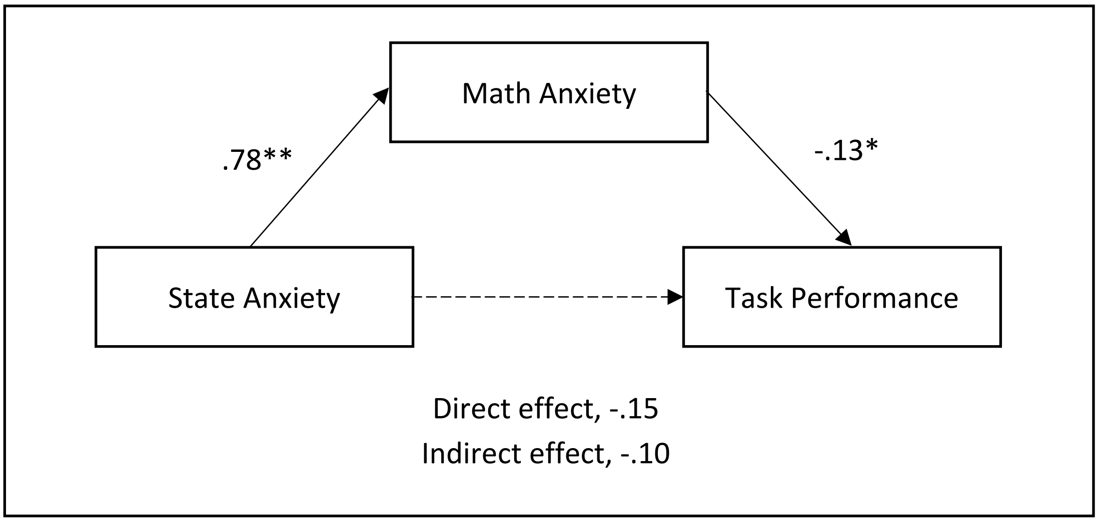
Measure	1	2	3	4	5
1. Math anxiety	–				
2. State anxiety	.47***	–			
	[.268, .635]				
3. Self-efficacy	-.57***	-.44***	–		
	[-.725, -.375]	[-.632, -.211]			
4. Engagement	-.03	.06	.04	–	
	[-.272, .221]	[-.197, .314]	[-.214, .267]		
5. Task performance	-.35**	-.28*	.43***	.16	–
	[-.539, -.144]	[-.513, -.021]	[.200, .623]	[-.115, .419]	

*p < .05. **p < .01. ***p < .001, two-tailed. BCa bootstrap 95% CIs are reported in brackets.

To further analyse the relationships found in the previous section, path analyses were conducted to examine if the found relations involve mediation of another variable. As shown in Figure 7, math anxiety mediated the relation between state anxiety and task performance. In step 1 of the mediation model, the regression of state anxiety on task performance, ignoring the mediator, was significant, $b = -.25$, $t(76) = -2.76$, $p = .007$. Step 2 showed that the regression of state anxiety on the mediator (math anxiety) was also significant, $b = .78$, $t(76) = 4.25$, $p < .001$. Step 3 of the mediation process showed that the regression of the mediator (math anxiety) on task performance, controlling for state anxiety, was significant, $b = -.13$, $t(76) = -2.24$, $p = .028$. Step 4 of the analysis revealed that, controlling for the mediator (math anxiety), state anxiety was not a significant predictor of task performance, $b = -.15$, $t(76) = -1.55$, $p = .125$. In other words, there was a significant indirect effect of state anxiety on task performance through math anxiety, with unstandardised bootstrapped (5000 samples) coefficients $b = -.10$, SE = .04, BCa 95% CI [-.186, -.020].

Figure 7

Path model for the relationship between state anxiety and task performance as mediated by math anxiety.

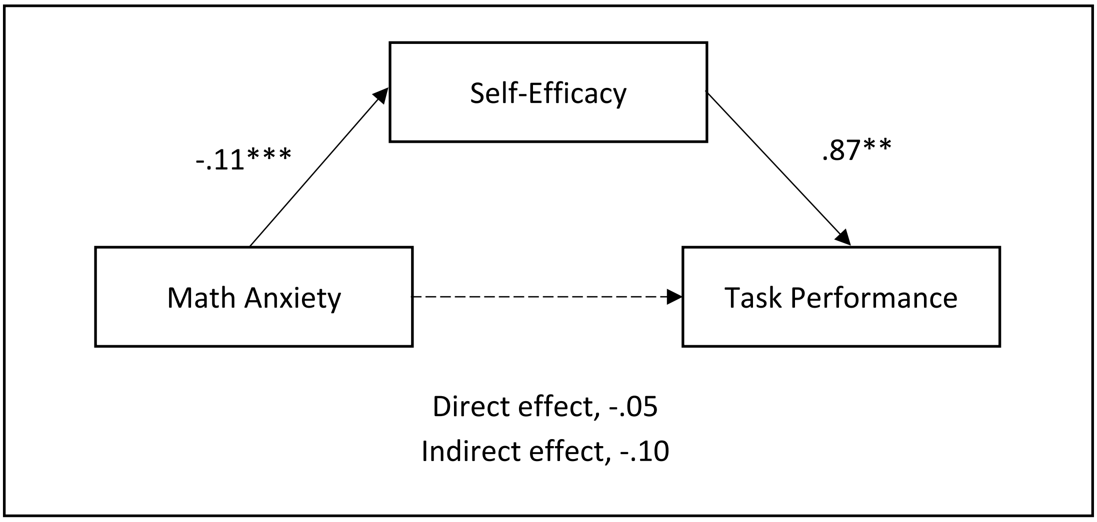


Note. Unstandardised regression coefficients for the relationship between math anxiety and task performance as mediated by self-efficacy. Solid lines represent significant relationships. Dashed lines represent non-significant relationships.
*$p < .05$. **$p < .01$. ***$p < .001$.

As shown in Figure 8, self-efficacy mediated the relation between math anxiety and task performance. In step 1 of the mediation model, the regression of math anxiety on task performance, ignoring the mediator, was significant, $b = -.14$, $t(79) = -2.87$, $p = .005$. Step 2 showed that the regression of math anxiety on the mediator (self-efficacy) was also significant, $b = -.11$, $t(79) = -6.27$, $p < .001$. Step 3 of the mediation process showed that the regression of the mediator (self-efficacy) on task performance, controlling for math anxiety, was significant, $b = .87$, $t(79) = 2.83$, $p = .006$. Step 4 of the analysis revealed that, controlling for the mediator (self-efficacy), math anxiety was not a significant predictor of task performance, $b = -.05$, $t(79) = -.79$, $p = .430$. In other words, there was a significant indirect effect of math anxiety on task performance through self-efficacy, with unstandardised bootstrapped (5000 samples) coefficients $b = -.10$, SE = .03, BCa 95% CI [-.160, -.030].

Figure 8

Path model of the relationship between math anxiety and task performance as mediated by self-efficacy.



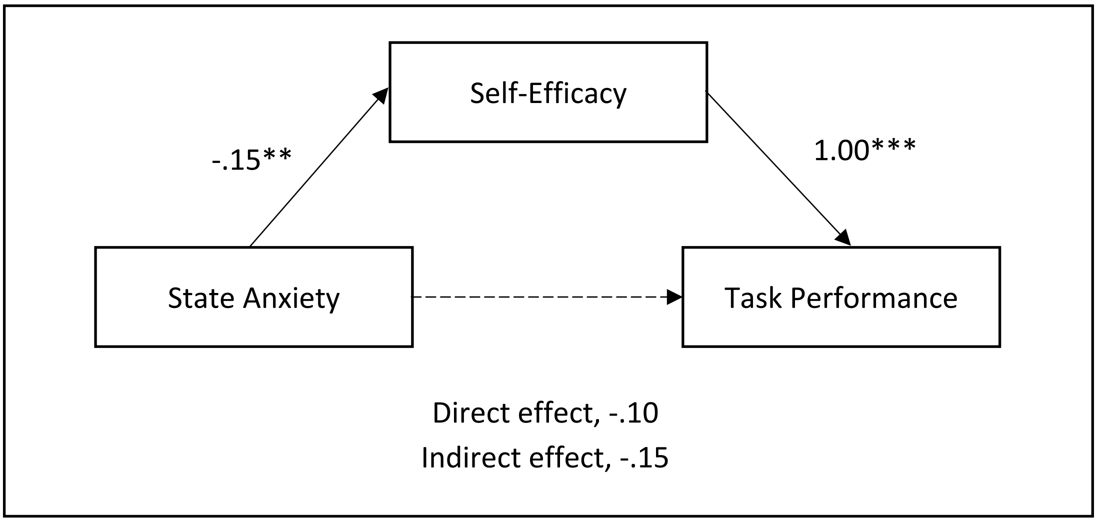
Note. Unstandardised regression coefficients for the relationship between math anxiety and task performance as mediated by self-efficacy. Solid lines represent significant relationships. Dashed lines represent non-significant relationships.

**$p < .01$. ***$p < .001$.

As shown in Figure 9, self-efficacy mediated the relation between state anxiety and task performance. In step 1 of the mediation model, the regression of state anxiety on task performance, ignoring the mediator, was significant, $b = -.25$, $t(76) = -2.76$, $p = .007$. Step 2 showed that the regression of state anxiety on the mediator (self-efficacy) was also significant, $b = -.15$, $t(76) = -4.33$, $p < .001$. Step 3 of the mediation process showed that the regression of the mediator (self-efficacy) on task performance, controlling for state anxiety, was significant, $b = 1.00$, $t(76) = 3.51$, $p = .001$. Step 4 of the analysis revealed that, controlling for the mediator (self-efficacy), state anxiety was not a significant predictor of task performance, $b = -.10$, $t(79) = -1.07$, $p = .287$. In other words, there was a significant indirect effect of state anxiety on task performance through self-efficacy, with unstandardised bootstrapped (5000 samples) coefficients $b = -.15$, SE = .01, BCa 95% CI [-.258, -.061].

Figure 9

Path model for the relationship between state anxiety and task performance as mediated by self-efficacy



Note. Unstandardised regression coefficients for the relationship between state anxiety and task performance as mediated by self-efficacy. Solid lines represent significant relationships. Dashed lines represent non-significant relationships.

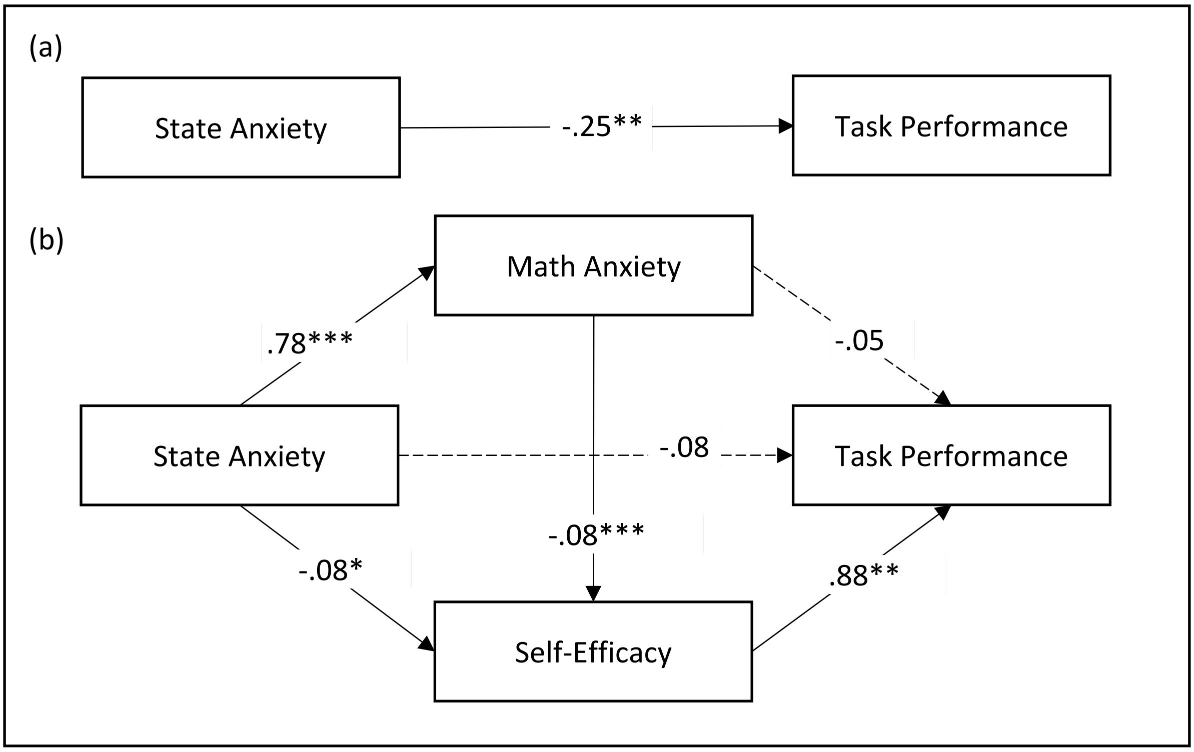
$^{**}p < .01$. $^{***}p < .001$.

To examine the previous found pathways more closely, a multiple mediator model was conducted, with state anxiety as a predicting variable, math anxiety and self-efficacy as two mediators, and task performance as an outcome variable (PROCESS macro for SPSS Model 6; Hayes, 2013). As predicted, there was a significant total effect (without the two mediators) from state anxiety to task performance, $b = -.25$, $t(76) = -2.76$, $p = .007$. This direct effect is shown in Figure 10a. Figure 10b shows the relations when math anxiety and self-efficacy are added as mediators. First, when math anxiety and self-efficacy were added as mediators, the direct effect from state anxiety to task performance became non-significant, $b = -.08$, $t(76) = -.81$, $p = .422$. This supports the mediating role of math anxiety and self-efficacy in the relationship between state anxiety and task performance.

As predicted, the sequential indirect effect of the pathway of *state anxiety* → *math anxiety* → *self-efficacy* → *task performance* was significant. The bootstrapped (5000 samples) unstandardised indirect effect was $b = -.06$, SE = .03, BCa 95% CI [-.113, -.015]. Specifically, state anxiety significantly predicted math anxiety, $b = .78$, $t(76) = 4.25$, $p < .001$, which significantly predicted self-efficacy, $b = -.08$, $t(76) = -2.43$, $p = .018$, which in turn significantly predicted task performance, $b = .88$, $t(76) = -2.75$, $p = .008$. The indirect pathway of *state anxiety* → *math anxiety* → *task performance* was not significant, with unstandardised bootstrapped coefficients $b = -.04$, SE = .04, BCa 95% CI [-.121, .029]. Although state anxiety significantly predicted math anxiety, math anxiety did not significantly predict task performance when self-efficacy was in the model, $b = -.05$, $t(76) = -.87$, $p = .390$. The indirect pathway of *state anxiety* → *self-efficacy* → *task performance* was significant, with unstandardised bootstrapped coefficients $b = -.07$, SE = .04, BCa 95% CI [-.176, -.004], indicating that self-efficacy uniquely mediated between state anxiety and task performance.

Figure 10

Multiple mediator model



Note. (a) Direct effect from state anxiety to task performance with no mediators. (b) Sequential mediation analysis (with math anxiety and self-efficacy as sequential mediators) of the relationships between state anxiety and task performance. Unstandardised regression coefficients. Solid lines represent significant relationships. Dashed lines represent non-significant relationships.
*p < .05. **p < .01. ***p < .001.

Discussion

The purpose of the present study was (a) to examine the effects of anxiety-reducing strategies on state anxiety, self-efficacy, student engagement, and task performance within the context of an online math lesson for primary school children of Grade 5, and (b) to examine the relationships between these constructs, including math anxiety. To do so, three groups (two experimental and one control group) were formed that had a similar distribution of children with low, medium, and high math anxiety levels. This adds value to the study, as it enables to rule out the possibility that any differences between the groups were due to math anxiety (Suárez-Pellicioni, Núñez-Peña, & Colomé, 2013). All groups had to make the same online math lesson about the metric system. For the experimental groups, this lesson was enhanced with problem-focused coping messages (problem group) and emotion-focused coping messages (emotion group).

Main findings

First, it was theorised that incorporating anxiety-reducing strategies to an online math lesson would result in decreased state anxiety (Huang & Mayer, 2016; Im, 2012; Shen, 2009), increased self-efficacy (Friedel et al., 2007; Huang & Mayer, 2019), increased student engagement (Huang & Mayer, 2016; Meyer & Turner, 2007; Patrick, Turner, Meyer, & Midgley, 2003), and increased task performance (Ader & Erktin, 2012; Huang & Mayer, 2019). However, the anxiety-reducing coping messages did not result in any significant differences between the treatment groups and the control group on the outcome measures.

The results contradict previous studies that show the effectiveness of addressing the worry component (e.g. Park, Ramirez, & Beilock, 2014) and the emotionality component (e.g. Huang & Mayer, 2016; Im, 2012) of anxiety. Several possible explanations might account for these findings. One explanation might be that although the coping messages were adapted to a high score or a low score on the task, the messages were not further personalised. Both emotion- and problem-focused coping messages may be more effective when they are designed in an adaptive way. This may also be a solution for increasing self-efficacy and student engagement. For instance, different types of messages tailored to the already measured level of anxiety (low, medium, high) could better meet the affective needs of students and therefore be more effective. Student with high anxiety are likely to need more emotional support to relieve their anxiety than students with low anxiety (Huang, Huang, & Wu, 2014).

Another possible explanation is that there is a mismatch between the target population and the pedagogical agent or the coping messages. A large variety of messages could be thought of, of which only a small selection has been made for this study. The messages may also be sent by a different type of agent and with a different tone. Each of these adjustments can produce different results and could be tested in future studies to find the best match for this target population.

Finally, the type of math tasks could also have had an influence on the results. These tasks turned out to be difficult and especially the first part of the tasks was largely based on estimation of measures of the metric system. Because these assignments were less familiar to the students, students may have behaved differently in terms of anxiety, self-efficacy, and engagement. As a result, the intervention may have been less effective. The tasks were also divided into two parts: estimating measures and converting metric units. This has made it more difficult to tailor the feedback and coping messages specific on the tasks. An unambiguous subject is therefore recommended for future studies.

Second, it was hypothesised that there are intertwined relations among the variables math anxiety, state anxiety, self-efficacy, student engagement and task performance. The results support hypothesis 5 largely. For the total group of participants, correlations were found between all variables, except for student engagement. As expected based on previous studies (Ashcraft & Moore, 2009; Luttenberger et al., 2018; OECD, 2013; Ramirez et al., 2018; Wang et al., 2015), the current study found negative correlations between math anxiety and task performance, and between state anxiety and task performance. Furthermore, the results show a positive correlation between math anxiety and state anxiety, which support previous studies (Endler & Kocovski, 2001; Miller & Bichsel, 2004; Paechter et al., 2017). Also, as expected (Betz and Hackett, 1983, Cooper & Robinson, 1991; Hackett, 1985, Lee, 2009; Lent et al., 1991; Scholz et al., 2002), negative correlations were shown between math anxiety and self-efficacy, and between state anxiety and self-efficacy. Finally, a positive correlation was found between self-efficacy and task performance, in line with previous research (Bandura, 1986; Collins, 1982; Lee, 2009; Spence & Usher, 2007). In general, these findings support the idea that students' positive emotions (in this case low anxiety and high self-efficacy) are associated with better math performance.

The absence of correlations with student engagement was not in line with the expectation based on previous research (Assunção et al., 2020; Coetzee & Oosthuizen, 2012;

Elmore & Huebner, 2010; Fredricks et al., 2004; Gilardi & Guglielmetti, 2011; Keller & Suzuki, 2004; Maloney, et al, 2010; Passolunghi, 2011; Reschly & Christenson, 2012; Reyna & Brainerd, 2007; Spence & Usher, 2007). A possible explanation is that in the current study the total time on the math task pages was used to measure student engagement. Although this is a good starting point as an indication of engagement (Henrie et al., 2015), such a computer-recorded frequency measure may not provide an adequate understanding of the quality of engagement (Appleton et al., 2008). In addition to on-task behaviour (time on task), measuring off-task behaviour (such as visiting non-learning websites for too long) could provide a more complete picture of engagement. This can be done with more advanced user activity measurement techniques or qualitative methods such as direct, video, or screen capture observations of student's behaviour during learning (Bluemink & Järvelä, 2004; Figg & Jamani, 2011; Henrie et al., 2015).

Further examination of the relationships showed that math anxiety was a mediator between state anxiety and task performance. The higher the state anxiety, the higher the math anxiety, and the lower the performance on the math tasks. This result indicates that a high level of math anxiety strengthens the negative relationship between state anxiety and task performance. This confirms the idea that the levels of state anxiety depend on both the person (trait anxiety, which is in this case math anxiety) and the stressful situation (Endler & Kocovski, 2001). As expected, the results show that math anxious persons experience more state anxiety in math-related situations (Paechter et al., 2017). This mediation demonstrates that math anxiety is an important and problematic concept that must be tackled to improve wellbeing and performance of students.

Furthermore, self-efficacy was found to be a mediator of the relationships between math anxiety and task performance and between state anxiety and task performance. The lower the anxiety, the higher the self-efficacy, and the higher the performance on the math tasks. This result suggests that improvement of self-efficacy improves task performance, and that low levels of anxiety stimulate this improvement. The current results are substantially supported by results of early studies to recent ones which report that self-efficacy is an important mediator between anxiety and performance for both state anxiety (Bandura, 1997; Burr & LeFevre, 2020; Chen, Gully, Whiteman, & Kilcullen, 2000; Chung, Ehrhart, Holcombe Ehrhart, Hattrup, & Solamon, 2010) and math anxiety (Meece, Wigfield, & Eccles, 1990; Pajares & Kranzler, 1995; Pajares & Miller, 1994; Randhawa, Beamer, and Lundberg, 1993). In specific, similar to the current study, Huang and Mayer (2019) have shown a mediating role of self-efficacy between task anxiety and learning outcome performance in the context of an online statistics lesson. These results clearly demonstrate the important role of self-efficacy in predicting math performance, both in an online and offline context. To improve math performance, educators should focus on improving self-efficacy beliefs in addition to reducing math anxiety.

Finally, to confirm this idea, a serial path analysis for multiple mediators was conducted. It was found that math anxiety and self-efficacy in sequence mediated the relationship between state anxiety and task performance. The lower the state anxiety, the lower the math anxiety, the higher the self-efficacy, and the higher the performance on the math tasks. This result demonstrates that the relationship between state anxiety (predictor) and performance (outcome) can be explained by math anxiety and self-efficacy. By reducing math anxiety and enhancing self-efficacy, the effect of state anxiety on performance will be reduced, which means performance will be improved. Although other studies have also found a sequential mediating role of math anxiety and self-efficacy between other variables (e.g. teacher-student relationship; Zhou et al., 2020; or condition; Huang & Mayer, 2019) and math performance, no previous studies could be found that reported the same mediation for state anxiety. This makes the current finding noteworthy.

Overall, the present study demonstrated intertwined and reciprocal relationships among the variables math anxiety, state anxiety, self-efficacy, and task performance, with math anxiety and self-efficacy as sequential mediators of the impact of state anxiety on task performance.

Theoretical implications

The present study responds to the call for more empirical evidence on the effectiveness of anxiety-reducing strategies in mathematics education (see for a review Luttenberger et al., 2018). In particular, this study contributes to the limited research on coping messages in computer-based environments (Im, 2012, Shen, 2009, Wei, 2010). This was done through the use of quantitative data on the impact of problem- and emotion-focused coping messages within an online math lesson, whereas most prior studies used qualitative data on the impact of interventions (Shen, 2009). These coping messages were provided by an animated pedagogical agent, given its social nature (Shen, 2009). This is in line with Dung and Deng's (2006) call for attention to children's social desires in e-learning design. The current study targets 10- and 11-year-old primary school students (Grade 5), a population that few studies have investigated (e.g. Ng & Lee, 2015). However, early adolescence is a key time to investigate math anxiety and to implement interventions (Lukowski et al., 2019), in order to prevent a peak in high school years (Hembree, 1990). From a developmental perspective, these are crucial years in which children learn to work more independently and gain insight into their abilities (Bolmeijer, 2016). Anxiety plays a powerful role in the math experience and in math learning and performance, that should not be overlooked (Maloney & Beilock, 2012). Attention to wellbeing can help students build self-efficacy and reduce anxiety.

Moreover, this study has followed the suggestion of prior research to measure both trait anxiety (which is in the current study math anxiety) and state anxiety, as state anxiety is influenced by both trait anxiety and situational stress (Huang & Mayer, 2016). Because of the absence of state and trait anxiety measures in previous studies, it was difficult to determine whether observed performance declines were due to trait anxiety or increased state anxiety levels, according to Ng and Lee (2015). By contrast, the present study was able to determine these relationships. In fact, as requested, the current study has tested several mediators, which made it possible to identify the directions of the relationships between the variables involved (Justicia-Galiano et al., 2017).

Thus, the current study’s findings have made an important contribution to our understanding of the relationship between anxiety and math performance, by including the variables math anxiety, state anxiety, self-efficacy, student engagement, and task performance into the study. It is now known that these variables, apart from student engagement, are interrelated. Also, it is now known that math anxiety and self-efficacy are sequential mediators between the relationship of state anxiety and math task performance. This indicates that by reducing math anxiety and enhancing self-efficacy, the effect of state anxiety on performance will be reduced, and thus performance will be improved. This finding is unique and contributes to the limited research on the impact of trait and state anxiety on performance and motivational outcomes (Huang & Mayer, 2016; Ng & Lee, 2015). This also contributes to a more complete picture of math anxiety as a complex and multidimensional phenomenon (Lukowski et al., 2019; Luttenberger et al., 2018; Ramirez et al., 2018).

Another strength is that the variables were specifically rather than globally assessed and as closely as possible to the math performance tasks. For instance, log data was used to measure student engagement. Such research in learning analytics of technology mediated learning experiences is relatively new (Henrie et al., 2018). Also, state-like variables are seen as more proximal predictors of performance than trait-like variables, as they give insight into math anxiety, self-efficacy and engagement in closer to real-time (Bandura, 1986; Chen et al., 2000; Lukowski et al., 2019).

Practical implications

This study has confirmed that math anxiety is a serious problem which has to be tackled. 18% of the students suffered from a high degree of math anxiety, which means that each class of 27 students contained approximately 5 students with severe anxiety. As stated above, this number can peak to 25% during high school years (see Ramirez et al., 2018; Ruijssenaars, Van Luit, & Van Lieshout, 2016). Given that mathematics is an important prerequisite for participation in society, math anxiety can have severe and lifelong consequences (Luttenberger et al., 2018). The findings of the current study underscore the importance of lowering math anxiety and enhancing self-efficacy to improve math performance. This insight can help to develop adequate interventions.

These findings have immediate implications for other researchers, designers, and teachers to further investigate interventions and to increase both wellbeing and performance of students in math. Interventions should be developed to reduce anxiety and to build self-efficacy when students learn mathematical content in an online learning environment. It is advisable to address math anxiety in the long term because math anxiety both as a trait and as a mediator turned out to have a significant impact on math performance. A structural approach to math anxiety in education could counteract the downward trend in students' mathematical performance in the Netherlands.

Today, a good technical basis has been laid for e-learning systems which are already used extensively all over the world. Now it is urgently time, and there is room, to focus the design on the psychological aspects of e-learning. Especially in an online lesson that offers minimal personal support, learning mathematics can involve a high degree of anxiety and a low degree of self-efficacy (Huang & Mayer, 2019). However, technology-based learning environments have great potential for delivering personal support, which makes it ideal to explore and integrate the best strategies (Huang & Mayer, 2019). Furthermore, interventions in online learning environments are relatively easy to implement in the classroom given the increasing presence of digital devices in primary schools.

Limitations and future directions

Besides its strengths, the current study has some limitations. First, due to the Covid-19 pandemic, it was not possible for the researcher to be physically present during the study. The researcher could only follow the students online from a distance and had no control over the progress and behaviour of the students during the online lesson. Although previous studies suggested to study interventions on math anxiety in real classroom settings (Luttenberger et al., 2018), it would have been desirable to examine this study's interventions in a more controlled setting first.

Second, the adaptivity of the pedagogical agent was limited, as the coping messages were only adapted to a high or low math task score. Further customised messages, for instance adapting the content and frequency of the messages to students' math anxiety levels, could meet students' affective needs and thus could be more effective. This can be achieved with advanced technology, such as using sensory-based technology to measure physiological responses. This objective measurement in combination with the subjective self-reports, gives a more complete picture about learner experiences and affective states. However, due to limited time and resources and hygiene issues because of the Covid-19 pandemic, it was not possible to conduct this type of research. Therefore, it is advisable for future studies to use this combination to get a more holistic picture.

Third, the anxiety-reducing coping messages of this study were implemented in only one online lesson. Although these interventions targeted state-like variables (state anxiety, self-efficacy, and engagement), the intervention time is relatively short to examine changes in psychological constructs (Wei, 2010). Some other studies have provided their interventions much longer, such as intensive 6- or 8-week programmes (Jansen et al., 2013; Supekar, Iuculano, Chen & Menon, 2015), or systematic treatments (Hembree, 1990), with more clearly visible effects. Longer treatment sessions of problem-focused and emotion-focused coping messages may reveal the expected effects on anxiety and self-efficacy.

Another implication for future research that may reveal effects is simultaneous examination of problem- and emotion-focused coping messages, rather than separate examination as in the current study, because problem- and emotion-focused coping can also facilitate one another (Carver et al., 1989; Lazarus, 2006). Effective problem-focused coping reduces the threat, as well as the distress caused by that threat. Effective emotion-focused coping reduces negative stress, making it possible to think more calmly about the problem, which may well lead to better problem-focused coping (Lazarus, 2006). Such an integrated approach may simultaneously address the two sources of anxiety (worry and emotionality) and may therefore be effective.

In addition, effects may reveal as well when future studies specifically focus on students with high math (trait) anxiety when testing the effectiveness of the anxiety-reducing strategies. Accordingly, coping efforts may be most helpful when there is a high level of stressors that is often experienced by students with high math anxiety (Moos & Holahan, 2003). This was the case for Wei (2010) who also did not find the impact of math-anxiety coping messages on math anxiety and learning, but did find significantly lower anxiety in high-anxious students after receiving the coping messages than their peers in the non-treatment group.

Also, interventions could be based on other promising theories to reduce anxiety and improve self-efficacy. For instance, Huang and Mayer (2019) developed four intervention strategies based on Bandura's four sources of self-efficacy (vicarious experience, mastery experience, social persuasion, and affective states; Bandura, 1997). Their strategies resulted in improvements of self-efficacy, anxiety, and learning outcomes, which showed the utility of Bandura's approach. As self-efficacy was found to be an important mediator of the relation between anxiety and performance, this would be a promising approach for future research. Finally, longitudinal designs are needed to examine the best interventions to prevent math anxiety at an early age (Luttenberger et al., 2018).

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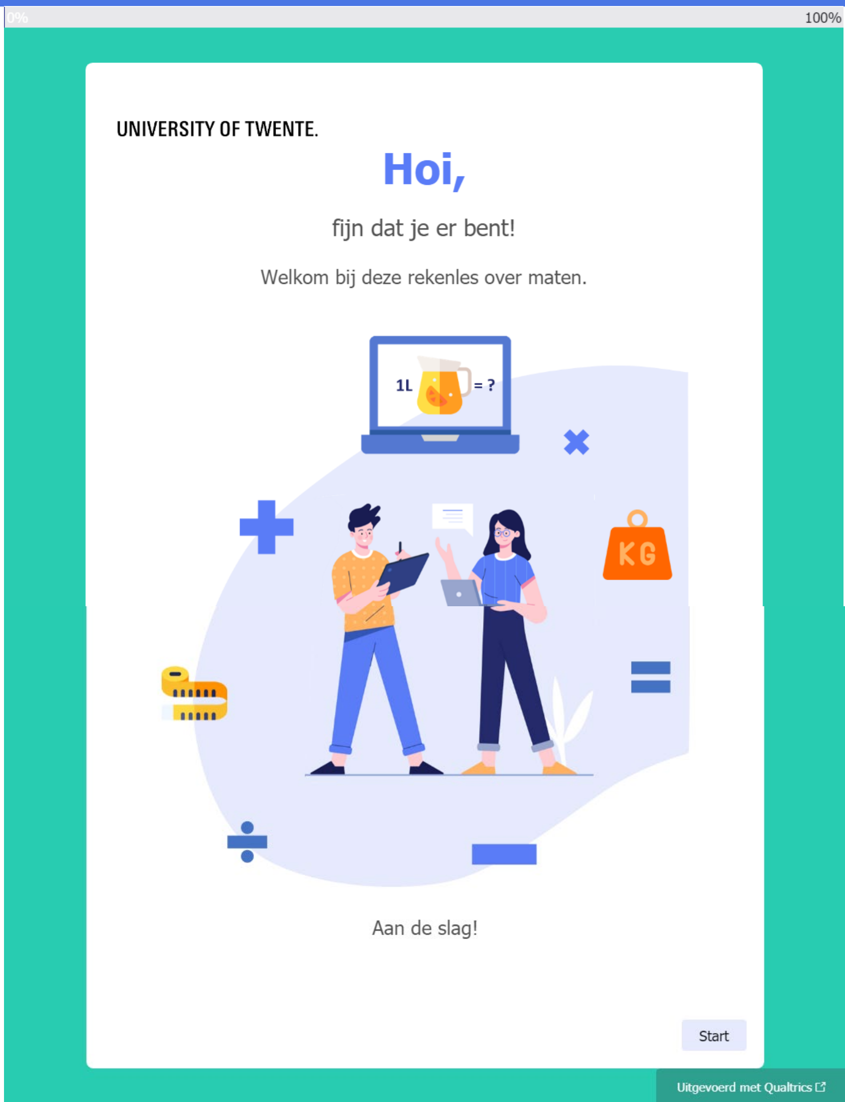
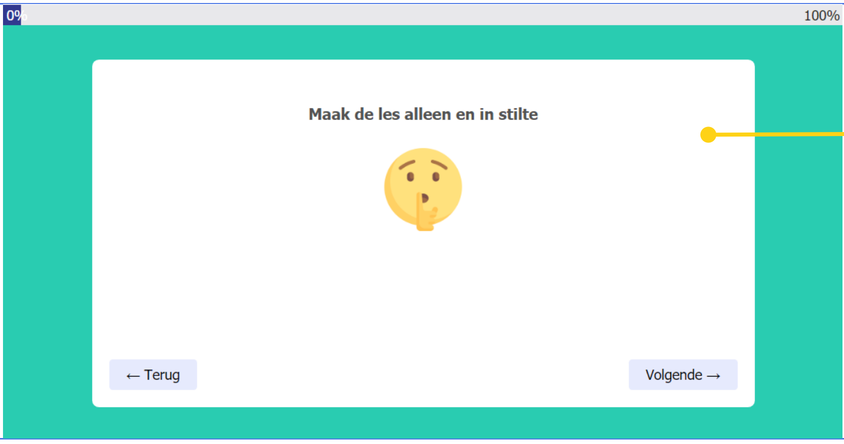
Appendix A

User Flow

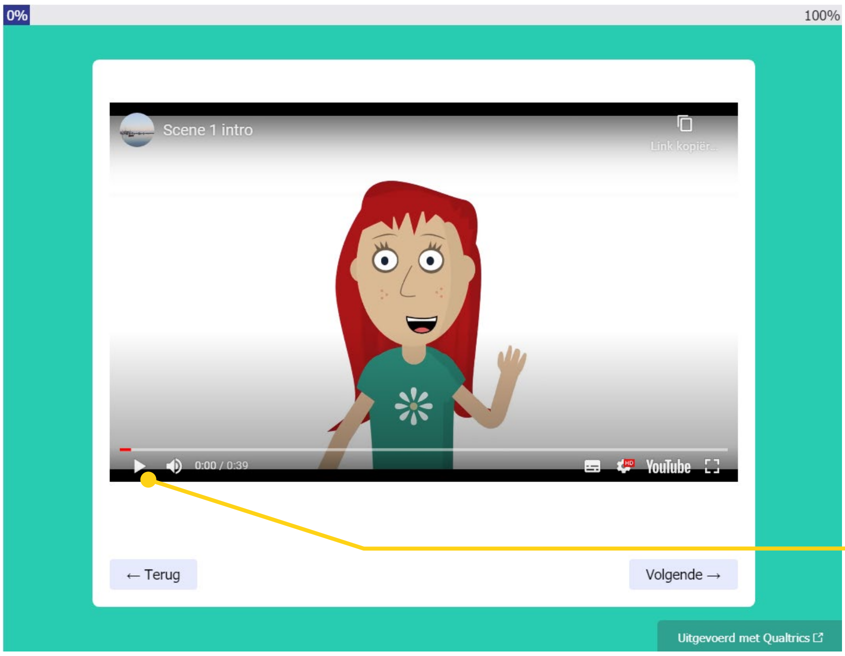
No.	Screen	Script/notes
1		**Links to the online lesson:** *Student version:* http://bit.ly/studentVersion *Note:* In the student version, the questions are required & the condition is randomly assigned, so you see one condition at a time Below, you can view the conditions per link. *Control version:* http://bit.ly/ControlCondition *Experimental-Problem version:* http://bit.ly/ExpProblem *Experimental-Emotion version:* http://bit.ly/ExpEmotion
2		**'Before you start' instructions** **Design principles** Constant, simple, and intuitive design & easy to navigate (Kim & Frick, 2011; Morrison et al., 2013)

3



Segmenting (Mayer & Fiorella, 2014) Small, manageable chunks of information (Xu et al., 2002).

4



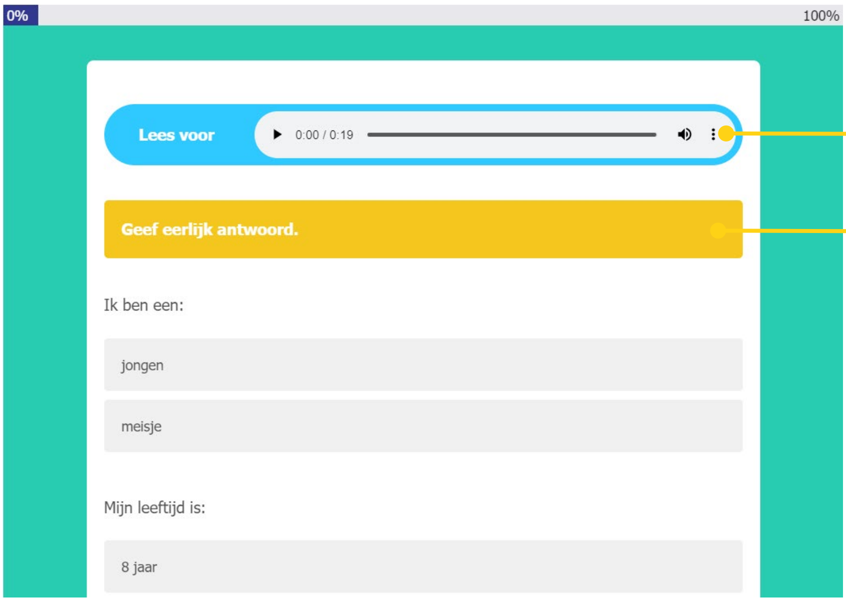
Study introduction

Klik

Script: *Hoi, fijn dat je er bent. Vandaag ben ik jouw digitale juf! Tijdens deze rekenles gaan we aan de slag met rekenen met maten. Door de coronacrisis heb je de afgelopen tijd waarschijnlijk al veel online lessen gevolgd. Deze les is speciaal gemaakt om te kijken hoe de online lessen verbeterd kunnen worden. Jij test deze les voor ons uit, en zo kunnen we andere kinderen later weer helpen. Én jij leert er beter door rekenen! We vinden het heel fijn als je goed meedoet.*

Learner Control Effect: pause, play, speed up and slow down buttons are controlled by the learner (Mayer & Fiorella, 2014)

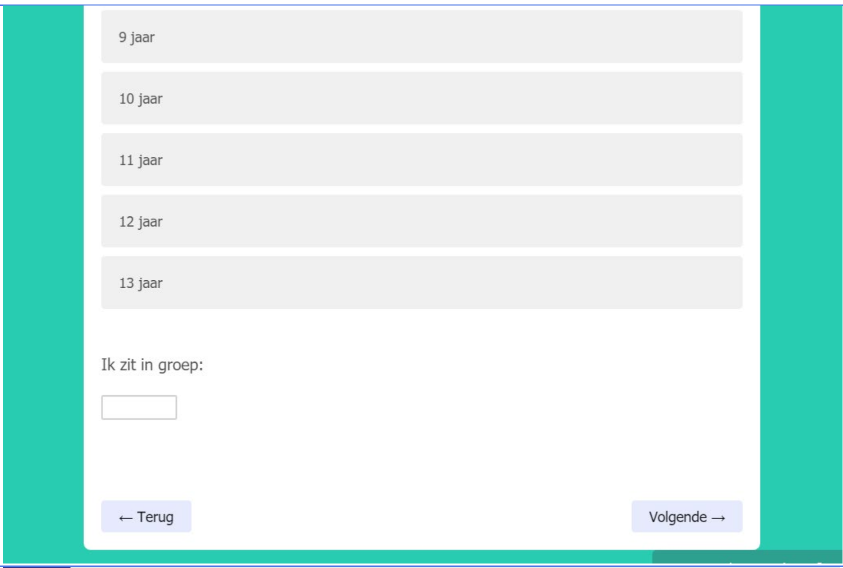
5



Demographics

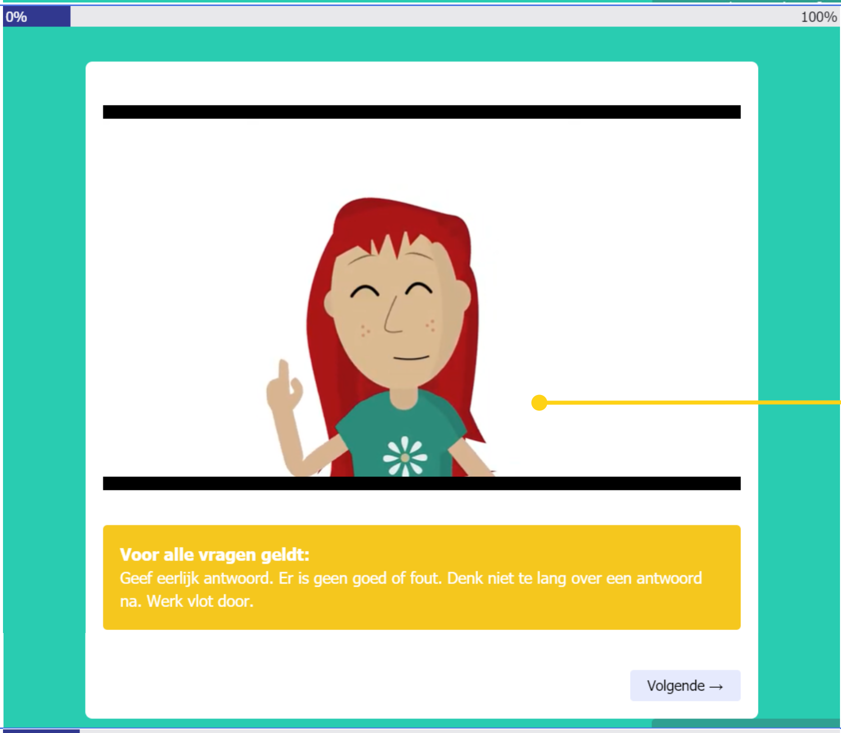
Read-Aloud Function (Wood et al., 2018)

Signalling; important information is highlighted with colour boxes (Mayer & Fiorella, 2014)



If a student is twelve years or older, she or he is automatically redirected to a consent page in order to proceed with the study.

6



Questionnaires instruction

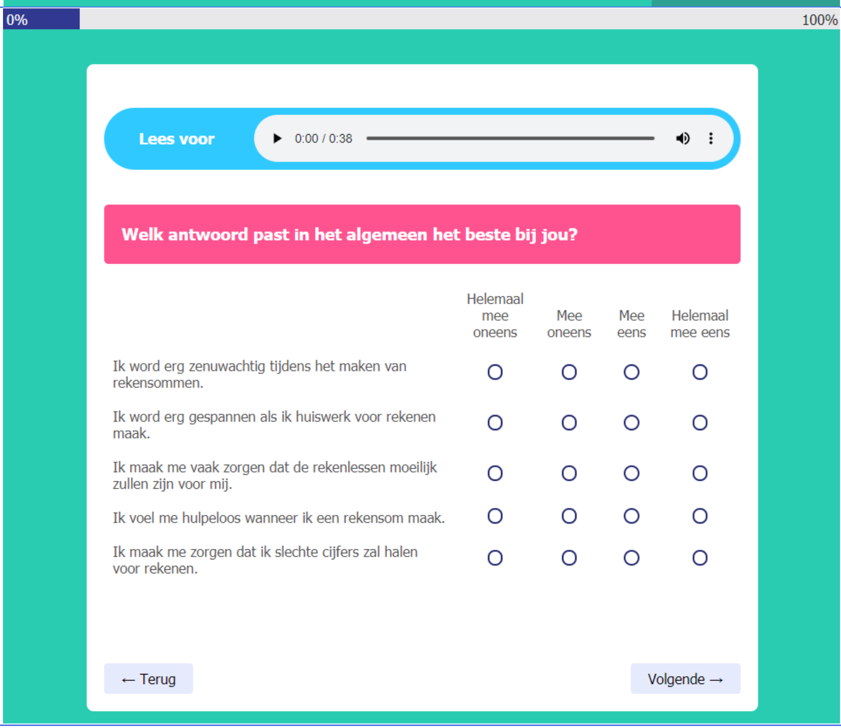
Script: *Je gaat nu een aantal vragen invullen voor het onderzoek. Dit doe je door steeds een antwoord te kiezen die bij jou past. Het is belangrijk dat je eerlijk antwoord geeft. Er is geen goed of fout. Denk niet te lang na, werk vlot door.*

Social Interaction, e.g. with an instructor or animated pedagogical agent (Kim & Frick, 2011)

Clear audio quality (Kühl, Eitel, Damnik, Körndle, 2014)

Personalisation: human voice (Clark & Mayer, 2016), first-person conversational speech (Van der Meij, 2013), & humanlike gesturing (Mayer, 2014).

7

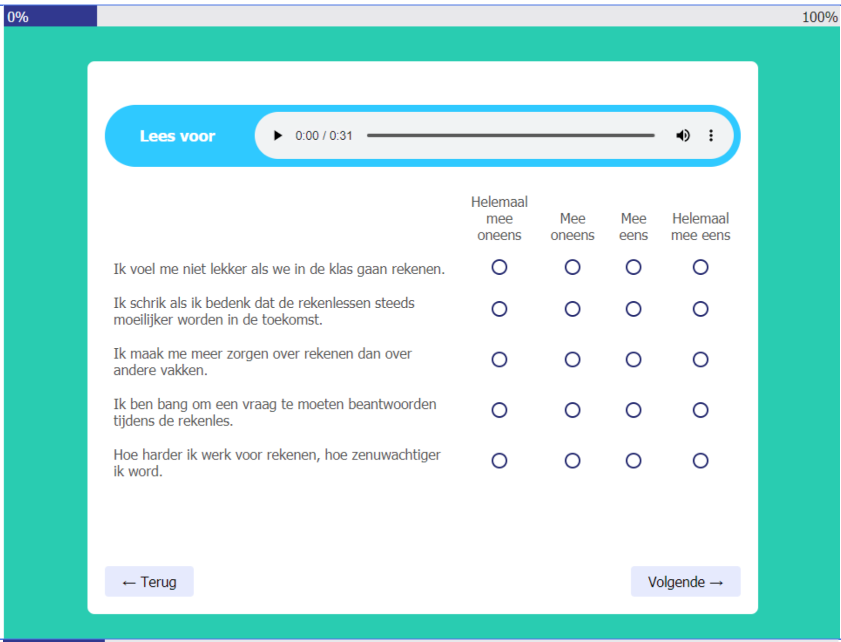


Math Experience Questionnaire (MEQ) (Rekenbelevingsschaal, RBS)

(1/3)

1. Ik word erg zenuwachtig tijdens het maken van rekensommen.
2. Ik word erg gespannen als ik huiswerk voor rekenen maak.
3. Ik maak me vaak zorgen dat de rekenlessen moeilijk zullen zijn voor mij.
4. Ik voel me hulpeloos wanneer ik een rekensom maak.
5. Ik maak me zorgen dat ik slechte cijfers zal halen voor rekenen.

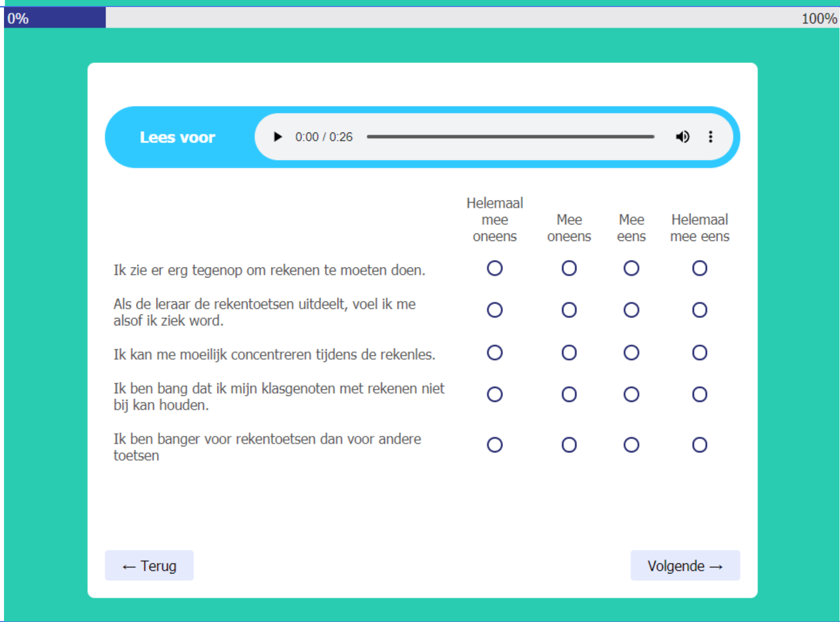
8



(2/3)

6. Ik voel me niet lekker als we in de klas gaan rekenen.
7. Ik schrik als ik bedenk dat de rekenlessen steeds moeilijker worden in de toekomst.
8. Ik maak me meer zorgen over rekenen dan over andere vakken.
9. Ik ben bang om een vraag te moeten beantwoorden tijdens de rekenles.
10. Hoe harder ik werk voor rekenen, hoe zenuwachtiger ik word.

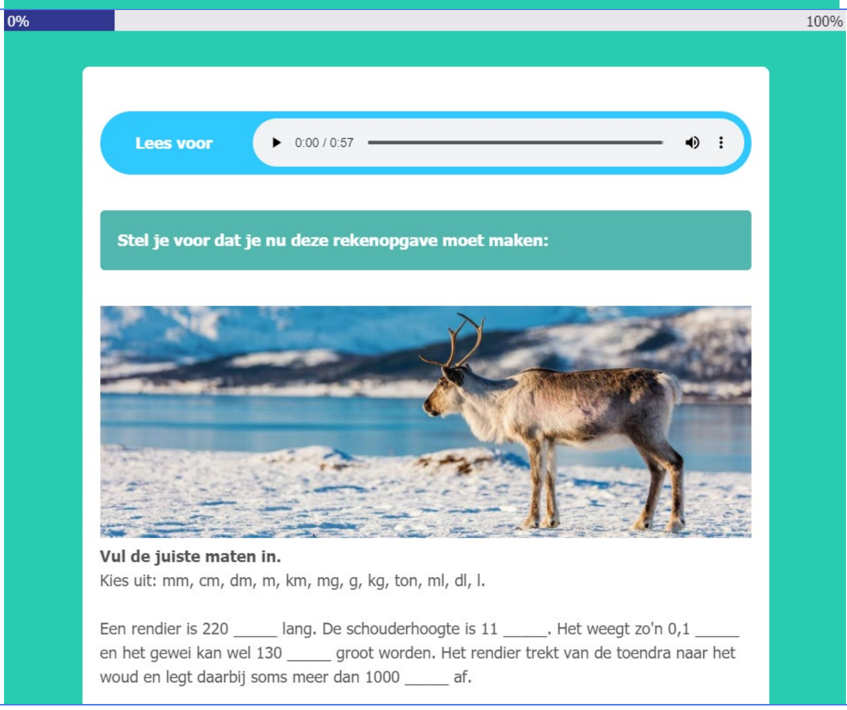
9



(3/3)

11. Ik zie er erg tegenop om rekenen te moeten doen.
12. Als de leraar de rekentoetsen uitdeelt, voel ik me alsof ik ziek word.
13. Ik kan me moeilijk concentreren tijdens de rekenles.
14. Ik ben bang dat ik mijn klasgenoten met rekenen niet bij kan houden.
15. Ik ben banger voor rekentoetsen dan voor andere toetsen.

10



Self-efficacy questionnaire (1/4)

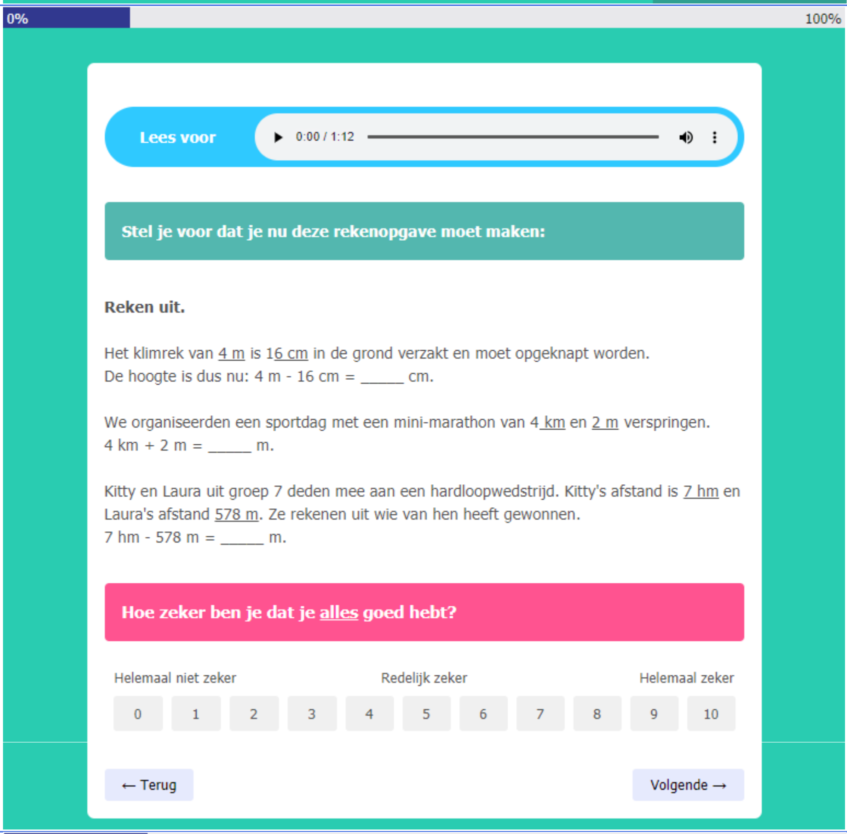
Stel je voor dat je nu deze rekenopgave moet maken:

…

Hoe zeker ben je dat je alles goed hebt?

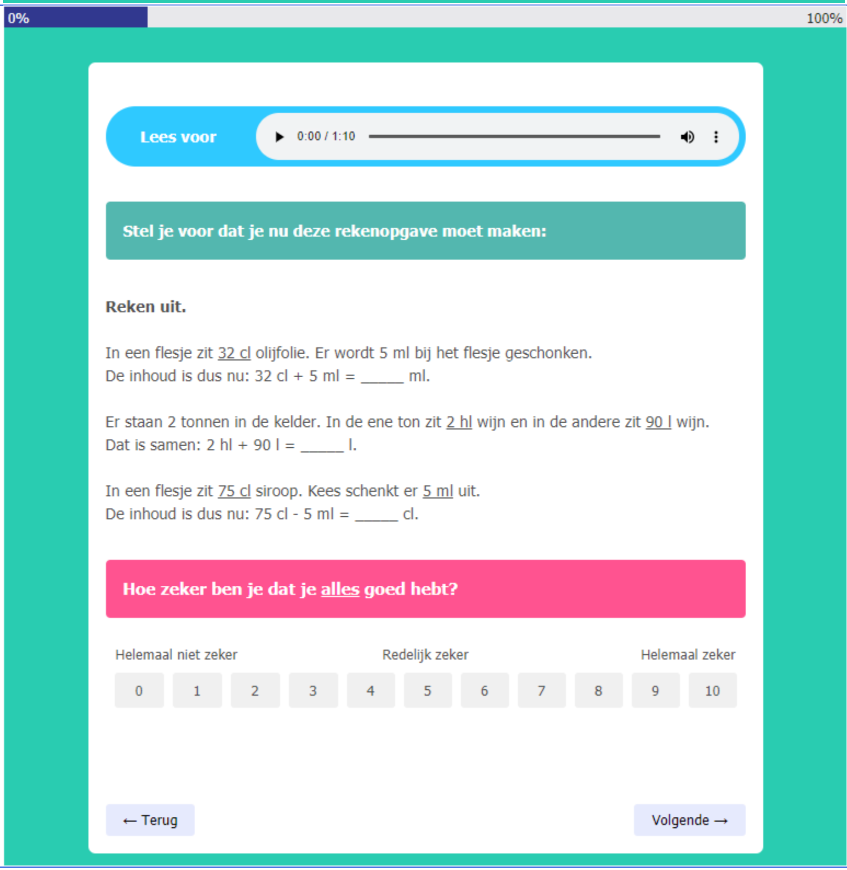

Hoe zeker ben je dat je alles goed hebt?
Helemaal niet zeker
Redelijk zeker
Helemaal zeker
0 1 2 3 4 5 6 7 8 9 10
Volgende →

11


0%
100%
Lees voor
0:00 / 1:12
Stel je voor dat je nu deze rekenopgave moet maken:
Reken uit.
Het klimrek van 4 m is 16 cm in de grond verzakt en moet opgeknapt worden.
De hoogte is dus nu: 4 m - 16 cm = _____ cm.
We organiseerden een sportdag met een mini-marathon van 4 km en 2 m verspringen.
4 km + 2 m = _____ m.
Kitty en Laura uit groep 7 deden mee aan een hardloopwedstrijd. Kitty's afstand is 7 hm en Laura's afstand 578 m. Ze rekenen uit wie van hen heeft gewonnen.
7 hm - 578 m = _____ m.
Hoe zeker ben je dat je alles goed hebt?
Helemaal niet zeker
Redelijk zeker
Helemaal zeker
0 1 2 3 4 5 6 7 8 9 10
← Terug
Volgende →

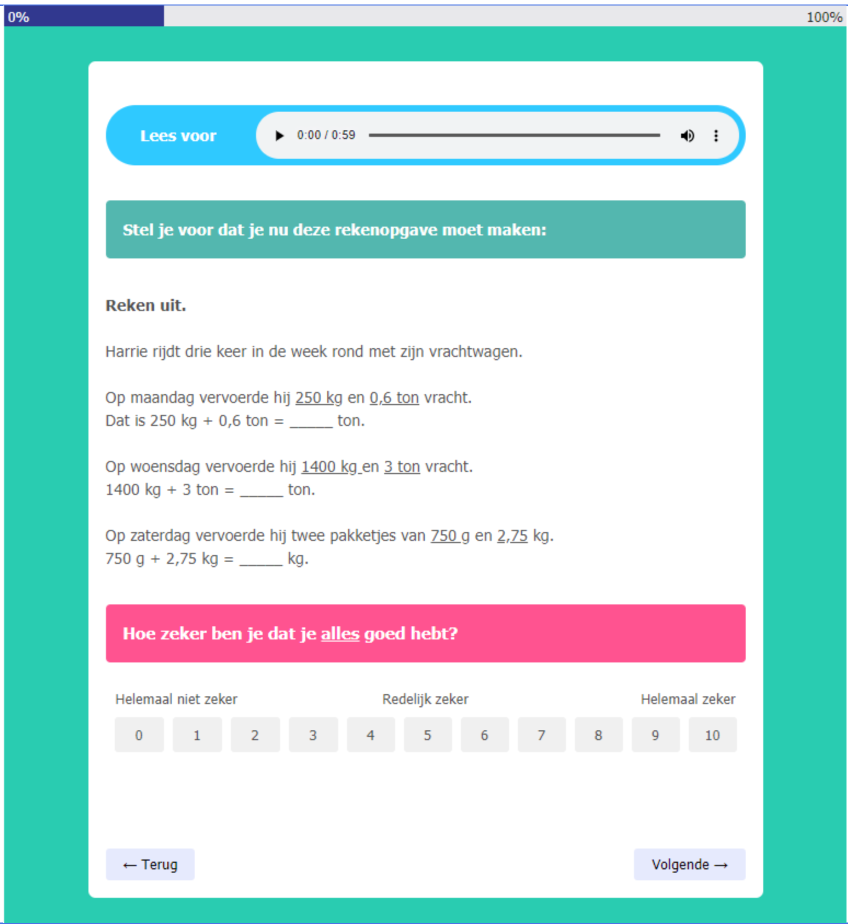
(2/4)

12


0%
100%
Lees voor
0:00 / 1:10
Stel je voor dat je nu deze rekenopgave moet maken:
Reken uit.
In een flesje zit 32 cl olijfolie. Er wordt 5 ml bij het flesje geschonken.
De inhoud is dus nu: 32 cl + 5 ml = _____ ml.
Er staan 2 tonnen in de kelder. In de ene ton zit 2 hl wijn en in de andere zit 90 l wijn.
Dat is samen: 2 hl + 90 l = _____ l.
In een flesje zit 75 cl siroop. Kees schenkt er 5 ml uit.
De inhoud is dus nu: 75 cl - 5 ml = _____ cl.
Hoe zeker ben je dat je alles goed hebt?
Helemaal niet zeker
Redelijk zeker
Helemaal zeker
0 1 2 3 4 5 6 7 8 9 10
← Terug
Volgende →

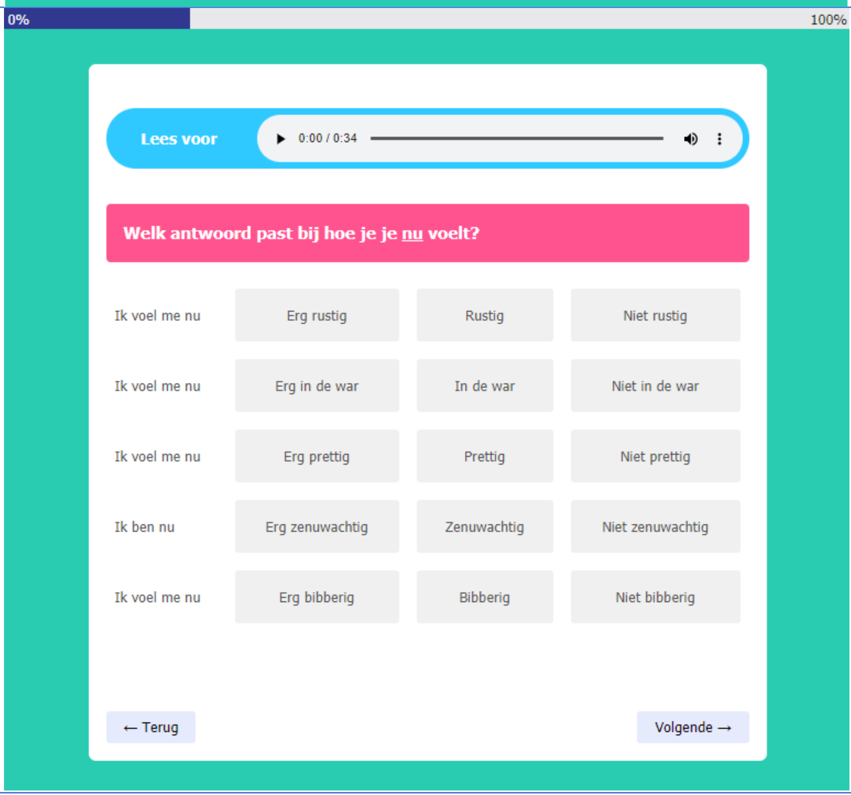
(3/4)

13



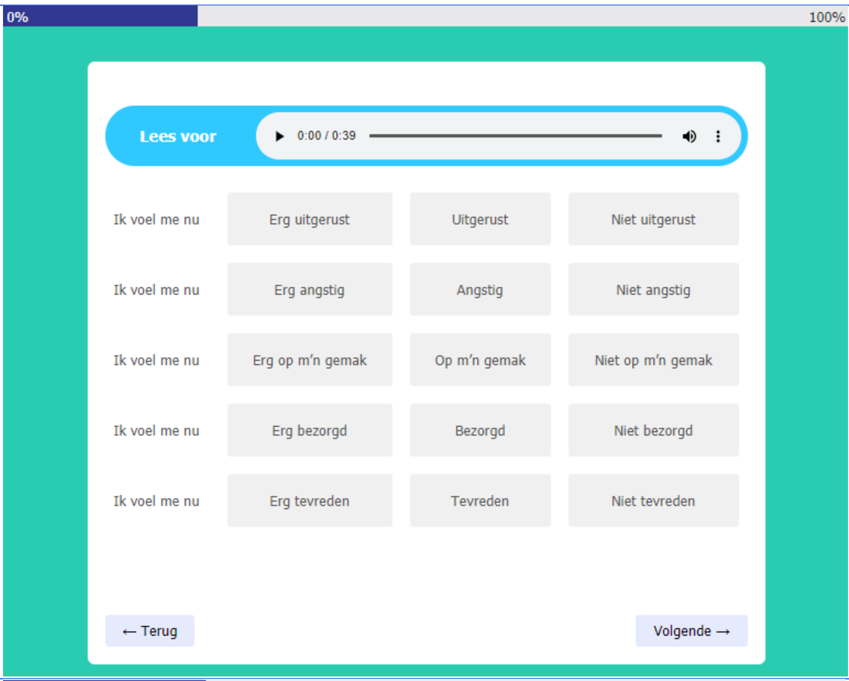
(4/4)

14



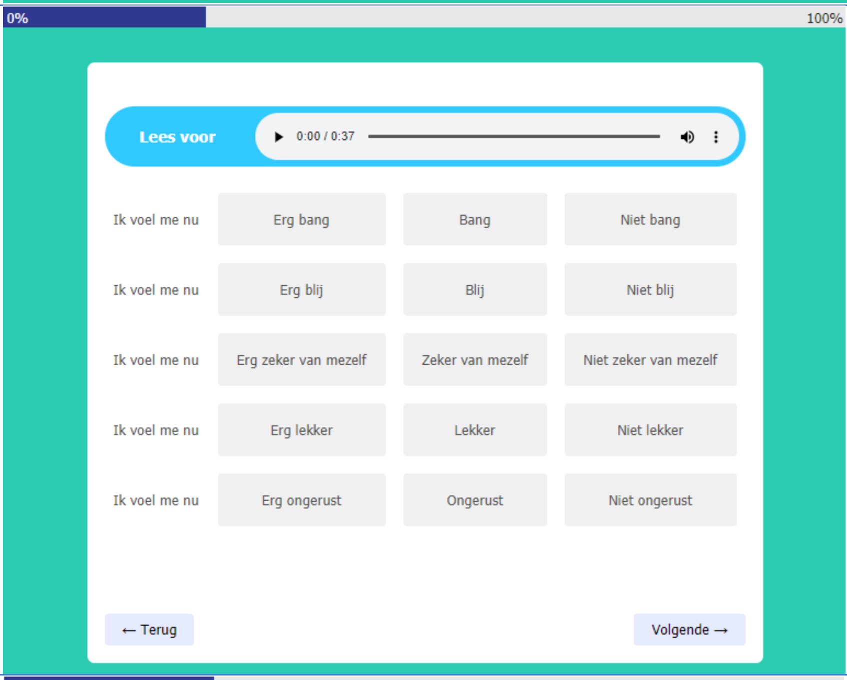
State anxiety questionnaire (1/4)

15



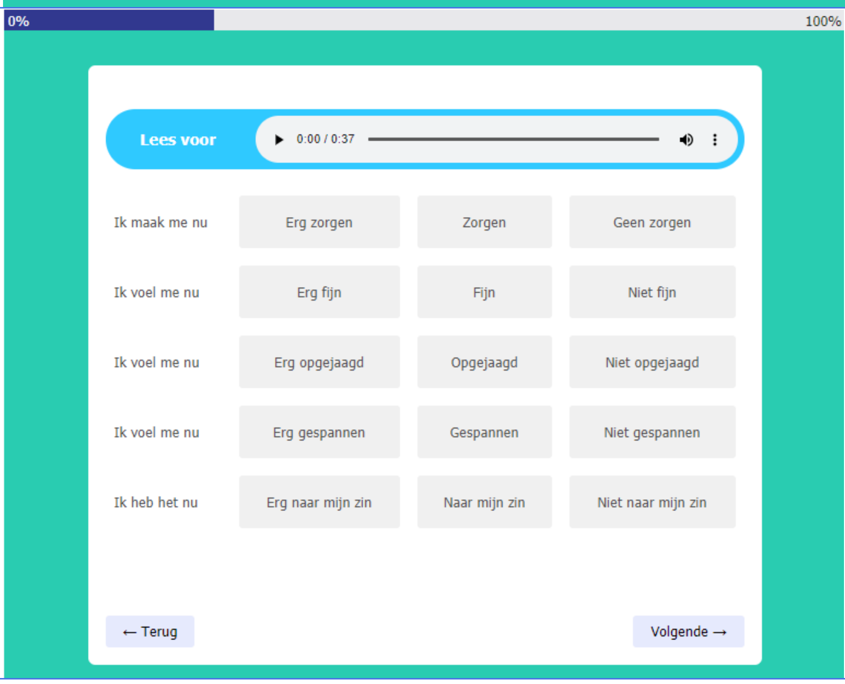
(2/4)

16



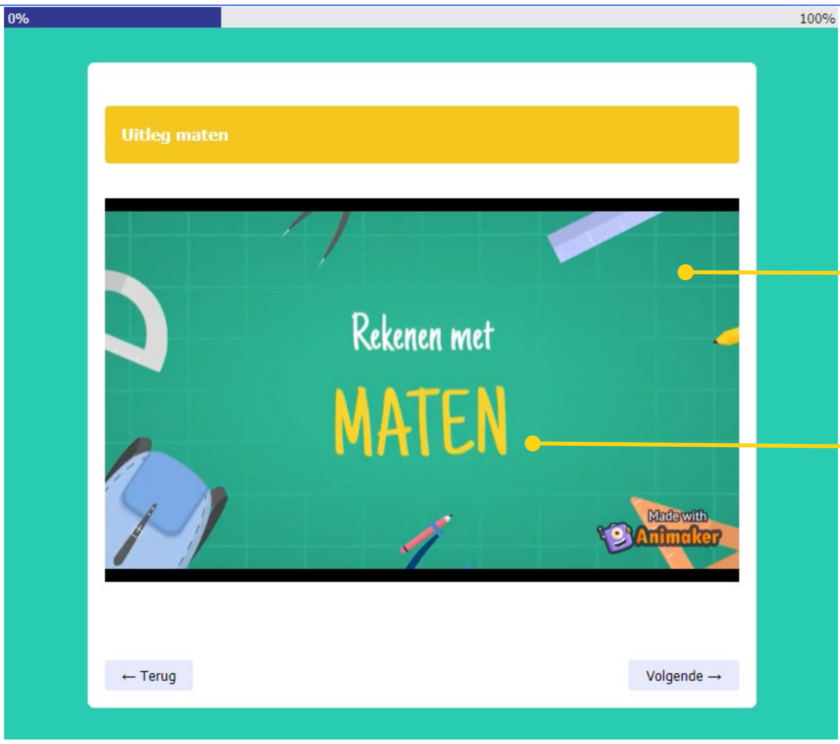
(3/4)

17



(4/4)

18



Metric system instruction

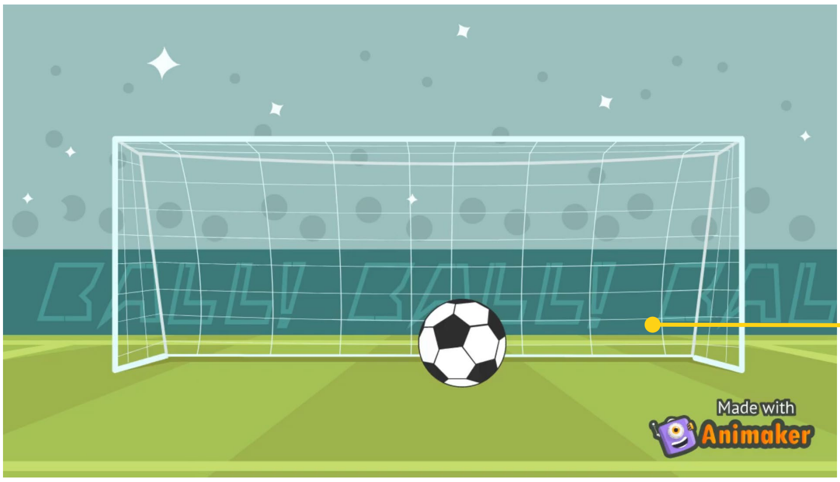
Script: *Rekenen met maten. Belangrijk, want maten hebben we eigenlijk overal nodig!*

Multimedia Principle (Mayer, 2014) Incorporate multimedia presentations that stimulate learner interest (Kim & Frick, 2011)

Provide learners with content that is relevant and useful to them (Kim & Frick, 2011) and material directly related to the learning goal (Coherence; Moreno & Mayer, 2000)

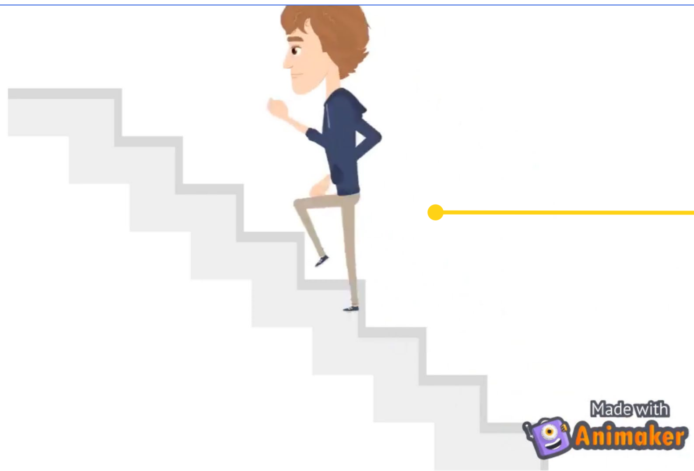
Bijvoorbeeld op de snelweg, hoe lang is het nog rijden naar je tante? Bij het sporten. In de supermarkt.

Explain why the learning is important and worth doing using real-world examples (Kim & Frick, 2011)



Het doel van deze les is: Dat je een beeld hebt bij de verschillende maten en dat je ze kunt omrekenen, bijvoorbeeld van kilometer naar meter, van gram naar kg. Maar hoe groot, hoe zwaar of hoeveel is alles dan precies? En hoe werken die maten ook alweer?

Expectation principle; present learning goal (Halpern et al., 2007)

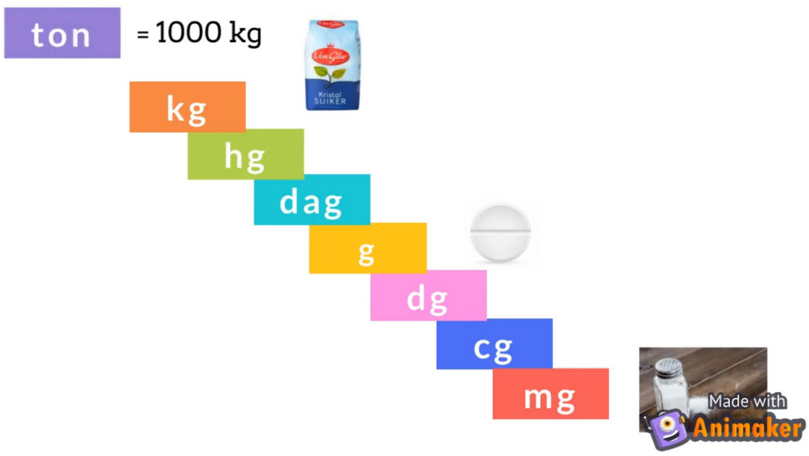


Weet je nog? Maten kun je ordenen van klein naar groot. Je kunt dit zien als een soort trap.

Prior knowledge activation (De Grave et al., 2001)
Coherence (Mayer & Fiorella, 2014)

We beginnen met de trap van de meters. Onderaan de trap beginnen we bij de kleinste maat, ja je raadt het al: millimeter. En die vind je al bij jezelf! Namelijk, de dikte van je nagel, dat is een millimeter.

We zetten een stap hoger op de trap. Daar vinden we de centimeter. Een centimeter is de breedte van je duim, handig! Dat is 10 keer een millimeter. Decimeter. Tussen je wijsvinger en je duim is één decimeter, oftewel 10 centimeter. Meter. Een flinke stap is 1 meter. Dat is 10 keer een decimeter. Een decameter is zo groot als een truck, dus 10 meter. Een hectometer is ongeveer de lengte van een voetbalveld. Een kilometer is een wandeling van ongeveer een kwartier. Een kilometer is 1000 meter.

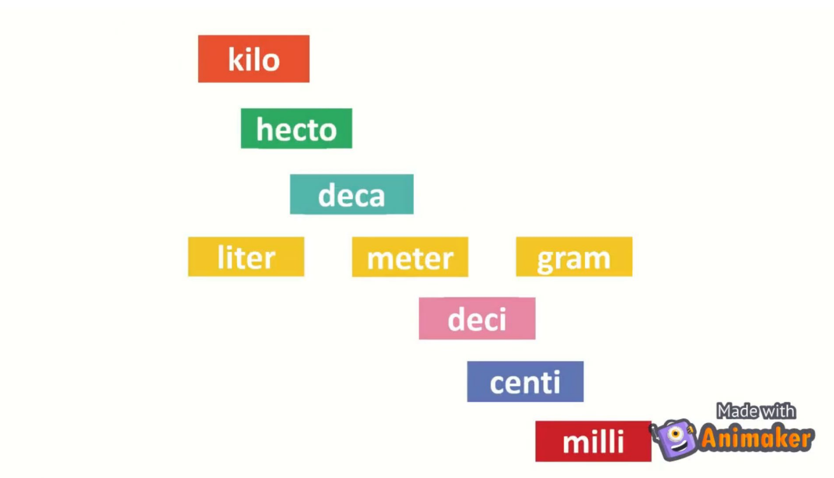


Als we kijken naar de grammen, dan is 1 milligram zo zwaar als een beetje zout. Daarna komen centigram en decigram. Een gram is zo zwaar als een paracetamol. Daarna hebben we decagram en hectogram. Een pak suiker weegt 1 kilogram. Dat is dus 1000 gram. En dan hebben we nog een ton. Dat is 1000 kilogram, 1000 pakken suiker dus!

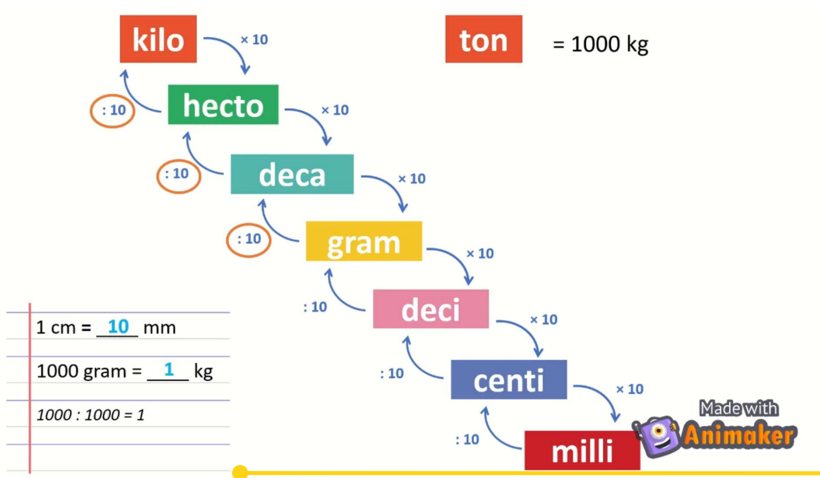
Bij de liters gaat dit ongeveer hetzelfde. Een druppel is een milliliter. Een pak melk is een liter. En een zwembad een kiloliter, 1000 liter dus.

Hé, is het je al opgevallen? Meter, liter en gram hebben dezelfde volgorde van kilo naar milli! Zo hoef je dus eigenlijk maar één rijtje uit je hoofd te leren waarmee je alles kunt omrekenen! Yes!

Math instruction should be attractive to both males and females (Luttenberger et al., 2018).

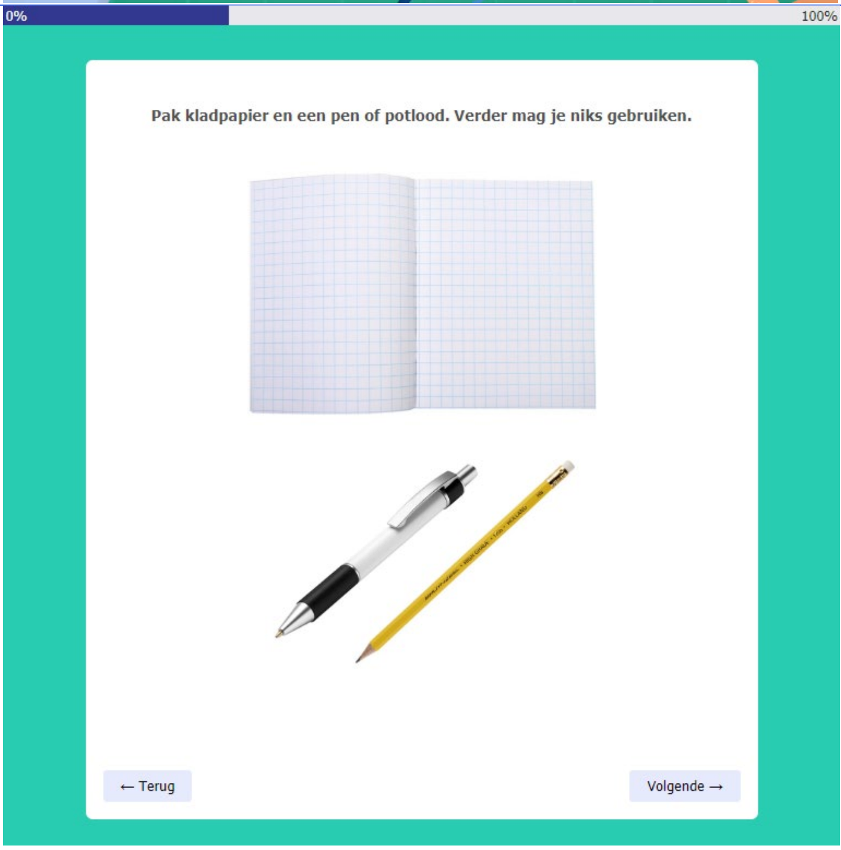


Laten we het eens vergelijken. Eerst komt kilo, dan hecto, dan deca, dan dus meter, liter of gram, dan deci, dan centi, en tot slot milli. Omdat die rijtjes hetzelfde zijn, kunnen we ze dus zien als 1 trap. Die trap zien we hier. Bij de trap geldt: een stapje omlaag op de trap is keer 10 en een stapje omhoog is gedeeld door 10.
Dus: 1 cm keer 10, dat is dus een stapje omlaag, is 10 millimeter.

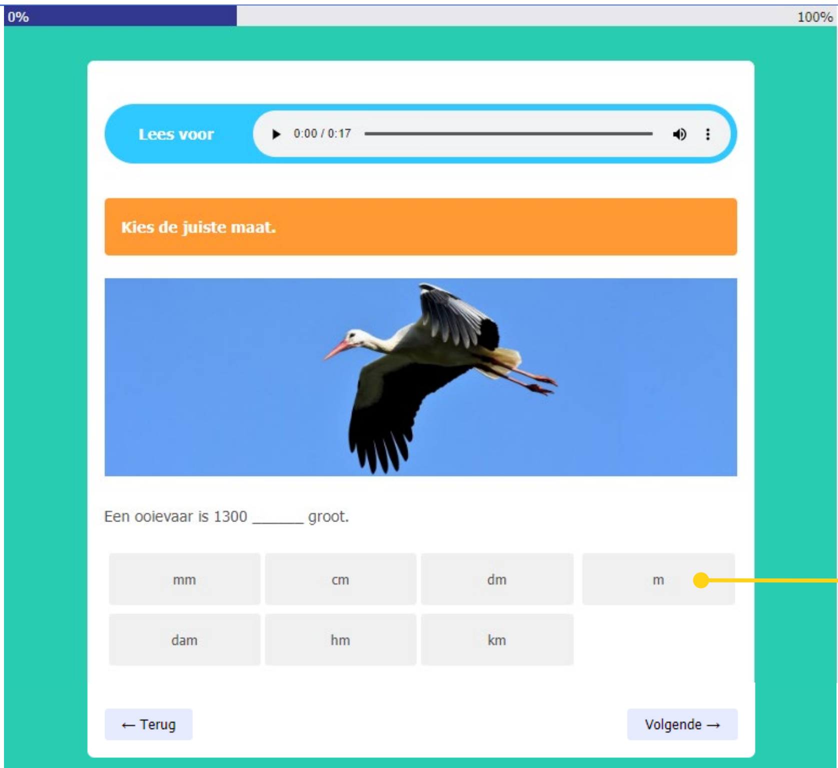


Voorbeeldopgave. 1000 gram is . . . kilogram, dat is dus, 1, 2, 3 stapjes omhoog, dus delen door 1000. 1000 : 1000 = 1. Dus 1000 gram = 1 kg.

Worked example effect (Atkinson et al., 2000; Chen et al., 2015; Morrison et al., 2013).

		*Nu is het aan jou! Je gaat straks oefenen met opdrachten. Pak leeg kladpapier erbij en een pen of potlood, verder mag je niks gebruiken. Klaar voor? Aan de slag!*
19		**Instruction before the tasks**

20



Task 1: Estimating measures of a stork

One item per screen with the exact same lay-out.

1. Een ooievaar is 1300 ___ groot.
2. De lengte van de snavel is ongeveer 0,28 ___.
3. Hij weegt 4,5 ___.
4. Tijdens de vogeltrek liegt hij 12000 ___ naar het zuiden.

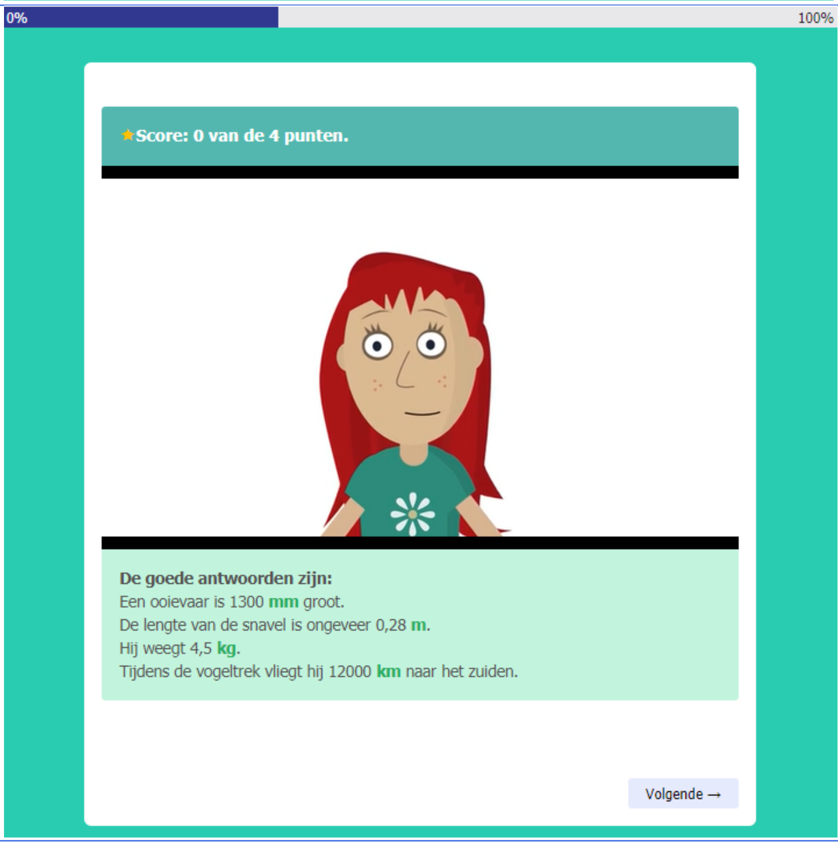
Provide learners with hands-on activities that engage them in learning (Kim & Frick, 2011).

21

Feedback page – control group

Provide learners with feedback on their performance (Kim & Frick, 2011).

22



Feedback page – experimental groups

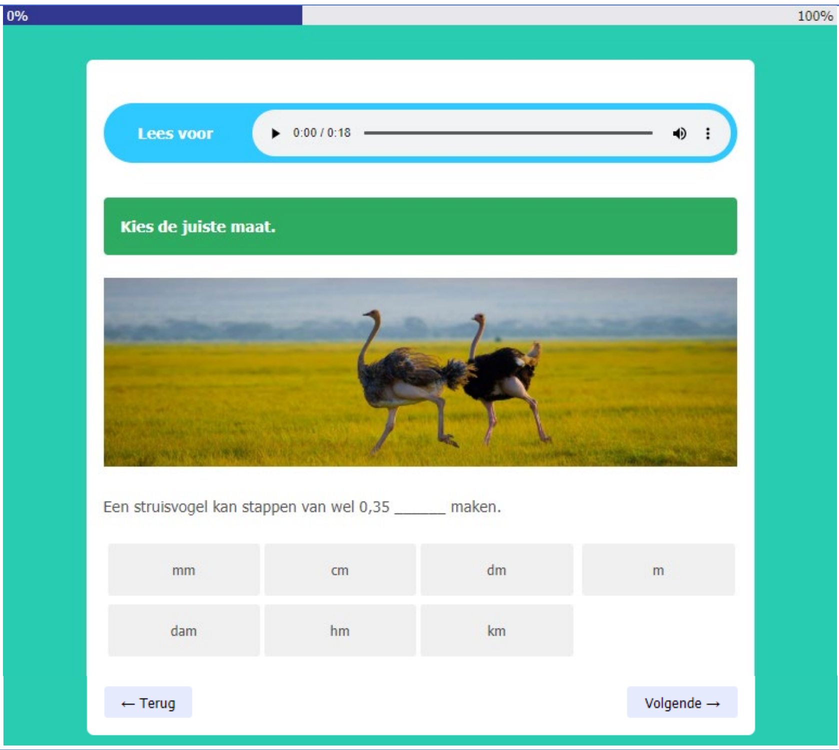
Problem group:

- **Majority wrong:** *Rustig blijven, bedenk bij de volgende opgave hoe je de vraag aan gaat pakken, maak een plan.*
- **Majority right:** *Goed zo, als je bedenkt hoe je de vraag aan gaat pakken en een plan maakt, dan gaat het goed.*

Emotion group:

- **Majority wrong:** *Rustig blijven, onthoud dat je weet dat het je gaat lukken.*
- **Majority right:** *Goed zo, onthoud dat je weet dat het je gaat lukken.*

23

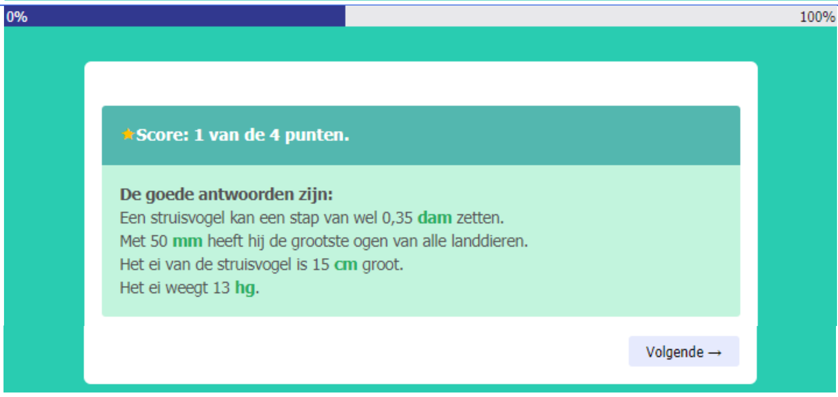


Task 2: Estimating measures of an ostrich

One item per screen with the exact same lay-out.

1. Een struisvogel kan stappen van wel 0,35 ___ maken.
2. Met 50 ___ heeft hij de grootste ogen van alle landdieren.
3. Het ei van de struisvogel is 15 ___ groot.
4. Het ei weegt 13 ___.

24



Feedback page – control group

25

Feedback page – experimental groups

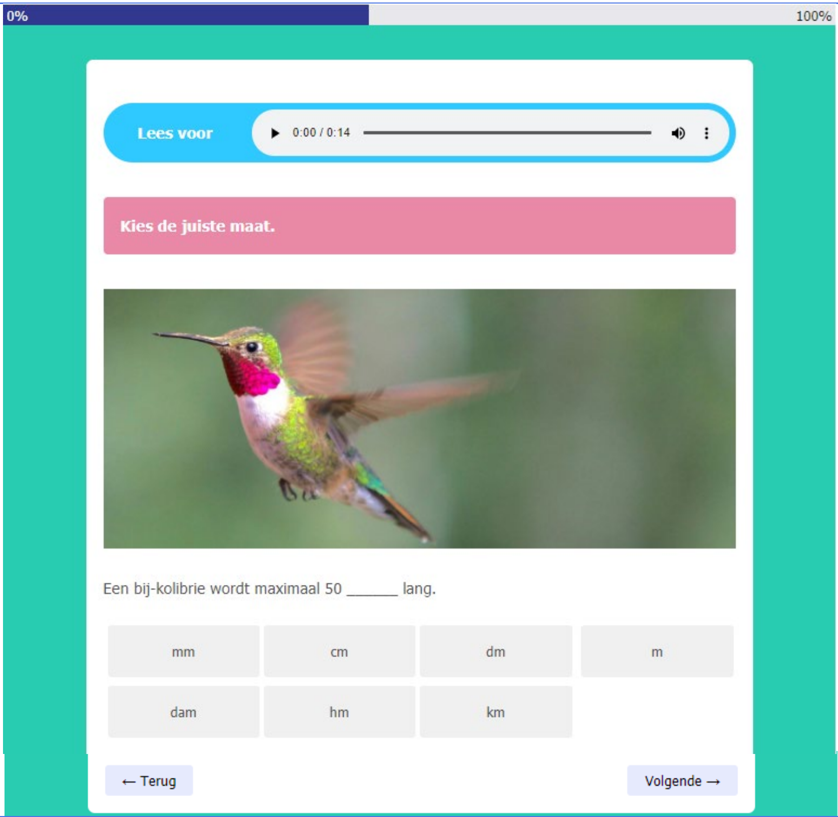
Problem group:

- **Majority wrong:** *Geef niet op, als je eerst bedenkt wat je al weet, dan kom je stap voor stap ook uit de moeilijkere dingen.*
- **Majority right:** *Goed zo, als je eerst bedenkt wat je al weet, dan kom je stap voor stap ook uit de moeilijkere dingen.*

Emotion group:

- **Majority wrong:** *Geef niet op, ook al is het moeilijk, als je het gewoon blijft proberen dan gaat het de volgende keer wel weer beter.*
- **Majority right:** *Top, ook al is het moeilijk, als je het gewoon blijft proberen en als je even doorzet, dan lukt het je wel!*

26



Task 3: Estimating measures of a hummingbird

One item per screen with the exact same lay-out.

1. Een bij-kolibrie wordt maximaal 50 ___ lang.
2. Het vrouwtje weegt 0,002 ___.
3. De eieren zijn 6 ___ groot.

27

Feedback page – control group

28

Feedback page – experimental groups

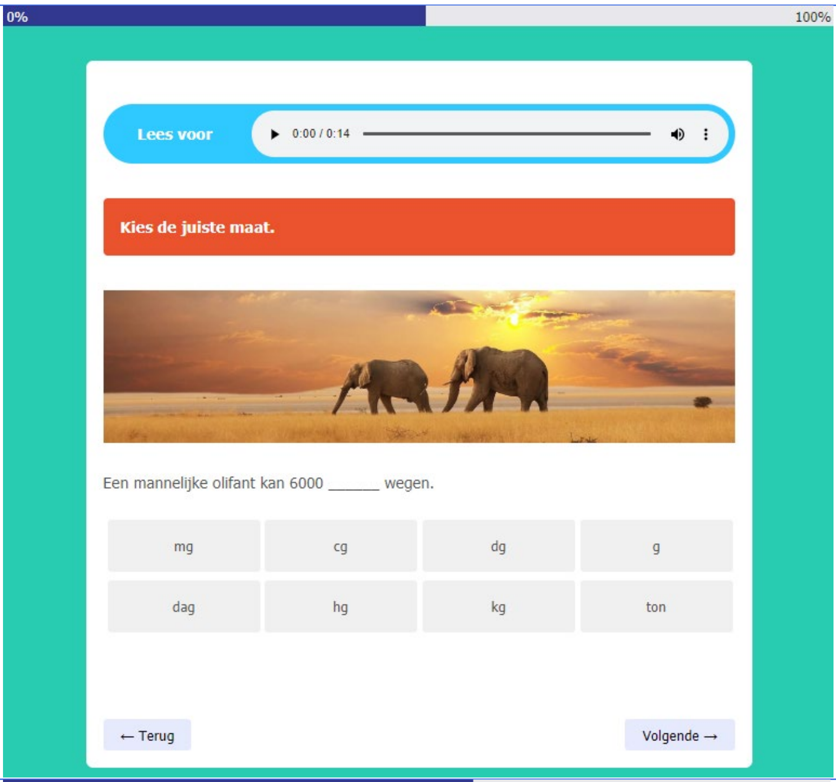
Problem group:

- **Majority wrong:** *Geef niet op, Bij de volgende som bedenk je welke manier je kunt gebruiken om de som uit te rekenen.*
- **Majority right:** *Goed gedaan, door te bedenken op welke manier je de som uit gaat rekenen, lukt het je de volgende keer ook!*

Emotion group:

- **Majority wrong:** *Het is oké. Als je je concentreert op wat er moet gebeuren, dan voel je je minder gespannen en lukt het je!*
- **Majority right:** *Goed zo. Als je je concentreert op wat er moet gebeuren, dan voel je je minder gespannen en lukt het je!*

29



Task 4: Estimating measures of an elephant

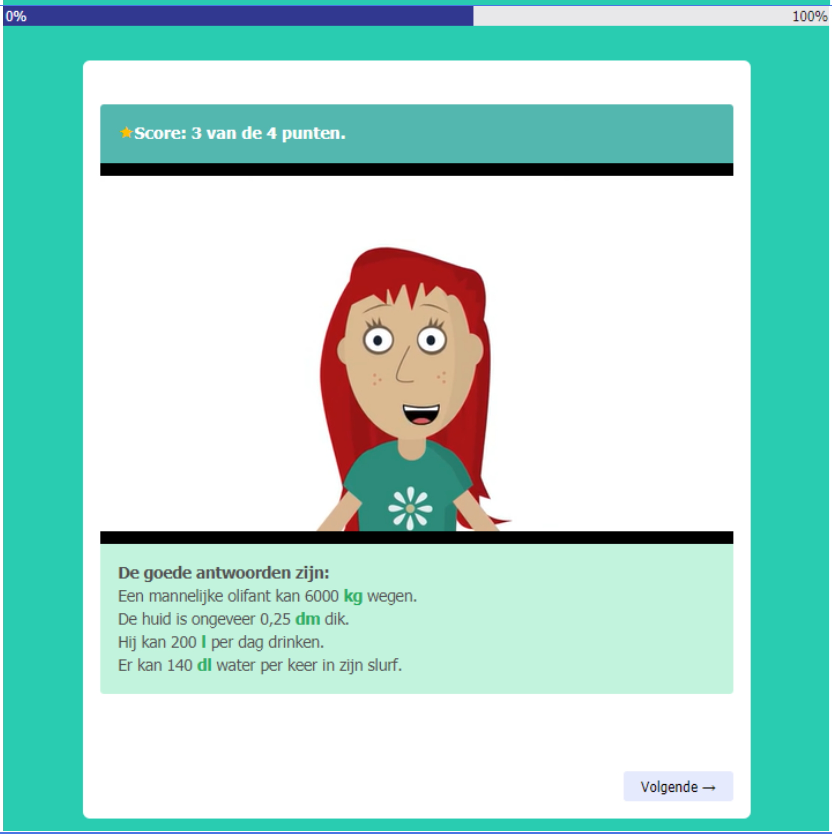
One item per screen with the exact same lay-out.

1. Een mannelijke olifant kan 6000 ___ wegen.
2. De huid is ongeveer 0,25 ___ dik.
3. Hij kan 200 ___ per dag drinken.
4. Er kan 140 ___ water per keer in zijn slurf.

30

Feedback page – control group

31



Feedback page – experimental groups

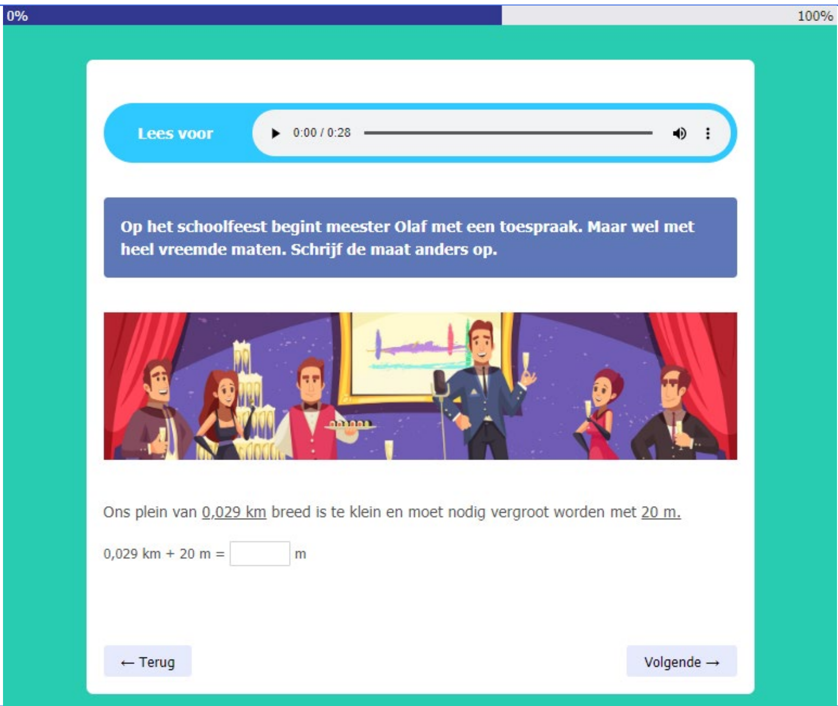
Problem group:

- **Majority wrong:** *Het is oké, als je de tijd neemt om de opdracht goed te lezen en na te denken, dan lukt het je.*
- **Majority right:** *Top, als je de tijd neemt om de opdracht goed te lezen en na te denken, dan lukt het je.*

Emotion group:

- **Majority wrong:** *Er zijn wel ergere dingen dan wel eens fouten maken. Haal een paar keer diep adem om even te relaxen en ga dan weer verder.*
- **Majority right:** *Goed zo. Haal een paar keer diep adem om even te relaxen en ga dan weer verder.*

32

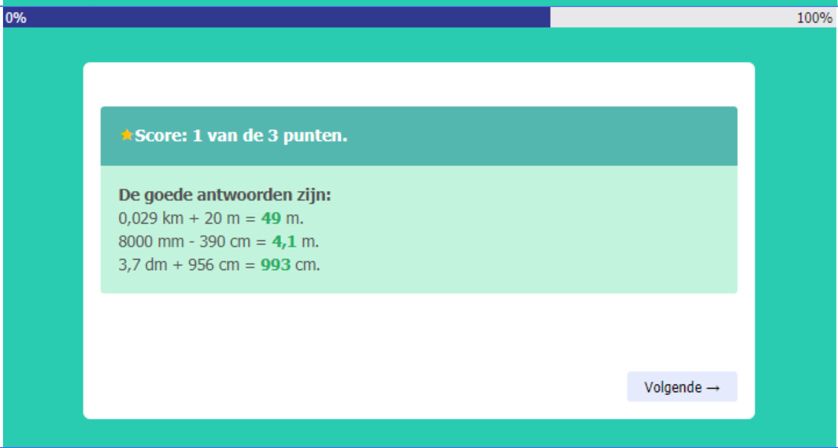


Task 5: Converting metric units of length

One item per screen with the exact same lay-out.

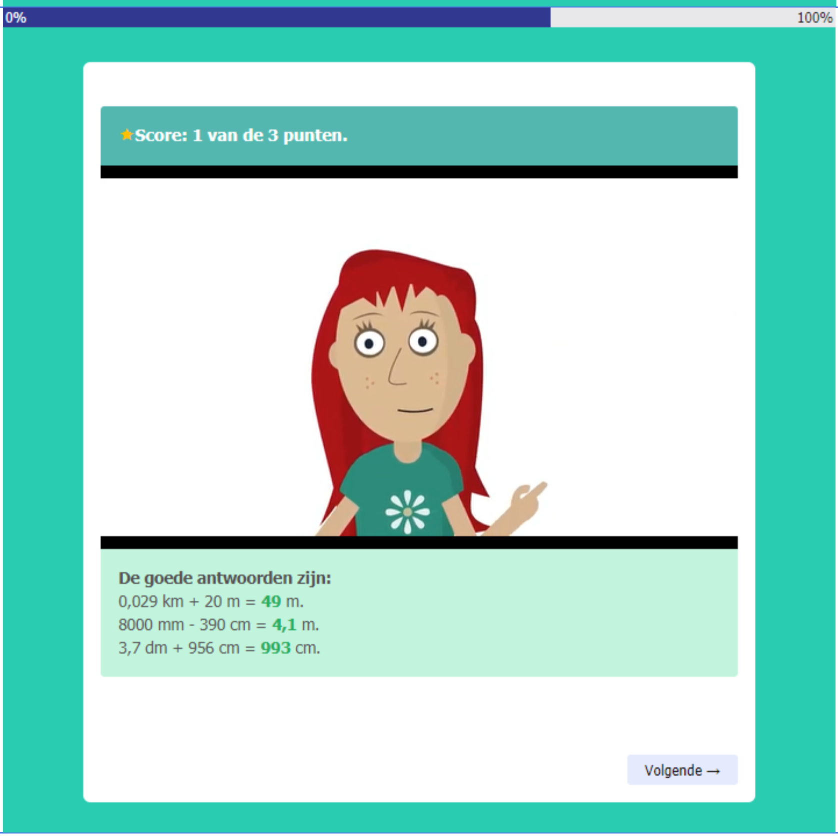
1. Ons plein van <u>0,029 km</u> breed is te klein en moet nodig vergroot worden met <u>20 m</u>.
   0,029 + 20 m = ___ m.
2. De zandbak van <u>8000 mm</u> neemt te veel ruimte in, dus hij wordt verkleind met <u>390 cm</u>.
   8000 mm – 390 cm = ___.
3. Er zijn zelfs twee posters van <u>3,7 dm</u> breed en <u>956 cm</u> gemaakt van het nieuwe plein.
   3,7 dm + 956 cm = ___ cm.

33



Feedback page – control group

34



Feedback page – experimental groups

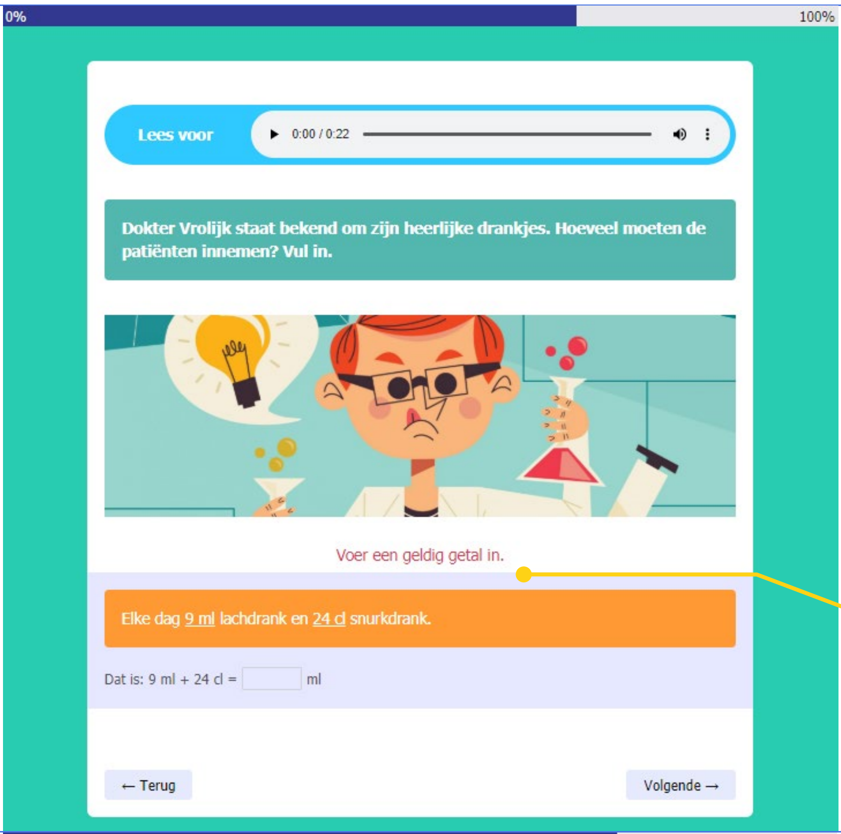
<u>Problem group:</u>

- **Majority wrong:** *Fouten maken is niet erg, gebruik goed je kladpapier om het oplossen van de som voor jou duidelijker te maken.*
- **Majority right:** *Keurig, als je goed je kladpapier gebruikt om het oplossen van de som voor jou duidelijker te maken, dan gaan de volgende sommen ook goed.*

<u>Emotion group:</u>

- **Majority wrong:** *Geef niet op, fouten maken hoort bij leren en oefenen. Daardoor leren we steeds meer en worden we steeds zelfverzekerder.*
- **Majority right:** *Goed gedaan, door te oefenen leren we steeds meer en worden we steeds zelfverzekerder.*

35



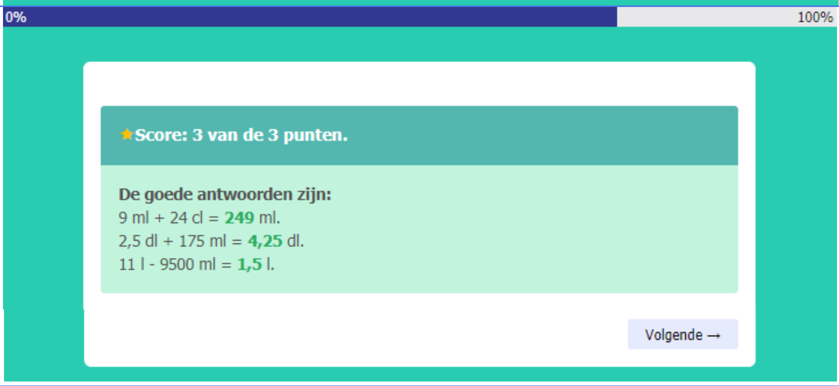
Task 6: Converting metric units of capacity

One item per screen with the exact same lay-out.

1. Elke dag 9 ml lachdrank en 24 cl snurkdrank.
   Dat is: 9 ml + 24 cl = ___ ml.
2. Elke dag 2,5 dl kruidendrank en 175 ml hoestdrank.
   Dat is: 2,5 dl + 175 ml = ___ dl.
3. De voorraad raakt op. Van de 11 liter is er al 9500 ml siroop op.
   Er is dus nog: 11 l - 9500 ml = ___ l.

Error Prevention (Tristán-López & Ylizaliturri-Salcedo, 2014)

36



Feedback page – control group

37

Feedback page – experimental groups

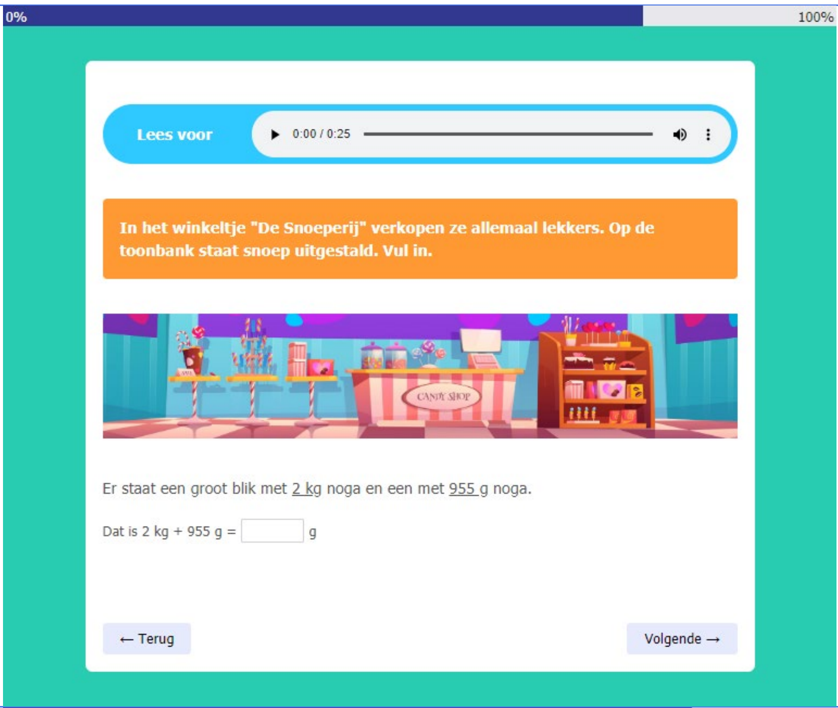
Problem group:

- **Majority wrong:** *Maak je geen zorgen, probeer de volgende som in kleine stapjes uit te rekenen.*
- **Majority right:** *Super, als je de sommen in kleine stapjes probeert uit te rekenen, dan lukt het bij de volgende opgaven ook goed.*

Emotion group:

- **Majority wrong:** *Maak je geen zorgen, ook al is het moeilijk, jij kan het aan! Als je maar je best doet, dan is het goed.*
- **Majority right:** *Super, ook al is het moeilijk, jij kan het aan! Als je maar je best doet, dan is het goed.*

38

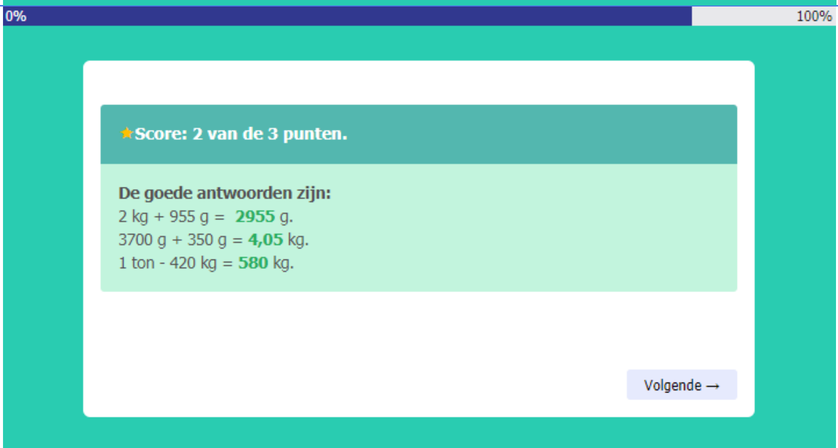


Task 7: Converting metric units of weight

One item per screen with the exact same lay-out.

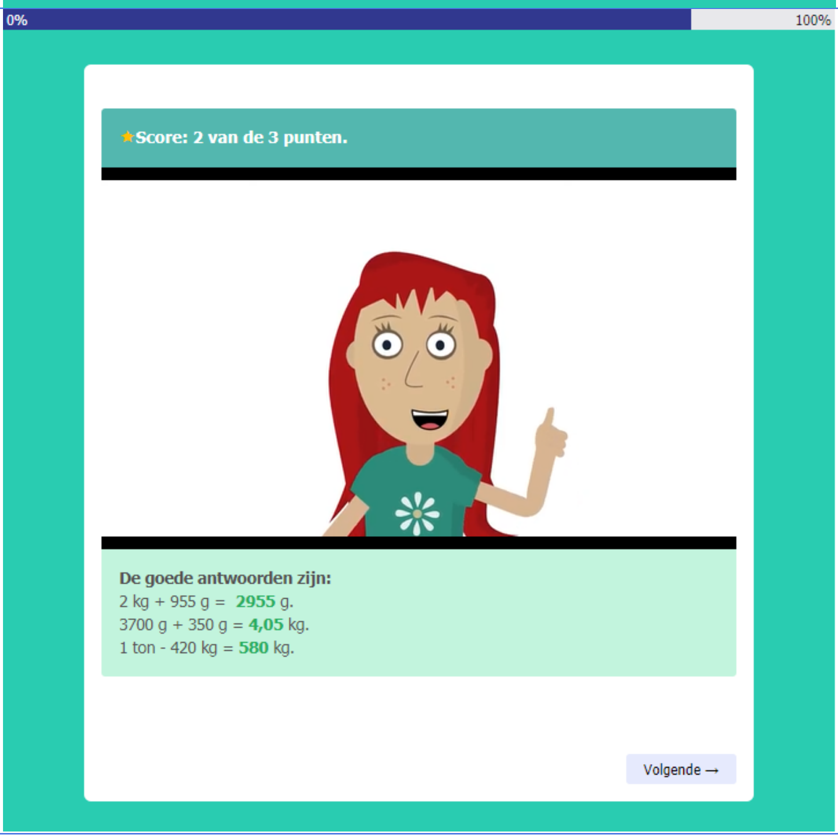
1. Er staat een groot blik met <u>2 kg</u> noga en een met <u>955 g</u> noga.
   Dat is 2 kg + 955 g = ___ g.
2. De glazen pot met zuurstokken weegt <u>3700 gram.</u> Hij wordt bijgevuld met <u>350 gram</u> extra zuurstokken.
   De pot weegt 3700 g + 350 g = ___ kg.
3. Er was een voorraad van <u>1 ton</u> ingeslagen voor Halloween. Na Halloween was er nog <u>420 kg</u>.
   Er is dus: 1 ton – 420 kg = ___ kg snoep gegeten.

39



Feedback page – control group

40



Feedback page – experimental groups

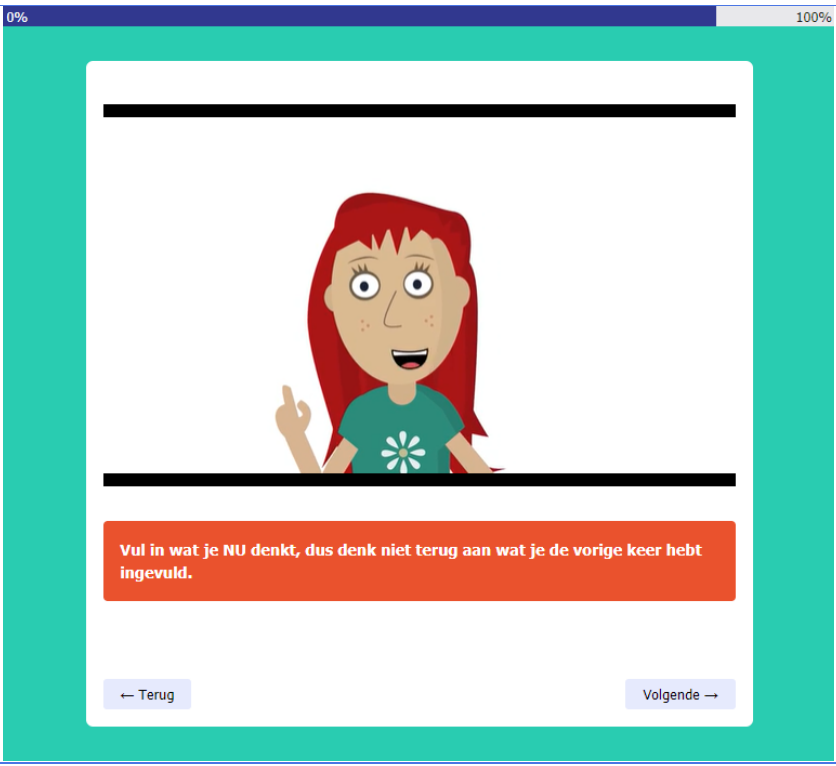
<u>Problem group:</u>

- **Majority wrong:** *Het is oké, zorg dat je niet afgeleid wordt door andere dingen. Als je je concentreert op de vragen, dan lukt het je beter.*
- **Majority right:** *Klasse, als je zorg dat je niet afgeleid wordt door andere dingen en je geconcentreerd blijft op de vragen, dan lukken ze.*

<u>Emotion group:</u>

- **Majority wrong:** *Het gaat prima. Door nu fouten te maken leer je en gaat het later goed op de toets.*
- **Majority right:** *Klasse, Ook al maak je misschien wel eens een foutje, het gaat prima. Door nu fouten te maken leer je en gaat het later goed op de toets.*

41



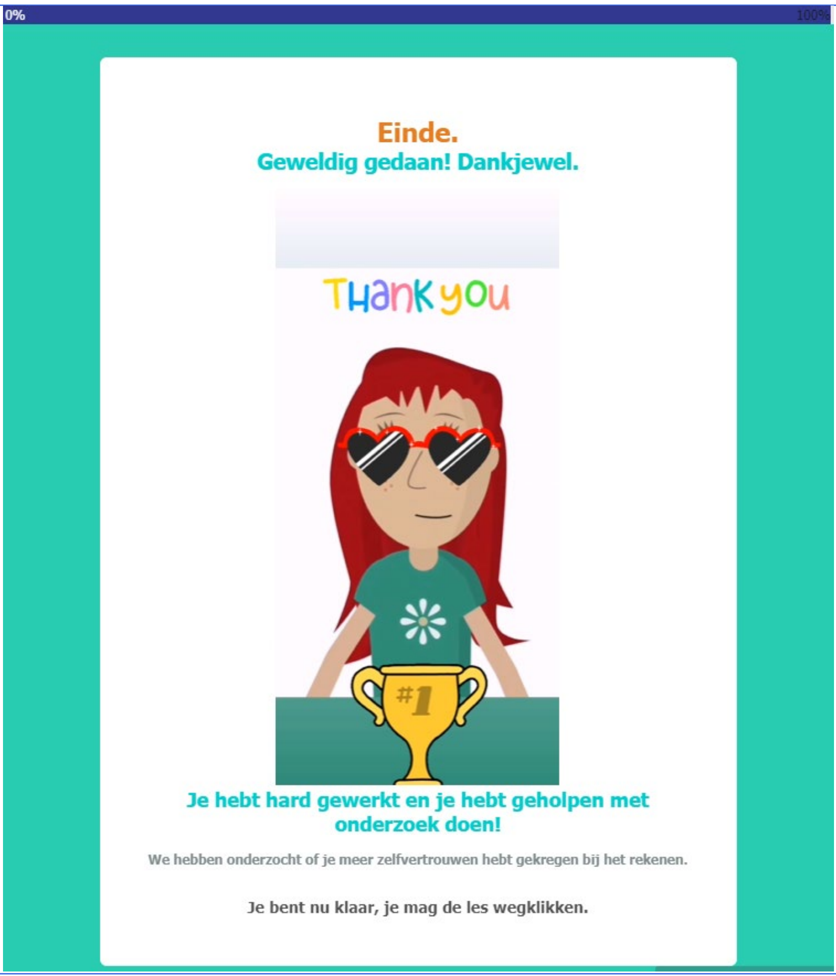
Post-test instruction

Script: *Nu ga je voor de laatste keer wat vragen invullen. Denk je nou: "Huh, nog een keer die vragen?", dat klopt! Deze vragen hebben wij nodig voor het onderzoek.*

42

The very same **self-efficacy questionnaire** and **math experience questionnaire** screens were presented here

43



End screen

Appendix B

Interviews

SENIOR TEACHER (F)

Currently of: Grade 5 (Dutch: groep 7)
Experience: 27 years (particularly for this Year).

Over de situatie in de coronacrisis na de meivakantie (vanaf 11-05-2020)

"De kinderen bij ons die moeten dan twee keer een dag naar school. En de andere helft van de groep, de andere twee dagen. En daar moeten we nog even een programmaatje voor maken."

"De kinderen krijgen dus twee dagen les. We moeten dus de komende tijd gaan clusteren, dus sommige dingen laten we vallen. We gaan echt heel gericht kijken: wat hebben ze nodig om goed de overgang te maken naar groep 8. Dan kijken we van: wat is hier heel erg belangrijk? En dan gaan we dus naast dat zij op school zijn, krijgen ze dus ook nog een weektaak om thuis verder te werken. En dat doen ze dan zelfstandig en verder geen hulp, omdat wij natuurlijk gewoon op school zijn om les te geven."

Organisatie van het online rekenonderwijs op dit moment

"We zijn eigenlijk een pilot gestart met groep 7 en 8, via het programma Snappet. Dus eerst hadden we daarmee een pilot voor rekenen. We hebben in eerste instantie toen de kinderen thuiskwamen, zijn we met Gynzy bezig geweest. Daar hebben we herhaald, omdat we dachten dat is het verstandigste. En nu zijn wij overgestapt naar Snappet en daarin hebben we ook spelling en taal enz. ook bij ingevoegd. Wij zetten de lessen klaar, en dan maken ze die, en ze hebben een weekoverzicht en daar staat in wat ze moeten maken en daar staat ook het doel van de les in, en vervolgens kunnen wij hen per som volgen. Er zit ook een chatfunctie in, dus kinderen die sturen ons vragen. Sommigen die zijn niet heel concreet, dus dan moet ik wel eens doorvragen van "wat voor soort som, wat bedoel je precies?". Of kinderen stellen ons vragen, maar wij kunnen ook kinderen benaderen via die chat. Dus dat vinden we heel handig. We kunnen het ook zelf zien als ze groeien. We waren eerst niet heel enthousiast, maar we zien ook wel weer voordelen hiervan. Dat is de manier waarop we het nu doen."

Hoe gaan leerlingen hiermee om? Hebben ze genoeg computervaardigheden en tools thuis om hiermee aan de slag te gaan?

"Ja hiervoor, wat ze nu doen voor rekenen, zeker."

De onderzoeker laat een voorbeeldopgave zien uit een andere lesmethode over rekenen met tijd die de docent van een andere participerende groep 7 heeft aangedragen voor het onderzoek.

"Dat is inderdaad, dit zijn dan de vragen en dan komen ze bij mij zo van "hé, hoe pak je dat aan?". Ook met de uren zeg maar. Dus dan merk ik dat of ze lezen de opdracht heel moeizaam, en iedereen die rekent het weer op zijn of haar manier uit. En daarin gewoon goede stappen te maken wat gewoon heel handige manieren zijn is voor sommigen nogal een hele klus."

Zijn er bepaalde strategieën die je dan in de klassikale les aanleert?

"Naja, ten eerste is het soms al voor kinderen lastig om dat verschil te maken tussen een uur met 60 minuten en een meter heeft dan 100 centimeters. Daar gaat het wel eens in mis, dat ze in plaats van 60 minuten, dat ze 100 minuten doen. Dat is soms al een klus. En de stappen waarvan ik denk: soms moet je eerst even aanvullen tot een heel uur. En van daaruit meestal eerst proberen te rekenen vanuit dat hele uur, maar ik heb hier nu niet de methode bij de hand omdat we zijn overgestapt naar [een online leermethode], maar ik ben volgende week of van de week ben ik nog op school, daar zou ik nog dingen uit kunnen halen. Wij werken dan met PlusPunt."

De docent gaat kijken welke opdrachten de leerlingen uit hun methode over het algemeen lastig vinden.

"Maar wat nog wel een ontbreekt bij deze leerlingen is dat ze in eerste instantie niet kritisch zijn op het lezen, maar ook niet kritisch zijn op het noteren. Ze doen veel te veel uit hun hoofd, in plaats van dat ze dingen opschrijven, of dat ze een klokje voor zich nemen. Ze zijn daarin wat te gemakkelijk vind ik.

Ook van de week weer, bij bepaalde opdrachten dan hebben ze het wel goed. Dan betaalt moeder zoveel procent van het bedrag, nou en dan hebben ze dat uitgerekend. En dan wordt er gezegd "Nou moeder die betaalt zoveel", maar dan moeten ze eigenlijk opschrijven, invullen, hoeveel dat kind dan nog moet betalen, dus dat lezen ze niet goed. Dan snappen ze de opdracht wel, maar dan komt weer begrijpend lezen om de hoek zetten. En ja naja dat is soms een ding."

Onderzoeker legt haar idee over het onderzoek uit

Reactie op motiverende berichten bij feedback "Dus eigenlijk wat ik doe in de chat. Ja mooi, want dat is ook wat ik doe maar soms dan reageer ik heel kort. Dat zet mij ook aan het nadenken van "hé hoe kan ik dat nou goed doen." Ook als ik 's ochtends om half 9 al achter mijn computer zit en dat ik ze goedemorgen wens "ik zie dat je al goed bezig bent" en dat de kinderen daar heel erg positief op reageren.

Vraag om via een link het onderzoek te delen met de leerlingen

“Ja, en ik zal ook even vooruitkijken waar het past. Dus ik zal even mijn huiswerk gaan maken, om te kijken van hé waar past dat. En ik zal ook even gericht kijken van hé waar zitten we precies in de leerstof en dan kan ik ook even die methode erbij pakken.

Ja ik vind het helemaal leuk. Ook jouw insteek. Ik merk zelf ook dat kinderen soms snel onzeker zijn, of inderdaad “doe ik het wel goed?”. En ook dat ze hun eigen strategie mogen gebruiken. Ik had ook nog een meetafspraak met een leerling via Google Meet en toen kwam de moeder erbij zitten. En dat ging dan over een bedrag van €1,65 gedeeld door 3. En toen zegt ze van: moet ik daar nou een staartdeling van maken? En dan denk ik: je maakt het jezelf moeilijk. Neem dan even een makkelijker getal: €1,50 en 15 cent, en dan denken ze veel te moeilijk.”

Uitleg over hoe de andere klas het onderzoek aangeboden krijgt (via een link in Google Classroom)

“Ik werk zelf met Google Meets, maar aan de andere kant, ik weet dat een vriendin van mij, die werkt ook in groep 7. Als je zegt van nou ik vind het leuk om nog meer klassen te hebben, dan zou ik ook haar altijd kunnen vragen. Die werkt ook met Google Classroom, en eigenlijk ik merk dat ik daar ook steeds meer handigheid in krijg. Het lijkt mij ook wel ideaal om daarmee te gaan werken, maar ik moet eigenlijk nog een beetje uitzoeken hoe dat werkt.”

Algemeen

27 jaar voor de klas. Vaak aan groep 7 lesgegeven. “Groep 7 vind ik echt een mooie leeftijd, ook de gesprekken die je met elkaar kunt hebben. Nog net geen puberfase.”

JUNIOR TEACHER (M)

Last year of: Grade 5 (*groep 7*), currently in special needs education
Experience: 2 years

Hoe pak je over het algemeen je rekenlessen aan in groep 7? Kun je me meenemen in de stappen?

"Wij werkten op school met dat Directe Instructiemodel. Dus we begonnen dan zeg maar met wat ze al wisten over het onderwerp. Dat we dat als eerste vroegen. Dat was dan wel klassikale instructie en daarna het doel van de les ook nog klassikaal en een soort voorbeeldopgave die daarbij zou kunnen horen. In de klas had iedere leerling zijn eigen whiteboard en daarmee moest iedereen dus even meedoen. Dan het antwoord opschrijven en dat dan klassikaal nog even behandelen. En dan daarna eigenlijk over op de les en daar had ik altijd een aantal leerlingen die dan gewoon meteen mochten beginnen, een aantal die mochten kiezen of ze al wilden beginnen en een paar die gewoon altijd meekeken."

Waar liepen deze 'zwakkere rekenaars' vaak tegenaan? Waarin begeleidde je ze?

"Nou, ik had heel veel dyslecten in mijn klas, misschien iets van 8 ofzo van de 28, en die rekenopdrachten worden steeds taliger. Dus vaak lukte de strategie dan nog wel, maar dan kwamen ze niet tot de strategie, omdat ze niet wisten wat ze in godsnaam uit die tekst moesten halen."

Stel, we denken nu aan alles digitaal, wat zou je dan aanraden voor die leerlingen aangezien ze toch vaak die contextvragen krijgen?

"Iemand kan van tevoren wat opnemen, dat je bijvoorbeeld een soort instructie maakt over hoe je de informatie eruit kan halen. Of dat je het in ieder geval voorleest, zodat ze dat auditief al hebben. En dat je dan gewoon die strategie blijft herhalen, van hé welke getallen zie je staan? Goh, welke getallen zou ik dan nodig hebben? En wat is nou de vraag? Dat talige dat blijft dan denk ik toch. Dat zullen ze ook in de echte toets krijgen, hoe jammer dat ook is."

Mogen dyslecten bij de toets ook voorgelezen worden?

"Ja, die krijgen alles digitaal, waarbij de tekst voorgelezen wordt."

Dat is wel een goeie, ik zou dus ook zo'n voorleesknop in de les kunnen bouwen.

"Ja, dat is wel een goeie, wat dan kunnen ze er ook vaker op klikken, en dat ze dan eerst bijvoorbeeld bedenken van: hé, wat is nou de vraag die hier wordt gesteld? Oké, eerste keer luisteren. Tweede keer luisteren, welke getallen hoor ik? En welke heb ik dan nodig?"

“Sommigen van hen hadden ook een soort stappenplan in hun laatje.”

Hoe motiveerde je goed of makkelijker presterende leerlingen?

“Nou, wij hadden heel veel pluswerk. Van hé, jij laat mij zien dat je dit al begrijpt, dat zie ik dan aan het begin van de les bij die voorbeeldopdracht. Als ik dan heb gezien van: hé dit zit wel goed, dan maakten zij meestal nog twee van de moeilijkste opdrachten uit het boek, en daarna gingen ze verder met pluswerk. En dat kon dan in projectvorm zijn, of gewoon een soort werkboekje dat ze ernaast kregen.”

Maken zij standaardfouten, bijvoorbeeld door te snel te lezen? Of hebben zij eigenlijk alles standaard goed?

“Nou, ik had er wel een paar die gewoon standaard alles goed hadden, maar ook wel een aantal die zichzelf wel overschatten. Maar ik heb ook wel eens in lezen, dat ik dan zei van: Kijk, vandaag mag je zelf bepalen of je meekijkt, en dan komen we er later op terug of dat een goede beslissing was. Maar heel vaak lezen inderdaad wel gewoon te snel, dat ze denken: nou goh ik weet wel wat het is.”

“Wat er in mij opkomt qua digitaal, dat je in de tussenstap, waar je vaak al veel tekst hebt, dat is dan voor de dyslecten al heel moeilijk, dat je er een paar getallen tussen zet die je eigenlijk helemaal niet nodig hebt voor de oplossing. Dus dat je een soort invuldingetje maakt van: wat is nu de vraag? En welke getallen heb je nou nodig? Dat ze dat al ergens in kunnen vullen, zodat je voordat ze überhaupt al starten met de strategie, dat je dan kan kijken van: oh misschien gaat het daar al mis.”

Aangezien nu alles digitaal is, moet je soms keuzes maken. De les moet bijvoorbeeld niet te lang zijn. Wat zijn volgens jou de belangrijkste onderdelen van een rekenles die echt terug zouden moeten komen?

“In ieder geval het doel, en ik vertelde er altijd bij waarom. Waarom moet je dit weten? Waar heb je het later voor nodig? Want soms, in groep 7 beginnen ze dan te puberen, en dan zeggen ze: ja, hèhè, dit is gewoon een stom trucje, waar kan ik dit voor gebruiken. Dan zeg ik bijvoorbeeld bij vierkante meters: stel je wil later een laminaatvloer leggen, dan wil je niet veel te veel kopen, want dat kost hartstikke veel geld. Dus de relevantie voor verder in het leven.”

Een andere docent heeft een les voorgesteld, die dan past in de komende weken en dat gaat onder andere over de juiste maten kiezen. *Laat de opdrachten van de docent zien*. Zij zei dat haar leerlingen dit nog niet zoveel hebben gehad. Ik wil hier in het specifiek nog even op ingaan. Hoe leerde jij deze stof aan, had je bijvoorbeeld ezelsbruggetjes of hoe visualiseerde je dat, het verschil tussen die maten?

"Ja, ik maakte eigenlijk gewoon heel stom en saai die trappetjes. En dan eigenlijk om te laten zien dat je met één trap, dat je bijna alles kan ondervangen. Bijvoorbeeld liters en meters, dan kan je gewoon zeggen, je hebt dan gewoon die L of die M, en voor de rest blijft die trap, dan heb je D, C, M van milli weer. Dus dat je eigenlijk niet heel veel verschillende trappen uit je hoofd hoeft te kennen om ze allemaal te kennen. Maar ik maakte daar niet iets heel keks van."

"Dan kregen ze vaak opdrachten met plaatjes, dat er in een pak melk, dat daar geen 1000 liter in zit.

Wat zijn hierbij veel gemaakte fouten die je je nog kan herinneren?

"Ze hadden bij mij niet super veel moeite hiermee. In dat opzicht zijn de verschillen natuurlijk best wel groot. Alleen centimeter millimeter was dan nog een soort van subtiel, subtiel verschil, maar meter en kilometer dat is natuurlijk best wel groot. Dat is wel duidelijk, dus dat ze net een stapje verkeerd doen. En ook misschien nog wel met hectometer en kilometer. Want hectometer is eigenlijk een beetje een onbekend begrip. Dat zijn we gewoon niet gewend, als je de 400 meter sprint doet, dan ga je niet de 4 hectometer lopen. Dus die is misschien ook niet meer superbelangrijk."

"Dit maten inschatten komt niet veel terug inderdaad. Ze hebben wel ieder hoofdstuk dat ze tafels, plus, min, gedeeld door, dat soort dingen. Maar dit komt echt weinig terug."

Hoe zou jij die leerlingen motiveren als ze alleen in hun kamertje achter die les zitten?

"Wat activerend, dus ik probeerde altijd wel steeds wat meer concreet materiaal te gebruiken. Dus bijvoorbeeld: nou, we hebben een les over maten. Je weet misschien nog van de vorige keer, je hebt in ieder geval liter, centiliter en milliliter, zet de video nu op pauze, zoek één ding waar een liter op staat, zoek een ding met centiliter, zoek iets waar milliliter op staat. Kom dan weer terug en zet de video weer aan."

"Dus het gewoon wat dichter naar ze toe halen."

"Het begint nu meteen weer te kriebelen, dat regulier onderwijs was toch ook wel grappig"

Appendix C

Needs & task analyses overview

Needs analysis

Based on interviews, and other contacts via social media

Problem/Need	Why?	Suggestions
Essential study material that pupils really need for the transition to Year 7 (groep 8)	Because of the school closures during the coronavirus followed by half weeks of classes, less learning material can be handled and some pupils lag behind	In this time period: lesson about the metric system - One teacher asked for: estimating the correct sizes -> This subject has not been covered much (see figure 1 below) - Another teacher asked for: converting measurements -> This is hard for most pupils. E.g. 1,5 cm + 5 mm = … cm
Providing proper feedback to pupils in online environments	Pupils respond very positively to this. Teacher: “I give feedback in the chat of Snappet, but sometimes I react very briefly. That also makes me think "Hey, how can I do that properly?".	Incorporate motivating feedback into the online learning environment
Reading support	Math questions are becoming increasingly linguistic. This is difficult for pupils (especially dyslexic pupils).	*Technical solution:* auditive support/read aloud tool *Instructional solution:* instruct the reading strategy and keep repeating it: Which numbers do you see? Well, which numbers would I need then? And what is the question?

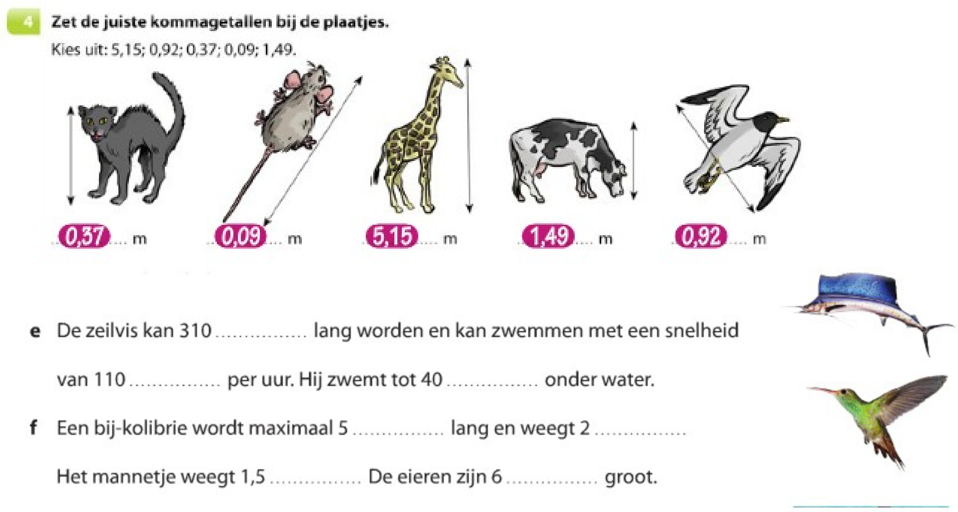


Figure 1. Part of the math tasks that the teacher wanted for the online lesson

Task analysis

Task Elements	Why Difficult?	Common Errors	Cues and Strategies
Read the question carefully	Many questions require reading comprehension for which pupils are often not critical enough or are rushing	Pupils interpret the question wrong or use the wrong numbers f.e.	Which numbers do you see? Well, which numbers would I need then? And what is the question?
Calculating the answer	Pupils are rushing or overestimate themselves, or are insecure about their strategies	Pupils do the steps by heart instead of writing them down, or they use the wrong strategies	Write down intermediate steps, enabling students to be more accurate and revisit their strategy later on
Choosing the right measurement unit	Some measurement units differ quite subtile or are quite unknown	Swapping centimeter and millimeter or use hectometer wrong	Real-world examples as a memory aid, e.g. grab a milk carton to see how much it contains
Converting measurements	Many steps to take, so one step could be forgotten more easily	Incorrect conversions: e.g. too much or too little zeros or the decimal point in the wrong place	Memorizing and using the ‘metric staircase’ in the correct way

Appendix D

Recruitment video and flyer

Click on the play button to directly play the recruitment video:

Source: https://youtu.be/H2to0Ys0DH4