Supporting students to study smart

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a Learning Sciences Perspective

Felicitas Biwer

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The research reported here was carried out at Maastricht University | Maastricht UMC+

in the School of Health Professions Education

in the context of the research school (Interuniversity Center for Educational Research)

Supporting Students to Study Smart – A Learning Sciences Perspective

ISBN: 978-94-6458-286-4

Provided by thesis specialist Ridderprint, ridderprint.nl
Printing: Ridderprint
Layout and design: Eduard Boxem, persoonlijkproefschrift.nl

Supporting Students to Study Smart

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Proefschrift

ter verkrijging van de graad van doctor aan de Universiteit Maastricht
op gezag van de rector magnificus prof. dr. Pamela Habibović,
volgens besluit van het college van decanen
in het openbaar te verdedigen
op vrijdag 8 juli 2022 om 10.00 uur

door

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geboren op 5 mei 1992
te Bonn (Duitsland)

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General Introduction

GENERAL INTRODUCTION

The transition from high school to university can be exciting and challenging at the same time. On the one hand, entering higher education might feel as learning without boundaries due to high levels of autonomy. On the other hand, students might feel overwhelmed when required to learn, retain, and apply a large amount of information. Both autonomy and managing a large amount of information require students to self-regulate their learning: They need to plan, monitor, and control their learning mostly outside the classroom during self-study (Broadbent, 2017; Zimmerman & Kitsantas, 2014). Self-regulated learning and using effective learning strategies are therefore essential for successful lifelong learning and student success (Richardson, Abraham, & Bond, 2012).

In the last decades, research in cognitive psychology and the learning sciences has developed a sound understanding of learning strategies and their effectiveness (Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013). Yet, survey studies indicated that 60-80% of students in higher education often use ineffective learning strategies to prepare for their next exam (Blasiman, Dunlosky, & Rawson, 2017; Hartwig & Dunlosky, 2012; Karpicke, Butler, & Roediger, 2009; McCabe, 2011; Persky & Hudson, 2016). For example, most students reread their notes, highlight the most important points of their summary and cram everything into memory, often shortly before the exam. Consequently, students end up with rather shallow knowledge and are prone to forget the just learned information quickly. As prior knowledge is a major predictor of successful future learning (Ertmer & Newby, 2013), students may find it difficult to continue and develop expertise given their superficial understanding of study materials. It is therefore an urgent question how to translate empirical evidence on effective learning strategies to applicable practices supporting higher education students to study more effectively.

In this dissertation, I aimed to investigate how we can support students to use more effective learning strategies during their self-study. This introduction first provides a description of self-regulated learning, different learning strategies and the role of desirable difficulties. Then, I will briefly describe existing interventions to support students in studying more effectively. I conclude by specifying the research questions underlying this dissertation, followed by an outline of the different chapters.

Self-Regulated Learning in Higher Education

Self-regulated learning (SRL) describes a process whereby students plan, monitor and control their cognition, behavior, and motivation to achieve their learning goals (Zimmerman, 2002). Different models of SRL conceptualize SLR in different phases and processes, but most models include three phases (for a review, see Panadero, 2017). In a preparatory phase, students analyze the learning task and set goals on what and how to learn. In the performance phase, students monitor and control their learning and goal progress. In a reflection phase, students reflect on their goal achievement and eventually adapt their learning strategies or goals for the next study session. This process is cyclical, wherein students use a variety of strategies to monitor and regulate their studying. These strategies can be differentiated into three main categories: cognitive strategies, metacognitive strategies, and resource management strategies (Boekaerts, 1999; Duncan & McKeachie, 2005; Schiefele & Wild, 1994; Weinstein & Mayer, 1986).

Cognitive strategies are used to select and organize to-be-learned information, to elaborate and connect new information with prior knowledge and to practice or rehearse the acquired knowledge (Weinstein, Acee, & Jung, 2011). This includes, for example, highlighting and summarizing to select and organize, self-explaining or visualizing to reach a better understanding, and rereading the information or practicing retrieval to practice the acquired knowledge. *Metacognitive strategies* refer to strategies used to monitor one's understanding and control the application of cognitive strategies. This includes, for example, goal setting prior to learning or comprehension monitoring during learning. *Resource management strategies* refer to the regulation of external resources, as in organizing one's workplace or time management, and internal resources, as in attention, effort, and motivation (Dresel et al., 2015). Resource management strategies are essential to initiate and continue learning and to manage distractions and procrastination (Schiefele & Wild, 1994). Not all cognitive learning strategies are, however, effective for long-term learning. Only part of the plentitude of learning strategies students can use to process information effectively stimulates sustained retention after a delay or fosters students' understanding for the long-term.

Using ineffective learning strategies can impair student achievement and lifelong learning. In an extensive review of the most commonly used learning strategies, Dunlosky et al. (2013) provided insight into which strategies actually have the strongest evidence to promote long-term learning and understanding (i.e., retrieval practice and distributed practice) and which strategies do not (i.e., highlighting, summarizing, rereading). What unifies the most effective learning strategies is that they create so-called *desirable difficulties* (Bjork & Bjork, 2014; Bjork & Bjork, 2020). Desirably difficult learning strategies make initial learning more difficult and effortful, but enhance retention, understanding, and transfer in the long-term. For instance, in distributed practice, students space out study sessions over time and structurally repeat the learning material (spacing; Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006). In interleaved practice, students mix related topics in a single study session (Yan, Bjork, & Bjork, 2016) as opposed to study one topic at a time. Another example is retrieval practice, in which students need to actively retrieve information from memory, e.g., by studying flashcards or making practice exams. The process of actively retrieving information from memory has been found to be much more effective compared to rather passive strategies, such as rereading (Roediger & Karpicke, 2006). This effectiveness is mainly explained by two mechanisms. According to the elaborative retrieval hypothesis, the act of retrieval stimulates learners to activate related information in long-term memory (Carpenter, 2009). According to the retrieval effort hypothesis, successful but difficult retrieval leads to better retention of information than successful but easy retrieval (Pyc & Rawson, 2009; Rowland, 2014). The effortful mental search in memory to retrieve the information is thought to change memory representations and facilitate later retrieval. The superior effect of retrieval practice, however, only appears after a delay of several days. This delayed effect and the effortful retrieval make it difficult for students to appreciate the benefit of retrieval practice, as their experienced learning differs from the actual learning.

Several aspects of desirably difficult learning strategies might explain why many students do not use these effective learning strategies during self-study. As already indicated above, first, experiences during learning can be misleading and delude students into believing that an ineffective strategy is effective. Learners tend to judge the degree of their own learning based on their subjective experiences, such as the sense of fluency in encoding to-be-learned information (Carpenter, Witherby, & Tauber, 2020; Finn & Tauber, 2015). For instance, reading a text again after an initial read (i.e., rereading) leads to a feeling of familiarity during encoding in learners and even higher recall of the text on an immediate test. In contrast, attempting to retrieve the information from the text is much more effortful and difficult than rereading, but will lead to higher performance after a delay (Bjork, Dunlosky, & Kornell, 2013; Nunes & Karpicke, 2015). Because of this 'experienced-learning-versus-actual-learning-paradox' (Biwer, oude Egbrink, Aalten, & de Bruin, 2020; Nunes & Karpicke, 2015; Roediger & Karpicke, 2006), students often overestimate the effectiveness of their self-chosen strategies.

Second, many students lack accurate metacognitive knowledge about the actual effectiveness of different learning strategies (Hartwig & Dunlosky, 2012; McCabe, 2011; Morehead, Rhodes, & DeLozier, 2016). Myths about learning, such as the learning style myth, are still omnipresent in students and teachers and impair students' judgments of how to study most effectively (Kirschner, 2017; Kirschner & van Merriënboer, 2013). Addressing these myths and idiosyncratic ideas about how learning happens is necessary to counteract inaccurate knowledge. However, students receive little to no instruction on effective learning strategies (Dunlosky et al., 2013). Only 20-40% of students reported studying the way they do because they were taught to study that way (Morehead et al., 2016). Curricula tend to emphasize the acquisition of content-based knowledge rather than teaching how to learn that content most effectively (Frank et al., 2010). Without awareness of desirable difficulties, however, students are more likely to continue using less effective learning strategies as the perceived costs of desirably difficult learning strategies outweigh their perceived utility (Finn & Tauber, 2015; Wigfield & Eccles, 2000).

Third and finally, the self-regulated use of desirably difficult learning strategies is challenging. Research has shown that even if students know about the effectiveness of practice testing or distributed practice, they still struggle to actually apply these strategies (Blasiman et al., 2017; Foerst, Klug, Jostl, Spiel, &

Schober, 2017). Putting knowledge into action is effortful, it requires deliberate practice and a behavior change over time (Fiorella, 2020). In addition, there are also more practical considerations related to resource management strategies. For instance, in applying retrieval practice, students need practice questions, which are not always available. Teachers often refrain from making old exams available due to the time and effort it takes to draft new exams every year. In that case, students would need to first generate their own questions before being able to practice retrieval with these self-generated questions. While there is some research -with mixed evidence- on the effect of simultaneously generating questions and answers on learning (Bugg & McDaniel, 2012; Hoogerheide, Staal, Schaap, & van Gog, 2018; Weinstein, McDermott, & Roediger, 2010), little is known on the effect of practicing retrieval with self-generated questions (Senzaki, Hackathorn, Appleby, & Gurung, 2017). More empirical research is needed to understand how practical solutions in supporting students to use practice testing can be designed effectively. In sum, in light of the abovementioned challenges in applying effective learning strategies on one's own, it seems of utmost importance to directly instruct students on effective learning strategies and how to apply them.

Supporting Students to Study Smart

In the last years, several training programs were developed that aimed at improving general self-regulated learning skills, i.e., to "study smart" (e.g., Bellhäuser, Lösch, Winter, & Schmitz, 2016; Dignath, Buettner, & Langfeldt, 2008; Dignath & Büttner, 2008; Dörrenbächer & Perels, 2016; Schuster, Stebner, Leutner, & Wirth, 2020; Weinstein, Husman, & Dierking, 2000). Self-regulated learning can either be directly activated through direct instruction on the why, how, and what of strategy use, or indirectly activated by creating a supportive learning environment, including for example prior knowledge activation or cooperative learning (Dignath & Veenman, 2020; Souvignier & Mokhlesgerami, 2006). Direct strategy instruction has been found to be more effective to support self-regulated learning than indirect instruction through the learning environment (Dignath & Veenman, 2020). Meta-analytic research showed positive effects of extended SRL training programs with direct strategy instruction on academic performance, strategy use and motivation

(Dignath & Büttner, 2008; Donker, de Boer, Kostons, Dignath van Ewijk, & van der Werf, 2014). In educational practice, however, self-regulated learning is mostly activated indirectly and instruction often focuses on cognitive strategies only, neglecting the importance of direct instruction on metacognitive and resource management strategies as well (Dignath & Veenman, 2020). Furthermore, most of these programs focus on primary or secondary school students, or on learning strategies that target particular domains, such as reading, writing or mathematics (Dignath & Büttner, 2008). Finally, existing SRL training programs do not explicitly address the effectiveness of different cognitive learning strategies for long-term learning, as in addressing students' knowledge and beliefs about desirably difficult learning strategies. Given all challenges concerning the application of desirably difficult learning strategies on the one hand, and their benefits for long-term learning on the other hand, it is highly important to directly address this issue in learning strategy instruction.

Within direct strategy instruction, one can distinguish theory-based and experience-based approaches. These approaches aim to increase students' knowledge about effective learning strategies and support their sustained and self-regulated use (Koriat & Bjork, 2006). In *theory-based approaches*, students receive direct information about learning strategies. This includes declarative knowledge about effective learning strategies (which strategies are effective for long-term learning), conditional or metacognitive knowledge (knowledge about when and why a specific strategy is effective) and procedural knowledge (how to use the strategy) (Weinstein et al., 2011). As shown in an experimental study by Ariel and Karpicke (2017), informing students about the effectiveness and mnemonic benefits of retrieval practice motivated them to use retrieval practice one week later. We thus argue that becoming aware of which strategies are (in)effective and for what purpose, and getting to know how to use them is a first step in successful self-regulated use of effective learning strategies.

Furthermore, as mentioned above, strong prior beliefs and misleading subjective experiences hinder students in mending their metacognitive illusions (Yan et al., 2016). This aspect requires guidance to recognize the differential effectiveness of strategies and to develop accurate metacognitive knowledge by reflecting on the experienced-learning-versus-actual learning paradox. Thus, in order to help students develop more accurate beliefs, an *experience-based approach* is needed, by letting students directly experience the effects of effective and ineffective learning (McDaniel & Einstein, 2020). In order to overcome the knowledge-practice gap, this, however, needs to be followed up with supported practice over time and reflection. Students may have gained metacognitive knowledge, but still struggle to apply the strategies during their self-study (Dembo & Seli, 2004; Foerst et al., 2017). The aspect of guided practice has been neglected in learning strategy trainings so far (Foerst et al., 2017). Moreover, it is unknown how to best provide a learning strategy training to students and what challenges arise for higher education institutes wanting to support students to study smart on a larger scale.

Successful self-regulated learning does not only include applying effective cognitive and metacognitive learning strategies during self-study but also involves adaptation to changing circumstances and successfully reacting to challenges posed by different learning environments. In the last years, educational environments experienced a great shift from on-site to online education, especially due to the COVID-19 pandemic. As learning is situated in specific contexts, self-regulatory processes will differ across contexts (Boekaerts & Niemivirta, 2000; Efklides, 2011). Regarding the adaptation to abruptly shifting learning circumstances, such as the emergency remote education during the COVID-19 pandemic (Hodges, Moore, Lockee, Trust, & Bond, 2020), resource management strategies play an important role to regulate cognitive, emotional, and motivational aspects of learning. Applying resource management strategies, as in managing time, distractions, or effort, can enable learners to then successfully apply cognitive and metacognitive strategies during learning. It is, however, unclear, how students adapt to changing circumstances, such as to emergency remote education, and whether students would need individualized support to counter this challenge.

Research Questions

Based on the abovementioned previous research findings and gaps in existing literature and training programs, the overarching aim of this thesis was to investigate how to support the self-regulated use of effective learning strategies. For this purpose, the following research questions were addressed:

1) How does a direct learning strategy intervention that addresses awareness, practice, and reflection affect students' metacognitive knowledge, use of effective learning strategies, and academic performance (Chapters 2 and 3)?
2) What are the prerequisites and challenges in implementing a learning strategy intervention on a large scale? (Chapter 4)
3) What are the effects of stimulating retrieval practice with limited support, by answering self-generated practice questions, compared to answering provided questions or rereading on long-term retention? (Chapter 5)
4) How did students adapt their resource management strategies to emergency remote education? (Chapter 6)

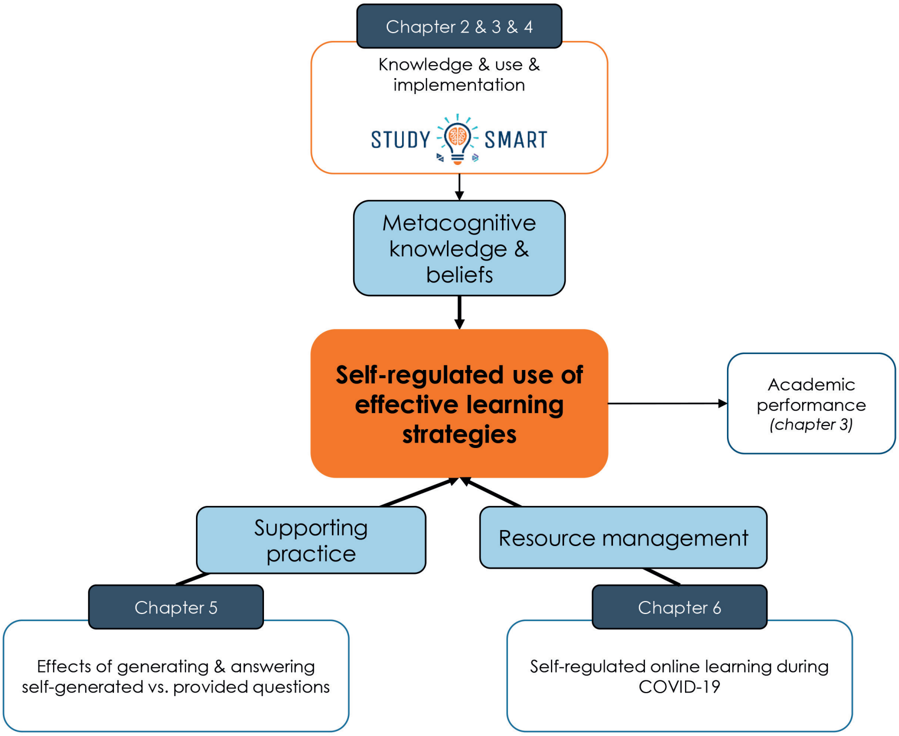

Figure 1.1. Overview of the dissertation

OUTLINE OF DISSERTATION

In this dissertation, I aim to answer the research questions outlined above by means of different approaches (see Figure 1.1). The first approach (chapters 2, 3, and 4) is to directly address students' metacognitive knowledge and beliefs about learning strategies with a direct learning strategy training, called 'Study Smart' (see for more details in the box 'Setting'). In **chapter 2**, we examined the effect of the Study Smart program on students' metacognitive knowledge about and use of learning strategies in a mixed-methods study. Through a waiting-list control group experiment and the use of focus group discussions, we gained in-depth insight into the perceived barriers and facilitators of using new and effective learning strategies during self-study. **Chapter 3** describes a study extending the findings of chapter 2. In this study, we examined the effects of the Study Smart program on metacognitive knowledge, use of learning strategies, and academic performance of all first-year students in a Pharmacology curriculum. We examined the effects on metacognitive knowledge and use of learning strategies before and after participating in the program and compared academic performance in two cohorts, of which one cohort received the Study Smart program. In **chapter 4**, we evaluated the implementation of the Study Smart program and reflected on the prerequisites and challenges in curriculum implementation. Using an educational design research approach, we continuously evaluated and redesigned the Study Smart program over a period of three years. The program was implemented to a different extent in several study programs of Maastricht University: It was either provided to all students of one cohort by their mentors, or offered by tutors or student advisers on a voluntary basis; that is, students interested in improving their learning strategies could sign up for the program. We reflected on the insights gained through focus group discussions with trainers and students, observations of training sessions, evaluation questionnaires and project team meetings and we discussed future steps.

Setting: The Study Smart Program at Maastricht University

Central to this dissertation is the 'Study Smart Program', a learning strategy training for first-year students, aiming to create awareness of, practice with, and reflection on effective learning strategies with the ultimate goal to sustainably increase students' use of these strategies and improve their learning. The Study Smart program was first developed in 2017 by a project team of the Maastricht University center for educational innovation, EDLAB. The project team consisted of members of each faculty of Maastricht University with different backgrounds and experiences in the learning sciences. The development and implementation of the Study Smart program was partially funded by a Comenius Teaching Fellowship from the Dutch Ministry of Education, awarded to project chair Anique de Bruin. The first version of the Study Smart program was subject of the first study of this dissertation, in which I examined the effects of the training on students' knowledge and use of effective learning strategies. Throughout this project, and through an educational design research cycle (McKenney & Reeves, 2014), the first version was continuously evaluated, developed and updated. Furthermore, when implemented in different faculties, study programs, or other universities, the program has been adapted to different contexts.

The program typically spans three 2-hour sessions with a small group of about 12 students with one teacher. Sessions are spread out over several weeks to enhance knowledge consolidation and stimulate application of the acquired knowledge. The first session, the "awareness session" aims to make students aware of their own learning strategies and scientific evidence of the effectiveness of different learning strategies for long-term learning. The second "reflection session" aims to stimulate reflection on study motivation, learning strategy use and challenges in applying effective learning strategies during self-study. The final "practice session" aims to enhance students' practice of effective learning strategies by letting them experience the 'experienced-learning-vs-actual-learning-paradox' and providing guidance and feedback in applying different strategies during self-study.

The second approach is to indirectly improve the self-regulated use of effective learning strategies by supporting practice. In **chapter 5**, we zoomed in on one of the practical barriers many students experience when aiming to use more retrieval practice in their self-study: the lack of available practice questions. In two experiments with a between-subjects design, we investigated the effect of answering self-generated questions compared to answering provided questions or to rereading on long-term text retention.

In **chapter 6**, we addressed the third approach and shifted the perspective from students' cognitive and metacognitive strategies to their resource management strategies. Due to the COVID-19 pandemic, students were forced from one day to the other to study remotely. We were interested in how students adapted to this emergency remote education, with a specific focus on their resource management strategies. Applying resource management strategies, such as time management or dealing with distractions, were assumed to be important factors in successfully adapting to the changed context. We distributed an online questionnaire consisting of both open and closed questions to all students at our university and asked students about their perceived adaptation to emergency remote education. Using an individual differences approach, we examined whether students differed in their ability to adapt and gained more insights in the why and how by analyzing students' open answers qualitatively through thematic analysis.

The general discussion chapter discusses the findings from the different studies described above in light of theoretical, methodological and practical considerations, limitations, and implications. In the impact chapter, I more specifically address the scientific and societal impact of this dissertation. For an overview of all empirical studies included in this dissertation, see Table 1.1.

Table 1.1. Overview of conducted empirical studies

	Chapters				
	2	**3**	**4**	**5**	**6**
Title	*Fostering effective learning strategies in higher education – a mixed-methods study*	*Study Smart – Impact of a learning strategy training on students' study behavior and academic performance*	*Future steps in teaching desirably difficult learning strategies*	*To ask or to answer – the effect of generating and answering self-generated versus provided questions on expository text retention*	*Changes and Adaptations – how university students self-regulate their online learning during the COVID-19 pandemic*
Aim	To examine the effect of the Study Smart training on students' knowledge about and use of learning strategies	To examine the effect of the Study Smart training on students' knowledge about and use of learning strategies long-term & on academic performance	To evaluate the implementation of the Study Smart program and reflect on prerequisites and challenges in curriculum implementation	To investigate the effect of generating & answering self-generated vs. provided questions on expository text retention	To explore how students adapted to emergency remote learning using an individual differences approach
Design	Waiting-list control group, between-subjects Mixed-methods	Pre-post cohort design	Educational Design Research	Two experiments with between-subjects design	Questionnaire study Cluster Analysis
Data Sources	Questionnaires pre-post, focus group evaluations	Questionnaires pre-post-long-term, academic grades	Evaluation questionnaires, focus group discussions with students and mentors, session observations, project team discussions	Learning performance data, pre and delayed posttest	Questionnaire with closed and open answers
Participants	49 first-year students FHML, international & Dutch	110 first-year pharmacology students, US	1500 first-year students, 50 teachers, different faculties of UM	Experiment 1: 138 Bachelor UM students; Experiment 2: 150 Bachelor students, Prolific	1800 Bachelor & Master students from UM, international & Dutch

REFLEXIVITY

I started this dissertation with a background in psychology and a specific focus on educational psychology, but also with my personal experiences in learning and studying as a student, just coming from university. I also started this dissertation holding different roles: one as PhD candidate, one as project member of the Study Smart project, and one as mentor and teacher. I did not only do research on the impact and effectiveness of the Study Smart program, but was also involved in the evaluation, analysis and redesign of the program, in teaching new Study Smart trainers, or giving the training to students myself. In my role as mentor, I often talked with my students about their learning strategies. The stories of their struggles also inspired my research. I was provided with the opportunity to discuss the influence of these different roles with my research team. The team included researchers with different professional backgrounds (cognitive and educational psychology, health professions education and physiology) and levels of involvement in the Study Smart project and the organization (project chair, scientific director of the FHML Institute for Education, student advisor, or outside of the organization). We shared insights and discussed our perspectives, they guided me taking a birds' eye view or zooming in on specific details. I would like to acknowledge that the interactions with my team members, teachers, students, and participants have enriched and guided my research and have either directly or indirectly influenced the way I focused on the frames of my research.

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Chapter 2

Fostering Effective Learning Strategies in Higher Education – A Mixed-Methods Study

This chapter has been published as:

Biwer, F., oude Egbrink, M.G.A.., Aalten, P. & de Bruin A.B.H. (2020). Fostering Students Learning Strategies in Higher Education – A Mixed-Methods Study. *Journal of Applied Research in Memory and Cognition, 9,* 186–203.

ABSTRACT

Cognitive psychological research from the last decades has shown that learning strategies that create desirable difficulties during learning, e.g., practice testing, are most effective for long-term learning outcomes. However, there is a paucity of research on how to effectively translate these insights into training students in higher education. Therefore, we designed an intervention program aiming to create awareness about, foster reflection on, and stimulate practice of effective learning strategies. In a first examination of the pilot intervention (N = 47), we tested the effects of the intervention on metacognitive knowledge and self-reported use of effective learning strategies during self-study, using a control-group mixed-methods design. The intervention program had positive effects on knowledge about effective learning strategies and increased the use of practice testing. Qualitative interview results suggested that to sustainably change students' learning strategies, we may consider tackling their uncertainty about effort and time, and increase availability of practice questions.

Keywords: Desirable difficulties, learning strategies, intervention program, metacognitive knowledge, university students

GENERAL AUDIENCE SUMMARY

In order to study and obtain positive and long-term learning outcomes, students should use effective learning strategies, for example taking a practice test or spacing out study sessions over time. Psychological research has indicated that strategies that make learning more difficult and effortful effectively enhance long-term retention. Most students, however, use rather passive, ineffective strategies, such as rereading or highlighting. These strategies make the learning process appear easier, which creates a feeling of fluency. As a result, students are overconfident about their long-term learning and overestimate their remembering, which has detrimental effects on their learning outcomes. In order to translate research evidence on effective learning strategies into students' self-study practice, we developed a learning strategy intervention program, called 'Study Smart'. In this program, we aimed to create awareness about, foster reflection on, and stimulate the practice of effective learning strategies. The program consisted of three two-hour sessions and was given to first- and second-year university students. After the intervention program, students had gained more accurate knowledge about effective learning strategies and developed the intention to change their study behavior and use more effective strategies. They also reported to use more practice testing during self-study. In group discussions, we dove further into facilitators and barriers of a learning strategy change. A perceived discrepancy between own strategy use and empirically effective learning strategies encouraged students to change. Qualitative interview results suggested that to sustainably change students' learning strategies, we may consider tackling their uncertainty about effort and time, and increase availability of practice questions. Altogether, this study shows that implementation of an evidence-based intervention program is a promising way to stimulate university students to use effective learning strategies.

INTRODUCTION

Entering higher education, students face the challenge of self-regulating their learning. Students are expected to be autonomous learners and to plan and monitor their own learning in a new context, less guided than in secondary education (Dresel et al., 2015). Using effective learning strategies during self-study is crucial for positive long-term learning outcomes and academic achievement (e.g., Donker, de Boer, Kostons, Dignath van Ewijk, & van der Werf, 2014). However, most students rely on ineffective strategies, such as rereading (Blasiman, Dunlosky, & Rawson, 2017; Hartwig & Dunlosky, 2012). Students are easily fooled by metacognitive illusions and mistakenly interpret short-term performance or ease-of-processing as reliable indicator for long-term learning (Kornell, Rhodes, Castel, & Tauber, 2011; Soderstrom & Bjork, 2015). As a consequence of this *experienced-learning-versus-actual-learning*-paradox, students are overconfident in their self-chosen learning strategies relative to academic performance (Winne & Jamieson-Noel, 2002) and often endorse ineffective learning strategies as being effective (McCabe, 2011; Soderstrom & Bjork, 2015).

Recent literature in cognitive psychology has established strategies that enhance effective learning for the long-term, such as *distributed practice* and *retrieval practice* (for reviews, see Adesope, Trevisan, & Sundararajan, 2017; Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013; Roediger & Pyc, 2012). Still, many first-year university students struggle to develop effective learning strategies. One potential reason is that effective learning strategies are 'desirably difficult' (Bjork, 1994; Bjork, Dunlosky, & Kornell, 2013): they require more effort during initial learning, but benefit long-term learning outcomes and transfer to other contexts (Yan, Clark, & Bjork, 2017). Without accurate *metacognitive knowledge* (i.e., knowledge about why and which learning strategies are beneficial for long-term learning), students probably keep using passive and ineffective strategies during self-study (Karpicke, Butler, & Roediger, 2009). Creating awareness about effective learning strategies, fostering reflection on desirable difficulties, and letting students encounter the experienced-learning-versus-actual-learning-paradox might enhance metacognitive knowledge and actual use of effective strategies during self-study (Yan, Thai, & Bjork, 2014).

Desirable Difficulties and Cognitive Learning Strategies

Students can use a diversity of learning strategies. Dunlosky et al. (2013) provided an overview of the effectiveness and utility of ten of the most common ones (summarized in Table 2.1).

Table 2.1. Overview of 10 commonly used learning strategies, ordered in their effectiveness for long-term learning (based on Dunlosky et al., 2013)

Learning strategy	Description	Effectiveness for long-term learning
Practice testing ('retrieval practice')	Actively retrieving information from memory by using practice tests or flashcards (quizzing)	High
Distributed practice	Spacing study in several sessions over time and reviewing learning material studied earlier in later sessions	High
Elaborative interrogation	Producing explanations by answering 'why' questions about facts and concepts after studying	Moderate
Self-explanation	Explaining how newly learned information is related to prior knowledge	Moderate
Interleaved practice	Mixing study of different, but related, learning materials or problems within one study session	Moderate
Summaries	Writing down the main points from a text	Low
Mental imagery	While studying, creating a mental image of the learning material	Low
Keyword mnemonics	When studying vocabulary or facts, creating a mental image to associate verbal materials	Low
Rereading	Rereading text material after initial read	Low
Highlighting	Marking important information by highlighting or underlining the learning material while reading	Low

The learning strategies of *retrieval practice* and *distributed practice* currently have the strongest empirical support for enhancing long-term learning and creating desirable difficulties (Bjork, Little, & Storm, 2014; Cepeda, Pashler, Vul, Wixted, &

Rohrer, 2006; Dunlosky et al., 2013). *Retrieval practice* refers to stimulating active retrieval of information from memory, e.g., by taking practice tests or *quizzing* by using flashcards. Retrieval practice improves long-term retention compared to rereading the material in the same amount of time (i.e., testing effect; see Roediger & Karpicke, 2006; Rowland, 2014). *Distributed practice* concerns spacing out studying over time and repeating the study material across different study sessions (Delaney, Verkoeijen, & Spirgel, 2010; Ebbinghaus, 1913). It refers to a particular learning schedule rather than a particular kind of learning (Dunlosky et al., 2013). A related strategy is *interleaved practice*, which refers to switching amongst topics in a single study session (Rohrer & Taylor, 2007).

Other effective strategies that encourage active processing and provide feedback about understanding are elaboration strategies, such as *elaborative interrogation* (e.g., Smith, Holliday, & Austin, 2010) and *self-explanation* (e.g., van Peppen et al., 2018). In elaborative interrogation, students produce explanations of the learning material by answering 'why' and 'how' questions. The strategy of self-explanation requires students to explain problems or concepts to themselves while studying. These strategies stimulate creating meaningful connections between learning material and other information (e.g., prior knowledge) and support metacognitive monitoring.

In contrast to the strategies mentioned above, more passive strategies, such as *highlighting* or *rereading*, make the learning process feel easier and mislead students' metacognitive judgments (Karpicke et al., 2009). Students base their judgments of learning on their ease-of-processing, which creates a *fluency illusion* (e.g., Kornell et al., 2011; Oppenheimer, 2008). Driven by biased experiences during learning, students are prone to choosing passive, ineffective learning strategies (Bjork et al., 2013), overestimating their remembering, and underestimating their forgetting (Kornell & Bjork, 2009). Being overconfident about learning can have detrimental effects on students' study behavior and learning performance (Dunlosky & Rawson, 2012). Thus, accurate metacognitive knowledge seems important to support students in self-regulated use of effective learning strategies.

Interventions on Knowledge and Use of Cognitive Learning Strategies

Few studies have investigated methods to improve metacognitive knowledge and to encourage effective learning strategies in higher education (Ariel & Karpicke, 2017; DeWinstanley & Bjork, 2004; Gurung & Burns, 2018; Koriat & Bjork, 2006; Tullis, Finley, & Benjamin, 2013; Yan, Bjork, & Bjork, 2016). Combining *theory-based methods* (i.e., providing information about the experienced-learning-versus-actual-learning-paradox) and *experience-based methods* (i.e., experiencing the difference between two learning strategies) is important for improving metacognitive knowledge (Koriat & Bjork, 2006). Using a theory-based method, Ariel and Karpicke (2017) informed students about the effectiveness and mnemonic benefits of repeated retrieval practice, which motivated students to use retrieval practice one week later. McCabe (2011) taught students in an introductory psychology course about applied learning and memory topics (e.g., on desirable difficulties). Students that received direct instruction on applied learning and memory topics gained higher metacognitive knowledge than non-instructed control students who attended a general introductory psychology course. In an experience-based study, students experienced the benefits of a desirably difficult learning strategy (i.e., generating word items) compared to rereading, which increased knowledge about the benefits of this strategy and motivated students to use that strategy during the next learning session (DeWinstanley & Bjork, 2004). A multi-site study by Gurung and Burns (2018) showed positive effects of retrieval and distributed practice on exam scores, when implemented in the classroom.

Most studies, however, investigated short-term effects within controlled learning environments, not during self-study practice. For instance, only 11% of the included experiments in the meta-analysis by Adesope and colleagues (2017) were conducted in classroom settings. This demonstrates the importance of research on how to translate evidence from lab-based studies to educational practice and of research aimed at getting students to use effective learning strategies in real educational settings (Brandmark, Byrne, O'Brien et al., 2020). Many students struggle to sustainably change old learning strategies into more effective ones (e.g., Dembo & Seli, 2004; Foerst, Klug, Jostl, Spiel, & Schober, 2017). Strong prior beliefs and misleading subjective experiences are obstacles in mending metacognitive illusions (Yan et al., 2016). Thus, explicit guidance in recognizing the differential effectiveness of strategies is needed to improve metacognitive knowledge and, in turn, encourage actual use (Tullis et al., 2013).

Taken together, the question remains to what extent informing students about the benefits of effective (but desirably difficult) learning strategies and letting students experience the experienced-learning-versus-actual-learning-paradox can improve metacognitive knowledge and stimulate the use of effective learning strategies during self-study in the long-term. Furthermore, it is unknown what factors motivate or hinder students in actually using effective learning strategies during self-study.

The Present Study

In the present mixed-method study, we investigated whether informing students about effective learning strategies and desirable difficulties (*awareness*), stimulating students' reflection about their learning strategies and motivation (*reflection*), and letting them experience the experienced-learning-versus-actual-learning-paradox (*practice*) improves metacognitive knowledge and enhances the actual use of effective learning strategies during self-study throughout several weeks. To this end, we compared the effects of an intervention condition, in which participants attended the so-called 'Study Smart' intervention program, with that of a waiting-list control condition on metacognitive knowledge and self-reported strategy use. In a first examination of the Study Smart program (N = 47), we tested the following hypotheses:

Metacognitive knowledge hypothesis: The Study Smart program leads to enhanced metacognitive knowledge as compared to the control condition.

Learning-strategy-use hypothesis: The Study Smart program leads to higher use of effective learning strategies during self-study as compared to the control condition.

We further aimed to gain more in-depth insight into the *barriers and facilitators* of using new and effective learning strategies during self-study with the use of focus group discussions.

METHOD

Participants

Participants were first- and second-year undergraduate students in Medicine, Biomedical Sciences, or Health Sciences at a problem-based learning (PBL) university in the Netherlands. Prior to the pretest, students were randomly assigned to either the Study Smart condition or the control condition. Of the 66 students that completed the pretest, 47 (age 20.6 ± 2.7 yr. (M ± SD); 85% female) completed the posttest, which constituted our final sample. Twenty-one of these students were part of the Study Smart condition (age 21.4 ± 3.6 yr.) and 26 of the control condition (age 19.9 ± 1.5 yr.). Both groups were comparable with regard to high school GPA and average grades during the first three courses of the academic year (all *p*'s > .287). In the final sample, 29 students were from Biomedical Sciences, ten from Medicine and eight students from Health Sciences.

The Study Smart Intervention Program

The Study Smart intervention program consisted of three sessions: awareness, reflection, and practice. See Figure 2.1. for an overview of the intervention and Appendix A for a detailed description of each session. Sessions took place every other week over a total period of six weeks, with the pretest in week 1 and posttest in week 6. Each session took approximately two hours and was led by the first and last author. The group size was 4-12 students, depending on the session and availability of the students. The ten learning strategies and the empirical evidence for their effectiveness as addressed in the Study Smart program were based on the review by Dunlosky et al. (2013), covering more than 700 experimental studies. See Table 2.1 for an overview of the learning strategies targeted in the intervention.

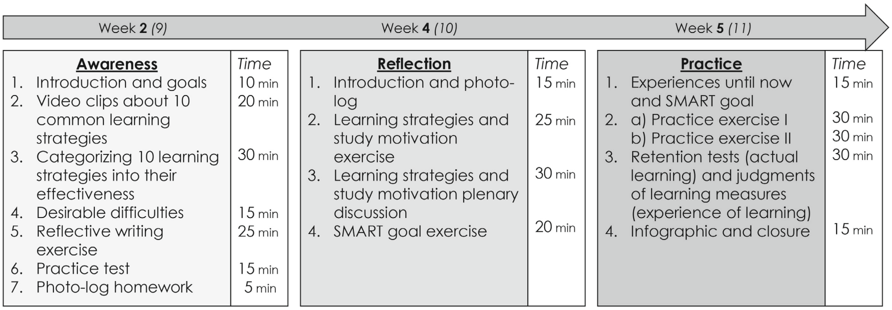

Figure 2.1. Overview of the 'Study Smart' intervention program

In line with the theory-based method, we informed students about the effectiveness of different learning strategies in the first session, focusing on *awareness*. This session aimed to challenge students' prior beliefs about the effectiveness of commonly used learning strategies and to provide information about empirical evidence. The experienced-learning-versus-actual-learning-paradox was explained and the importance of desirable difficulties and the testing effect were presented (Roediger & Karpicke, 2006). More specifically, the session started with a short introduction of the program facilitator and students in order to create an open atmosphere in the group. Second, the facilitator showed short informative video clips (30 seconds each) about ten learning strategies. Each video displayed a student performing one of the strategies; accompanied by a voice-over explaining the strategy. After each clip, the facilitator asked whether and when students used these strategies, and what their beliefs were about their effectiveness. Third, students categorized the strategies into highly effective, moderately effective and non-effective strategies using card sorting. The facilitator explained the effectiveness of each strategy (based on Dunlosky et al., 2013), how much training is required to use a strategy, and how to implement the strategies in problem-based learning. Fourth, the facilitator addressed the role of desirable difficulties. Students watched a video (6 min) about the importance of deliberate practice and of investing effort and time to become good at something. Afterward, the facilitator explained the testing effect and the difference between experienced learning and actual learning, illustrated by graphs from empirical studies (taken from Roediger & Karpicke, 2006; Nunez & Karpicke, 2015). In the fifth part, students prepared for change by means of a reflective writing exercise. They reflected upon a memory of when they successfully developed a new skill or habit through extended practice (e.g., sports, arts, music) or changed their behaviour after a long time. The facilitator instructed the students to write about this memory (in about 300 words) in as much detail as possible and to relate this memory to the challenges they expect when using effective learning strategies. The awareness session ended with a practice test consisting of seven open questions about the nature of the learning strategies, for instance, "For what type of study materials is interleaved practice useful? Why only for this material?". This practice test aimed to strengthen and recap the information taught in the awareness session. Since this was meant as retrieval practice, students' responses were discussed in the group, but not further analyzed. As homework for the following session, students were asked to keep a photolog of their study behavior to enhance reflection on their learning strategies.

The second session, focusing on *reflection*, addressed students' study motivation and academic goal orientation (Elliot & McGregor, 2001). The session started with a short introduction and presentation of students' photologs. Students presented the learning strategies they had used the last week to each other. Second, students completed two questionnaires; one about their learning strategies (based on the survey by Kornell and Bjork, 2007) and one about their academic goal orientation (questionnaire by Elliot & McGregor, 2001). The questionnaire exercise aimed to create awareness about students' learning strategies and study motivation and to encourage students to reflect on what they would like to achieve with their studies. Students calculated their scores and received a response sheet to check where their motivation was the highest. Third, students shared their main findings of the questionnaire with their partner and subsequently reflected about their study motivation in the group. The program facilitator emphasized the importance of long-term learning. Fourth, students formulated an individual learning goal according to the SMART principle (Doran, 1981; specific, measurable, achievable, relevant, and timebound), about how to practice effective learning strategies during self-study. Each student picked one strategy s/he wanted to try in the upcoming period and formulated a specific goal about that learning strategy.

The third session, focusing on *practice*, aimed to let students experience the difference between effective and ineffective study strategies. This session started with a plenary discussion about students' study behavior during the previous exam period. Students discussed their SMART-goal as set in the previous session and the reasons for (not) having experimented with the proposed learning strategies. In the second part, students were divided into two groups and applied either highlighting (ineffective strategy) or practice testing (effective strategy) on a scientific article. After 30 minutes, they switched roles and applied the other strategy on another scientific article. In an 'exam' test, students had to answer questions on the study material to let them experience the effectiveness of the different learning strategies. After completing the potential exam questions, students estimated their performance and noted the grade they thought they would receive for their answers. Afterward, students scored their answers using an answer sheet and compared their judgments and actual grades. Third, students shared their experiences during the exercises. The facilitator clarified that the learning impact of practice testing cannot be experienced within a 2-hours session and that the purpose of this exercise was about experiencing the differences in effort while using the learning strategies. The practice session ended with an infographic handed out to the students, summarizing the effectiveness of different learning strategies.

In the Study Smart condition, two participants did not attend the reflection session, while one other participant missed the practice session. These students received all materials and information about the session they missed via e-mail and got the possibility to ask the program facilitator further questions in the next session.

Measures

As dependent variables, we measured metacognitive knowledge about learning strategies, and use of learning strategies with several instruments in the pretest and posttest, in order to triangulate the results and to gain a holistic picture of the effects. The use of learning strategies was additionally measured in short weekly learning surveys. Perceived barriers and facilitators for the use of effective learning strategies were investigated in focus group discussions, as well as in the weekly learning surveys.

Metacognitive knowledge. We distinguished between declarative knowledge (that is knowledge about which learning strategies are effective) and conditional knowledge (that is knowledge about when and why these strategies are effective). To measure declarative metacognitive knowledge, participants rated the effectiveness for long-term learning of each of the strategies addressed in the Study Smart program on a rating scale from 1 (not at all effective) to 5 (extremely effective). The following ten strategies were rated: highlighting, summarizing, rereading, keyword mnemonics, mental imagery, elaborative interrogation, self-explanation, interleaved practice, distributed practice, and practice testing (by taking practice tests or quizzing with flashcards). Conditional knowledge was assessed using seven scenario descriptions (adapted from McCabe, 2011; Morehead, Rhodes, & DeLozier, 2016). Each scenario described two strategies with different levels of empirically supported effectiveness in a specific situation (see Appendix B). Students rated for each scenario the extent to which the two contrasting strategies do or do not benefit learning as measured by subsequent performance on a delayed test for each scenario. They rated the value of all strategies on a scale from 1 (not at all beneficial to learning) to 7 (very beneficial to learning), with a value of four indicating a neutral evaluation (i.e., the strategy is neither rated as effective nor ineffective; Morehead et al., 2016). The scenarios described the value (more effective strategies are marked in italic) of *testing* vs. restudying (Roediger & Karpicke, 2006), blocking vs. *interleaving* (Rohrer & Taylor, 2007), *spacing* vs. massing, rereading vs. *elaborative interrogation*, *self-explanation* vs. mental imagery, making summaries with and *without textbook*, rereading with vs. without highlighting (both ineffective). In an open answer format, students elaborated on their answers and explained the reasons for why one strategy would be more effective than the other would. Open answers were coded on a scale from 0 (omission and commission errors) to .5 (partially true) and 1 (completely true) per scenario. The maximum score was seven points. The first author made a coding scheme and coded all answers. Coding was also done (independently) by a research assistant. Initial interrater reliability was Cohen's Kappa κ = .86 in the pretest and Cohen's Kappa κ =.90 in the posttest.

Discrepancies between coding were solved through discussion. See Appendix C for an example of the coding scheme.

Learning strategy use. In pretest and posttest, as well as in six weekly learning strategy surveys during the intervention, students rated the extent to which they used the strategies central to the Study Smart program during self-study on a 6-point Likert scale from 0 (never) to 5 (very often). We added the weekly learning surveys in order to gain a more reliable measurement of actual use during self-study than possible with a single assessment point (Hadwin, Winne, Stockley, Nesbit, & Woszczyna, 2001). Furthermore, we used an adaptation of the *Study of Learning Questionnaire* (SLQ; based on Bartoszewski & Gurung, 2015) with 34 items answered on a 6-point Likert scale from 1 (strongly disagree) to 6 (strongly agree) in pretest and posttest. The questionnaire assessed the use of highlighting, summarization, imagery for text, rereading, elaborative interrogation, self-explanation, practice testing, and distributed practice with several items. An example item is “I frequently highlight or underline the information within one page”. Due to low Cronbach’s α values, we deleted the item “I prefer to use or study material that has been previously highlighted or underlined by a previous user” in the scale for highlighting (new Cronbach’s α = .82) and the item “I use summaries written by somebody else” (new Cronbach’s α = .59) in summarization.

Barriers and facilitators for using effective learning strategies. In all six weekly learning strategy surveys, we asked students two open questions: (1) whether they would like to change something in the way they study, and (2) what factors influenced the way they studied during the last week. Open answers were coded and categorized.

All students were invited to participate in a focus group discussion after they had attended the Study Smart program. Ten students (age 20.9 ± 1.6 yr.; 90% female) participated in two focus group discussions. The first focus group took place in week 10 with five students from the Study Smart condition, the second focus group took place in week 12 with five students from the control condition, after they had also attended the Study Smart program (see Figure 2.2). The focus group sessions lasted 60-90 minutes. Participation was voluntary and informed consent was obtained from all participants prior to the discussion; participation was rewarded with a

€10 gift voucher. The focus groups were led by a research assistant experienced in moderating focus groups and observed by the first author. First, the moderator prompted a discussion about each session. Students' opinions of and experiences in the sessions were gathered. Secondly, the moderator led a discussion on how the students used different learning strategies during their self-study and what facilitators and barriers they encountered. The observer asked additional questions in order to deepen the discussion at interesting points.

Both focus groups were audio-recorded and transcribed non-verbatim. Template analysis, a specific form and step-wise approach of thematic analysis, was used when analyzing the data (Braun & Clarke, 2006; King, 2004). After thoroughly reading the transcripts, the first and last author developed a coding template consisting of a priori themes (based on initial read). Next, the first author coded the first transcript with the initial themes while continuously modifying and advancing the template as the analysis progressed. Then, the first author applied the modified template to the whole data set. A research assistant coded 50% of the transcripts using the modified template. The initial and modified themes and codes were discussed (first author, last author, and research assistant) until a final solution was reached.

Procedure

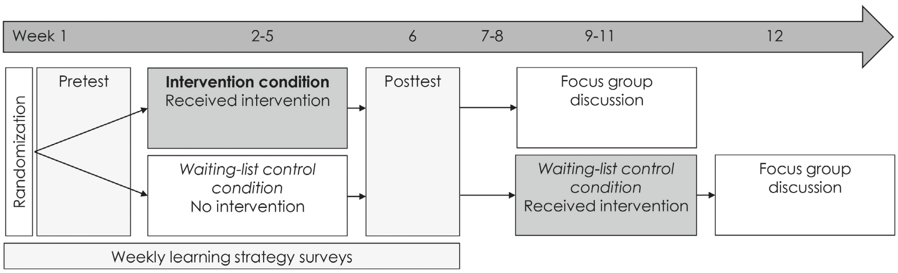

Figure 2.2. Overview of the study procedure, in which the Study Smart program represents the intervention

The study procedure is illustrated in Figure 2.2. First- and second-year students were invited via bulletin boards, e-mails by course coordinators, and announcements in lectures and tutorials. Participation was voluntary and informed consent was obtained from all participants prior to the start of the study. Pretest, posttest and weekly learning strategy surveys were delivered online, using the questionnaire tool Qualtrics (Qualtrics, Provo, UT).
Prior to the pretest, students were randomly assigned to either the Study Smart condition or waiting-list control condition; students in the control condition attended the Study Smart program after the posttest. In week 1, all participants received the pretest. Participants in the Study Smart condition attended the three sessions in week 2, week 4, and week 5. In week 6, all participants received the posttest. Participants in the control condition attended the sessions in week 9, week 10, and week 11. The focus groups took place after students had attended the Study Smart program and took 60 to 90 minutes. From week 1 until week 6 of the study, all students completed the learning strategy survey about their study behavior of the past week on Fridays. As a reward, participants received €20 gift vouchers for completing the pretest and posttest and another €10 gift voucher for completing the learning strategy surveys. The study was approved by the ethical review board of the Netherlands Association for Medical Education (NVMO, reference number 1002).

Data Analysis

An alpha level of .05 was used for all statistical tests. As effect size measure, we used partial eta squared with values of 0.01, 0.06, and 0.14 representing small, medium, and large effects, respectively (Cohen, 1988). Although participants were randomly assigned to the conditions, we examined baseline equivalence on metacognitive knowledge and use of learning strategies to ensure that the conditions were similar. For that purpose, we conducted two-tailed t-tests for all dependent variables (pretest measures). We conducted the analyses with condition (intervention = 1, control = 0) as between-subjects factor and time (pretest versus posttest) as within-subjects factor. Only significant interaction effects are reported. With respect to the actual use measured by the weekly learning strategy surveys, we report the outcomes averaged across student ratings from week 1 until 6 (i.e., averaged across all surveys completed by each student).

RESULTS

Baseline

Concerning the attrition from pretest to posttest, students who completed both pre- and posttest did not differ significantly from students who completed the pretest only, regarding their high-school GPA, $t(63) = -1.25$, $p = .216$ and average grades of their first three courses of the academic year, $t(63) = 0.32$, $p = .747$. Regarding baseline equivalence, the Study Smart group did not differ from the control group at pretest, except for perceived effectiveness of keyword mnemonics, $t(30.86) = 3.12$, $p = .004$, $d = 0.97$, elaborative interrogation, $t(27.35) = 3.06$, $p = .005$, $d = 0.98$, and the scenario rating of rereading, $t(43.5) = 2.25$, $p = .030$, $d = 0.65$. The control group judged all strategies as more effective than the Study Smart group.

Effects on Metacognitive Knowledge

Declarative metacognitive knowledge. Descriptive statistics for effectiveness ratings at pre- and posttest are shown in Table 2.2.

Both time, $F(11, 35) = 5.89$, $p < .001$, $\eta_p^2 = .65$, and the time x condition interaction, $F(11, 35) = 6.63$, $p < .001$, $\eta_p^2 = .68$, had a significant multivariate effect on declarative metacognitive knowledge, showing that the overall difference between pre- and posttest scores was significant but the magnitude differed between conditions. Follow-up repeated measures ANOVA revealed significant interaction effects between time and condition for students' effectiveness rating of highlighting, $F(1, 45) = 41.53$, $p < .001$, $\eta_p^2 = .48$, summarization, $F(1, 45) = 21.15$, $p < .001$, $\eta_p^2 = .32$, rereading, $F(1, 45) = 9.40$, $p = .004$, $\eta_p^2 = .17$, and practice testing, $F(1, 45) = 10.70$, $p = .002$, $\eta_p^2 = .19$. Students in the Study Smart condition gained more accurate metacognitive knowledge, and rated the effectiveness of highlighting, summarization and rereading as barely effective and practice testing as highly effective, as compared to the control condition. See Figure 2.3 for an overview of the posttest ratings for both conditions.

Table 2.2. Means and standard deviations for declarative metacognitive knowledge, measured by effectiveness ratings at pretest and posttest

Effectiveness ratings	Pretest				Posttest			
	Study Smart condition		Control condition		Study Smart condition		Control condition	
	M	(SD)	M	(SD)	M	(SD)	M	*(SD)*
Practice testing**	4.15	(0.91)	4.25	(0.79)	4.86	(0.36)	3.92	(1.06)
Quizzing	3.86	(1.01)	4.13	(0.91)	4.57	(0.75)	4.35	(0.94)
Distributed practice	4.05	(1.16)	4.08	(0.63)	4.48	(0.68)	4.00	(0.85)
Elaboration	3.63	(1.12)	4.44	(0.54)	3.52	(0.98)	4.19	(0.90)
Self-explanation	3.57	(1.08)	3.92	(0.83)	3.52	(1.08)	4.04	(0.82)
Interleaving	3.41	(0.91)	3.41	(0.63)	3.29	(0.96)	3.50	(0.95)
Summaries***	3.90	(0.62)	3.91	(0.84)	2.62	(0.74)	3.88	(1.03)
Mental imagery	3.76	(0.94)	4.10	(0.91)	3.10	(1.09)	3.92	(0.98)
Keyword mnemonics	3.41	(1.02)	4.20	(0.60)	2.76	(1.00)	3.81	(1.33)
Rereading**	3.24	(1.00)	3.29	(0.76)	2.29	(0.72)	3.38	(0.80)
Highlighting***	3.55	(0.97)	3.78	(0.57)	2.10	(1.09)	3.81	(0.63)

Note. Ratings on a scale from 1 (not at all effective) to 5 (extremely effective). Significant interaction effects between time and condition are marked with $^{*}p < .05$ $^{**}p < .01$ $^{***}p < .001$

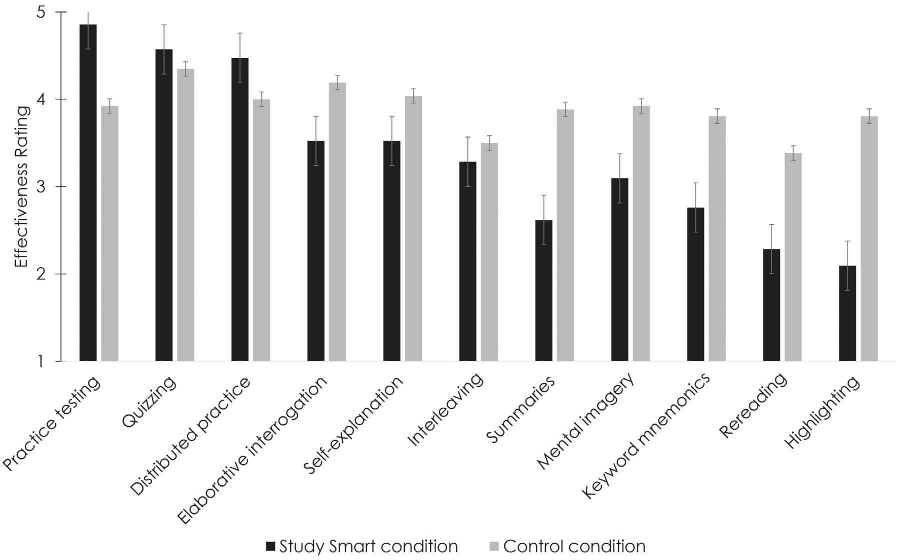

Figure 2.3. Average posttest ratings of to what extent students think the strategies are effective for long-term learning, from 1 (not at all effective) to 5 (extremely effective). Strategies are ordered in their (approximate) effectiveness for long-term learning from left (highly effective) to right (less effective); see Table 2.1 for more detail. Error bars represent standard errors of the mean

Conditional metacognitive knowledge. With regard to conditional metacognitive knowledge, we compared the difference between effective and ineffective learning strategies across all scenarios (the so called 'difference-score'). We assumed that, at posttest, the difference between effective and ineffective strategies would be positive and higher in the Study Smart condition compared to the control condition. Descriptive statistics for scenario ratings at pre- and posttest are shown in Table 2.3.

Table 2.3. Means, standard deviations, and difference scores for conditional metacognitive knowledge, measured by scenario ratings at pretest and posttest

Scenario ratings		Pretest				Posttest			
		Study Smart condition		Control condition		Study Smart condition		Control condition	
		M	*(SD)*	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*
1	*Practice testing*	5.00	(1.45)	4.96	(1.31)	5.29	(1.01)	5.19	(1.30)
	Rereading	3.57	(1.03)	4.42	(1.55)	3.57	(1.29)	4.08	(1.57)
	Difference-score	1.43	(1.83)	0.54	(2.49)	1.71	(1.27)	1.12	(2.39)
2	*Interleaving*	3.38	(1.50)	3.77	(1.63)	4.71	(1.57)	4.12	(1.48)
	Blocking	5.67	(0.86)	5.23	(1.45)	4.62	(1.47)	5.04	(1.64)
	Difference score*	-2.29	(2.08)	-1.46	(2.67)	0.10	(2.76)	-0.92	(2.84)
3	*Spacing*	6.05	(0.92)	6.19	(0.90)	6.24	(0.77)	6.46	(0.58)
	Massing	3.10	(1.26)	3.58	(1.24)	3.52	(1.36)	3.38	(1.24)
	Difference score	2.95	(1.60)	2.62	(1.68)	2.71	(1.42)	3.08	(1.38)
4	*Elaborative interrogation*	5.71	(1.23)	6.12	(0.86)	6.10	(0.70)	6.35	(0.63)
	Rereading	4.48	(1.36)	4.77	(1.24)	3.57	(0.93)	4.23	(1.24)
	Difference score	1.24	(2.02)	1.35	(1.32)	2.52	(0.93)	2.12	(1.28)
5	*Self-explanation*	5.62	(0.92)	6.00	(0.75)	5.67	(0.80)	5.69	(0.74)
	Mental imagery	5.38	(1.02)	5.96	(1.08)	4.57	(1.08)	5.96	(0.92)
	Difference score*	0.24	(1.45)	0.04	(1.11)	1.10	(0.89)	-0.27	(0.83)
6	*Summary from memory*	5.33	(1.06)	5.38	(1.24)	5.57	(1.16)	5.15	(1.41)
	Summary with notes	5.14	(1.39)	4.96	(1.00)	3.86	(0.85)	5.08	(0.89)
	Difference score**	0.19	(1.78)	0.42	(1.75)	1.71	(1.15)	0.08	(1.90)
7	Reading without highlighting	3.81	(1.03)	3.77	(1.50)	3.33	(1.28)	3.81	(1.58)
	Reading with highlighting	5.95	(0.80)	5.88	(1.03)	4.00	(1.55)	5.54	(1.48)
	Difference score*	-2.14	(-1.20)	-2.12	(-1.58)	-0.67	(-1.20)	-1.73	(-1.69)

Note. Strategies in italics are the empirically supported strategies per scenario. Scenario ratings from 1 (not at all beneficial to learning) to 7 (very beneficial to learning), with a value of four indicating a neutral evaluation. Higher values indicate higher endorsement of the strategy. A difference-score of 0 indicates that both strategies were rated as equally effective, positive difference scores indicate correct endorsement of the effective strategy, negative difference scores indicate endorsement of the ineffective strategy. Significant interaction effects in the difference-scores between time and condition are marked with $^{*}p < .05$ $^{**}p < .01$ $^{***}p < .001$

Both time, $F(7, 39) = 9.39$, $p < .001$, $\eta_p^2 = .63$, and the time x condition interaction, $F(7, 39) = 4.60$, $p < .001$, $\eta_p^2 = .45$, had a significant multivariate effect on conditional metacognitive knowledge, showing that pre- and posttest difference-scores were significantly different, but the magnitude varied between conditions. Follow-up repeated measures ANOVA revealed significant interaction effects between time and condition for the difference-scores of the scenarios *interleaving vs. blocking*, $F(1, 45) = 19.72$, $p = .010$, $\eta_p^2 = .14$, *self-explanation vs. mental imagery*, $F(1, 45) = 7.88$, $p = .011$, $\eta_p^2 = .14$, *active vs. passive summarization*, $F(1, 45) = 20.31$, $p = .001$, $\eta_p^2 = .21$, and reading without vs. with highlighting, $F(1, 45) = 6.92$, $p = .024$, $\eta_p^2 = .12$. The difference between the effective and ineffective strategy in these scenarios always became more positive and higher in the Study Smart condition compared to the control condition, showing that students in the Study Smart condition showed higher correct endorsement of the more effective strategies in these four scenarios.

2

In the scenarios *practice testing vs. rereading*, *spacing vs. massing,* and *elaborative interrogation vs. rereading*, there was a significant main effect of scenario only. Analyses showed that, both at pretest and posttest, all participants correctly rated practice testing as more effective than rereading, $F(1, 45) = 20.94$, $p < .001$, $\eta_p^2 = .32$, spacing as more effective than massing, $F(1, 45) = 232.42$, $p < .001$, $\eta_p^2 = .84$, and elaborative interrogation as more effective than rereading, $F(1, 45) = 108.99$, $p < .001$, $\eta_p^2 = .71$.

Regarding the quality of verbal elaborations on each scenario, the Study Smart condition outperformed the control condition in the posttest, $F(1, 45) = 10.86$, $p = .002$, $\eta_p^2 = .19$ (Figure 2.4). Students in the Study Smart condition were able to give more elaborated answers on the working principles behind the effective learning strategies described in each scenario, $M\ (SD)_{pre} = 2.00\ (1.14)$; $M\ (SD)_{post} = 3.26\ (1.34)$, compared to the control condition, $M\ (SD)_{pre} = 1.98\ (1.43)$; $M\ (SD)_{post} = 1.88\ (1.02)$.

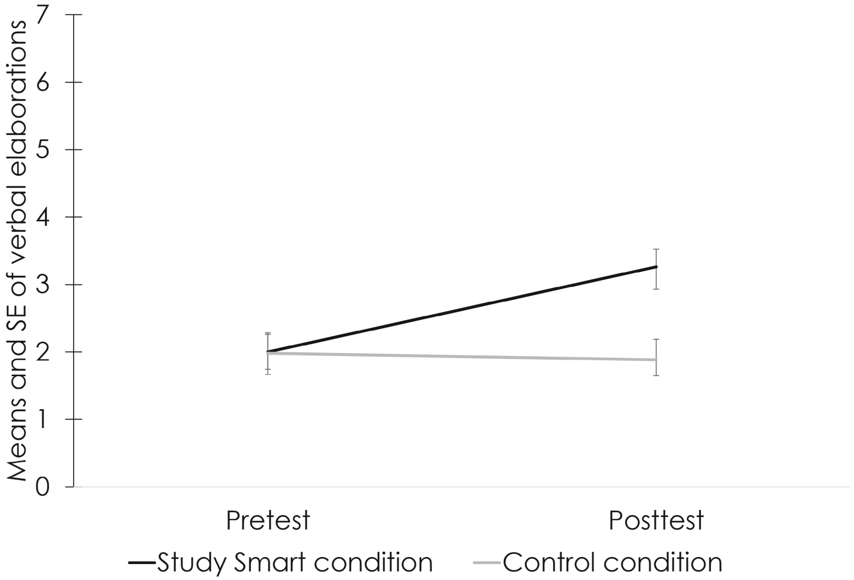

Figure 2.4. Average pre- to posttest elaboration scores on scenario ratings, from 0 (no correct explanation) to 7 (correct explanations for all seven scenarios). Error bars represent standard errors of the mean

Effects on Use of Effective Learning Strategies

With regard to the extent of use of the learning strategies, we conducted an 11 (strategies) x 2 (condition: Study Smart vs. control) repeated measures analysis of variance, with the post scores of extent of strategy use, as well as with the weekly aggregated scores. Descriptive statistics for extent of strategy use at pretest, posttest and aggregated weekly ratings are shown in Table 2.4.

Table 2.4. Means and standard deviations for extent of use of the learning strategies, measured at pretest, posttest and aggregated weekly scores

	Pretest				Posttest				Aggregated weekly scores			
	Study Smart condition		Control condition		Study Smart condition		Control condition		Study Smart condition		Control condition	
	M	*(SD)*	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*
Practice testing	2.38	(1.94)	1.54	(1.98)	2.86	(1.49)	1.23	(1.88)	0.72	(0.94)	0.17	(0.54)
Quizzing**	1.24	(1.67)	1.54	(1.88)	2.38	(1.75)	0.88	(1.45)	0.71	(0.82)	0.22	(0.55)
Distributed practice	2.05	(2.09)	1.81	(1.92)	3.19	(1.83)	1.96	(2.01)	1.59	(1.46)	0.67	(1.19)
Elaborative interrogation	1.19	(1.72)	1.65	(2.08)	1.29	(1.93)	1.27	(1.82)	0.57	(0.66)	0.88	(0.94)
Self-explanation	1.00	(1.64)	1.50	(1.56)	0.90	(1.70)	1.54	(1.68)	1.01	(1.07)	0.98	(1.04)
Interleaving	0.62	(1.32)	0.65	(1.26)	1.29	(1.71)	0.81	(1.33)	0.44	(0.70)	0.23	(0.54)
Summarization	2.95	(1.75)	3.42	(1.88)	2.52	(2.16)	3.65	(1.74)	2.04	(1.77)	2.83	(1.67)
Mental imagery	1.81	(1.94)	2.08	(2.02)	0.95	(1.60)	1.92	(1.96)	0.48	(0.70)	0.92	(1.15)
Keyword mnemonics	1.90	(1.87)	2.38	(2.00)	0.57	(1.25)	1.54	(1.90)	0.29	(0.68)	0.87	(1.39)
Rereading	2.57	(1.86)	2.88	(1.95)	2.38	(2.20)	3.31	(1.64)	1.83	(1.21)	2.10	(1.61)
Highlighting	2.95	(2.11)	3.62	(1.96)	2.48	(2.16)	3.62	(1.53)	1.06	(1.06)	2.41	(1.60)

Note. Ratings on a scale from 0 (never used) to 5 (very often). Significant interaction effects between time (pretest and posttest) and condition are marked with $*p < .05$ $**p < .01$ $***p < .001$

2

Concerning the aggregated weekly scores, the strategy x condition interaction was statistically significant, $F(10, 450) = 4.38$, $p = .001$, $\eta_p^2 = .089$, which indicates that a different pattern of weekly strategy use arose between the Study Smart condition and the control condition during the intervention period. Figure 2.5 shows the differences in strategy use between conditions using the aggregated weekly ratings. Similarly, we found a strategy x condition interaction with the posttest scores, $F(10, 450) = 4.68$, $p < .001$, $\eta_p^2 = .094$. Figure 2.6 shows the differences in strategy use between conditions using the posttest ratings.

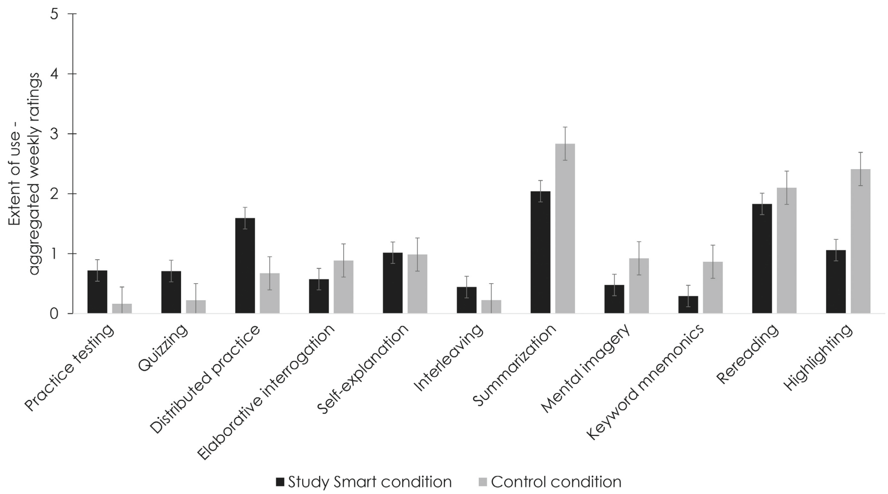

Figure 2.5. Average aggregated weekly ratings of to what extent students used the learning strategies, according to the weekly learning strategy surveys, from 0 (never used) to 5 (very often), indicated per condition. Strategies are ordered in their (approximate) effectiveness for long-term learning from left (highly effective) to right (less effective); see Table 2.1 for more detail. Error bars represent standard errors of the mean

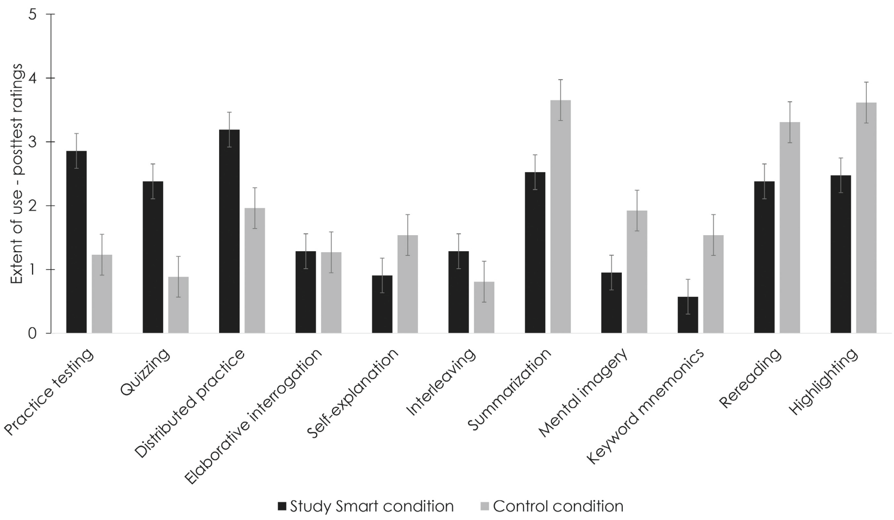

Figure 2.6. Average posttest ratings of to what extent students used the learning strategies, from 0 (never used) to 5 (very often), indicated per condition. Strategies are ordered in their (approximate) effectiveness for long-term learning from left (highly effective) to right (less effective); see Table 2.1 for more detail. Error bars represent standard errors of the mean

Follow-up repeated measures ANOVA revealed one significant interaction effect between time and condition, which concerned the extent of quizzing, $F(1, 45) = 9.90$, $p = .003$, $\eta_p^2 = .18$. Students in the Study Smart condition showed a significantly higher increase in the use of quizzing from pretest to posttest than controls.

With regard to the SLQ, both time, $F(8, 38) = 3.13$, $p = .008$, $\eta_p^2 = .40$, and the time x condition interaction, $F(8, 38) = 2.86$, $p = .014$, $\eta_p^2 = .38$, had a significant multivariate effect on learning strategy use, showing that the overall difference between pretest and posttest scores was significant but the magnitude differed between conditions. Repeated measures ANOVA revealed significant interaction effects between time and condition for highlighting ($F(1, 45) = 6.29$; $p = .016$; $\eta_p^2 = .12$), rereading ($F(1, 45) = 9.21$; $p = .004$; $\eta_p^2 = .17$) and practice testing ($F(1, 45) = 7.29$; $p = .010$; $\eta_p^2 = .14$). Students in the Study Smart condition reported to use more practice testing and less highlighting and rereading compared to the control condition at posttest. Descriptive statistics of the SLQ at pre- and posttest are shown in Table 2.5.

Table 2.5. Means and standard deviations for use of learning strategies, measured by the Strategy of Learning Questionnaire (SLQ) for each measurement point and condition

SLQ scales	Pretest				Posttest				Cronbach's α
	Study Smart condition		Control condition		Study Smart condition		Control condition		pre/post
	M	*(SD)*	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*	
Highlighting*	4.25	(1.05)	4.46	(1.08)	3.81	(1.36)	4.72	(0.66)	.82/.81
Summarizing	4.06	(0.79)	4.47	(0.73)	3.79	(0.92)	4.31	(0.71)	.59/.59
Visualizing	4.13	(1.08)	4.35	(1.04)	3.94	(1.26)	4.06	(1.26)	.81/.92
Rereading*	4.60	(0.71)	4.54	(0.66)	3.90	(0.92)	4.45	(0.67)	.58/.79
Elaboration	4.33	(0.98)	4.60	(0.95)	3.90	(1.25)	4.27	(1.18)	.85/.92
Self-explanation	4.51	(0.58)	4.44	(0.68)	4.39	(0.72)	4.49	(0.81)	.73/.85
Practice testing*	4.39	(0.68)	3.99	(0.84)	4.67	(0.81)	3.46	(1.04)	.80/.91
Distributed practice	4.30	(0.73)	4.06	(1.02)	4.67	(0.61)	3.98	(1.09)	.76/.84

Note. Ratings on a scale from 1 (strongly disagree) to 6 (strongly agree). Significant interaction effects between time and condition are marked with *p < .05 **p < .01 *** p < .001

Barriers and Facilitators of Learning Strategy Use

In the weekly learning strategy surveys, students reported factors that influenced the way they had studied during the previous week. Most mentioned factors were social and personal commitments (17%), amount of learning material (13%) and difficulties with time management (13%). On the question of whether students would like to change something in the way they study, students mostly mentioned that they would like to use practice testing (31%) and increase the amount of invested study time (10%).

In follow-up focus groups, we dove deeper into the barriers and facilitators of effective strategy use. Using the template analysis approach, we constructed a model describing the factors that students reported to influence learning strategy use during self-study and factors that they considered supported or hindered the transfer of metacognitive knowledge about learning strategies into actual practice.

This model is shown in Figure 2.7 and depicts the interpretation of the qualitative data.

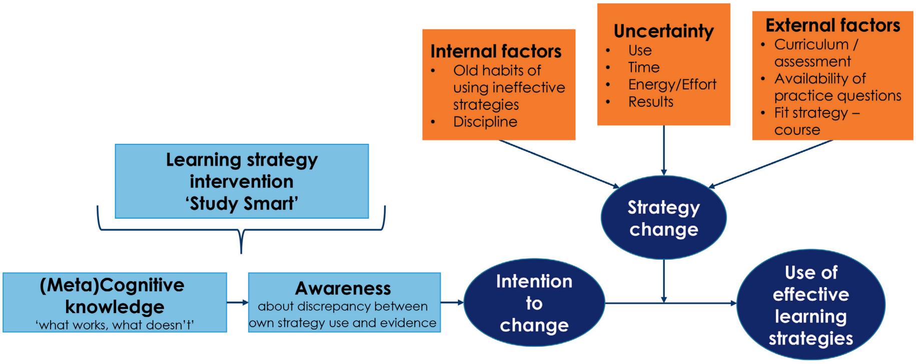

Figure 2.7. Barriers and facilitators in using effective learning strategies

As illustrated in this model, students perceived that the Study Smart program improved their metacognitive knowledge about the effectiveness of different learning strategies, which increased their awareness about the discrepancy between own strategy use and empirical evidence. Students mentioned that this, in turn, increased their intention to change and their intention to use more effective learning strategies during self-study:

> *"I only did highlighting and summarizing, which are the worst ways of studying, but then I really felt that those sessions activated me to use it on my own, to my own studies. So not, it was awareness but it was also motivating me to actually practice them."* (Focus group 2, participant 3)

However, students reported difficulties in actually applying effective strategies during their self-study. The main challenge in using effective learning strategies was described as the process of changing strategies, mainly influenced by uncertainty about how to use these strategies, how much time and energy they would cost and being uncertain about exam results when using these new strategies.

> *"It also scared me because I really want to try it out and of course I did, but if it went wrong, the result is you failed like a whole block."* (Focus group 1, participant 2)

The structure of exams (multiple choice, open answer) and the perceived fit between course content and a learning strategy were mentioned as external factors influencing strategy change. If students did perceive a learning strategy as not helpful for studying a specific course content, they hesitated to use that strategy. Factors that facilitated students to use effective learning strategies mainly originated from the curriculum and assessment system. When practice questions were available, students mentioned to be more likely to use practice testing as a strategy. In case of a lack of practice questions, students reported falling back into uncertainty, for example about how to make good practice questions.

> *"If I'm practice testing, if I have the questions provided, I don't think it takes me that much energy to do it, because I have the questions and I just have to apply the knowledge to it. Whereas if I'm trying to do flashcards [...] where I really have to pick out the information myself, I feel that takes me more time and more effort."* (Focus group 2, participant 2)
> *"It's quite hard, [...] I used a lot of practice testing for the last exam but I couldn't really make the practice test by myself. When I did, I felt I was only studying certain parts of the topic.* (Focus group 1, participant 5)

Perceived internal factors that influenced strategy change were mostly old habits of using ineffective strategies and the discipline to stick to new strategies. In case of uncertainty and lack of time, students mentioned to be more prone to fall back into their old habits and routines. As one student explained:

> *"I tried, but eventually, [...] I don't see any progress, so then I just went back to my old ways. But because I didn't have enough time left to do it the right way."* (Focus group 1, participant 2)

To actually use effective learning strategies during self-study, students have to undergo a change of behavior, which is perceived as time intensive. Students that added effective strategies to their old habits reported to be more successful:

> *"I think it will become a change of behavior. Because now [...] we are more in old strategies, and practice testing is one of the new strategies that is given us, [...] I think the most effort is to change our behavior and I think that will take some time."* (Focus group 2, participant 1)

DISCUSSION

This study investigated whether a newly developed learning strategy intervention ('Study Smart'), focusing on awareness, reflection, and practice, can improve students' metacognitive knowledge and stimulate the use of effective learning strategies during self-study. Using a variety of measures, our study indicates that the Study Smart program increased metacognitive knowledge on learning strategies and increased students' use of practice testing. Furthermore, students relied less on rereading and highlighting, strategies known as ineffective regarding long-term learning. Moreover, we developed a model illustrating the barriers and facilitators that influence the change process towards the use of effective learning strategies.

Confirming our metacognitive knowledge hypothesis, students who attended the Study Smart program gained more accurate declarative knowledge and judged the strategies highlighting, rereading, and summarization as less effective, and practice testing as more effective as compared to control students. Additionally, students in the Study Smart condition were better able to explain the reasons and underlying principles of effective learning strategies. However, the low mean scores indicate that giving correct explanations was still difficult. Therefore, explaining the underlying principles of effective and ineffective learning strategies may need more attention in the intervention. Compared to earlier studies (Blasiman et al., 2017; Morehead et al., 2016), our student sample appeared to have high prior declarative knowledge about the effectiveness of practice testing, distributed practice and elaboration strategies, potentially explaining why we did not find an intervention effect on knowledge about these strategies. The relatively high prior knowledge of our students about practice testing, distributed practice and elaborative interrogation may have resulted from the fact that they study in a problem-based learning curriculum, where content and study sessions are distributed over time, and active elaboration during the tutorial groups is required (Dolmans, De Grave, Wolfhagen, & van der Vleuten, 2005).

We also hypothesized that the Study Smart program would encourage students to use more effective learning strategies during their self-study. We indeed saw changes in strategy use: students that participated in the Study Smart program reported to use less ineffective strategies, such as highlighting or rereading, and more effective strategies, such as practice testing or quizzing, throughout the study period. Triangulating the results from different measurements, we can partially confirm the learning-strategy-use hypothesis: after the Study Smart program, students were more prone to use effective learning strategies, especially quizzing, while highlighting and rereading were used less. However, the extent to which students actually used effective strategies during self-study was low (see Figure 2.5 and 2.6). Although students had quite accurate prior-knowledge about effective learning strategies and gained more accurate knowledge during the Study Smart program, there was still a gap between knowledge and actual use.

The model based on the template analysis provides insights into barriers and facilitators that could influence that gap. It illustrates that the Study Smart program succeeded in creating accurate metacognitive knowledge and made students aware of a potential discrepancy between their own strategy use and empirically effective learning strategies. Subsequently, students developed an intention to change their study behavior and use more effective learning strategies. However, the qualitative data reveal an intention-behavior gap and factors that facilitated or complicated successful strategy change. The model shows clear parallels with the *Theory of Planned Behavior* (TPB; Fishbein & Ajzen, 2011). According to TPB, successful behavior is predicted by a positive intention and the skill to perform the behavior, and the absence of environmental restrictions. Relating this theory to our model, the Study Smart program stimulated students to develop a strong intention to perform the behavior (i.e., to use more effective learning strategies).

However, limited external support (e.g., no available practice questions) combined with uncertainty about skill level and actual outcomes of using effective learning strategies hindered students to actually perform the behavior.

One potential limitation of this study is that learning strategy use was measured by self-report only. Due to potential demand characteristics, participants in the Study Smart condition may have felt inclined to give more normative responses and to rate the strategies that were discussed in the program as more effective. Objective measures of learning strategy use during self-study, such as video observations, are very hard to use, also for ethical reasons. Although missing such objective measures, we aimed to gain a holistic picture of learning strategy use by applying and triangulating different instruments. The weekly measures, for example, provide a more nuanced view on how students chose their learning strategies over time. During the program, students were asked to bring a photolog, as a documentation of what strategies they had actually implemented. As all measurements painted a similar picture of strategy use, we believe that we gained a reliable picture of which learning strategies students used during the study period. However, the extent of use was lower according to aggregated scores than posttest scores, indicating that students seem to overestimate their actual use when asked only once. Using single measurement points might provide a biased picture of actual study behavior (Hadwin et al., 2001). An interesting pathway for future research would be to measure students' actual strategy use during self-study, e.g., by experience-sampling-methods (Xie, Heddy, & Vongkulluksn, 2019), log-data in online learning environments, or observations and think-aloud during self-study.

Another limitation is the small student sample. As we conducted a first examination of the pilot-intervention, we openly recruited students across different study programs. Consequently, only students already interested in improving their learning strategies may have signed up for this study. Another potential limitation is the fact that both groups differed on metacognitive awareness concerning the strategies keyword mnemonics, elaborative interrogation and rereading already at the pretest, possibly due to the small sample size. This may have had a positive influence on the effects, but was taken into account by the repeated measures analysis procedure, analyzing the interaction effects between time and condition

(Huck & McLean, 1975; Leppink, 2019). To generalize the effects to a broader student population, an important direction for future research would be to implement the Study Smart program in a non-selective sample, for instance by providing the program to all first-year students of a curriculum. Future research could then investigate effects of the Study Smart program on academic performance. Due to ethical reasons, we offered the program to all students in our study; those randomly assigned to the control-condition received it after the posttest. Consequently, we were not able to measure effects on long-term learning or academic performance.

We investigated a three-stage intervention, in which the sessions focusing on awareness, reflection, and practice built upon each other. The awareness session was the most important session to enhance students' knowledge about effective learning strategies. In the focus group discussions, students described that this session made them not only aware of, but also motivated them to use these strategies because they realized a discrepancy between their own strategy use and empirical evidence. The session that students felt they learnt from least, but were motivated to invest in more, was the practice session. Students asked for more specific practice exercises with their own learning materials rather than a general practice session. To enhance students' use of effective learning strategies, more guidance and practice are necessary. This also underlines that the awareness session alone, although valuable, is not sufficient. Future research could test the effect of a practice session separately, including guided practice and support in applying effective learning strategies, on students' use of effective learning strategies in later self-study.

Our findings are important for educational practice: making students aware of effective learning strategies and desirable difficulties, stimulating reflection on achievement motivation and letting them experience the experienced-learning-versus-actual-learning-paradox is a promising way to motivate students using effective learning strategies. Educators could facilitate the use of practice testing, for example, by making practice questions available. Supporting and modeling the use of effective learning strategies could be another pathway, for instance by adding a practice-based method to the earlier theory-based and experienced-based principles of strategy interventions. To support students in overcoming the intention-behavior gap, it seems important to not only inform students about desirable difficulties and effective learning strategies, but also provide process support by guiding students in adding active learning principles to old strategies.

CONCLUSION

Overall, this study shows that making students aware of effective and ineffective learning strategies and of the value of desirable difficulties can raise their intention to use more effective learning strategies during self-study. The current intervention raised metacognitive knowledge about the effectiveness of different learning strategies and encouraged students to use more practice testing, an effective learning strategy for long-term learning. Moreover, this study offers valuable insights into factors hindering or facilitating strategy change.

AUTHOR CONTRIBUTIONS

All authors were responsible for the design of the study. The last author and the first author gave the sessions together and were responsible for data collection. The first author performed analysis of the data, in close collaboration with the last author and the second author. The first author drafted the article, incorporating edits, and feedback from all other authors. All authors made a substantial contribution to the interpretation of the data for this work.

ACKNOWLEDGMENTS

The authors would like to thank the Dutch Ministry of Education for funding the design of the Study Smart program through a Comenius fellowship grant. We would also like to thank the team of EDLAB, the Maastricht center for educational innovation, for collaboration in designing the Study Smart program. Finally, we thank Sanne Rovers for her contribution as the second coder of all qualitative data and her thoughts on the model.

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Appendix A

Pilot-intervention 'Study Smart': Sessions, goals, and exercises

Session	Goals	Exercises and activities	Time
Awareness	Creating a good atmosphere in the group	Introduction and goals of the session	10 min
	Creating awareness about different learning strategies and own strategy use	Video clips about 10 common learning strategies Students watch short video clips (30 sec) about the 10 common learning strategies one by one. The videos show a student performing the strategy accompanied by a voice over explaining the strategy. After each clip: plenary discussion on whether students use the strategy, why and how they use this strategy or why not	20 min
	Creating awareness about the differential effectiveness of different strategies and how to use effective learning strategies	Categorizing 10 learning strategies into their effectiveness Using card sorting, students categorize the 10 strategies in highly, moderately, and not effective in a plenary discussion, the program facilitator explains the effectiveness based on empirical evidence, how much training is required to use the strategy and how to implement this strategy in problem-based learning	30 min
	Creating awareness about the importance of 'desirable difficulties' and that it is difficult to accurately judge one's own learning	Desirable difficulties students watch a video (6 min) about the importance of deliberate practice and investing effort and time in order to become good at something (an animated summary of the book 'Outliers' by Malcom Gladwell) Presentation of the testing effect (Roediger & Karpicke, 2006) and the difference between experienced and actual learning (Nunez & Karpicke, 2015). The facilitator shows the graphs of these studies and explains the testing effect and the experienced-learning-vs-actual-learning paradox	15 min

Pilot-intervention 'Study Smart': Sessions, goals, and exercises (continued)

Session	Goals	Exercises and activities	Time
	Creating awareness about the role of effort and difficulty in developing a new behavior / skill or changing their behavior to prepare students for changing their learning strategies	Reflective writing Students write (in about 300 words) about a memory when they (a) have learned something/developed a new skill through extended practice (e.g. sport, arts, music) or (b) changed their behavior or strategies after a long time Students end their writing with a take-home-message: What would they say to themselves if they had to do it again? Students share and discuss their memories in groups of three Students discuss how their memory relates to the challenge they face now to develop effective learning strategies to succeed at university. How is that comparable? Think of desirable difficulties. What advice would you give yourself?	25 min
	Strengthening and recapping the information taught in this session	Practice test Students complete a practice test consisting of seven open questions about learning strategies, e.g. "For what type of study materials is interleaved practice useful? Why only for this material?" The answers are discussed plenary	15 min
	Becoming aware about own learning strategies and study routines	Photolog Homework for following session: Take 1-3 pictures about how you study and think about internal and external factors that influence your studying	5 min
Reflection	Reflection on own learning strategies	Introduction and Photolog Students are sharing their photologs with each other	15 min

Pilot-intervention 'Study Smart': Sessions, goals, and exercises (continued)

Session	**Goals**	**Exercises and activities**	**Time**
	Reflection on own learning strategies, barriers and facilitators, and study motivation	Exercise Learning strategies and study motivation Students are completing a questionnaire about their learning strategies and complete the academic achievement questionnaire (Elliot & McGregor, 2001) Students calculate their score and receive a response sheet on which they can see their strongest type of motivation They compare their results with their neighbor and illustrate the learning strategies they are using with the photolog	25 min
	Becoming aware about how to implement effective learning strategies	Plenary discussion Learning strategies and study motivation Students share briefly their main finding of the questionnaire exercise and presents the learning strategies they are using The program leader facilitates a discussion about how to put different learning strategies into practice and gives examples on how to use effective learning strategies in daily practice	30 min
	Building a bridge from intention to implementation of effective learning strategies	SMART goals Students formulate one individual learning goal according to the SMART principle (specific, measurable, achievable, relevant, timebound) about how to practice effective learning strategies in the upcoming period Students share their goals with their partner and get feedback on it by the facilitator	20 min
Practice	Motivating students to make the promoted learning strategies a sustainable part of their learning behavior	Experiences until now and SMART goal Students share their experiences with the learning strategies until now in a group discussion The facilitator asks the students if and how they have worked on their SMART goal from the last session. The discussion is facilitated with questions like "Did you already try out different learning strategies?", "What barriers do you experience in adopting new learning strategies?"	15 min

Pilot-intervention 'Study Smart': Sessions, goals, and exercises (continued)

Session	Goals	Exercises and activities	Time
	Practicing one effective and one ineffective learning strategy and experiencing the 'experienced-learning-versus-actual-learning' paradox	a) Practice Exercise I The group is divided in two. Group 1 studies the article "What works, what doesn't by Dunlosky et al. (2013) using practice-testing, group 2 studies the text using highlighting. Group 1 gets 30 minutes to read the text and self-test themselves with provided propositions while group 2 reads the texts and rereads while using highlighting.	30 min
		b) Practice Exercise II The two groups switch roles and study the article "Problem-based learning: Future challenges for educational practice and research" by Dolmans et al (2005) with the other learning strategy	30 min
	Practicing one effective and one ineffective learning strategy and experiencing the 'experienced-learning-versus-actual-learning' paradox	Retention tests (actual learning) and judgments of learning measures (experience of learning) Students are handed out potential exam questions on both articles and answer the questions individually Students estimate their performance and note the grade they think they will receive for their answers Students score their answer using a provided answer sheet Students share their judgments and actual grades The facilitator makes clear that the impact of practice testing can't be experienced within a 2-hours session and that this exercise is more about experiencing the effort while using a different learning strategies	30 min
		Infographic and closure Program facilitator discusses resolutions to internalize and continue using learning strategies and hands out an infographic (a graphical summary of the different strategies) showing tips and pitfalls	15 min

Appendix B

Scenario descriptions (based on McCabe, 2011; Morehead, Rhodes, & DeLozier, 2016).

Scenario 1: Testing versus rereading.

In two different tutorial meetings, a 1000-word text passage about a specific topic is presented. In tutorial A, students first study the passage for ten minutes, and then are asked to write down from memory as much of the material from the text as they can. In tutorial B, students first study the passage for ten minutes, and then are asked to study the passage again for another ten minutes. After one week, all students are asked to recall as much of the text as they can remember in a short-answer test.

Scenario 2: Blocking versus interleaving.

Two radiology professors present 6 x-ray images of 12 different diseases (72 x-rays total). The professors want the students to learn which x-ray belongs to which disease. Professor A presents all six x-rays from one disease consecutively (i.e., grouped), and then moves on to the next disease and so on, until all x-rays from all diseases have been presented. Professor B presents the x-rays in an intermingled fashion (i.e., mixed), such that a single x-ray from one disease would be followed by an x-ray from a different disease. At the end of the period (4 weeks later), students are tested whether they can correctly identify the x-rays (new x-rays which they have not studied) to their respective disease.

Scenario 3: Spacing versus cramming.

Two students are studying for an open-answer exam in a course in statistics, which will come up in one week. The students have to learn and be able to apply five different statistical methods with a focus on correlation and regression. Student A goes over all the material on each of the following seven days and spends 2 hours each day studying the different statistical methods. Student B starts studying two days before the exam and goes over all learning material for seven hours on Wednesday and seven hours on Thursday. Both students spend the same total amount of hours (14 hours).

Scenario 4: Rereading versus elaborative interrogation.

The exam in the course 'Food for life' will be a multiple-choice exam with 52 questions with 5 answer options. Each of the five answer options can be true or false. In order to prepare for the exam, student A reads the textbook and other course materials, and rereads the materials and notes from the course carefully and with great attention. Student B reads the textbook and course materials once and after each paragraph, she asks herself questions such as 'Saliva must mix food to initiate digestion. Why is this so?'. Both students study one hour for this course in each of the seven weeks before the exam.

Scenario 5: Self-explanation versus mental imagery.

For the next post-discussion in the tutorial meeting (problem-based learning step 7), students have to collect more information and learn about the human blood circulatory system. Student A reads the textbook chapter and a summary about the system. While reading, she explains the described processes and mechanisms to herself after each paragraph. Student B reads the same textbook chapter and a summary about the system. While reading, he makes a mental image of the processes and tries to visualize the processes and mechanisms.

Scenario 6: Passive versus active summarization.

In order to prepare for the next post-discussion session, student A and B have to read several texts from a textbook-chapter and a few articles about the process of carbohydrate, fat and protein digestion transport. Student A makes a summary of the textbook-chapter by rereading it very attentively and copying the most important facts from the chapter in a summary. Student B makes a summary of the textbook-chapter by writing everything down he remembers from initial reading and connects it to the facts the tutorial group has discussed in the pre-discussion.

Scenario 7: Rereading without and with highlighting.

In order to prepare for the upcoming exam, student A reads the summaries from the course. Student B reads the same summaries, but also highlights and underlines the most important parts in the texts. Both students invest the same amount of time to prepare for the exam. One week later, both students have to take the exam, which consists of short-answer questions, where they have to combine and apply the information and content from the course. Shortly before the exam, both students review the summaries again. Student A reads the summary without highlights, student B reads the highlighted and underlined summary.

Appendix C

Coding scheme for verbal elaborations on scenario 1 'Testing versus Rereading' for four sample answers.

Sample answer (scenario 1)	Code
I think tutorial A is better for learning, because if you write things down, you can better remember them.	0
In tutorial A, the students had to recall the information they read, so they actively thought about it. In tutorial B, they only studied passively by reading, which is less effective than recalling information.	1
With writing down you ask yourself to reproduce what you just read. Only study is in my opinion not enough	0.5
When you first study and then actively retrieve the study material from your memory, you will remember the study material better than just studying it twice.	1

Chapter 3

Study Smart – Impact of a Learning Strategy Training on Students' Study Behavior and Academic performance

This chapter is revised and resubmitted as:

Biwer, F., de Bruin A.B.H., & Persky, A. (2020). Study Smart – Impact of a Learning Strategy Training on Students' Study Behavior and Academic performance.

ABSTRACT

Recent research shows the importance to teach students self-regulated learning skills and effective learning strategies at university. However, the effects of such training programs on students' metacognitive knowledge, use of learning strategies, and academic performance in the longer term are unknown. In the present study, all first-year pharmacology students from one university attended a learning strategy training, i.e., the 'Study Smart program', in their first weeks. The 20% (n = 25) lowest scoring students on the first midterm received further support regarding their learning strategies. Results showed that students gained accurate metacognitive knowledge about (in)effective learning strategies in the short- and long-term and reported to use less highlighting, less rereading, but more interleaving, elaboration, and distributed practice after the training program. Academic performance was compared to the prior cohort, which had not received the Study Smart program. While in the previous cohort, students in the top, middle, and bottom rank of midterm 1 stayed in these ranks and still differed significantly in the final exam, students in the Study Smart cohort that received the training program improved throughout the year and differences between ranks were significantly reduced. A learning strategy training including a remediation track for lower performing students can thus support students to study more effectively and enhance equal chances for all students at university.

Keywords: learning strategies, study skills, desirable difficulties, academic performance, metacognitive knowledge

INTRODUCTION

All health sciences students are required to learn and retain a high amount of information during their undergraduate study needed to treat patients in their later working life. Students need to plan, monitor, and control their learning in a self-regulated way, mostly outside the classroom during self-study (Broadbent, 2017). As such, self-regulated learning and using effective learning strategies for long-term learning are essential factors contributing to lifelong learning and student success (Richardson, Abraham, & Bond, 2012). However, many students do not know what are effective learning strategies (Bjork, Dunlosky, & Kornell, 2013) and often use passive and shallow learning strategies to prepare for their next exam, such as re-reading their notes or summarizing (e.g., Persky & Hudson, 2016). These strategies, however, have been proven to be ineffective regarding long-term retention and understanding (Bjork, Dunlosky, & Kornell, 2013; Hartwig & Dunlosky, 2012; Karpicke, Butler, & Roediger, 2009). Often, information is forgotten soon, and students need to spend time and effort to re-learn the information. Hence, there is a high need for training programs to support effective learning strategies among health sciences students to prepare them well for their future work.

Research in cognitive and educational sciences has shown the effectiveness of so-called desirable difficulties for long-term retention (Bjork & Bjork, 2014; Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013). Desirably difficult learning strategies create difficulties and cost more effort during the initial learning phase, but enhance retention and understanding in the long-term. This is for example the case in retrieval practice or distributed practice (for reviews about these strategies, see Adesope, Trevisan, & Sundararajan, 2017; Cepeda, Pashler, Vul, Wixted, & Rohrer, 2006; Delaney, Verkoeijen, & Spirgel, 2010). Research in cognitive psychology has demonstrated that practicing retrieval of information from memory (e.g. by answering test questions) produces better long-term retention compared to repeated rereading of the material (Adesope et al., 2017; Rowland, 2014). Test-enhanced and distributed learning are also highly effective in medical education contexts and effects transfer to clinical application with standardized patients (Dobson, Linderholm, & Stroud, 2019; Larsen, Butler, Lawson, & Roediger, 2013).

However, the contributions of cognitive psychological research to the practice of medical education are still limited (Schmidt & Mamede, 2020).

The reasons why most students do not use these desirably difficult learning strategies are multifaceted. First, intuitions during studying are misleading. Students tend to use immediate access to judge the effectiveness of a learning strategy. This in turn leads to an overestimation of their performance with rather passive strategies, such as rereading, and an underestimation of their performance with desirably difficult strategies, such as retrieval practice (Nunes & Karpicke, 2015). Second, students are lacking metacognitive knowledge about which learning strategies are effective and which ones are not (Hartwig & Dunlosky, 2012; Morehead, Rhodes, & DeLozier, 2016). Myths about learning, such as the learning style myth, are misleading but still omnipresent in students and teachers (Kirschner, 2017; Kirschner & van Merriënboer, 2013; Newton, 2015). Third, the self-regulated use of effective learning strategies is challenging. Effective learning strategies for long-term learning are more effortful and benefits pay off after a delay. Putting these strategies into practice requires deliberate practice and a behavior or habit change over time (Fiorella, 2020). Finally, students receive either no or very little instruction on effective learning strategies and how to use them (Dunlosky et al., 2013). Competence-based curricula emphasize the acquisition of content and development of competences rather than teaching how to learn that content most effectively (Frank et al., 2010). Without formal training on the effective use of learning strategies, students are likely to follow their potentially misleading experiences during initial learning and continue to use ineffective learning strategies. In light of the abovementioned difficulties in applying effective learning strategies on one's own, it seems highly important to teach students effective learning strategies and how to use them.

Existing training programs have generally aimed at improving students' self-regulated learning, strategy use, and motivation (Dignath & Büttner, 2008; Dörrenbächer & Perels, 2016; Hattie, Biggs, & Purdie, 1996; Nunez et al., 2011; Schuster, Stebner, Leutner, & Wirth, 2020; Weinstein, Husman, & Dierking, 2000) in order to ultimately foster academic performance. Most existing programs, however, focused on primary or secondary school students, or on learning strategies targeting particular domains, such as reading, writing or mathematics (Donker, de Boer, Kostons, Dignath van Ewijk, & van der Werf, 2014). A recent meta-analysis on self-regulated learning training programs for university students including 49 studies (Theobald, 2021) showed promising effects that training programs fostered academic performance, self-regulated learning strategies, and motivation of university students. Underachieving students benefited more from the training, probably as there was more room for improvement. Yet, it is unclear whether all students will benefit similarly from a learning strategy training program or will need continuous individualized support. Furthermore, most training programs did not address how to train learning strategies for transfer to self-study (i.e., the self-regulated use of learning strategies). The long-term effects of such training programs on sustained strategy use after the training are still unclear.

With the aim to increase students' knowledge about effective learning strategies and ultimately support students in using these effective learning strategies, a few frameworks and training program approaches were developed in recent years (Biwer, de Bruin, Schreurs, & oude Egbrink, 2020; Biwer, oude Egbrink, Aalten, & de Bruin, 2020; Endres, Leber, Böttger, Rovers, & Renkl, 2021; McDaniel & Einstein, 2020; McDaniel, Einstein, & Een, 2021). Although framed differently, these programs addressed at least one of the following components: *declarative knowledge* about effective learning strategies (which strategies are effective for long-term learning), *conditional knowledge* (knowledge about when and why a specific strategy is effective), *beliefs* about the effectiveness of strategies (by addressing the experienced-learning-versus-actual-learning paradox), *motivation* to use effective learning strategies (by formulating learning goals and an action plan), and supporting *practice* (by guided strategy practice or classroom demonstrations). In first researcher-led investigations, studies showed that these training programs increased students' metacognitive knowledge about effective learning strategies and heightened students' intention to use effective learning strategies (Biwer, oude Egbrink, et al., 2020; Endres et al., 2021). Open questions are, however, what effects these interventions have in the long-term, when implemented in a curriculum for all first-year students. Even though it is desirable to implement such a training for all first-year students, students might benefit differently from it. Moreover, it remains an open question whether a direct learning strategy training can support students in not only using more effective learning strategies but eventually improve their grades as well. As changing behavior is difficult, students may resist change as applying new strategies is perceived as time consuming, stressful, and leads to uncertainty in performance. Finally, research has shown that lower performing students are less metacognitively accurate and may require more support in their study strategies to develop these skills (Hacker, Bol, & Bahbahani, 2008). As such, a program may need to be longitudinal reinforcing concepts over time in context of actual course work, especially for lower achieving students.

The current study has therefore two main aims. First, we investigated the effect of the learning strategy training 'Study Smart' on students' metacognitive knowledge as well as use of effective learning strategies in the short- and long-term. The Study Smart program consisted of three training sessions for all first year students. In addition, following a competency-based education model, the 20% lowest performing students at the first exam received regular support on study strategies in a remediation pathway. Second, we investigated if a learning strategy training can improve academic performance when comparing the current cohort to the previous one, which did not receive a learning strategy training. The results of this study can help inform programs on how best to help students develop better learning strategies and how to use these to achieve mastery in a competency-based curriculum.

METHODS

Participants

The Study Smart cohort (2020) consisted of all 126 students of the first-year class (PY1) enrolled at the UNC Eshelman School of Pharmacy. The average age was 23 years (*SD* = 2) and 71% were females. Of all 126 enrolled students that attended the Study Smart program, 111 students completed all pretest, posttest, and long-term measures. One student completed the long-term questionnaire in shorter than 1.5 minutes and was thus excluded from further analysis. The final sample consisted of 110 students. The control cohort (2019) consisted of 158 enrolled students, 77%

were females. Students of both cohorts were nearly identical regarding their prior college GPA (3.6 out of 4 in both years) and PCAT (Pharmacy College Admission Test) standardized exam (89 in 2019 and 88 in 2020). All participants signed an informed consent to release their grades and use their data at the end of the semester. The study was approved by the ethical review board of the University of North Carolina at Chapel Hill (IRB Study #20-02045).

The Study Smart Program

The Study Smart Program entailed three sessions: awareness, practice, and reflection. Each session was 90 minutes, online due to the COVID-19 pandemic restrictions, and was led by the last author. Prior to each session, students completed some individual exercises and preparation for the next session. For an overview about the program elements, see Table 3.1. The training was based on the learning strategies and their effectiveness as discussed in the review by Dunlosky et al. (2013).

Table 3.1. Study Smart Outline

	Pre-Class	In-Class	Prior to Next	Components
Day 1: Awareness	1. Narrated slideshow on Desirable Difficulties	1. Goals of Study SMART 2. Categorize 8 learning strategies 3. Desirable Difficulties 4. Practice Test 5. Intro Photolog	6. Photolog	Declarative knowledge, conditional knowledge, beliefs
Day 2: Practice		1. Experiences and Implementation Intentions Goals 2. Sharing experiences from practice exercise 3. Practicing two strategies together in class		Motivation, practice, conditional knowledge
Day 3: Reflection	1. Exercise study motivation (Academic achievement Survey) 2. Reflection on perceived difficulties / challenges in using effective LS	1. Plenary discussion about motivation 2. Intervision session ‘critical incident method’		Motivation, practice

The aim of the first session, awareness, was to challenge students' prior beliefs about the effectiveness of commonly used learning strategies and to provide information about their empirical evidence. Prior to the session, students watched a narrated slideshow on the importance of desirable difficulties to prepare them for the importance of effort during studying. In-class, students shared their commonly used learning strategies. The facilitator structured this brainstorm, explained the learning strategies and asked students about their beliefs concerning the effectiveness of each learning strategy for long-term learning. Students categorized the strategies into highly effective, moderately effective, and non-effective strategies. Afterward, the facilitator explained the empirical evidence of each strategy regarding their effectiveness for long-term learning, how much training is required to use a strategy, and how to implement the strategies in the classroom setting (based on Dunlosky et al., 2013). The facilitator addressed the role of desirable difficulties, the importance of deliberate practice, and the importance of investing effort and time to become good at something. Then, the facilitator explained the testing effect and the difference between experienced learning and performance, illustrated by graphs from empirical studies (taken from Nunes & Karpicke, 2015; Roediger & Karpicke, 2006). Afterward, students reflected upon a memory of when they successfully developed a new skill through deliberate practice (e.g., sports, arts, music) in a reflective writing exercise. This exercise aimed to make students aware about the importance of effort and practice for competence development. The session ended with a short practice test consisting of seven open questions about the nature and effectiveness of the addressed learning strategies. This test aimed to strengthen the information taught in the awareness session. As homework to prepare for the next session, students were asked to keep a photolog of their study behavior in the coming week. Students were given the option to send photos via Instagram to the facilitator.

The aim of the second session, practice, was to let students practice effective learning strategies with their own learning materials. In the beginning of the session, students shared their study behavior during the previous week using their photologs. Students discussed reasons for (not) having experimented with the proposed learning strategies. This was followed by a discussion of common obstacles and strategies to overcome these obstacles. Next, students were divided into small groups (4-5 students per group) and applied either self-explanation, retrieval practice, or visualization on actual course material. After 15 min, they switched groups and applied another strategy on another set of course material. Afterward, the facilitator discussed spacing and interleaving with the students making a calendar on how and when they would study the course material for the final exam, which was approximately 10 days away. The session concluded with the students writing implementation intentions – how they will use these strategies for studying, what obstacles they expect to encounter and their strategies to encounter that obstacle.

The aim of the third session, reflection, was to address students' study motivation and commitment. The session was split across two different days. In the first day, students completed two questionnaires: one about their learning strategies (based on the survey by Kornell & Bjork, 2007), and another one about their academic goal orientation (questionnaire by Elliot & McGregor, 2001). The questionnaire exercise intended to make students more aware about their learning strategies and study motivation and to stimulate students to reflect on what they would like to achieve with their studies. Students shared their main findings of the questionnaire and their thoughts on these with the class. In the second day, after their final examinations were completed, students reflected on the obstacles during the past week using the critical incident method (Vachon & LeBlanc, 2011). They then watched two videos of students explaining their obstacles with learning strategies and were asked to reflect on these videos. The session ended with students again making a new set of implementation intentions for the remaining part of the semester. Finally, the facilitator emphasized the importance of long-term learning.

The Remediation Pathway

The 20% lowest performing students in the first midterm exam of the Study Smart cohort were additionally assigned to the remediation pathway. The remediation pathway involved developing new implementation intentions (Gollwitzer & Sheeran, 2006) on how they would study for the next examination and completing a calendar of when they would study for the next midterm examination. Students in the remediation pathway received weekly reminders of common learning strategies discussed in the Study Smart Program. They were also asked to make a recorded PowerPoint® that had them teach a (theoretical) family member about the course content they performed poorly on (Hoogerheide, Visee, Lachner, & van Gog, 2019). The remaining students of the Study Smart cohort were sent reminders of common learning strategies discussed in the Study Smart Program and were given access to the other materials the bottom 20% students were provided but they were not required to complete them. However, only students in the remediation pathway completed the additional exercises and received feedback from the instructor; none of the other students actually completed the additional exercises.

Measures

All measures were delivered online, using the questionnaire tool Qualtrics (Qualtrics, Provo, UT). As dependent variables, we measured metacognitive knowledge about learning strategies in the pretest, posttest, and long-term retention test. Use of learning strategies was measured via self-report in the pretest and posttest, and additionally measured in weekly surveys during the study smart intervention program, and at the time of examinations. Academic performance was measured via exam scores.

Metacognitive knowledge. Declarative metacognitive knowledge was measured by participants rating the effectiveness for long-term learning of the strategies highlighting, summarizing, rereading, visualization, elaboration, self-explanation, interleaved practice, distributed practice, and practice testing on a rating scale from 1 (not at all effective) to 5 (extremely effective). To measure conditional knowledge, we used seven scenario descriptions (Biwer, oude Egbrink, et al., 2020; McCabe, 2011; Morehead et al., 2016). Each scenario described two strategies with different levels of empirically supported effectiveness in a specific situation. Participants rated for each scenario the extent to which the two strategies do or do not benefit learning as measured by subsequent performance on a delayed test. They rated the effectiveness of each strategy on a scale from 1 (not at all beneficial to learning) to 7 (very beneficial to learning), with a value of four indicating a neutral evaluation (i.e., the strategy is neither rated as effective nor ineffective; Morehead et al., 2016).

The scenarios described the strategies (the more effective strategy marked in italic) *testing* vs. rereading, *interleaving* vs. blocking, *spacing* vs. cramming, rereading vs. *self-explanation*, *self-explanation* vs. mental imagery, summarization with vs. *without textbook (from memory)*, and reading with vs. without highlighting (both rather ineffective).

Use of learning strategies. Students rated the extent to which they used the strategies on a 5-point Likert scale from 1 (never) to 5 (every time I studied). Students completed these surveys in pretest and posttest, as well as in nine learning strategy surveys during the intervention and the semester. Due to very low completion rates of these nine surveys throughout the semester, we did not include these in our further analyses. There was no use measurement at the long-term test, as students had no classes during that week.

Academic performance. We measured students' academic performance of both cohorts via their exam grades of Exam 1, Exam 2 and the final Exam 4. Exam 3 was not taken into consideration for this study as it was different in both years and therefore, not comparable between both cohorts. Exams included 70 multiple-choice questions (each with four answer options and one correct answer); a maximum of 70 points could be reached per exam. Exam scores are displayed as percentage-points. Questions tested mainly knowledge application (70% of the questions), and knowledge retention (30% of the questions). Exam 1 and exam 2 assessed content from the weeks before the respective exam, the final exam tested knowledge of the whole course. Exam questions were about 85% the same in both cohorts, 15% was different. It must be noted that in 2019, exams took place on campus while in 2020, exams were done online due to the COVID-19 pandemic. Exams were proctored synchronously, that means all students had two devices. On the first device, the student was monitored with videoconferencing software. On the second device, the student took the exam via computer-based testing software (Hall, Spivey, Kendrex & Havrda, 2021).

Procedure

For an overview of the procedure see Figure 3.1. This study took place during the fall semester across two core courses. The first course was a pharmacy bridging course (PHCY 500) intended to review prerequisite content essential for future learning. This course occurred during the first four weeks of the semester (i.e., August). All students of the Study Smart cohort received the Study Smart Program as mandatory part of PHCY 500. In week 1 of the course, students completed the pretest. Students attended the awareness session in week 2, the practice session in week 3, and the reflection session in week 4, and completed the posttest at the end of week 4. The second course, pathophysiology (PHCY 502), occurred in the subsequent 14 weeks (i.e., September through December). After Exam 1 in PHCY 502, the 20% lowest performing students were assigned for the remediation pathway. Students who performed poorly on Exams 2 and 3 were also offered this remediation pathway, but it was the cohort of Exam 1 that was the primary interest for this study. In week 24, students were asked to complete the long-term retention survey. As shown in Figure 3.1, the control cohort had the same courses (PHCY 500 and PHCY 502) and exams, but did not receive the Study Smart Program nor the possibility of the Study Smart remediation.

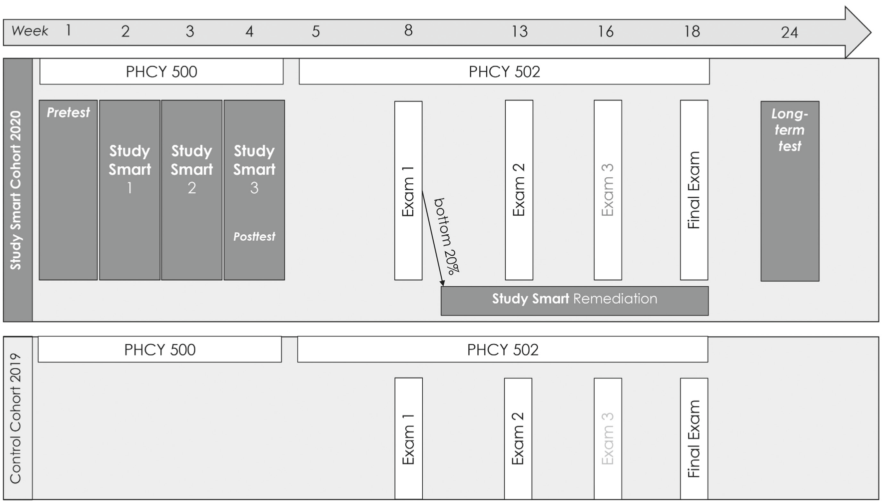

Figure 3.1. Overview of the study procedure

Data Analysis

An alpha level of .05 was used for all statistical tests. As effect size measure, we used partial eta squared with values of 0.01, 0.06, and 0.14 indicating small, medium, and large effects, respectively (Cohen, 1988). In 15% of the participants, there were missing values ranging from 1 to 13.8%, a percentage still considered acceptable (Peng et al., 2006). As indicated by Little's MCAR test, $\chi^2 = 1377.7$, $p = .214$, data were missing completely at random. Therefore, listwise deletion was used to handle missing data.

To measure effects of the training on metacognitive knowledge and use of learning strategies, we conducted a repeated-measures MANOVA with time (pretest, posttest, long-term test) as repeated within-variable. Differences in academic performance between the cohorts with (2020) and without the study smart program (2019) were compared using a 3 (midterm 1, midterm 2, final exam) x 2 (cohort) x 3 (rank) three-way mixed ANOVA. Rank was used to distinguish between the lower 25 and top 25 students and the middle group (2019: n = 108; 2020: n = 76) based on the first midterm exam.

RESULTS

Metacognitive Knowledge

Descriptive statistics for the effectiveness ratings at pre-, posttest, and long-term retention test are shown in the Appendix and in Figure 3.2.

There was a significant main effect of time, $F(18, 888) = 12.69$; $p < .001$; $\eta_p^2 = .72$. The strategies rereading, summarizing, highlighting, visualization and self-explanation were rated as significantly less effective in the post-test and long-term compared to pretest. Distributed practice was estimated as more effective in post and long-term, compared to the pretest. In the pretest, students rated all strategies as moderately or highly effective. In the posttest, the passive learning strategies highlighting, rereading, and summarizing were rated as not effective and thus more accurate with regard to scientific evidence (Dunlosky et al., 2013).

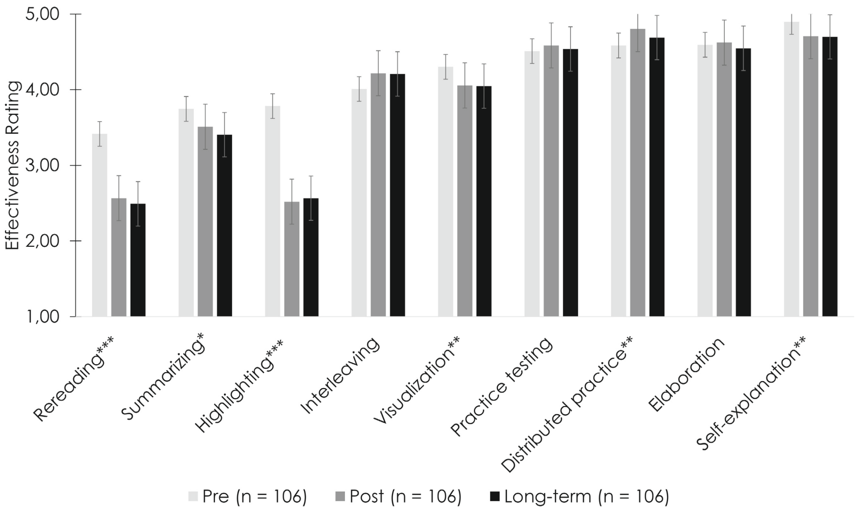

Figure 3.2. Declarative metacognitive knowledge per measurement point (pre, post, long-term)

Note. Ratings on a scale from 1 (not at all effective) to 5 (extremely effective). Significant effects of time are marked with $*p < .05$; $**p < .01$; $***\ p < .001$.

Regarding conditional metacognitive knowledge, we compared the difference between effective and ineffective learning strategies across all scenarios. We expected that, at posttest and long-term, the difference between effective and ineffective strategies would be positive and higher compared to the pretest. Descriptive statistics for scenario ratings at pretest, posttest, and long-term are shown in the Appendix and in Figure 3.3.

There was an overall significant multivariate effect of time, $F(14, 85) = 9.88$; $p < .001$; $\eta_p^2 = .62$. Follow-up univariate analyses showed significant time effects for the scenarios testing vs. rereading, $F(1.8, 178.3) = 4.77$, $p = .012$, $\eta_p^2 = .05$; interleaving vs. blocking, $F(1.8, 178.9) = 16.67$, $p < .001$, $\eta_p^2 = .15$; rereading vs. self-explanation, $F(2,196) = 22.48$, $p < .001$, $\eta_p^2 = .19$; summarization with vs. without textbook, $F(2, 196) = 29.91$, $p < .001$, $\eta_p^2 = .23$; and rereading with vs. without highlighting, $F(2, 196) = 16.94$, $p < .001$, $\eta_p^2 = .15$. The ratings of these scenarios were more accurate in the posttest and long-term compared to the pretest.

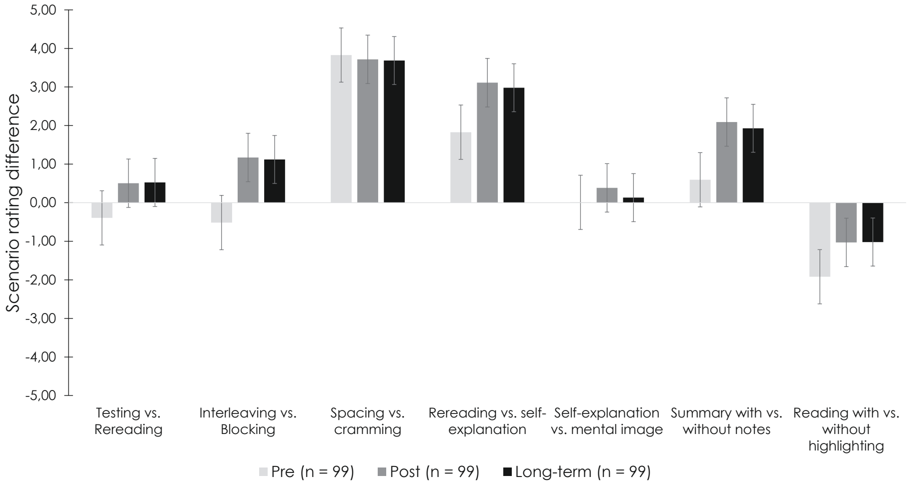

Figure 3.3. Conditional Knowledge (Scenario Difference) per scenario and measurement point (pre, post, long-term)

3

Learning Strategy Use

The self-reported strategy use was measured pre-post. There was an overall significant multivariate effect of time, $F(9, 96) = 11.31$; $p < .001$; $\eta_p^2 = .52$, showing that strategy use differed between pre and post-test. Follow-up univariate analyses showed significant time effects for the use of highlighting, $F(1, 104) = 52.26$; $p < .001$; $\eta_p^2 = .33$, rereading, $F(1, 104) = 24.14$; $p < .001$; $\eta_p^2 = .19$, interleaving, $F(1, 104) = 35.85$; $p < .001$; $\eta_p^2 = .26$, elaboration, $F(1, 104) = 15.85$; $p < .001$; $\eta_p^2 = .13$, and distributed practice, $F(1, 104) = 14.31$; $p < .001$; $\eta_p^2 = .12$. As shown in Figure 3.4 (and the Appendix), students reported to use less highlighting, less rereading, but more interleaving, elaboration, and distributed practice after the training program.

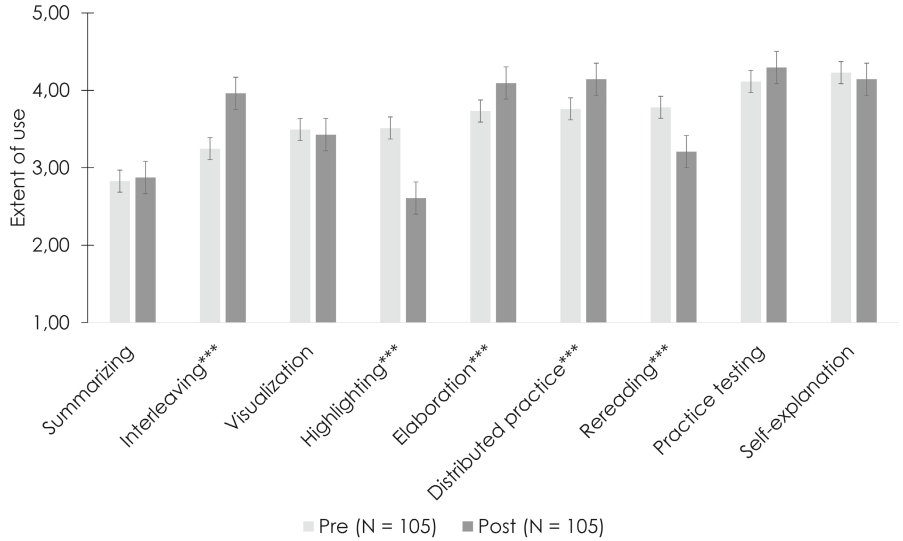

Figure 3.4. Self-reported use of learning strategies (pre, post)

Note. Ratings on a scale from 1 (never) to 5 (every time I studied). Significant effects of time are marked with $*p < .05$; $**p < .01$; $*** p < .001$.

Academic Performance

For descriptive statistics see the Appendix and for a visualization of the results Figure 3.5. We compared both cohorts, 2019 and 2020, using a three-way mixed ANOVA with cohort (2019 or 2020) and rank (top, middle, bottom) as between variables and exam scores over time (midterm 1, midterm 2, and final exam) as within variable.

There was a significant main effect of exam performance, $F(2, 556) = 106.25$, $p < .001$, $\eta_p^2 = 0.28$, showing that exam performance differed across groups and ranks between the different exams. There was a significant interaction effect between exam and cohort, $F(2, 556) = 137.80$, $p < .001$, $\eta_p^2 = 0.31$, showing that exam performance over time differed between the two cohorts. Follow-up pairwise comparisons with Bonferroni correction showed that in the 2019 cohort, exam performance only differed significantly between exam 1 and 2, with a mean difference of 1.9 points ($SE = .74$; $p = .026$). In the 2020 cohort, however, exam performance differed between exam 1 and 2 ($M = 8.14$, $SE = .79$, $p < .001$), exam 2 and 3 (M = 8.01, SE = .84, p < .001) and exam 1 and 3 (M = 16.15, SE = .74, p < .001) with an average increase of 12.02 points. That is, students in cohort 2020 showed more knowledge growth across exams than in cohort 2019.

Furthermore, the interaction between exam, cohort, and rank was significant, $F(4, 556) = 5.67$, $p < .001$, $\eta_p^2 = 0.039$. Tests of simple effects showed that in the cohort of 2020, students in the top and middle group did not differ significantly in their final exam test scores, p = .078, with a mean difference of 3.2 points (SE = 1.45). Furthermore, the difference between the bottom and the middle group was reduced, yet still significant, p = .049, mean-difference of 3.5 points (SE = 1.45). In the cohort of 2019, all groups still significantly differed, ps < .001 in their test performance, with a mean-difference of 10.0 points (SE = 1.4) between the top and middle group and a mean-difference of 6.8 (SE = 1.4) between bottom and the middle group.

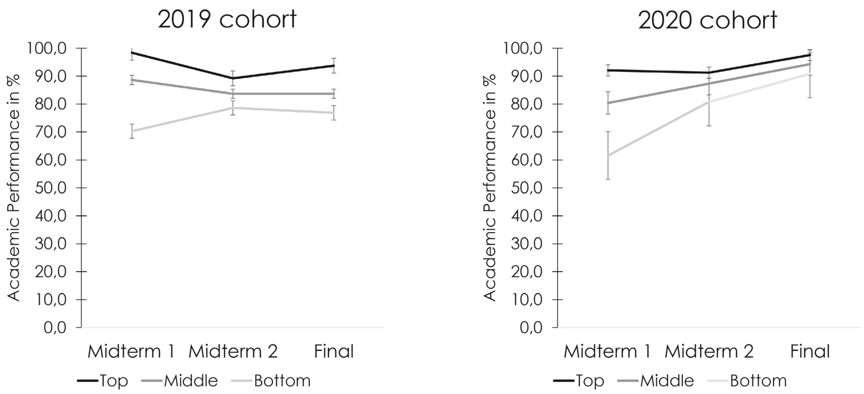

Figure 3.5. Academic Performance in % per cohort (2019 and 2020) and rank (top, middle, bottom)

Exploratory Analyses

In exploratory analyses, we examined correlations between reported strategy knowledge and strategy use (at posttest) and academic performance at midterm 1. There was a negative correlation between the effectiveness rating of rereading and exam score on midterm 1, r = -.196, p = .040 and a positive correlation between the effectiveness rating of practice testing and exam score on midterm 1, r = .218, *p* = .022. Regarding reported strategy use, there was a positive correlation between the reported use of practice testing and exam score on midterm 1, *r* = .339, *p* = .001.

DISCUSSION

This study examined whether a learning strategy training ('Study Smart program') implemented for all first-year students, can improve students' metacognitive knowledge and enhance the use of effective learning strategies. Novel to the existing learning strategy intervention literature was to provide lower achieving students a remediation track to offer continuous support in developing self-regulated learning skills. Furthermore, we investigated the effect of the Study Smart program on academic performance over the course of the year by comparing the Study Smart cohort with the previous cohort.

Regarding our first aim, we found that the Study Smart Program improved declarative and conditional metacognitive knowledge not only in the short-term (Biwer, oude Egbrink, et al., 2020) but also in the long-term, up until twelve weeks after the intervention. Before the training program, students already had relatively high prior knowledge on the efficacy of practice testing, self-explanation, elaboration and distributed practice. However, students overestimated the efficacy of less effective strategies such as highlighting or rereading and gained more accurate knowledge about these strategies after the training, measured in an immediate posttest as well as long-term after twelve weeks. The conditional and declarative metacognitive knowledge changes are consistent with prior studies, although there were some nuanced differences (Biwer et al., 2020). Regarding the use of learning strategies, we found that students reported to use more effective learning strategies, such as interleaving, elaboration, and distributed practice after the training, and less non-effective strategies such as highlighting or rereading. This was, however, only measured on the post-test, due to the fact that students did not have classes in the week prior to the long-term test. In further exploratory analyses, we found that students, who, after attending the Study Smart training, reported to use more practice testing scored higher on the first midterm exam.

The second aim was to examine the effect of a learning strategy training such as the Study Smart Program on academic performance. In comparison to the previous cohort, students in the Study Smart cohort improved significantly from exam to exam, with an average increase of 10 percentage points, from 79% in the first exam to 94% in the final exam. In the previous year, students' exam performance stayed rather stable from exam to exam, on 85%. We further examined whether and how the Study Smart Program can help poorly performing students reach competency. From midterm 1 to midterm 2, we saw improvements in the bottom 25 students of the first midterm, who failed the first midterm with an average score around 60% to earning a B with an average score of 80% on midterm 2. This change could be attributed to differences in content (easier content on midterm 2), time effects that students became accustomed to how they were assessed and their expectations, or the reinforcement of study strategies. The first two reasons, however, are not supported by the comparison between the two cohorts. Midterm 1 and Midterm 2 had the same content year to year and while students in the 2019 cohort stayed in the bottom group, students of the bottom group in the Study Smart cohort improved significantly. In the Study Smart cohort, the bottom performing students had a positive change from midterm 1 to midterm 2 (19 percentage points) and from midterm 2 to the final exam (10 percentage points). In contrast, in the prior year, this change was much smaller (8 percentage points) from midterm 1 to midterm 2 and even negative from midterm 2 to the final exam (-1.8 percentage points). These results are promising with regard to supporting lower achieving students in their first year to adapt to university and increase success rates. While we cannot pinpoint whether these changes are due to the fact that students used more effective learning strategies or whether the structured reflection sessions supported students in their planning and study motivation, it seems important to provide students more and continuous support in their self-regulated learning. This aligns with research on non-completion in higher education that showed the importance of study- or learning strategy trainings, but also of coaching and remedial training to protect for non-completion (Delnoij, Dirkx, Janssen, & Martens, 2020). In future research, it would be important to disentangle the working ingredients of such a remediation track to advance the support, especially needed in times of online or distance education.

The study design has several limitations. Due to the implementation in a complete cohort and ethical reasons to provide the Study Smart program to all students, a control-group design was not possible. Changes in knowledge and use of strategies pre-post might be also partly due to time effects as students develop more accurate knowledge over the year. However, as known from previous research about the experienced-learning-versus-actual-learning paradox (Kirk-Johnson, Galla, & Fraundorf, 2019; Nunes & Karpicke, 2015), it is quite unlikely that students gained their more accurate knowledge through experience. A related issue is that we cannot pinpoint whether and which factors of the remediation track contributed to the improvement in grades of the lower-performing students in the Study Smart cohort.

Second, the comparison in academic performance between the Study Smart cohort and the previous cohort has to be considered in light of a different context. As in 2020, the COVID-19 pandemic forced students to study completely online. All sessions were offered online, also lectures and seminars. In the year before, lectures were offered hybrid, students who lived too far away from campus already studied online, others came to campus. Nevertheless, neither the instructional approach of lectures nor the intended learning outcomes of the course changed between both cohorts. Furthermore, general performance of the Study Smart cohort was comparable to the previous cohort.

Third, the use of learning strategies was only measured via self-report pre-post, and not long-term. We cannot rule out that some students might have answered socially desirable or not completely accurate. In future research on students' learning strategy use, it would be interesting to use different ways of measuring strategy use, for example by applying experience-sampling methods or using log-data in online learning environments to gain more objective measurements of students' learning behavior (Nett, Goetz, Hall, & Frenzel, 2012; Xie, Heddy, & Vongkulluksn, 2019). Another interesting avenue for future research could be to include more long-term measures of strategy use, not only over the period of a course but over the complete first year or undergraduate program.

The fact that students in the Study Smart cohort, and specifically those in the remediation pathway, improved their academic performance demonstrates the importance of academic tutoring and providing additional support to students. Due to higher submission rates, more and more students are being admitted to studies like pharmacology. However, students who are not prepared to study in a self-regulated way are likely to struggle and build shallow knowledge. Providing support in their first year on how to study more effectively is a promising way to ensure equal chances for all students in their first academic year.

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Appendix A

Means and standard deviations for declarative metacognitive knowledge, measured by effectiveness ratings, at pretest, posttest, and long-term, sorted by rated effectiveness at pretest

	Pre (n = 106)		**Post (n = 106)**		**Long-term (n = 106)**		**Time**	
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*(df)	η_p^2
Rereading***	3.42	1.09	2.57	0.99	2.49	0.92	F(2, 210)=43.5***	.29
Summarizing*	3.75	0.92	3.51	1.01	3.41	1.05	F(2, 210) = 4.45*	.04
Highlighting***	3.78	1.00	2.52	1.00	2.57	1.02	F(2, 210) = 87.63***	.46
Interleaving	4.01	0.98	4.22	0.97	4.21	0.89	F(1.88, 197) = 2.19	.02
Visualization**	4.30	0.87	4.06	0.80	4.05	0.81	F(2, 210) = 4.86**	.04
Practice testing	4.51	0.76	4.58	0.66	4.54	0.78	F(1.86, 172.5) = 0.46	.01
Distributed practice**	4.58	0.63	4.80	0.40	4.69	0.56	F(1.85, 172) = 4.96**	.05
Elaboration	4.59	0.61	4.62	0.58	4.55	0.66	F(2, 186) = 0.57	.01
Self-explanation**	4.90	0.31	4.71	0.53	4.70	0.52	F(2, 186) = 7.44**	.07

Note. Ratings on a scale from 1 (not at all effective) to 5 (extremely effective). Significant effects of time are marked with *$p < .05$; **$p < .01$; *** $p < .001$.

Appendix B

Means and standard deviations for conditional metacognitive knowledge, measured by scenario difference scores at pretest, posttest, and long-term

	Pre (n = 94)		**Post (n= 94)**		**Long-term (n = 94)**		**Time**	
	M	*SD*	*M*	*SD*	*M*	*SD*	*F*(df)	η_p^2
Testing vs. Rereading	-0.39	2.87	0.51	3.08	0.53	2.98	*F*(1.82. 178.3) = 4.77*	.05
Interleaving vs. Blocking	-0.52	3.48	1.17	2.84	1.12	2.85	*F*(1.84. 179.9) = 16.67***	.15
Spacing vs. cramming	3.83	1.65	3.72	1.62	3.69	1.72	*F*(2. 196) = 0.31	.00
Rereading vs. self-explanation	1.83	1.53	3.11	1.61	2.98	2.05	*F*(2. 196) = 22.48***	.19
Self-explanation vs. mental image	0.01	1.22	0.38	1.52	0.13	1.22	*F*(2. 196) = 2.58	.03
Summary with vs. without notes	0.60	1.63	2.09	1.55	1.93	1.86	*F*(2. 196) = 29.9***	.23
Reading with vs. without highlighting	-1.92	1.43	-1.03	1.55	-1.02	1.41	*F*(2. 196) = 16.93***	.15

Note. Ratings on a scale from 1 (not at all effective) to 5 (extremely effective). Significant effects of time are marked with *$p < .05$; **$p < .01$; *** $p < .001$.

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Appendix C

Means and standard deviations for self-reported extent of use, measured pre and post

	Pre (n = 105)		**Post (n= 105)**		**Time**	
	M	*SD*	*M*	*SD*	*F*(df)	η_p^2
Summarizing	2.83	1.26	2.88	1.19	*F*(1, 104) = 0.12	.00
Interleaving***	3.25	1.08	3.96	1.00	*F*(1, 104) = 35.85	.26
Visualization	3.50	1.26	3.43	1.13	*F*(1, 104) = 0.31	.00
Highlighting***	3.51	1.15	2.61	1.18	*F*(1, 104) = 52.26	.33
Elaboration***	3.73	0.98	4.10	0.83	*F*(1, 104) = 15.85	.13
Distributed practice***	3.76	0.97	4.14	0.94	*F*(1, 104) = 14.31	.12
Rereading***	3.78	1.04	3.21	1.07	*F*(1, 104) = 24.14	.19
Practice testing	4.11	0.95	4.30	0.85	*F*(1, 104) = 3.04	.03
Self-explanation	4.23	0.79	4.14	0.84	*F*(1, 104) = 0.82	.01

Note. Ratings on a scale from 1 (never) to 5 (every time I studied). Significant effects of time are marked with *$p < .05$; **$p < .01$; *** $p < .001$.

Appendix D

Means and Standard Deviations for exam scores of both cohorts (2020 and 2019) for midterm 1, midterm 2 and final exam

		2020 (Study Smart cohort)				2019 (Control cohort)			
		Top (n = 25)	Middle (n = 76)	Bottom (n = 25)	*Total*	Top (n = 25)	Middle (n = 108)	Bottom (n = 25)	*Total*
Midterm 1	M	92.06	80.39	61.57	78.98	98.40	88.63	70.30	87.28
	SD	2.75	4.96	6.76	11.00	1.22	5.25	4.69	9.45
Midterm 2	M	91.22	87.30	80.78	86.79	89.19	83.68	78.64	83.75
	SD	4.36	5.80	6.59	6.60	6.20	7.51	7.89	7.92
Final	M	97.54	94.31	90.81	94.25	93.72	83.69	76.86	84.19
	SD	3.26	4.02	6.03	4.82	4.29	7.71	8.63	8.82

Chapter 4

Future Steps in Teaching Desirably Difficult Learning Strategies: Reflections from the Study Smart Program

This chapter has been published as:

Biwer, F., oude Egbrink, M.G.A., Schreurs, S. & de Bruin A.B.H. (2020). Future steps in teaching desirably difficult learning strategies: Reflections from the Study Smart Program. *Journal of Applied Research in Memory and Cognition, 9*, 439-446.

ABSTRACT

Applying effective learning strategies during self-study is important to build long-term knowledge. However, students rarely use such strategies, because they lack metacognitive knowledge and believe they are too effortful. To facilitate students' use of these so-called desirable difficulties during self-study, we developed the "Study Smart program", an intervention geared toward creating awareness of, reflection on, and practice with effective learning strategies. Based on a three-year design and implementation process, we share the problems we encountered and illustrate with student testimonials. Moreover, we reflect on future steps to be taken in research and practice. Among them is the need to debunk naïve theories about learning strategies in students and teachers and to support the behavior change needed to develop effective study habits by implementing effective learning strategies in teaching and providing follow-up reflection sessions.

Keywords: desirable difficulties, learning strategies, educational design research, implementation

INTRODUCTION

One of the biggest challenges that students face when entering higher education is to self-regulate their learning. In contrast to high school, university teachers offer limited guidance about how, when, and what to learn. Students often lack knowledge about the science of learning and trust intuitions and routines developed in high school. However, these intuitions about which learning strategies are effective are often misleading (Kirk-Johnson, Galla, & Fraundorf, 2019). For instance, students mistake feelings of fluency for effective learning when studying and therefore prefer strategies that feel easy, compared to those that take more effort (Finn & Tauber, 2015; Karpicke, Butler, & Roediger, 2009; Koriat & Bjork, 2006).

Some of these more effortful learning strategies create so-called *desirable difficulties*. That is, they initially complicate learning, but enhance retention and understanding in the long term (Bjork, 1994; Yan, Clark, & Bjork, 2017). Examples of learning strategies that can create such desirable difficulties are *retrieval practice, distributed practice,* and *interleaved practice*. The first, retrieval practice, refers to the act of actively retrieving information from memory by answering practice questions or by free recall (Adesope, Trevisan, & Sundararajan, 2017; Rowland, 2014). Second, distributed practice denotes the spacing out of study sessions over time leading to repeated study of the same learning materials. Due to longer lags between study sessions compared to massed practice, retrieval difficulty is increased and long-term retention is enhanced (Benjamin & Tullis, 2010). Finally, interleaved practice refers to the mixing of different topics during one study session. This contrasts to blocked practice, in which students study one topic until finished before switching to the next topic (Roediger & Pyc, 2012).

Although evidence from research on effective, evidence-based learning strategies is clear and known to cognitive psychologists (Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013), it has barely found its way to academic support centers (McCabe, 2018), teachers (Glogger-Frey, Ampatziadis, Ohst, & Renkl, 2018; Morehead, Rhodes, & DeLozier, 2016; Pomerance, Greenberg, & Walsh, 2016; Surma, Vanhoyweghen, Camp, & Kirschner, 2018) and, no less important, students (Weinstein, Madan, & Sumeracki, 2018). Students in higher education still hardly receive instruction on how to study effectively, because specific interventions focusing on the importance of creating desirable difficulties during learning are scant (McCabe, 2011; McCabe, 2018; Morehead et al., 2016).

To support students' use of effective and desirably difficult learning strategies, we developed a learning strategy intervention coined the "Study Smart program". Based on theoretical principles from cognitive psychological research (Dunlosky et al., 2013), the program spans three two-hour sessions focusing on awareness, reflection, and practice. Sessions are spread out over several weeks and take place in groups of about 12 students with one teacher. Session 1 aims to raise awareness about effective learning strategies and desirable difficulties by inviting students to discuss the strategies they use and how effective they believe the strategies are and by presenting the empirical evidence backing particular strategies. Session 2 encourages reflection on study motivation and learning strategy use by having students complete a questionnaire about their academic goal orientation and set goals for strategy practice. Session 3 fosters the practice of effective learning strategies by asking students to practice different effective learning strategies with their own learning materials. This includes, for example, making flashcards or planning their study schedule of the week in an interleaved manner. A detailed description of the initial version of the program can be found in a report by Biwer, oude Egbrink, Aalten, and de Bruin (2020).

After a first experimental study (Biwer et al., 2020), the Study Smart program was adapted and improved in an educational design cycle consisting of a design, evaluation, and redesign phase over three years (2018-2020). It was implemented in five different faculties at a Dutch university, with approximately 1,500 students and 50 teachers participating. The degree of implementation varied per faculty, depending on available resources. More specifically, some faculties offered the program to all first-year students as an integral part of their mentoring program, while other faculties had student counselors offer the program to individual students on a voluntary basis. All faculties offered the awareness session. The reflection and practice sessions were sometimes combined, depending on the capacities of each faculty. We collected data from evaluation questionnaires, focus group discussions with students and teachers, and observations of training sessions, as well as other measures during the train-the-trainer program, which we offered to all teachers. See the appendix for an overview about the implementation in each faculty and the type of data collected.

Based on a synthesis of our experiences as program designers, program facilitators, and observers, as well as the collected data, we formulated challenges and future steps to be taken in an iterative process. First, each author individually formulated challenges to be addressed based on experiences and insights. The first, second, and third author subsequently discussed and refined this first draft. We then performed a thematic template analysis (King, 2004) of the qualitative data from the observations, open questions in evaluation questionnaires, and focus-group discussions with students and mentors, using the initially formulated challenges as a template. In an iterative process, we tested whether the initially formulated challenges were represented in the data, and refined the challenges where needed. Finally, we shared this list of challenges and problems with teachers of the Study smart program (not part of the research team) in one additional focus group discussion. Based on this longitudinal educational design cycle, we share the challenges we encountered throughout the redesign phases of the Study Smart program (see Table 4.1 for an overview) and, more importantly, we reflect on necessary future steps in research and practice to support students in applying effective learning strategies.

Table 4.1. Challenges and Necessary Future Steps in Research on and Teaching of Desirable Difficulties

Challenge	Future steps: Research questions
One-size-fits-all approach	Should every student receive learning strategy instruction?
It’s about time	When is the right moment to address the importance of desirable difficulties in learning?
There will be resistance	How to debunk naïve theories about learning strategies?
Change does not happen overnight	How to support the use of effective learning strategies during self-study by students?
Practice what you preach	How to implement principles of effective learning in teaching and instruction?

4

One-size-fits-all approach: Should every student receive learning strategy instruction?

Through the Study Smart program we learned that educators often assume that their students know how to prepare for tutorials or exams and how to study effectively. Research has shown, however, that students rarely receive formal instruction on how to learn and study (Hartwig & Dunlosky, 2012; Morehead et al., 2016). Students repeatedly engage in rereading their notes, but self-testing or distributed practice are rarely used in practice (Blasiman, Dunlosky, & Rawson, 2017; Karpicke, Butler, & Roediger, 2009). Indeed, the students in our program reported they had never learned how to study effectively before entering university, although they considered such knowledge as an important requirement for success. Many students expressed a need for more information and knowledge about learning strategies and had expected to be taught how to study more effectively when entering university, as the following quote from a student enrolled in the program clearly illustrates:

> *When I came to university, I really expected there to be a course about self-studying or at least more than just the hints how to use the library .... So I tried to do something by myself, I tried to borrow books in the library about how you should study but ... I didn't feel that the books were really reflective of my situation, the student situation, and then I heard about the training and I thought it would be a perfect opportunity to learn more.*

The foregoing raises the question if and to what extent educational institutes should offer a learning strategy program to all their first-year students. Learning strategies are a consistent, but modifiable predictor of dropout in higher education (Delnoij, Dirkx, Janssen, & Martens, 2020). Moreover, as many students fail to seek help (Karabenick & Dembo, 2011), we suggest that education institutes should offer a learning strategy program to all their first-year students in order to ensure adequate knowledge of and practice with effective learning strategies. Of course, some students might already be wielding the desired learning strategies and hence do not necessarily need the program. Nevertheless, they may grow in confidence, gain more practice, and help other learners improve.

A further challenge then is whether a learning strategy program can really be a one-size-fits-all approach. On the one hand, it can be, because evidence-based learning strategies have been shown to strengthen long-term learning for people in general, regardless of prior knowledge and in various settings. The mechanisms that explain the effects of these learning strategies are based on memory principles that apply to all humans (Dunlosky et al., 2013). On the other hand, it is necessary that students first appreciate the need to change their learning strategies. Students' willingness to act on the information received depends on multiple factors, such as their satisfaction and perceived success with the learning strategies hitherto applied, as well as their knowledge and academic achievement orientation (Dembo & Seli, 2004; Geller et al., 2018). An imperative next step in research is to address individual differences and difficulties in implementing effective learning strategies during self-study (Bjork & Bjork, 2019). How do individual differences in motivation or personal learning goals influence students' reactions and adaptations of strategies based on desirable difficulties.

It's about time: When is the right moment to address the importance of desirable difficulties in learning?

Transitioning from high school to university presents a great challenge to most students (van Rooij, Jansen, & van de Grift, 2018). The question arises whether this demanding transition period is the right moment to address the importance of desirable difficulties in learning. We encountered this issue many times; in the first round of our intervention, we provided the program at the end of the first year. At that time, some students would have preferred the training earlier:

> *The time factor was a thing for me because I really wanted to try to learn in a new way but I was also scared to do so late in the course. So I tried the practice testing, but I felt I didn't have enough time to cover everything.*

In the following year, we offered the program in one of the first weeks of the new academic year. Here we encountered resistance, especially by students with strong habits of summarizing, highlighting, and re-reading. Their commonly used strategies were experienced as effective during high-school, and students were hesitant to try different and more effortful strategies without having had a first exam experience at university, as one student explained:

> *I feel like I know how I should study, and that my way is the highway. Not because I don't believe in what's being supplied by the university, but I've always been [...] left alone in my study process. And that's what has gotten me this far and for me costs quite little energy.*

To determine the optimal timing of such interventions, future research should compare the effect of different timings on students' willingness to change and actual strategy use. Based on our experiences from the Study Smart program, we recommend that students receive instruction on effective learning strategies as early as possible. First, because it is easier to create new learning practices than to change existing, habitual ones. Context cues automatically activate specific habitual responses, which are difficult to change in the same context (Carden & Wood, 2018). Given the change in context for students when going from high-school to university, this transition time seems a favorable moment to introduce desirable difficulties to students (Walker, Thomas, & Verplanken, 2014). Second, early instruction can give students ample time to try to implement new strategies such as distributed practice or practice testing, especially when it is offered *before* their first exams. This timing may help them to develop good learning habits from the beginning of higher education. In order for students to learn the most from their experiences, a follow-up reflection session *after* the first exams can address the hurdles they might have encountered. The follow-up session may prevent students from reverting to their former learning habits, which often happened. As one mentor of Psychology and Neuroscience students reported during a focus group, "Students are afraid of using new study strategies; they want to pass their exams and they easily fall back into their old habits."

There will be resistance: How to debunk naive theories about learning strategies?

Many students have strong beliefs, albeit often incorrect, about how to study most effectively. Such beliefs make it difficult to convince them of the need to apply more effective strategies, especially because they take more effort and feel more difficult. One example is the omnipresent myth about learning styles that so-called "visual learners" learn more easily from visual materials and that "aural learners" learn more easily from auditory learning materials (Kirschner, 2017; Kirschner & van Merriënboer, 2013). Another example is the belief that strategies that feel easy, such as highlighting, rereading, and summarizing, are more effective for long-term learning than strategies that feel more difficult, such as practice testing. We recommend that teachers debunk these myths as soon as possible.

Such conceptual change, however, will not be achieved simply by offering students evidence of effective strategies. To refute misinformation effectively, apprehension of misbeliefs and the correct information must be co-activated to concurrently fill the mental gap created by the correction (Paynter et al., 2019; de Bruin, 2020). It is furthermore important not only to explain that information is false but also why it is false. This can be achieved by providing detailed evidence and refuting misinformation through visualizations (MacFarlane, Hurlstone, & Ecker, 2020). In the Study Smart program for example, we tackled this by first inviting students to brainstorm about the learning strategies they were using or other commonly used strategies. Subsequently, we asked them to sort these strategies into highly, moderately, and hardly effective ones. The teacher then presented the empirical evidence of all strategies, providing detailed explanations as to why desirably difficult strategies were more beneficial to long-term learning and how to wield them during self-study. After this presentation, teachers and students discussed how to make the strategies that students were already using more effective. When presented with the evidence about learning strategies that promote long-term learning and those that do not, students verbalized this as experiencing a "shock" or "wake-up call". Any discrepancies between the strategies hitherto applied and those underpinned by empirical evidence might increase students' willingness to change, as depicted in the following quote from a teacher:

> *They recognized that retrieval is much more difficult, while rereading feels good. You saw that this feeling hit them: "oh yes, maybe it is not good what I am doing." Students realized they don't learn in a good way though they thought they did. So that was very important in making them want to change behavior.*

It is important to carefully consider how to effectively debunk naïve beliefs and idiosyncratic ideas held by students to make them aware of such beliefs while minimizing resistance (e.g., "but my strategies work for me"). Dealing with students' resistance to change is a big challenge in desirable difficulties instruction. Starting with students' own strategies and taking small steps to make these strategies more effective seemed important in making them willing to change, as one teacher of the program described:

> *At the beginning of the session, I did an inventory round about what you are doing now, and there were also many other techniques that came up, so in that sense you can also activate your students a bit more: what are you already doing? Not "we want you to do this," because that doesn't work. Because then you get that shock, and also "yes, but I don't have time for that."*

Simply creating an open atmosphere may dampen reluctance to change idiosyncratic ideas but cannot prevent resistance entirely. Finding a balance between constructive versus destructive confrontation is a challenge worth addressing more specifically in future research.

Related to this issue is the challenge of how to translate scientific evidence to students' practice. One potential route to explore is to not only use scientific evidence, but also relate to concrete student examples. More specifically, scientific evidence will ensure the credibility of the learning strategy program. Such evidence might include graphs and data from cognitive psychological research about the testing effect as well as proof that students' perceptions of learning differ from actual learning outcomes (e.g., Nunez et al., 2011; Roediger & Karpicke, 2006). Despite ample research showing that desirably difficult learning strategies, such as retrieval practice, are effective in classroom settings (Moreira, Pinto, Starling, &

Jaeger, 2019), students find it hard to translate such evidence to their own situation (e.g., Wissman, Rawson, & Pyc, 2012). The evidence still seems abstract, making students prone to think that it does not apply to them personally (Hofer, 2004). Examining how to include relatable student examples in the program to prepare students for change is a necessary future step in research. These examples could take the form of authentic written or videotaped narratives—stories by students who have changed the way they studied and describe their struggles, efforts, and setbacks in this process. Although said narratives have a potential to improve behavior (Hinyard & Kreuter, 2007), students' use of new strategies remains dependent on their individual struggles, such as uncertainty about time, effort, and consequences concerning exam results (Biwer et al., 2020).

Change does not happen overnight: How to support the use of effective learning strategies during self-study by students?

To effect sustainable change in students' learning behavior, the desired learning strategies must first and foremost fit in the learning context (Nilson, 2018). Students are often hesitant to transition to effective learning strategies, because they harbor many uncertainties. For instance, they worry about how to apply them to their own learning materials, how much energy and time it will take them, or how a strategy change will influence their exam grades, as clearly is depicted in the following remark from a student:

> *You have to apply new study strategies that are also more time consuming, so for me it was really stressful at one point. [...] I think it is really difficult to know how you get into that routine and I think that is something I miss in the training as well.*

This uncertainty in using new learning strategies is an issue that links closely to matters of behavior change (Sheeran, 2002). How to deal with the uncertainties of implementing new study behavior and how to cope with the difficulty of sustaining these over time is in many ways similar to, for example, improving eating behavior or exercise routines. We see a great need for research inspired by the behavior change literature on habit formation. As Fiorella (2020) pointed out, habit formation contributes to effective self-regulation and educational research can therefore learn from the literature on behavior change interventions. We see a parallel between changing poor learning habits and changing other kinds of habits, such as unhealthy eating. Changing your eating behavior requires accurate knowledge of healthy eating, being motivated to change, and possessing adequate strategies to change eating behavior. For example, a US national campaign on eating more fruits and vegetables that presented information about the advantages of eating healthy, increased people's knowledge and motivation to change, but had only limited effect on actual eating habits (Casagrande, Wang, Anderson, & Gary, 2007). Similarly, in the first version of the Study Smart program, including adequate information but only limited practice sessions, participants' knowledge about effective learning strategies and the intention to change increased, but more specific practice was needed to lead to a sustained use of these strategies (Biwer et al., 2020).

An interesting avenue for future research from the field of behavior change is the use of *implementation intentions*. Implementation intentions are if-then plans that specify the when and where (if), and specific action (then) of a planned behavior and were shown to facilitate initiating and pursuing goals (Gollwitzer & Sheeran, 2006). Potentially, implementation intentions could support the use of more desirably difficult learning strategies. Furthermore, habit-based interventions focusing on identifying cues that may trigger the use of beneficial learning strategies may foster the development of effective habits in students (Wood & Neal, 2016). We see a potential merit in applying insights from behavior change research in the health domain to learning-strategy research, for example, from research on implementation intentions (Gollwitzer & Sheeran, 2006), nudging (Hansen, Skov, & Skov, 2016), or narratives (Hinyard & Kreuter, 2007). Although metacognitive training can be a starting point for learning strategy change, students need continuous support in the form of guided practice and follow-up meetings to reflect on experiences. Consequently, relevant future research should determine which types of support and cues will help students to acquire beneficial learning-strategy habits. For example, teachers could organize regular in-class quizzes or provide practice questions to their students to facilitate retrieval practice. Another question for future research concerns how long this support should be provided to evoke sustainable learning-strategy changes.

Practice what you preach: How to implement principles of effective learning in teaching and instruction?

Not only students, but teachers, too, can have strong, idiosyncratic ideas about different learning strategies (Morehead et al., 2016), especially if they have no background in educational sciences or cognitive psychology and are therefore unfamiliar with the scientific evidence. During the train-the-trainer sessions, we observed that many teachers ran into the same conceptual issues as students. However, only when teachers learn about this evidence themselves will they be able to teach their students how to study more effectively. Likewise, only if they are aware of the benefits of desirably difficult learning strategies, can teachers support students' sustained use of effective strategies. Teachers need to learn how to implement principles of effective learning in their teaching and instruction. Practically, this could take the form of short quizzes during lectures to reduce mind wandering and improve retention (e.g., Szpunar, Khan, & Schacter, 2013) or letting students generate, share and answer peer-generated questions to enhance retrieval practice in the classroom (Kelley, Chapman-Orr, Calkins, & Lemke, 2019). Additionally, teachers can connect good self-regulators with weaker students, for whom they can serve as role models (Rovers, Stalmeijer, van Merriënboer, Savelberg, & de Bruin, 2018). Future research is needed to further investigate such effective classroom interventions and how to support teachers in implementing these.

In conclusion, supporting students to learn more effectively requires a shift in teaching approach, from knowledge transmission towards learning strategy support. While to teachers this shift may appear to diminish content knowledge and result in uncertainty about students' knowledge level, it will likely make their teaching more effective (Loyens, Magda, & Rikers, 2008). Moreover, if we want to prepare our students for lifelong learning, higher education institutions should focus not only on teaching knowledge and skills, but also on teaching how to gain and retain that knowledge and skills.

CONCLUSION

Despite the growing body of research into desirably difficult learning strategies, implementing an intervention that fosters students' knowledge and use of these strategies is no easy feat. Such interventions require deliberate design, implementation, and guidance in order to guarantee students a high-quality learning experience and qualified support. Based on our experiences in designing and implementing such an intervention, we presented challenges that others may run into as well and how our efforts generated questions for future research that should be addressed. As diverse as the student population might be, the struggle to put desirable difficulties into practice is common and unifying.

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Appendix

Implementation of Study Smart in each faculty

Faculty	Year	Implementation	Sessions	Students	Teachers	Data collected
Faculty of Health Medicine and Life Sciences (FHML)	2018	Pilot study*	A, R, P	N = 47	2 researchers	- Evaluation questionnaires - 2 FG with students** - Observations
Faculty of Psychology and Neurosciences (FPN)	2018/2019	In mentor groups; all first-year students	A, R	N = 403	27 mentors	- Evaluation questionnaires - 2 FG with students - 1 FG with mentors - Train-the-trainer program
	2019/2020	In mentor groups; all first-year students	A, R, P	N = 400	27 mentors	- Evaluation questionnaires - 1 FG with mentors - 14 observations - Train-the-trainer program
School for Business and Economics (SBE)	2018/2019	Available for all first-year students; twice a year	A, R	N = 30	3 dedicated teachers; student counselors	- Evaluation questionnaires - Train-the-trainer program
	2019/2020	Available for all first-year students; twice a year	A, R, P	N = 30	3 dedicated teachers	- Evaluation questionnaires - Train-the-trainer program
Faculty of Law (LAW)	2018/2019	Integrated in Dutch Law course; targeted at all undergraduate students	A, R	N = 250	7 tutors	- Train-the-trainer program
	2019/2020	Integrated in Dutch Law course; targeted at all undergraduate students	A, R, P	N = 250	7 tutors	- Train-the-trainer program
University College Maastricht (UCM)	2018/2019	Part of faculty introduction and skills course	A, R	N = 215	10 tutors	- Evaluation questionnaires - Train-the-trainer program
	2019/2020	"Introduction to academic skills"	A, R	N = 268	10 tutors	

Note. A = Awareness session, R = Reflection session, P = Practice session, FG = Focus group discussion
*The experiment data of this pilot study (not used in the current analyses) were published in Biwer et al. (2020)
**Data of these focus groups was also used in Biwer et al., (2020) to develop a model of barriers and facilitators in using effective learning strategies.

Chapter 5

To ask or to answer? The effect of generating and answering self-generated versus provided questions on expository text learning

This chapter has been submitted as:

Biwer, F., Wiradhany, W., oude Egbrink, M.G.A., de Bruin, A.B.H. (submitted). To ask or to answer? The effects of generating and answering self-generated versus provided questions on expository text learning.

Chapter 6

Changes and Adaptations: How University Students Self-Regulate Their Online Learning during the COVID-19 Pandemic

This chapter has been published as:

Biwer, F., Wiradhany, W., oude Egbrink, M., Hospers, H., Wasenitz, S., Jansen, W., & de Bruin, A. (2021). Changes and adaptations: How university students self-regulate their online learning during the COVID-19 pandemic. *Frontiers in Psychology*, 12(1206). doi:10.3389/fpsyg.2021.642593

ABSTRACT

During the COVID-19 pandemic, universities had to shift from face-to-face to emergency remote education. Students were forced to study online, with limited access to facilities and less contact with peers and teachers, while at the same time being exposed to more autonomy. This study examined how students adapted to emergency remote learning, specifically focusing on students' resource management strategies using an individual differences approach. One thousand and eight hundred university students completed a questionnaire on their resource management strategies and indicators of (un)successful adaptation to emergency remote learning. On average, students reported being less able to regulate their attention, effort, and time, and less motivated compared to the situation before the crisis started; they also reported investing more time and effort in their self-study. Using a *k*-means cluster analysis, we identified four adaptation profiles and labeled them according to the reported changes in their resource management strategies: the overwhelmed, the surrenderers, the maintainers, and the adapters. Both the overwhelmed and surrenderers appeared to be less able to regulate their effort, attention and time, and reported to be less motivated to study than before the crisis. In contrast, the adapters appreciated the increased level of autonomy and were better able to self-regulate their learning. The resource management strategies of the maintainers remained relatively stable. Students' responses to open-answer questions on their educational experience, coded using a thematic analysis, were consistent with the quantitative profiles. Implications about how to support students in adapting to online learning are discussed.

Keywords: COVID-19, self-regulated learning, resource management strategies, emergency remote learning, cluster analysis, higher education

INTRODUCTION

In Spring 2020, universities across the globe had to shift their face-to-face education to online due to the COVID-19 outbreak. From one day to the next, university students were forced to study online, either in isolation, in student housing, or in family settings – exposing them to many distractions. Furthermore, anxiety and uncertainty about the unprecedented situation may have caused additional stress (Son, Hedge, Smith, Wang, & Sasangohar, 2020). Altogether, this sudden change to online education, termed *emergency remote education*, and subsequently *emergency remote learning* (Hodges, Moore, Lockee, Trust, & Bond, 2020), posed many challenges to students. At the same time, the shift to emergency remote education gave students more autonomy and it increased the need for taking control of their own learning process (Dillon & Greene, 2003; Garrison, 2003). As emergency remote education is different from regular online education, it is important to understand whether and how students adapted to emergency remote learning. The aim of the present study was to gain insight into university students' adaptation to emergency remote learning, specifically focusing on aspects of their self-regulated learning. Moreover, we wanted to know if students differed in their adaptation approach in order to gain insights in how to provide individual support.

Self-Regulated Learning during Emergency Remote Learning

In both on-site and online higher education environments, university students already have a considerable amount of autonomy. They need to plan, monitor, and control their own learning process during self-study and thus engage in self-regulated learning (Nelson & Narrens, 1990; Zimmerman, 2002). Three main categories of learning strategies can be differentiated in self-regulated learning: cognitive, metacognitive, and resource management strategies (Duncan & McKeachie, 2005; Panadero, 2017). Cognitive and metacognitive strategies are used to process information, and monitor and control one's understanding, while resource management strategies are used to create optimal learning conditions. Resource management strategies refer to managing external resources, as in seeking for help or organizing one's workplace, as well as to managing and regulating internal resources, such as effort regulation, time management, attentional regulation and motivation (Dresel et al., 2015).

Given the sudden shift to emergency remote education at the start of the COVID-19 pandemic, combined with external stress factors, such as uncertainty about the situation, distraction at home and reduced social interaction (Son et al., 2020), as well as higher levels of autonomy, resource management strategies may have played an important role in adapting successfully to emergency remote education. Students probably already adopted effective cognitive and metacognitive strategies due to their experience of independence during higher education, but they had to quickly adapt these strategies to apply them in the new situation (Wood, Tam, & Witt, 2005). Effective resource management strategies have been shown to have a positive link to cognitive, emotional, and motivational aspects of learning. In relation to cognitive factors, resource management strategies, specifically effort regulation, time management and attentional regulation (concentration and dealing with distraction), were positively associated with academic performance in both face-to-face (Richardson, Abraham, & Bond, 2012) and online learning environments (Broadbent & Poon, 2015; Broadbent, 2017). With regard to emotional factors, facets of resource management strategies, such as the organization of academic study time and motivation to invest effort in studying, are negatively affected by negative emotions (Mega, Ronconi, & De Beni, 2014). Furthermore, resource management strategies like effort regulation and time management as well as intrinsic motivation have been found to be positively associated with academic adjustment (van Rooij, Jansen, & van de Grift, 2018), which might be an indicator of their importance in adapting to emergency remote learning.

Adapting to higher levels of autonomy and successfully applying these resource management strategies is, however, no easy feat for many students. A recent systematic review showed that students who choose to participate in online (blended) education struggle to use these strategies adequately; they experience self-regulation, motivational control, help-seeking, and their technological competencies as main challenges (Rasheed, Kamsin, & Abdullah, 2020). During the COVID-19 pandemic, students might experience similar but also additional challenges. Other than regular online education, emergency remote learning during COVID-19 involves learning in suboptimal spaces and isolation, putting a higher load on learners' resource management. Due to not having access to their regular study environment such as the library or other university buildings, students might have trouble to find a quiet study space, which potentially influences their attentional regulation (Dabbish, Mark, & González, 2011). In addition, compared to regular online education, the change to emergency remote learning during COVID-19 was not voluntary, which may have had a negative influence on students' study motivation (Hsu, Wang, & Levesque-Bristol, 2019). Furthermore, given the sudden shift to online education, students may not have had access to all technical resources (e.g. stable internet connection) or support from teaching staff and peers. Given the uniqueness of the situation, it is important to build an understanding on whether and how students were able to adapt their resource management strategies when confronted with emergency remote learning.

Unraveling Individual Differences in Adaptation to Emergency Remote Education

There is increasing evidence that self-regulatory processes, including resource management strategies, vary across individuals (Barnard-Brak, Lan, & Paton, 2010; Dörrenbächer & Perels, 2016). Additionally, students with better self-regulated learning skills have been shown to have higher academic performance (Barnard-Brak et al., 2010; Broadbent & Fuller-Tyszkiewicz, 2018; Kitsantas, Winsler, & Huie, 2008) and better self-regulated learning intervention outcomes (Dörrenbächer & Perels, 2016). Given the individual differences in self-regulated learning, students might respond differently in the situation of emergency remote learning: some students might find it difficult to concentrate, while others might double their efforts to cope with the new environment (Usher & Schunk, 2018). This is in line with the social cognitive framework on self-regulation, which suggests self-regulated learning as an interaction between personal, behavioral, and environmental factors (Usher & Schunk, 2018). Learning is situated in specific contexts and self-regulatory processes may differ depending on the context (Boekaerts & Niemivirta, 2000; Efklides, 2011; Pintrich, 2000). For example, Broadbent & Fuller-Tyszkiewicz (2018) examined profiles in self-regulated learning for online and blended learning students. The authors uncovered five profiles of self-regulation, with online learners being more likely to belong to more adaptive profiles. Students with the highest grades had also the highest levels of time management, effort regulation, and motivation, indicating that individual approaches to learning impact performance. Uncovering subgroups of students, e.g. those who struggle significantly and those who are able to adapt more easily, and understanding different profiles of adaptation during emergency remote learning could yield important insights in how to provide tailored support to students (Barnard-Brak et al., 2010; Broadbent & Fuller-Tyszkiewicz, 2018).

In the current study, we examined how and to what extent university students adapted their resource management strategies during emergency remote learning due to the COVID-19 pandemic. Using a mixed-method approach, we first investigated to what extent the sudden shift from face-to-face to emergency remote education influenced students' self-regulated learning, with a specific focus on their resource management strategies: their effort and attentional regulation, motivation, time management and time- and effort investment. Specific questionnaires are available to assess students' online self-regulated learning in the contexts of MOOCs or blended learning environments. These questionnaires are adaptations of classical self-regulated learning questionnaires for on-site education to online education (Barnard, Lan, To, Paton, & Lai, 2009; Jansen, van Leeuwen, Janssen, Kester, & Kalz, 2017). Due to the context-specificity of self-regulated learning and unique characteristics of emergency remote learning, we decided to take changes in context into account when measuring how students adapted to emergency remote learning. We therefore modified existing online self-regulated learning questionnaires (Barnard et al., 2009; Jansen et al., 2017) in order to measure changes in students' time management, effort regulation, attentional regulation, motivation, and effort- and time investment. We expected these dimensions to be most influenced by emergency remote education.

Our second goal was to examine whether students adapted differently to emergency remote learning using a person-centered approach. In contrast to variable-centered approaches that assume that relationships between self-regulatory processes observed at group level are representative for the whole sample, person-centered approaches assume potential differences between subgroups of students (Laursen & Hoff, 2006). Here, we explored whether potential differences between subgroups of students were related to their general experience with education before and after the shift to online learning, engagement, and well-being as indicators of (un)successful adaptation to the situation. Third, we investigated students experienced as difficulties and benefits of emergency remote learning, by examining their reactions to open-answer questions on this topic. By gaining insight into the different difficulties, but also potential benefits that students experienced, we aim to further inform and generate ideas about how to support students. In summary, we address the following research questions:

1. How did the sudden shift from face-to-face to emergency remote education influence university students' self-regulated learning, focusing on their resource management strategies?
2. Did students adapt differently to emergency remote learning?
3. What are the main difficulties and benefits of emergency remote learning for students?

METHODS

Setting and Participants

In March 2020, the Dutch government announced measures to stop the spread of COVID-19, among others by forcing all universities to shift all their education from face-to-face to online. At Maastricht University, education is based on Problem-Based Learning (PBL), applying four core learning principles: constructive, collaborative, contextual and self-directed learning (Dolmans, De Grave, Wolfhagen, & van der Vleuten, 2005). Students work on authentic, real-world cases in small tutorial groups consisting of 10-15 students. A tutor moderates the tutorial sessions as facilitator. The academic year is usually divided into six course periods of eight or four weeks, each period focusing on a specific theme. The shift to online education occurred at the end of course period four.

In May 2020, all bachelor and master students at Maastricht University (N = 17182) were invited to complete an online questionnaire about their experiences during emergency remote learning. In total, 1817 students (M_{age} = 21.3 yr., 68% females) participated, which corresponds to a response rate of 10.5%. The sample included 1543 bachelor students and 274 master students from all six faculties: Faculty of Science and Engineering (25%), School of Business and Economics (23%), Faculty of Health, Medicine, and Life Sciences (20%), Faculty of Law (14%), Faculty of Arts and Social Sciences (9%), and Faculty of Psychology and Neurosciences (9%).

Measures

Demographic Survey

Respondents were asked to report their age, gender, program level (bachelor or master), faculty of study, study program, and whether they were a regular Maastricht University student or an exchange student from another university.

Resource Management Strategies

We composed a questionnaire (17 items) that assesses how the new situation influenced students' use of resource management strategies, based on existing questionnaires on online self-regulated learning (Barnard et al., 2009; Jansen et al., 2017). The adapted theoretical scales included attentional regulation (four items), effort regulation (five items), motivation (three items), time-management (five items), and effort- and time-investment (two items). We were specifically interested to what extent students were able to manage their resources and adapt to emergency remote learning. Therefore, all items prompted students to think about the current situation and to retrospectively compare it to the situation before the change on a 5-point Likert scale from -2 (much less) to +2 (much more); i.e., the value of zero means no change. An example item is "In the current situation I get *much less/less/to the same extent/more/much more* distracted during self-study than before the crisis" (attentional regulation, reversed). See Appendix A for all items.

Measures of Students' Adaptation to Emergency Remote Education

To assess the extent to which the educational experience changed due to the shift to emergency remote education, we asked students to rate their overall experience with education before and during the pandemic on a scale from one to ten. Furthermore, we assessed how students' engagement changed, as measured with four items on connectedness with peers, teaching staff, personal interest and understanding on a 5-point Likert scale from -2 (decreased a lot) to +2 (grown a lot). An example item is "Since the beginning of the global health crisis, my sense of being connected with my fellow students has *decreased a lot/decreased/remained the same/grown/grown a lot*". As indicator for the extent of adaptation to the situation, we further asked students to rate their mental well-being ("Compared to before the beginning of the global health crisis, how do you rate your mental well-being?") on a scale from -2 (much worse) to 2 (much better).

Benefits and Difficulties

To assess potential benefits and difficulties of emergency remote learning, we asked two open-answer questions: "What did you like most during your online learning experience?" and "What did you dislike most during your online learning experience?".

Procedure

Data collection took place in May 2020. The invitation to fill out the online questionnaire about their experiences after the shift to emergency remote education was sent in week six of the fifth course period to ensure that students had experienced the effects of the shift from face-to-face to emergency remote education for several weeks. At the start of the questionnaire, students provided their informed consent. Besides measures on students' resource management strategies, demographical variables, and indicators of adaptation, the questionnaire also asked more specifically about students' experiences in tutorials, lectures, and online tool use. These data were only of interest for an internal report and not analyzed in this study. Students completed the questionnaire at home using their own digital devices. Completion of the questionnaire took approximately 15-20 minutes. This study was approved by the Ethical Review Board of the Faculty of Health, Medicine, and Life Science (approval number: FHML-REC/2020/065).

Data Analysis

The quantitative data were analyzed using SPSS version 24 and SPSS AMOS. We examined the validity and reliability of the resource management strategies questionnaire through confirmatory factor analysis using maximum likelihood estimation and calculation of Cronbach's alpha value for each subscale used. We tested a five-factor correlated model. Due to the sensitivity of the chi-square statistic to sample size (Marsh, Balla, & McDonald, 1988), we used RMSEA (root mean square error of approximation) and SRMR (standardized root mean square residual) as overall model fit indicator, and the TLI (Tucker-Lewis Index) and CFI (comparative fit index) as comparative fit indices (Schermelleh-Engel, Moosbrugger, & Müller, 2003). RMSEA analyses the difference between the theoretical model and the population covariance matrix, with values between .05 and .08 indicating acceptable fit. The SRMR should be less than .05 to indicate good fit. The CFI compares the fit of the theoretical model to the fit of the independence model with all latent variables uncorrelated; values of > .95 indicate acceptable fit. The TLI measures relative fit of the theoretical model compared to the independence model, with values between .95 and .97 indicating acceptable fit (Schermelleh-Engel et al., 2003).

To determine differences between students, we used an iterative partitioning method, the *k*-means cluster analysis, to classify students into groups based on their scores on attentional regulation, effort regulation, time management, motivation, and effort- and time-investment. Neither the group membership of the students nor the number of groups was defined beforehand. The aim of the *k*-means cluster analysis is to form homogeneous clusters by partitioning data in such a way that within-cluster variance is minimized and between-group variance is maximized. We followed the procedure outlined in Kusurkar et al. (2020). First, all clustering variables were standardized using *z*-scores. In the scale on attentional regulation, seventeen cases were identified as outliers (*SD* > 3) and excluded before further analyses as cluster analyses are highly sensitive to outliers. For the 1800 participants included in the analyses, we tested 2-cluster, 3-cluster, 4-cluster, 5-cluster, and 6-cluster solutions. As an indication for model fit, we calculated the ratio between the between-clusters variance and the within-clusters variance for each solution using an ANOVA F-test. An acceptable cluster solution needed to explain at least 50% variance in the clustering variables scores. The optimal number of clusters was selected based on the explained variance, parsimony and interpretability of the solution (Kusurkar et al., 2020; Vansteenkiste, Sierens, Soenens, Luyckx, & Lens, 2009). As a validation procedure, we conducted a double-split cross-validation procedure to examine the stability of the chosen cluster solution (Vansteenkiste et al., 2009). We split the sample into two random subsamples, and conducted the *k*-means cluster analysis again in these two subsamples. We computed Cohen's kappa with cluster membership of each subsample and the complete sample for checking the stability of the cluster solution. Subsequently, to explore the external validity of the cluster solution, we examined whether cluster profiles differed regarding their educational experience, engagement, and well-being using multivariate analysis of variance (MANOVA) and post hoc comparisons using Bonferroni adjustments.

The qualitative data, i.e., the answers to the open questions, were thematically coded following a template approach (King, 2004) using several iterations. First, HH, SW, and WJ thematically coded the written answers to both questions, each of them being randomly assigned to a certain proportion of the data. Beginning with an open coding scheme, they continuously discussed, modified and advanced the coding template until agreement was reached that the coding template covered all text sections. Second, we grouped the codes to the code groups of interest (i.e., the clustering variables and indicators of adaptation), see Appendix B. Third, after finalizing the cluster analysis, we split the complete qualitative data set into subsets representing the identified clusters. SW and FB coded two subsets each, using the final coding template, while being blinded for the identity of the clusters. After a first round of coding, they discussed the codes and acted as second coder for each other's subsets, respectively. See Appendix C for an example. The data obtained from the thematic coding per cluster were summarized and compared to the data from the quantitative questionnaire for the same cluster. The entire research team was involved in this stage of triangulation of the cluster groups with the qualitative data. Relations and meaning of the themes were discussed in the research team, taking the analysis from the categorical to a conceptual level. ATLAS.ti qualitative software, version 8 (Scientific Software Development GmbH, Berlin, Germany) was used to analyze and manage the qualitative data.

Reflexivity

The research team included an educational psychologist working as a Ph.D. candidate (FB); a cognitive psychologist working as professor in psychology (WW); an educational psychologist working as professor in education at FHML (AdB); and a physiologist and professor in education, working as scientific director of FHML Educational Institute at Maastricht University (MoE). HH, SW, and WJ have a background in social and educational sciences and were part of the project team for an internal report.

RESULTS

Students' Resource Management Strategies during Emergency Remote Learning

To test the theoretical factor structure of the questionnaire on resource management strategies, we conducted a confirmatory factor analysis using SPSS AMOS (see Table 6.1). Confirmatory factor analyses showed an acceptable fit to the model according to the indices RMSEA, SRMR, and CFI; the TLI is just outside the acceptable ranges. Chi square was significant, for model acceptance, it should be non-significant. However, Chi square is highly dependent on sample size (Kline, 2005). Therefore, we chose to focus on RMSEA and the abovementioned model fit indices. The reliability of the scales provides further information regarding the model fit. All scales show acceptable to high internal consistency indicated by Cronbach alpha values ranging from .75 to .89. See the Appendix for all items. Overall, these model fit indices indicate that the theoretical model of our adapted questionnaire has an acceptable fit. Internal consistency of the engagement scale was also acceptable with Cronbach's alpha of .73.

Table 6.1. Model Fit Statistics for Confirmatory Factor Analyses

Fit Indices	Theoretical model	Threshold for acceptable fit
X^2	806.21 (p = .000; df = 109)	
RMSEA (90% CI)	0.060 (0.056-0.064)	0.05 < RMSEA < 0.08
TLI	0.948	>0.95
CFI	0.958	>0.95
SRMR	0.045	<0.05

Descriptive statistics and correlations between all variables measured are presented in Table 6.2. Students' attentional regulation, referring to their ability to concentrate and deal with distractions, decreased the most in the current situation (M = -0.87, SD = 0.86). Furthermore, students' motivation (M = -0.70, SD = 0.89), ability to manage their time (M = -0.38, SD = 0.86), and ability to regulate their efforts (M = -0.40, SD = 0.49) were perceived to decreased as well. The only positive value was related to effort- and time-investment (M = 0.18, SD = 1.02), showing that students indicated that they put more time and effort in their self-study compared to the situation before the crisis.

6

Correlations between all subscales of resource management strategies were positive and statistically significant (p < .001), except for the correlation between effort regulation and effort- and time-investment (r = 0.039, p = .10). The highest correlations were found between attentional regulation and time management on the one hand, and motivation on the other. A second correlational analysis was conducted between all subscales of resource management strategies and the three indicators of adaptation: engagement, well-being and overall educational experience during the crisis. All correlations were positive and significant (p < .001). The highest correlations were found between engagement and motivation, well-being and effort regulation, and educational experience during the crisis and engagement.

Table 6.2. Means (and Standard Deviations) of and Correlations between Measured Variables

	M (SD)	1	2	3	4	5	6	7	8	9
1 Attentional Regulation	-0.87 (0.86)	-								
2 Effort Regulation	-0.40 (0.94)	0.567	-							
3 Time Management	-0.38 (0.86)	0.717	0.581	-						
4 Motivation	-0.70 (0.89)	0.645	0.518	0.662	-					
5 Effort-/Time-Investment	0.18 (1.02)	0.300	0.039^{ns}	0.361	0.397	-				
6 Well-being	-0.47 (0.93)	0.462	0.540	0.458	0.411	0.099	-			
7 Engagement	-0.75 (0.65)	0.467	0.478	0.517	0.602	0.211	0.434	-		
8 Educational experience before the crisis	8.02 (1.04)	-0.202	-0.134	-0.156	-0.160	-0.098	-0.117	-0.083	-	
9 Educational experience during the crisis	5.72 (1.93)	0.423	0.424	0.498	0.535	0.202	0.365	0.573	0.121	-

Note. Scales for variables 1-7 range from -2 to 2; scales for variables 8 and 9 range from 1 to 10. All correlations are significant with $p < .001$, except when indicated with ns = non-significant.

Differences between Students in Adapting to Emergency Remote Learning

In the cluster analysis, the four-cluster solution fitted the data best, based on the explained incremental variance, parsimony, and interpretability of the solution. The four-cluster solution explained 62.8% variance in the attentional regulation scores, 51.8% variance in the effort regulation scores, 65.7% in the time management scores, 56.4% in the motivation scores, and 60.1% in the effort- and time-investment scores. Figure 6.1 shows the four different groups identified based on the clustering variables, while Table 6.3 also presents their indicators of adaptation and demographic characteristics.

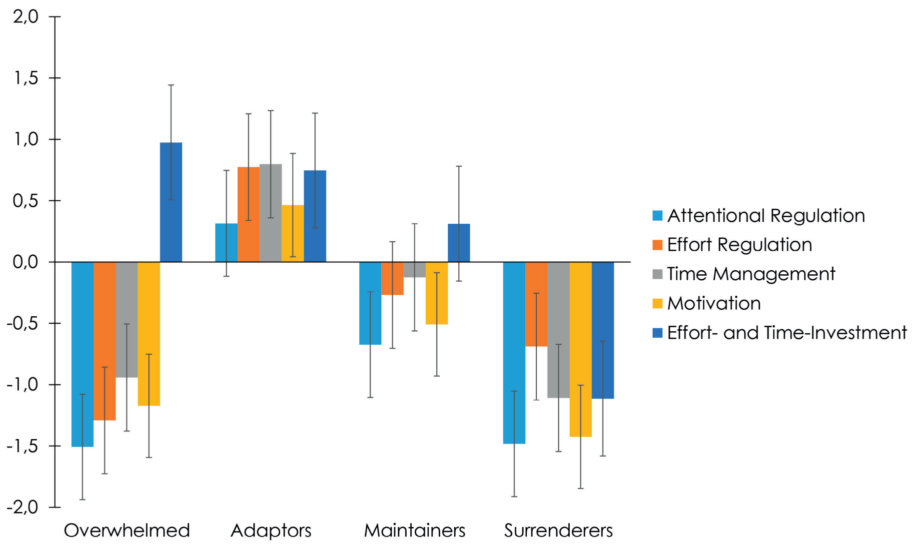

Figure 6.1. Four-Cluster Solution Showing the Adaptation in Resource Management Strategies per Cluster. Data are presented as means with standard error, values of zero indicating no change

Table 6.3. Resource Management Strategies, Indicators of Adaptation, and Characteristics for Each of the Four Identified Clusters

	Overwhelmed (n = 393)		Adapters (n = 340)		Maintainers (n = 610)		Surrenderers (n = 457)	
	M	*(SD)*	*M*	*(SD)*	*M*	*(SD)*	*M*	*(SD)*
Clustering variables								
1 Attentional Regulation	-1.51	(0.48)	0.31	(0.61)	-0.67	(0.53)	-1.48	(0.49)
2 Effort Regulation	-1.29	(0.56)	0.77	(0.68)	-0.27	(0.65)	-0.69	(0.72)
3 Time Management	-0.94	(0.50)	0.80	(0.48)	-0.12	(0.51)	-1.11	(0.52)
4 Motivation	-1.17	(0.65)	0.46	(0.65)	-0.51	(0.56)	-1.43	(0.53)
5 Effort-/Time-Investment	0.97	(0.65)	0.75	(0.66)	0.31	(0.71)	-1.11	(0.54)
Indicators of Adaptation								
6 Well-being	-1.01	(0.76)	0.37	(0.90)	-0.38	(0.77)	-0.77	(0.83)
7 Engagement	-1.06	(0.54)	-0.12	(0.59)	-0.67	(0.53)	-1.06	(0.54)
8 Educational experience score before the change	8.09	(0.92)	7.58	(1.28)	8.09	(0.97)	8.19	(0.92)
9 Educational experience score after the change	4.82	(1.84)	7.36	(1.45)	6.07	(1.60)	4.79	(1.73)
Characteristics								
Females (%)	275	(70.0%)	230	(67.6%)	437	(71.6%)	288	(63.0%)
Males (%)	117	(29.8%)	108	(31.8%)	169	(27.7%)	167	(36.5%
Bachelor (%)	336	(85.5%)	287	(84.4%)	501	(82.1%)	408	(89.3%)
Master (%)	57	(14.5%)	53	(15.6%)	109	(17.9%)	49	(10.7%)
Age in years (SD)	21.3	(2.4)	21.7	(4.7)	21.3	(4.3)	20.8	(2.2)

Note. Scales for variables 1-7 range from -2 to 2; scales for variables 8 and 9 range from 1 to 10.

The four clusters were labeled based on the reported resource management strategies of the students in each cluster. The first cluster ($n = 393$) showed negative values in attentional regulation, effort regulation, time management, and motivation, showing that these students reported being less able to regulate their resources during emergency remote learning than in the situation before the crisis started. At the same time, this group reported investing more time and effort in their self-study. We therefore labeled the first cluster as *the overwhelmed*. The second cluster ($n = 340$) was characterized by positive values in all clustering variables, indicating that this group managed to regulate their attention, effort, and time better, and reported being more motivated than before the crisis. At the same time, they also mentioned investing more time and effort in their study. This group was classified as *the adapters*. The third group ($n = 610$) was characterized by negative values in attentional regulation and motivation, and a relatively small increase in effort and time investment. This group changed their resource management strategies the least compared to the other groups. We labeled this group as *the maintainers*. The fourth group ($n = 457$) was characterized by negative values on all scales, showing that they were heavily and negatively impacted by the situational change. On top of that and in contrast to the first group, they also reported investing less effort and time in their self-study. This group was therefore labeled as *the surrenderers*.

As a validation procedure, we conducted the double-split cross-validation procedure as outlined in the Methods section (data analysis). This resulted in Cohen's kappa's of 0.968 ($p < .001$) between the total sample and the first subsample and 0.954 ($p < .001$) between the total sample and the second subsample, indicating a stable cluster solution.

To evaluate the external validity of our resulting clusters, we conducted a MANOVA with cluster group as independent variable and well-being, engagement, and educational experience scores after the change as dependent variables. Results indicated a significant overall difference between the clusters, $F(9, 5385) = 99.07$, $p < .001$, $\eta^2 = .14$. Follow-up ANOVAs showed univariate effects for well-being, $F(3, 1795) = 202.7$, $p < .001$, $\eta^2 = .25$, engagement, $F(3, 1795) = 247.3$, $p < .001$, $\eta^2 = .29$, and educational experience scores during the global health crisis, $F(3, 1795) = 205.3$, $p <$

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.001, η^2 = .26. Bonferroni post-hoc tests showed that the overwhelmed (cluster 1) and the surrenderers (cluster 4) did not differ significantly from each other regarding engagement, p = 1.00 (CI = -.09 to 0.10), and educational experience scores, p = 1.00 (CI = -.27 to 0.33). All other cluster groups differed significantly in their mental well-being, engagement, and educational experience. The overwhelmed showed the highest decrease in well-being, and the overwhelmed and the surrenderers both showed the highest decrease in engagement and the lowest educational experience scores.

Additionally, we explored potential cluster differences regarding gender, bachelor or master level, and age. Gender distribution did not vary across the clusters, χ^2 (3) = 10.42, p = .108, but regarding bachelor or master level, χ^2 (3) = 10.7, p = .013, and age, F(3, 1797) = 4.45, p = 0.004, η^2 = .007, we did find differences. Inspecting the distribution across the clusters, proportionally more master students than bachelor students were in the maintainer profile. Bonferroni post-hoc tests showed that students in the adapter cluster and the surrenderer cluster differed significantly in their age, with the adapters being older (M_{age} = 21.7) than the surrenderers (M_{age} = 20.8), p = .002 (CI = .24 to 1.61).

Difficulties and Benefits related to Emergency Remote Learning

We further investigated differences and commonalities between the cluster profiles in the qualitative analysis of reactions to the open-answer questions on benefits and difficulties related to emergency remote learning. In the following section, we will discuss the different profiles and their approach and adaptation to the situation, focusing on their attentional and effort regulation, motivation, time-management and effort- and time-investment. We illustrate key aspects with representative quotations from the written answers of participants. The profiles should not be interpreted as stable and fixed traits, but rather as reflecting the different adaptations and reactions of students to emergency remote learning.

The Overwhelmed

The overwhelmed were generally negative about emergency remote learning and the overall online learning experience. Concerning attentional regulation, students mentioned difficulties to concentrate and focus due to distractions at home, being online, and not having access to the library or other study facilities. Effort regulation was perceived as harder; spending long hours in front of a screen and internet connection problems were described as straining. Motivation was described to be negatively affected due to the lack of socialization and interaction with others; some students feeling isolated and depressed. The lack of external structure and organization was also mentioned to be negatively influencing their motivation. Although the overwhelmed appreciated studying at home in a comfortable space and saving travel time, maintaining a daily routine became more difficult:

> *I dislike that we cannot do much meaningful discussions. I dislike that my internet connection is not helping. I dislike that my concentration from home is much worse than being at the [lecture] hall. I dislike that the libraries are closed and that I can't find a place to study well.*

The increased workload and stress were salient; students felt unsure about the online exams and extra assignments, and did not feel well-supported by the university:

> *All of this has to be understood in the context of not having proper schedules anymore. I guess some students have been able to adapt easily, but in my case, [...] it's as if there was no sense of being able to take breaks anymore. Lectures are becoming much longer than 2hs with the new materials given, and overall, I feel as if the study-load has increased.*

The Adapters

In general, the adapters appreciated the increased level of autonomy and self-directedness of the online setting. Students reported saving travel time, were better able to plan their days and make their own study schedule, and felt more in control of their day. Being able to watch the lectures at their own pace enabled students to check their understanding and study at times when they were more productive.

This positively influenced their attentional and effort regulation, but also their time management:

> *I really loved the fact that all the lectures were recorded. I think it should be like that all the time. Because of this, I was able to skip a lecture and watch it later (at a later time when I was more productive). In this period, I have learned how to manage my time very well. I really like online education overall.*

Nevertheless, the adapters missed the informal social contact with their tutors and peers, and experienced collaboration with other students as more difficult online. These students also perceived that online exams caused more stress and higher workload:

> *The only thing which I do not like about online education is the limitations which were imposed for online exams, such as limited time, inability to change previous answers, higher intensiveness, more stress. [...] There can be a lot of unexpected technical problems which we cannot be responsible for.*

Many students in the adapter profile described themselves as either too shy to participate in normal, offline settings or having long commuting times to and from university. The online setting enabled these students to save time and to study in a safe space at home, at their own pace:

> *It [online learning] took my anxiety away and made the uni experience much less stressful. It also lessened the pressure I was feeling and I feel that my mental health has improved extraordinarily. Another great side effect was saving time that it took to go to and from university every day and has proven how much more efficient online communication is for me.*

The Maintainers

In the maintainer profile, the experiences with online learning appeared to be more diverse. While appreciating the comforts of studying at home and saving time, the maintainers recognized the challenge of staying concentrated and motivated outside their regular study environment:

> *That you are no longer in this direct academic environment. Normally I would go to the library before or after and I really need that because it has always been difficult to concentrate at home best. Of course you are online with everyone you would be in a tutorial with and while that can also have benefits because you can do it comfortably from your home, it also took away some motivation from me for sure.*

Students further missed the direct contact with their tutors and peers and criticized education to be less interactive and effective than usual. Nevertheless, many maintainers showed understanding for the uniqueness of the situation and appreciated the communication of the university and guidance by tutors and course coordinators:

> *In general, I am not too excited about online education, but the flexibility it brings to follow education from wherever is sometimes nice. I appreciate how hard the university is trying to communicate and develop.*

The Surrenderers

Comparable to the overwhelmed, students in the surrenderer profile described their general educational experience as negative; they experienced great difficulties with attentional regulation, motivation and time management. Some students in this profile also mentioned an increase in stress and workload, similarly to the overwhelmed. Most students mainly experienced a decrease in their motivation due to the lack of interaction with others and their general educational experience, which might explain the drop in their effort- and time-investment:

> *The absolutely most essential thing about university is getting excited about what you learn. I easily get excited for what I learn. This period is different. Lacking friends and staff members all around me to bump into and exchange ideas with*

was THE stimulating thing at university. Now that is completely missing and I wake up wondering why I am studying at all. This lack of a common area and extrinsic motivation brings down the quality of what everyone contributes to PBL significantly.

At the same time, they did not invest as much time and effort in their study as the overwhelmed. Students in this profile perceived the increase in self-direction and autonomy as a burden. While they appreciated saving time and studying at home in a comfortable environment, the surrenderers had difficulties to regulate their resources during self-study:

My motivation significantly decreased. I am also studying way less than I would usually do. Though I never missed any activities before the COVID-situation, now I no longer follow my timetable and leave the lectures for later.

Furthermore, many students in the surrenderer profile felt a mismatch between their PBL-learning experience in an on-site setting as compared to the online setting. They were, moreover, critical about online learning in general:

Online learning is not working. Quality of education provided by the university through online learning was significantly less. This was not because tutors were not prepared, but because online learning does not fit PBL and most courses.

In summary, during emergency remote learning, all students faced similar challenges, but students of the different cluster profiles coped with these challenges differently. Students of all profiles missed the personal contact with teachers and peers. The reduced collaboration and interaction negatively influenced their motivation. All students saved travel time, but the adapters appreciated the increase in autonomy and self-directedness, being able to study at their own pace. The overwhelmed and surrenderers struggled most to manage their time, attention and efforts effectively.

DISCUSSION

The aim of this study was to examine how and to what extent university students adapted to emergency remote learning in the context of the COVID-19 pandemic. Using a mixed-methods approach, we first investigated how the sudden shift from face-to-face to emergency remote education influenced students' self-regulated learning, specifically focusing on their resource management strategies. We administered a questionnaire on students' resource management strategies during emergency remote learning and on indicators of (un)successful adaptation: general educational experience, engagement, and mental well-being. Our findings indicate that in general, students experienced more difficulties in managing their time, regulating their attention and efforts, and reported being less motivated than before the shift to online education. Furthermore, on average students mentioned investing more time and effort in their self-study. In line with the difficulties in managing their resources, students experienced a decrease in their mental well-being and engagement with their studies, and their general educational experience dropped significantly.

Given the uniqueness of the situation and individual differences in self-regulated learning (Dörrenbächer & Perels, 2016), we assumed that students would differ in their abilities and approach to adapt to emergency remote learning. With the use of a person-centered approach (Kusurkar et al., 2020), we identified four adaptation profiles and labeled them according to the reported changes in their resource management strategies: the overwhelmed, the adapters, the maintainers, and the surrenderers. These profiles allowed for a differentiated perspective on the ways students adapted to emergency remote learning. Most students were classified as maintainers (n = 610, 34%). Although their attentional regulation and motivation decreased compared to before the crisis, students' ability to regulate their efforts and to manage their time, as well as their time- and effort investment did not change significantly. Both the overwhelmed (393 students, 22%) and the surrenderers (457 students, 25%) experienced difficulties to adapt to emergency remote learning. These students reported being less motivated, and less able to concentrate, manage their time and regulate their efforts. At the same time, the overwhelmed reported investing more time and effort in their self-study, whereas the surrenderers showed a decreased investment of time and effort in self-study activities. Both groups rated the educational experience as worse than before the crisis, while their engagement and well-being dropped, indicating that students in these profiles were unsuccessful in adapting to emergency remote learning. The fourth subgroup of students, classified as the adapters (340 students, 19%), can be considered as the group that was most adaptive to the new situation: these students reported to be more motivated, better able to regulate their attention, effort and time than before. At the same time, this group also invested more time and effort in their self-study. Students in the adapter profile reported even a slight increase in their well-being, whereas their educational experience stayed relatively stable compared to before the crisis.

Some students struggled more on time and effort investment, while others struggled more regarding attention and motivation. This multidimensionality of resource management strategies suggests a tailored support approach for students. While the surrenderers might benefit from more structure and social interaction, the overwhelmed might need more support on stress management. These results further support prior person-centered research on self-regulated learning and motivational profiles by identifying different subgroups ranging from high to low adaptability regarding resource-management strategies (e.g., Vansteenkiste et al., 2009; Broadbent & Tyskiewicz, 2018). However, in contrast to the online students in the study by Broadbent & Tyskiewicz (2018), most students in our sample related to non-adaptive profiles. This stresses the difference between students who actively chose for online learning and students who were forced to study in an emergency remote learning setting. The latter group might need more guidance and support in an online learning environment.

To gain a deeper understanding of the differences between the profiles, we analyzed the answers regarding experienced difficulties and benefits of emergency remote learning for each profile. While the above-mentioned differences between the profiles were clearly represented in the open answers, similarities were noted as well. Students of all profiles appreciated the recorded online lectures and being able to study at home. However, the quality of interaction and level of active learning while studying at home differed. While the adapters mentioned being able to study in their own pace, and play and pause the online lectures to monitor and control their understanding, the surrenderers rather appreciated the comfort of staying at home and not having to travel to university. This finding illustrates the difference between students in their ability to effectively apply self-regulated learning strategies, and resource management strategies in particular. Not having access to learning facilities, such as the library, was mentioned to be a clear disadvantage and hampering students' attention and effort-regulation. Students in the surrenderer profile, for example, mentioned to be highly reliant on the library to study and distractions at home hindered their resource management.

With the majority of students not being able to take advantage of the higher levels of autonomy associated with emergency remote learning and given the importance of these skills for academic achievement in online learning (Puzziferro, 2008), it is necessary to support such students in their self-regulated learning. Future research could investigate, for example, whether prompts included in online lectures can support students in the low-adapting profiles to monitor and control their understanding and enhance their attentional regulation and motivation (Lehmann, Hähnlein, & Ifenthaler, 2014). The difference between students in their ability to adapt to emergency remote learning might be further explained by personality factors. Some students in the adapter profile mentioned to be shy; they felt safer participating in online education. More extraverted students on the other hand might suffer more from isolation and reduced collaboration in education. Furthermore, consistent with previous research, older age appeared to be related to a higher adaptive profile (Johnson, 2015). Age might be a proxy for more experience in higher education and therefore for a better ability to self-regulate. Tailored support, depending on the ability to adapt to emergency remote learning, could be beneficial (Dörrenbächer & Perels, 2016). While this study helped identifying the different groups of learners, further research into the specifically applicable interventions is needed. It would be worthwhile to examine in a longitudinal study whether these different adaptation profiles are stable. In that case, it would be of interest to measure students' resource management strategies at the beginning of an online course to provide tailored support and mentoring during the online learning experience.

Students of all four profiles reported having missed the social contact and interaction with their teachers and peers. The reduced collaboration was described as less motivating compared to face-to-face education. Online communication and collaboration, especially in tutorials, was experienced as more straining due to long screen times and the lack of non-verbal communication. These findings resonate with the challenges of blended online learning environments, such as increased feelings of isolation and disinterest, and students feeling alienation and isolation in online learning (McInnerney & Roberts, 2004; Rasheed et al., 2020). How to facilitate collaboration in online education and address students' isolation are important questions for future research. For example, as suggested by McInnerney and Roberts (2004), social interaction in the online environment could be enhanced through increasing the use of synchronous communication and dedicating time to form a sense of community. For instance by starting synchronous contact with low stakes learning tasks, using visual cues to guide learners attention and prioritize tasks and resources that require low bandwidth to reduce internet connection problems (Green, Burrow, & Carvalho, 2020). In order to create and maintain academic communities and relationships, it is necessary to scaffold communication and collaboration carefully and to combine both synchronous and asynchronous contact with teachers and peers (Nordmann et al., 2020).

The fact that students in the current study were used to a highly interactive and collaborative educational format (PBL) may have contributed to the abovementioned difficulties to adapt to a less collaborative format. Students that had initially chosen to study in a highly collaborative setting were now forced to study in a highly autonomous learning environment with online contact only. Students in the low-adapting profiles (surrenderers and overwhelmed) often mentioned a general mismatch between their online and on-site experiences with PBL. Their negative attitude was also reflected in their general educational experience scores. In a transition from face-to-face to online education, it seems therefore important to guide the transition and align the expectations of students and teachers towards the online format (Kebritchi, Lipschuetz, & Santiague, 2017;

Nordmann et al., 2020). Most students also experienced increased workload and invested more time in their self-study. They often mentioned exam-related stress and uncertainty about assignments and online proctoring as a reason. Managing the expectations of students regarding the online format and the way how exams are structured through more guidance and communication, could alleviate stress and experienced workload.

This study has several limitations. First, the generalizability of our results might be limited given the PBL context in which the participants of this study were studying. Students were used to participate in small, discussion-based tutorial sessions. In the crisis situation, tutorial sessions continued online, with less active discussions and a lack of non-verbal communication, which may have had a larger effect on students' self-regulated learning strategies than in a more traditional curriculum. Furthermore, the response rate of 10.5% was rather low. Given that non-respondents may be students who have experienced significantly more or less difficulties due to the pandemic, this might have biased the results. However, the composition of the sample was highly diverse, with students of all faculties and including bachelor and master students of different years, and may therefore be considered as relatively representative for this university.

Second, the measurement of students' adaptation to the situation was based on self-report and may have been altered by retrospective bias (Stone & Shiffman, 2002). As respondents were asked to compare the current situation to the situation before the shift to emergency remote education, no conclusions can be drawn regarding the general level of self-regulation; the findings only provide information about the level of adaptations to the change. Moreover, we adapted existing questionnaires on online self-regulated learning to capture the level of self-regulation during a change to emergency remote learning. We specifically focused on students' resource management strategies given the increased relevance of these strategies during the crisis, and did not assess students' cognitive and metacognitive strategies. Future research on how students adapt to online learning could include all aspects of self-regulated learning to generate a complete picture.

CONCLUSION

While the emergency part of emergency remote learning may not be as emergent anymore and universities might go back to full face-to-face education as soon as possible, online and remote education are likely to remain part of future educational formats. The current study sheds light on how students adapted to online education in the context of a crisis. While many students experienced difficulties to manage their resources and engage in self-regulated learning, different profiles of adaptation emerged: the overwhelmed, the surrenderers, the maintainers and the adapters. These profiles may serve as framework for future research on tailored interventions to support students adapting to online and remote education. Important aspects entail the focus on facilitating online collaboration and socialization to conquer feelings of isolation, guiding attentional and effort regulation during self-study, and managing students' expectations about online learning.

ACKNOWLEDGMENTS

We would like to thank Matthijs Krooi for assisting in the coding of the open answers.

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Appendix A

Questionnaire on Resource Management Strategies, with Means (M) and Standard Deviations (SD) per item and Internal Reliability of all Scales (Cronbach's Alpha)

		M	SD	α
AR1	In the current situation, I encounter __ distractions in my study environment than before the crisis (reversed)	-0.90	0.99	
AR2	In the current situation, my mind wanders __ during my self-study than before the crisis. (reversed)	-0.89	0.96	
AR3	In the current situation, I get __ distracted during self-study than before the crisis. (reversed)	-0.91	0.97	
AR4	In the current situation, I can concentrate __ during self-study than before the crisis.	-0.80	1.04	
AR	**Attentional regulation (scale)**	**-0.87**	**0.86**	**.89**
ER1	In the current situation, I feel __ exhausted after a self-study session than before the crisis. (reversed)	-0.54	1.05	
ER2	In the current situation, I am __ able to manage my energy during a study day than before the crisis.	-0.43	1.13	
ER3	In the current situation, I am __ able to relax in my free time than before the crisis.	-0.24	1.27	
ER	**Effort regulation (scale)**	**-0.40**	**0.94**	**.75**
ET1	In the current situation, I put __ effort in my self-study sessions than before the crisis.	0.12	1.07	
ET2	In the current situation, I put __ time in my self-study sessions than before the crisis.	0.23	1.15	
ET	**Effort and time-investment (scale)**	**0.18**	**1.02**	**.82**
M1	In the current situation, I experience __ motivation to prepare for tutorial meetings than before the crisis.	-0.71	1.05	
M2	In the current situation, I experience __ motivation to keep up with the course program than before the crisis.	-0.65	1.04	
M3	In the current situation, I experience __ motivation to prepare for exams than before the crisis.	-0.75	1.02	
M	**Motivation (scale)**	**-0.70**	**0.89**	**.83**
TM1	In the current situation, I choose specific times when I study effectively __ than before the crisis.	-0.09	1.05	
TM2	In the current situation, I find it __ hard to stick to a study schedule than before the crisis. (reversed)	-0.65	1.06	
TM3	I currently have an effective study routine that has helped me in the past.	-0.20	1.07	
TM4	I find it difficult to adapt my study routine to the current situation. (reversed)	-0.44	1.22	
TM5	In the current situation, I am able to continue my study routine as before.	-0.52	1.16	
TM	**Time-management (scale)**	**-0.38**	**0.86**	**.83**

Note. AR = Attentional regulation, ER = Effort regulation, ET = Effort- and time-investment, M = Motivation, TM = Time management; N = 1800.

Appendix B

Coding scheme per theme group

Theme group	Themes per question	
	What did you like about online education?	What did you dislike about online education?
Motivation	· Increased autonomy and self-directedness · Assessment structure (formative, asynchronous)	· Lack of personal contact · Less motivated / engaged/ connected · Less collaboration
Time management	· More flexibility: Studying at own pace · More flexibility: study at home · More flexibility: save time (less travel time)	· Lack of structure · Self-directedness · Workload and stress increased
Effort regulation	· Comfort of study at home, getting more rest	· Too much screen time
Attentional regulation	· Online lectures: easier to follow/ able to re-watch/ check understanding · Concentration: easier to follow shorter tutorials / lectures	· Connection issues · Concentration: cannot focus · Concentration: no access to study facilities
Time and Effort investment		· increased workload
Educational Experience	· positive attitude towards online learning	· negative attitude towards online learning
Wellbeing	· feeling at ease / less stressed/ more rest	· feeling stressed, negative mood

6

Appendix C

Coding scheme example for Cluster 4 'The surrenderers'

1. What did you like about online education?	2. What did you dislike about online education?	Themes
"I was able to be at home and I didn't need to travel back and forth. I could also adjust the times when I wanted to watch a lecture or practical. It enabled me to have more time to eat and to take care of myself, I was less in a rush."	"My motivation significantly decreased. I am also studying way less than I would usually do. Though I never missed any activities before the Covid situation, now I no longer follow my timetable and leave the lectures for later."	1.More flexibility: Save time (less travel time) 1. More flexibility: Study at home 1. Comfort of study hat home 2. Less motivated/engaged/ connected 2. Lack of structure 2. Time-investment
"Nothing. Literally nothing. I hated the whole experience. I hate having to interact with people through screens for extended periods of time, and especially on academic related subjects. I cannot stress how much I liked no aspect whatsoever of this whole thing."	"The fact I cannot interact with other people naturally. The fact I have to go through a screen to interact with anyone. if I wanted an online course on anything, I would have gotten an online degree. I hated this learning experience. Whilst I do understand the necessity of online learning to an extent, I don't believe this is the crux of your question. This was a miserable experience."	2.too much screen time 2. less motivated/engaged/ connected 2. negative attitude towards online learning
"All the lectures and material were online so people could go at their own pace. Recording lectures should be a normal practice at UM. Attendance was not mandatory (this is very important)"	"Feeling disconnected from the class, not getting to know the teacher nor the fellow students."	1.More flexibility: study at own pace / study at home 2. lack of personal contact 2. less engaged/connected
"More peaceful and less stress"	"No motivation, feeling alone, hard to get into studying even if you make a planning or want to work you just can't, missing friends"	1.More flexibility: save time / study at home 2. Less motivated / engaged/ connected 2. Lack of personal contact

Chapter 7

General Discussion

Parts of this chapter have been accepted for publication as
Biwer, F. & de Bruin, A.B.H. (**In Press**). Teaching Students to 'Study Smart' – A Training Program based on the Science of Learning. In C. E. Overson, C. M. Hakala, L. L. Kordonowy, & V. A. Benassi (Eds.). *In their own words: What scholars want you to know about why and how to apply the science of learning in your academic setting* **(pp. xxx-xxx)**. Society for the Teaching of Psychology.

GENERAL DISCUSSION

The central aim of this dissertation was to gain an understanding in how to effectively support learners in their self-regulated use of effective, desirably difficult learning strategies. I approached this general aim from three perspectives. First, by investigating the effects of a direct learning strategy intervention on students' knowledge about, and use of effective learning strategies, as well as the prerequisites and challenges of implementing such an intervention. Second, we zoomed in on the practical support of effective learning strategies and specifically examined the effects of answering self-generated questions, compared to answering provided questions or rereading on long-term learning. Third, we investigated the role of resource management strategies in adapting to a changing learning environment, namely the forced change to remote education due to the COVID-19 pandemic. This final chapter provides a synthesis of the main findings per research question[1] and discusses the theoretical and practical implications.

Synthesis of Main Findings

How does a direct learning strategy intervention affect students' metacognitive knowledge, use of effective learning strategies, and academic performance?

The newly developed learning strategy intervention, named 'Study Smart', was central to this research question. The intervention addressed awareness about, practice with, and reflection on effective, desirably difficult learning strategies, which require students to invest more effort in learning to gain better retention in the long-term. We found that students gained more accurate metacognitive knowledge about the effectiveness of learning strategies (chapter 2, 3). In contrast to earlier survey research (Blasiman, Dunlosky, & Rawson, 2017; McCabe, 2011), students in our samples correctly endorsed testing over restudying already before the intervention. This might be explained by the fact that students experienced a problem-based learning curriculum that encourages active participation (Dolmans,

1 Given that the findings of chapter 2 have mostly practical implications, those are discussed in the section 'practical implications'

De Grave, Wolfhagen, & van der Vleuten, 2005). The highest knowledge gain was found in recognizing commonly used passive strategies, i.e., highlighting or rereading, as ineffective (chapter 2, 3). After having attended the training program, students reported using more desirably difficult strategies, such as quizzing or interleaved practice, and relied less on rereading and highlighting.

Even though knowledge and use of desirably difficult learning strategies increased through the intervention, the extent to which students reported to use these strategies during self-study was still rather limited (chapter 2, 3). Based on insights from focus group discussions, several factors were found to hinder students' strategy uptake: uncertainty about the specifics of learning strategy use, external factors, such as the lack of available practice questions, and internal factors, such as strong old habits of using ineffective strategies. These factors resonate with earlier research on the discrepancy between knowledge about and actual use of self-regulated learning strategies (Foerst, Klug, Jostl, Spiel, & Schober, 2017), also stating uncertainty about time and application of strategies as well as high perceived effort as reasons for not using specific strategies. The findings highlight the need of making students aware of the challenges and pitfalls of desirably difficult learning strategies (Dunlosky, Rawson, Marsh, Nathan, & Willingham, 2013), but also to support them more specifically in implementing these strategies in their daily practice (Fiorella, 2020).

Regarding academic performance, when compared to a previous cohort that did not receive any learning strategy instruction, students in the Study Smart cohort improved their academic performance throughout the year. Differences between initially low and high performing students were significantly reduced at the time of the final exam (chapter 3). These results suggest that a direct intervention aiming at the importance of desirably difficult learning strategies for long-term learning, combined with continuous support on the use of learning strategies, can support academic success, especially for lower achieving students. This aligns with research on drop-out in higher education that showed that study or learning strategy trainings, but also coaching and remedial training, can be protecting factors against non-completion of the first year in higher education (Delnoij, Dirkx, Janssen, & Martens, 2020).

What are the effects of stimulating retrieval practice by answering self-generated practice questions compared to answering provided questions or restudy on long-term retention?

The second research question addressed was based on a practical problem students encounter when aiming to apply retrieval practice during self-study (i.e., the lack of available practice questions) and aimed to unravel whether answering self-generated practice questions invokes a testing effect, similar to answering provided questions. We, however, did not find a benefit of answering self-generated questions over answering provided ones or restudying the study materials. Answering provided questions was more effective for long-term learning than both answering self-generated questions and restudy, but only when students could seek feedback after initial retrieval (chapter 5, experiment 2). This was in line with previous research showing that feedback enhances the benefits of retrieval practice compared to retrieval without feedback (Kang, McDermott, & Roediger, 2007; Van der Kleij, Feskens, & Eggen, 2015), as it helps to correctly encode information that was initially not retrieved. By investigating the underlying cognitive mechanisms of mental effort and perceived difficulty, we found that even though generating questions was a more effortful and difficult learning activity than restudying, students did not benefit from this additional effort. In line with the transfer-appropriate account (Adesope, Trevisan, & Sundararajan, 2017), one possible explanation for the lack of benefit could be that students did not generate relevant questions, as topic overlap with post-test questions had a positive influence on learning outcomes (chapter 5). However, in our study, topic overlap between generated and provided questions was rather low. Therefore, students might need further support in generating their own practice questions before being able to benefit from answering them. This support could include direct feedback on (1) whether the generated question is relevant regarding the intended learning outcomes and (2) whether the generated questions are of high quality, i.e. conceptual rather than factual. Future research is needed to investigate the effectiveness of different kinds of support to disentangle whether and under which circumstances students might benefit from answering their self-generated questions.

How did students adapt their resource management strategies to emergency remote education?

In the last part of the thesis (chapter 6), we investigated the role of resource management strategies in adapting to emergency remote education due to the COVID-19 pandemic. We found that students generally experienced more difficulties in managing their time, regulating their attention and effort, and felt less motivated than before the crisis. At the same time, they spent more time and effort in their self-study. By using a person-centered approach (Kusurkar et al., 2020), we identified nuanced differences between students, described in four adaptation clusters: the overwhelmed, the adapters, the maintainers, and the surrenderers. While in three of these four clusters, students experienced great difficulties in managing their resources due to distractions, lack of social support and feelings of isolation, students in the adapter profile managed to thrive and successfully apply effective learning strategies in online learning (chapter 6). These results stress the importance of tailored interventions to align the support for students in adapting to online education with their individual needs and competences.

Supporting Students to Study Smart - Theoretical Considerations

Overall, this dissertation contributes to understanding how students can be supported to study more effectively, that is, to use more desirably difficult learning strategies that promote long-term learning. As shown in a meta-analysis by Theobald (2021), the underlying theoretical background of a learning strategy intervention can have an impact on its effectiveness. Study skills trainings are mostly based on cognitive theories and teaching strategies for specific academic tasks, such as reading or writing (e.g., Bail, Zhang, & Tachiyama, 2008). Trainings that are based on social cognitive theories (e.g., Bellhäuser, 2016; Zimmerman, 2002) focus on motivational aspects of learning and on managing one's resources. Trainings that are based on metacognitive theories, such as the Study Smart program, emphasize metacognitive strategies and reflection, as in planning, monitoring, and evaluating the learning process, but rarely cover resource management strategies (Flavell, 1979; e.g., Rezvan, Ahmadi, & Abedi, 2006). The latter have been found to be most effective in enhancing the use of metacognitive strategies, academic performance, and cognitive strategies, possibly through fostering reflection about how to adapt a specific strategy for a different task (Theobald, 2021). The Study Smart program, which was central to chapters 2-4, mainly focuses on teaching cognitive and metacognitive strategies and reflection, and can be considered as direct metacognitive training (Theobald, 2021).

In existing SRL programs, however, the aspect of paying specific attention to desirably difficult learning strategies has been mostly neglected (for an exception, see McDaniel & Einstein, 2020). Given the specific challenges of these strategies, such as the experienced-learning-versus-actual-learning paradox, the strong and often incorrect idiosyncratic ideas about learning, as well as the high effort these strategies cost, we deemed it important to specifically add the aspect of desirable difficulties in the intervention. The effort of applying desirably difficult strategies, was indeed mentioned as one major challenge and barrier students perceived when wanting to use more effective learning strategies (chapter 2). By specifically addressing the role and importance of effort, debunking myths about learning styles or other idiosyncratic ideas, we managed to increase the accuracy of students' knowledge. As experiences during learning are convincing but misleading, students will not become effective, self-regulated learners, without specific, direct instruction, but also feedback on the accuracy of their experiences during learning (Hui, de Bruin, Donkers, & van Merriënboer, 2021a, 2021b). Integrating direct instruction on desirable difficulties in self-regulated learning is thus one way forward to better prepare students to become life-long learners.

In aiming to describe the optimal didactic approach to teaching effective learning strategies, McDaniel and Einstein (2020) recently introduced the *knowledge-belief-planning-commitment* framework. The framework describes four components essential to support sustained strategy self-regulation: knowledge instruction about strategies, belief about the effectiveness of strategies, commitment to use the strategies, and planning of strategy application. This framework partly aligns with the Study Smart approach (chapter 4), but misses the crucial aspect of supporting practice. It aligns by first taking a theory-based approach, as in instructing students about the when, why, and how to use specific learning strategies and making them aware of common misconceptions in learning. Indeed, similar interventions that aim to encourage learners to use more desirably difficult learning strategies (Rivers, 2021) showed that direct instruction could increase the accuracy of students' knowledge and change their beliefs about the effectiveness of different strategies (Ariel & Karpicke, 2017; Broeren, Heijltjes, Verkoeijen, Smeets, & Arends, 2021; Hui et al., 2021b). Second, the framework aligns with Study Smart by including an experience-based approach to let students experience the effectiveness of a strategy while engaging in a relevant learning task. While experience-based approaches may be compelling to convince learners about the usefulness of specific strategies, the exact implementation and usefulness for the longer term are mostly unknown. Future research could investigate whether students should be provided with individual performance feedback (Hui et al., 2021a; Tullis, Finley, & Benjamin, 2013), or feedback on their perceived learning, perceived effort, and actual learning to showcase the paradox and the value of desirably difficult strategies. Both experience-based and theory-based approaches may be limited in their applicability in single training sessions (see chapter 2, 4) and in their ability to transfer the acquired knowledge outside of the specific context. With the addition of considering sustainable self-training, future research should also try to disentangle the optimal balance between and combination of direct instruction and experience-based interventions, for example in combination with providing individual experience or performance feedback.

Study Smart addresses practical support and thus stimulates transfer of the acquired knowledge to a different context, which is missing in previous frameworks (McDaniel & Einstein, 2020; McDaniel, Einstein, & Een, 2021) and other experimental interventions (Rivers, 2021). As shown in chapter 2 and 3, one major challenge many students experienced was to translate the acquired knowledge to their daily study practice. This uncertainty in using new learning strategies is closely linked to matters of behavior change (Sheeran, 2002). The qualitative model of chapter 2 resembles the theory of planned behavior (Fishbein & Ajzen, 2011), a behavior change theory showing that students' attitudes, subjective norms, and perceived behavioral control predict the intended learning strategy behavior. We consider educational research inspired by the behavior change literature and habit formation as an important next step in learning strategy research. Parallels between changing poor learning habits and changing other kinds of habits, such as smoking or unhealthy eating, could offer important insights in how to support students in changing their learning habits and study behavior more sustainably (Fiorella, 2020).

Supporting students' practice may take different routes: First, by investigating how students can independently apply effective learning strategies during their self-study with limited external support. Chapter 5 contributed to the understanding of how a practical solution with regard to practice testing could be designed effectively. Our findings indicated that generating and answering own questions did not benefit learning compared to restudy, but induced higher perceived effort. Programs and teachers should invest in making practice questions more available, as retrieval practice with provided questions led to the best learning outcomes. Generating questions is a complex strategy that could be improved by more guidance to recognize important topics and direct feedback in order to be beneficial. Future research on the effect of answering self-generated questions could address the effect of students generating questions and answers simultaneously and providing feedback on these questions and answers, before letting students practice retrieval with these questions. Another avenue for research could be the effect of answering peer-generated questions or collaborative practice testing, which has been shown to increase the likelihood of students to quiz themselves compared to when studying alone (McCabe & Lummis, 2018; Wissman & Rawson, 2016).

A second route supporting students' practice of effective learning strategies could take is by a context-embedded awareness-practice-feedback cycle. Some context or materials may lend itself better to use certain strategies (for example, interleaved practice lends itself to recognize different lung diseases on an x-ray; Rozenshtein, Pearson, Yan, Liu, and Toy (2016)). Recognizing and learning how to flexibly use a set of strategies in different contexts might benefit from more part-task practice and a cycle of instruction, practice and feedback with authentic learning materials and a decreasing level of support (Kirschner & Van Merriënboer, 2014). This approach would require that the learning strategy instruction is closely embedded within one study program with close collaboration between scientific experts and educational advisers. This would ask for more professional development of teachers, and more research on how to effectively implement learning strategy instruction and practice within a course or even curriculum. The Study Smart program is currently implemented within the mentor program of several study programs within and outside of Maastricht University (chapter 4), and is mostly content independent, as awareness about the importance of desirable difficulties in learning is relevant for all students, irrelevant of their individual study program. This ubiquitous content-independence comes with the advantage of being able to implement such a program on a large scale and in different curricula and contexts. At the same time, the program is very adaptable to individual students' context, by for example integrating exercises in which students use their own study materials. However, one practice session and one reflection session may be too limited in their effect of supporting especially lower-achieving students to transfer the knowledge to their own specific context. A more extended awareness-practice-feedback cycle with different learning-strategy exercises in consecutive courses could improve this aspect and increase the effect of the 'standard' Study Smart program.

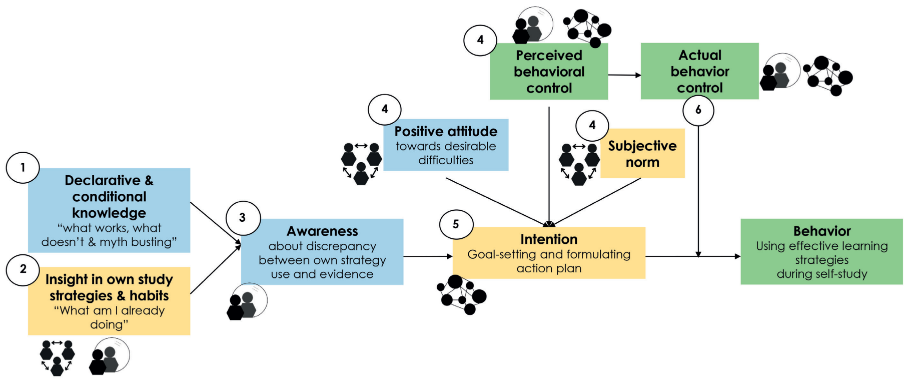
A third route to support students' practice is by enabling students to effectively manage their resources. As shown in chapter 6, resource management strategies played a large role in students' ability to adapt to changing circumstances. When confronted with higher levels of autonomy (as common in higher education settings or online learning environments), being able to effectively regulate one's time, effort, attention, and motivation are important factors to sustain. Especially motivational and regulation strategies have been found to be important determinants of university students' academic performance, which may reduce dropout rates (Richardson, Abraham, & Bond, 2012; Schneider & Preckel, 2017). However, students' ability to adapt to changing contexts (emergency remote education) differs to a great extent (chapter 6). Person-centered research on self-regulated learning also showed that students differ in their ability to self-regulate their learning, specifically regarding motivational and attentional factors (Vansteenkiste, Sierens, Soenens, Luyckx, & Lens, 2009). Consequently, addressing this heterogeneity in students' ability to manage their resources is important to unravel further moderating factors in intervention research. That way, tailored interventions could increase individual students' perceived behavioral control (e.g., by increasing social support or providing more chances for practice and feedback).

Supporting Students to Study Smart - Practical Implications

I now propose a set of principles important to address when teaching students how to study more effectively, structured around the theory of planned behavior and based on research on the implementation of the Study Smart program. 'Study Smart' is one way of addressing these principles, but they can be applied in various ways. The principles can serve as a design framework when designing a similar intervention. Figure 7.1 depicts the Study Smart Model relating the principles to the three program sessions – awareness, practice, and reflection – and to the underlying teaching methods of collaborative learning, reflective learning, and contextual learning. The three program sessions overlap and address several principles. Several principles are also addressed in more than one session; the colors indicate the focus of a session. The symbols indicate where the underlying teaching principles of collaborative learning, reflective learning, and contextual learning are applied.

Principle 1: Students need to acquire scientific knowledge about effective learning strategies

Many students lack accurate knowledge about how learning works and which learning strategies are most effective for long-term learning. For example, studies showed that students fail to correctly predict the benefit of spaced practice compared to massed practice, practice testing compared to restudy, and interleaved compared to blocked practice (Birnbaum, Kornell, Bjork, & Bjork, 2013; Kornell & Bjork, 2008, 2009; McCabe, 2011; Roediger & Karpicke, 2006). Furthermore, common myths about learning, such as the learning style myth (Kirschner, 2017; Kirschner & van Merriënboer, 2013; Nancekivell, Shah, & Gelman, 2020) impede knowledge acquisition and mislead students from appreciating the most effective learning strategies. Therefore, students need to acquire knowledge about learning and gain insight into how, why, and when these strategies work.



Principles[1]

1. Students need to acquire scientific knowledge about effective learning strategies
2. Address students' existing study habits
3. Students need to gain insight into (potentially) misleading subjective learning experiences
4. Address uncertainty and resistance to change
5. Students need to set specific goals
6. Students need guided practice and context-embedded support in using effective learning strategies

Teaching principles


collaborative learning


reflective learning


contextual learning

Program sessions

Awareness

Practice

Reflection

[1] Note that the principles are numbered in the order in which they need to be addressed in the training. This does not always lead to a logical numbering in the model, since the model integrates the six principles.

Figure 7.1. The Study Smart Model (Biwer & de Bruin, 2022)

This knowledge includes not only declarative knowledge about which learning strategies are effective or not, but also conditional knowledge about when (i.e., in which situations and for which learning materials), why (i.e., the working mechanisms of effective learning strategies), and how (i.e., how to apply these strategies).

As discussed in chapter 4, all students should receive learning strategy instruction. One challenge is whether such a training program can be a one-size-fits-all approach. On the one hand, evidence-based learning strategies based in cognitive science apply to all humans, thus are relevant for all students to a similar extent (Dunlosky et al., 2013). On the other hand, students' willingness and ability to apply the acquired knowledge to their self-study differ. How individual differences in motivation and personal learning goals shape students' reactions and adaptations of desirably difficult learning strategies is an important question for future research.

Principle 1 in Study Smart:
In the first session of the training program, called 'awareness', the teacher presents students with empirical evidence on the effectiveness of the most commonly used learning strategies (based on Dunlosky et al., 2013). Students are asked to rank the strategies based on their perceived effectiveness to enhance long-term learning. The results are discussed afterward, and the teacher explains the different cognitive learning strategies functions, such as organization, elaboration, and rehearsal (Weinstein, Jung, & Acee, 2010), as well as their metacognitive effects. These effects include which learning strategies provide students with feedback that would help them to monitor their learning progress. Students receive additional information on the basic principles and the importance of active learning and effort investment. In the second session, called 'practice', students are equipped with more specific, conditional knowledge about how to apply different learning strategies in different situations by specific practice exercises per learning strategy.

Principle 2: Address students' existing study habits

When entering higher education, students arrive with strong study strategy routines from high school (see chapter 2). The most commonly used strategies are rereading notes or textbooks (83%, Karpicke et al., 2009; 66%, Hartwig & Dunlosky, 2012), underlining or highlighting (72%, Kuhbandner and Emmerdinger, 2019), and cramming before the test (66%, Hartwick & Dunlosky, 2012). Because prior habits are the main predictors of future behavior (Danner, Aarts, & de Vries, 2008) and breaking existing habits is more effortful than making new habits (Lally & Gardner, 2013), addressing and connecting to students' prior learning strategies early is vital in facilitating change towards more effective strategy use.

The right timing to address the importance of desirable difficulties in learning is challenging (chapter 4). Given that a change in context, such as the transition from high-school to university, is a favorable moment to create new habits (Carden & Wood, 2018), a learning strategy training should be incorporated early in the first year of the academic curriculum. However, some students might not yet recognize the need to change the way they learn or try something new (chapter 4). Therefore, including regular reflection moments throughout the first year may offer opportunities to steer by and address hurdles students might have encountered at a later moment.

Principle 2 in Study Smart:
The awareness session starts with a guided brainstorm about commonly used learning strategies. Students are asked to share their favorite strategies and how they use these strategies to prepare for lectures or exams. To stimulate reflection, students prepare a photo log of their academic experiences. They are asked to take a picture that reflects an academic experience, challenge, or a typical study situation, and to write a reflection on external and internal factors that affected their learning in that situation. The photologs are meant to help students become aware of their existing study habits and strategies and to set goals for using more effective learning strategies. In general, Study Smart should be incorporated as early as possible in the first year of the academic curriculum, because learners will likely be more open to adapt new habits in the transition to higher education.

Principle 3: Students need to gain insight into (potentially) misleading subjective learning experiences

Experiences during learning can often be misleading, which can potentially lead to ineffective strategy decisions. Students very likely base their strategy decisions on perceived learning, which can greatly differ from actual learning (Kirk-Johnson, Galla, & Fraundorf, 2019). This experienced-learning-versus-actual-learning paradox makes students susceptible to mistakenly interpret a sense of familiarity or fluency (e.g., during rereading) as indicative of effective learning (Kornell, Rhodes, Castel, & Tauber, 2011; Oppenheimer, 2008; Yan, Bjork, & Bjork, 2016).

Gaining insight into these subjective learning experiences is, however, not easy and requires a multimodal approach. First, educating students about these experiences (theory-based methods; e.g., Ariel & Karpicke, 2017). Second, demonstrating and letting students experience the difference between two strategies (experienced-based methods; e.g., DeWinstanley & Bjork, 2004; Einstein, Mullet, & Harrison, 2012). Third, providing explicit feedback about perceived effort, perceived learning, and actual learning while using desirably difficult learning strategies is a further promising avenue to aid students in developing that insight (e.g., Hui et al., 2021a).

Principle 3 in Study Smart:
A second element of the awareness session is the explication of the experienced-learning-versus-actual-learning paradox (chapter 2, 3). Using a theory-based approach, research studies on the testing effect and judgments of learning (Nunes & Karpicke, 2015; Roediger & Karpicke, 2006) are discussed. Students then reflect with their peers about their own experiences with this paradox. Applying an experience-based method in one session is challenging, due to the often-delayed benefits of desirably difficult strategies on learning results, which could have a length of at least two days. We, therefore, focus on specific examples from research, comparing one effective strategy (e.g., interleaving) with one ineffective strategy (e.g., blocking), and ask students to predict the results. We then ask students to reflect on their experiences with these strategies in light of empirical evidence just reviewed. Letting students gain insight into misleading subjective learning experiences is crucial, but challenging to achieve in one study session, due to the often delayed effect of desirable difficulties. Online experience-based modules, outside the face-to-face training sessions, could offer a possible solution for this dilemma. For example by letting students studying vocabulary pairs with either testing or restudy in an online learning environment, and having a final test one week later demonstrating the effects of both strategies and providing feedback.

Principle 4: Address uncertainty and resistance to change

According to the theory of planned behavior, behavioral intentions are influenced by the attitude towards the behavior, subjective norm, and perceived behavioral control (Ajzen, 2020). How does this translate to the intention of using more effective, but also more effortful, learning strategies? First, students need to develop a positive attitude both towards these strategies and towards effort (Inzlicht, Shenhav, & Olivola, 2018). Ideally, students become motivated through recognition of a discrepancy between their learning strategies and evidence-informed strategies. However, changing from passively summarizing to actively practice testing requires time and effort and hence increases perceived costs. Although students often view effort as costly and tend to avoid it, effort is necessary for learning. In domains other than learning, such as sports or music, effort is valued and rewarded (Inzlicht et al., 2018). Thus, championing the value and importance of effortful learning—that is, the attitude towards effort—is one important factor to increase the intention to use desirably difficult learning strategies. As discussed in chapter 4, one challenge to this regard is that there will be resistance. Many students still have strong idiosyncratic beliefs about their own learning; they believe that they are unique in the way they learn best. It is important to refute these idiosyncratic ideas effectively, address misbeliefs, and correct information to concurrently fill the mental gap created by the correction (de Bruin, 2020).

Second, subjective norms regarding what strategies other students use and regarding requirements from the assessment system may further influence students' intention. Is it necessary to use more active but effortful learning strategies to get a good grade? Is it normal to use practice testing as a learning strategy? How do other students distribute their learning over time? The expected utility of a strategy for students' goals in relation to the costs of that strategy is at stake (Zepeda, Martin, & Butler, 2020). When one is not certain that the invested effort will result in higher grades, motivation to use these more effortful strategies will probably be low, as student learning is often motivated by what will be assessed (Al-Kadri, Al-Moamary, Roberts, & Van der Vleuten, 2012). Innovation in higher education towards implementation of more formative assessment opportunities, as in 'assessment *for* learning' instead of 'assessment *of* learning', are stimulating students and teachers to put more effort in deep approaches of learning, using desirably difficult learning strategies (such as retrieval practice) and to build a stronger base for life-long learning. In order to enable students to engage in desirably difficult learning strategies, a learning culture focused on improvement rather than on performance is needed (Watling & Ginsburg, 2019).

Third, perceived behavioral control (e.g., whether students perceive that they are able to apply these learning strategies given their available time, resources, and skills) can influence students' intentions. However, students will likely experience many challenges and drawbacks when engaging in desirably difficult learning strategies; these strategies tend to be unfamiliar and generally require more effort through active processing. In chapter 2, students reported being uncertain about how and when to use which strategies and wondered how to effectively apply the strategies to their subject domain. They were also uncertain about the effects these changes would have on their academic performance. Consequently, it is essential to reflect on students' uncertainty and motivation to ultimately foster their intention to use more effective learning strategies.

Principle 4 in Study Smart:
First, to prepare students for the importance of effort and to improve their attitude towards effort, we include a reflective writing exercise in the first session. Students are asked to think about an experience where they either acquired a new skill (e.g., learned a musical instrument) or changed past behavior (e.g., started to eat more healthily). Guided by reflective prompts, students write about what they have learned or changed, how they approached it, what challenges and difficulties they encountered, and how they eventually overcame these difficulties. In our experience, this reflection helps students to recognize the benefit and value of effort and difficulty in learning something new or when changing past behavior. Together with peers, students translate their take-home message from this reflection to the new challenge of using desirably difficult learning strategies during self-study.
Second, to address the subjective norm, collaborative learning is an essential part of the Study Smart program. In small groups of 10-15, students discuss and share their favorite learning strategies, challenges they experience, and how to solve them. Furthermore, we emphasize the use of desirably difficult learning strategies as a group effort by, for example, inviting students to share self-generated practice questions with each other. It is important to address in what way the assessment system may influence students' study motivations. Are students mainly motivated to achieve high grades or to avoid failure? Desirably difficult learning strategies do not immediately result in high grades. Depending on the assessment system, short-term learning strategies might be sufficient to pass exams. However, desirably difficult learning strategies support long-term learning and support transfer to other contexts (e.g., a profession). Addressing the subjective norm and students' motivation is crucial to increase their attitude and intention to invest in more effortful, but effective learning strategies.
Third, several exercises aim to increase perceived behavioral control. In the practice session, students practice different strategies using their own learning materials, with peers and guided by the teacher, to alleviate uncertainty about how to apply the strategies. In a time planning exercise, students plan their next week including all activities to achieve a realistic overview of their available resources. In the reflection session, students reflect with their peers about encountered challenges and how to overcome them.

Principle 5: Students need to set specific goals

Without a specific action plan on how to set the intention to use more effective learning strategies, however, the intention is likely to remain just an intention (Gollwitzer & Sheeran, 2006). To bridge the intention-behavior gap, past research has stressed the importance of formulating specific goals and action plans, such as implementation intentions (Gollwitzer & Sheeran, 2006).

Implementation intentions specify when, where, and how to obtain a goal in the form of an if-then plan. For example, to increase the use of practice testing, one might specify a situation that is usually associated with studying, specify an action designed to start using practice testing in that situation, and link the situational cue with the goal-directed response using the if-then format (e.g., 'If the tutorial meeting is over, I will go to the library and write down three practice questions.'). Formulating implementation intentions has been shown to improve the intended behavior, even when participants had to break weak or unwanted habits (Webb, Sheeran, & Luszczynska, 2009). In line with the cyclical model of self-regulated learning (Zimmerman, 2002), it is important to not only include goal-setting, but also continuous self-reflection and evaluation of these goals to promote their attainment.

Principle 5 in Study Smart:
Study Smart sessions include a goal-setting activity at the end of each session and follow-up on these goals at the beginning of the next session. Thus, students engage in goal-setting and reflection throughout the entire Study Smart program. At the end of the first session, students think about how to make their existing and favorite learning strategies more effective. With peers, students critically check their strategies and make a specific plan on how to make this strategy more effective, for example, by creating an opportunity for retrieval practice. Peers and teachers check whether these goals are 'SMART' (specific, measurable, achievable, relevant, and timebound) (Bjerke & Renger, 2017). The second session follows-up on these goals and potential difficulties or challenges students might have encountered. After students engage in guided practice exercises about these strategies, students formulate and refine their goals. The third session includes a reflection exercise using a critical incident method (Branch, 2005). Together with peers, students analyze which challenges they encountered while studying (e.g., how to manage a high amount of information; how to set a distributed study schedule) and collect ideas on how to master these challenges (e.g., focus on main parts; use an app that facilitates distributed practice). Afterward, students set specific implementation intentions, including back-up plans to initiate and facilitate the development of the habit of effective strategy use.

Principle 6: Students need guided practice and context-embedded support in using effective learning strategies

The last principle might be the most important one to support students in sustainably implementing effective learning strategies during self-study. Having the intention to engage in more effective learning strategies typically requires a substantial change from students' existing study habits. How and when can this be supported?

First, transitioning to college or university is a life transition. This can be the ideal time and context to disrupt old habits and facilitate the development of new, beneficial habits. However, as shown in chapter 6, there are great individual differences between students in their ability to adapt to changing contexts. In less supportive contexts, such as remote learning, in which students encounter many distractions, lack of resources or social support, many students are overwhelmed. To achieve the development of effective study habits in a transition phase, it is important that the new context enables effective strategy use and creates a supportive environment for beneficial learning strategies and resource management (Fiorella, 2020; Lally & Gardner, 2013). For example, teachers could start or end a lecture with a low-stakes practice test or build in reflection moments (with feedback) for students on their study behavior. Developing a new habit does not happen overnight. As shown in a study by Lally, van Jaarsveld, Potts, and Wardle (2010), building a consistent habit took participants between 18 to 254 days, depending on the complexity of the behavior. More complex behaviors, such as exercising after dinner, took longer to reach automaticity than less complex behaviors, such as drinking a glass of water after breakfast. Because using desirably difficult learning strategies can be considered a complex behavior, it is necessary to provide continuous support over a long time.

Second, guided practice can take different forms and shapes, whether provided by teachers, peers, or tools (e.g., an app). For example prompting students to regularly use practice testing by providing automatized reminders by wearable technology such as smartwatches (Cleary et al., 2021) is a promising tool to support students in actually using these strategies. Other applications, such as 'Anki' (https://apps.ankiweb.net), include smart algorithms that prompt spaced repetition and remind students regularly to practice retrieval. The role of teachers in guiding the practice of effective learning strategies should not be underestimated. Teachers can remind students of their learning goals or implement practice quizzes in their lectures to scaffold the use of effective learning strategies (Carpenter et al., 2017). However, only when teachers themselves are aware about desirable difficulties will they be able to teach their students how to study more effectively (Morehead, Rhodes, & DeLozier, 2016). Related to the challenge of 'practice what you preach', more research is needed about how to effectively implement principles of effective learning in teaching and instruction (chapter 4).

Principle 6 in Study Smart:
The Study Smart program is embedded as much as possible in students' learning contexts. Working with a train-the-trainer principle (e.g., Pearce et al., 2012), researchers are training mentors or tutors to provide the Study Smart program to their students. In small groups, first-year students attend the training sessions, which are divided across the first half of their first academic year. The advantage of such a context-embedded training program is that mentors also meet students individually, and can provide additional support or feedback on struggles students face when changing to more effective learning strategies. Addressing guided and context-embedded practice, students receive step-by-step support in using effective learning strategies. Exercises on how to write a summary using the read-recite-review method (McDaniel, Howard, & Einstein, 2009), how to generate good flashcards (Lin, McDaniel, & Miyatsu, 2018), how to use self-explanations (Dunlosky, 2013), and how to use the dual-coding method (Mayer & Anderson, 1991) are provided. By distributing the three sessions (awareness, practice, and reflection) over several weeks, students have the opportunity to try out the strategies in their own context and then return to the session to receive more support and guidance.

Methodological considerations and limitations

One strength of this thesis is the mixed-method approach. This thesis is grounded in quantitative and controlled experimental approaches (chapter 2, 3, 5, 6), but also combined with qualitative approaches (chapter 2, 4, 6), which enabled us to gain more in-depth insight into the underlying mechanisms or future challenges. Additionally, the studies of this thesis draw from different research disciplines, using methodologies from applied cognitive psychology and educational design-based research. Controlled experimental research in an educational context is challenging, due to ethical and practical considerations: All students should receive the best instruction and would be disadvantaged in a control group. As shown in chapter 2, the use of waiting-list control group designs could be a way to conduct more controlled experiments in an educational context. Waiting-list control group and mixed-methods designs are especially important for future research that aims to examine the effect of training self-regulation skills in the context and complexity of real-life higher education practice.

Another strength is that the Study Smart approach was implemented and investigated in different contexts, faculties, and countries. Starting with a small-scale, controlled experiment and then upscaling to full implementation in several curricula allowed us to examine the effects of the training program in different settings, which offers more insights and generalizability. Another aspect increasing the generalizability of the findings in this dissertation is that we investigated students' self-regulated learning under normal circumstances, but also in an extreme situation, i.e., the COVID-19 pandemic.

Of course, our studies also come with certain limitations. Specific methodological limitations of the specific studies have been discussed in the corresponding chapters. One overall limitation concerns the way in which the self-regulated use of learning strategies was measured. In this dissertation, we only used self-report measures of learning strategies or resource management. Students might have felt inclined to give more normative responses, to rate the strategies that were discussed in the program as more effective, or answers might have been biased because they were given retrospectively. Although we did not use objective measures, such as video observations, we aimed to gain a holistic picture of learning strategy use by combining and triangulating different instruments, such as weekly surveys, knowledge tests, and qualitative data. Using single measurement points might have created a biased picture of actual study behavior (Hadwin, Winne, Stockley, Nesbit, & Woszczyna, 2001; Rovers, Clarebout, Savelberg, de Bruin, & van Merriënboer, 2019). More objective measures, such as experience-sampling methods (Nett, Goetz, Hall, & Frenzel, 2012), behavioral trace data in online learning environments (Hartwig & Malain, 2022), observations in the library or think-aloud during self-study could advance the field of learning strategy research.

Furthermore, the Study Smart program, central to this dissertation, is a three-stage intervention, in which the sessions focusing on awareness, practice, and reflection build upon each other. We did not try to disentangle the effects of the single working ingredients; the effects were always investigated based on the whole program. This might be inherent in design-based research, but clashes with the standards of more experimental research. Future research could test the effect of (parts of) single elements of the program.

CONCLUSION

In this dissertation, we investigated how to support students' self-regulated use of effective, desirably difficult learning strategies. The direct learning strategy instruction (Study Smart program) aimed to support students in becoming effective, self-regulated learners and to decrease inequality between students in learning strategy skills. By creating awareness about the experienced-learning-versus-actual-learning-paradox and the importance of desirable difficulties for learning, students gained more accurate metacognitive knowledge and were stimulated to use more effective strategies during self-study. The long-term application of effective learning strategies during self-study was still challenging due to uncertainty about time, effort, and results of this behavior change. We emphasize the importance of a context-embedded learning strategy training to support students in their self-regulated use of these effortful, but more effective learning strategies. A direct learning strategy training, such as Study Smart, which is context-embedded as much as possible and supports students in their behavior change, is a first and important step. In order to stimulate sustainable change, the learning culture must change towards a culture of improvement and long-term learning, and curricula must embrace the development of self-regulation skills. Future research should be conducted to assess the efficacy of different approaches supporting students' sustained practice, as in supporting goal setting, habit formation, and addressing individual differences.

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Impact

RESEARCH SUMMARY

When entering university, many students feel overwhelmed with the amount of information they need to learn and the freedom they get in doing so. Teaching students how to learn is important. This equips them with the skills to acquire and retain new knowledge and regulate their learning more effectively and sustainably. One specific challenge in teaching students how to regulate their learning is that students' perceptions about what works best often deviates from what actually helps learning. Research has repeatedly shown that students learn best with strategies that produce so-called 'desirable difficulties' (Bjork & Bjork, 2020). Desirably difficult learning strategies initially require more effort (for example, it is more effortful to test yourself than to reread learning material), but they provide a greater learning benefit in the long term. However, many students do not know which strategies are actually effective for long-term learning, and why. Even if they do, they often avoid using them because of the additional effort it takes. Instead, students often feel that they would learn more with passive strategies, such as rereading or highlighting. Therefore, this dissertation aimed to examine how we can support students to use more effective, desirably difficult, learning strategies during their self-study.

We developed the 'Study Smart program', a direct training for students that focuses on awareness about, practice with, and reflection on desirably difficult learning strategies. Students who attended the training gained more accurate knowledge about which strategies are effective and why, and they reported using more active and effective learning strategies, such as quizzing. Students also reported struggling to sustainably implement these effective strategies during self-study. They mentioned being uncertain about how to apply the strategies in their own context, for instance. Thus, they easily fell back into old ineffective study habits and reported the lack of external support, as in no available practice questions, as one major challenge. With regard to the latter, we investigated whether students could benefit from answering their self-generated questions, in case no practice questions were provided. We conducted two experiments to assess the benefit of answering self-generated questions compared to answering provided questions or restudying and found that answering self-generated questions offered no benefit compared to restudying the text. Rereading a text once and then answering provided questions with feedback appeared to be the most effective strategy. These findings stress the importance of providing students with more external support, as in more guidance on how to make good practice questions or providing a database of relevant practice questions.

Besides this example of how to support students' practice of one specific learning strategy (retrieval practice), we also investigated the effects of the Study Smart training when implemented in different contexts and on larger scale. We found that attending the training in combination with regular follow-up support can help lower-achieving students to improve their grades over the course of their first year, compared to students from an earlier cohort that did not receive the training. When implementing a learning strategy training on a larger scale, we recommend - based on our findings - to provide the training to all students as early as possible. Ideally, the training is embedded in the context of the curriculum, which enables teachers to apply the principles of active learning and desirable difficulties in their teaching.

Furthermore, we investigated how students adapted to remote learning during the COVID-19 pandemic. We found that students differed in their ability to adapt to online learning: some students struggled to concentrate and manage their time or energy effectively (the 'overwhelmed' and 'surrenderers'). Other students just maintained their level from before the crisis (the 'maintainers') or succeeded to effectively manage their energy, keep up attention and studied successfully online (the 'adapters'). With this last study, we contributed to a better understanding of the challenges students experienced in managing and regulating their resources in online learning.

SCIENTIFIC IMPACT

The research conducted in this dissertation sets an example of how to investigate the effect of an evidence-based learning strategy training that focuses on desirable difficulties. Our findings add to previous research on self-regulated learning by demonstrating the importance of combining theory-based methods (i.e., direct instruction on the effectiveness of different learning strategies) with experience-based methods (i.e., letting students experience the benefits of different strategies), and supporting practice (i.e., guiding students in their practice with learning strategies). Future research can progress by investigating the best balance between theory- and experience-based methods to convince students about the effectiveness of desirably difficult learning strategies and to support students implementing these strategies during self-study. Furthermore, the Study Smart program has been shown to be an important first step in teaching students self-regulated learning skills. A next step is to examine how training of self-regulation skills can be integrated in the complexity of real-life higher education practice. For instance, by developing a course framework that incorporates professional development of teachers, enabling them to support their students' self-regulation skills.

The COVID-19 years have demonstrated the importance of the ability to adapt to a fast-changing world. When students were forced to study online, with less resources and support than they were used to, the importance of successful self-regulation of learning became even more evident. We showed that students differed greatly in their ability to regulate their resources (e.g., motivation, effort, attention, time) and to adapt to online learning. Our approach highlights the individual differences in self-regulated learning skills, which in turn provides a more nuanced interpretation of the data (Kusurkar et al., 2020). Future research could provide knowledge on how to deal with this heterogeneity. This could facilitate the development of more personalized interventions and customized support for students who experience different challenges in adapting to changing contexts, such as online learning.

In this dissertation, we combined different methods and perspectives, from an educational design research perspective to a cognitive psychology perspective. We combined different types of data: qualitative data from focus groups and observations and quantitative data from evaluations and self-report measures. Lastly, we combined surveys and controlled experiments. This variety of methods and perspectives demonstrates the challenges but also the richness of research in the learning sciences: to understand the working ingredients of a training on the one hand, and to bridge basic experimental and applied classroom research on the other.

SOCIAL IMPACT

This project contributes to the Maastricht University quality agreements on supporting student success and assisting students in acquiring skills to 'maintain a healthy study-life balance, stimulating a habit of personal responsibility and lifelong learning'. The insights gained from the research studies presented in chapters 2, 3, and 4 have been directly implemented in the mentor programs of different faculties at this university. As a result, students starting at Maastricht University are now taught how to study more effectively with the Study Smart program. In the future, Study Smart will be continued through a Maastricht University central project on student success and integrated with research on student advising.

The Study Smart program is also implemented in other higher education institutions in The Netherlands and abroad, and receives national and international attention and interest. It has been implemented, for example, in the Pharmacology program at Utrecht University and the University of Chapel Hill (United States), and in the Biomedical Sciences program at the University of Aveiro (Portugal). Other institutions that are interested in offering the program to their students and adapting it to their own needs and context can find more information on the website www.studysmartpbl.com.

TARGET GROUPS THAT CAN BENEFIT FROM THIS RESEARCH

Our first and foremost target group are all students in higher education, at different levels (research universities, universities of applied science) and in different study programs whom we reach by training their mentors, student counsellors, and teachers. The Study Smart program aims to make students more aware of their own learning strategies and to teach them about effective strategies for long-term learning, to support their practice of these learning strategies and to stimulate reflection on study motivation and self-regulated strategy use. We aim to teach students how to study more effectively for the long term and to enable them to become life-long learners.

Second, our findings are especially relevant for teachers, mentors and student counsellors, who can find guidelines on how to support students in studying more effectively. Support in self-regulated learning is a common topic in mentor-student meetings. However, in many study programs, mentors do not necessarily have a background on learning sciences, although they are usually experienced staff members. The Study Smart program can offer useful guidelines on how to start and continue a discussion on self-regulated learning skills with their students, and support them individually in developing an effective strategy, using findings that are based on empirical evidence.

Third, educational and curriculum designers, including course coordinators and program directors, can apply our findings in educational practice. They should facilitate the provision of practice exams and questions, and build an organizational support system for their teachers. Higher education organizations can contribute to create a study and learning environment that enables students to use effective learning strategies in an authentic context.

Fourth, educational researchers and designers could use our findings to develop a study strategy training adapted to their own context and target group.

SCIENTIFIC AND SOCIETAL ACTIVITIES

Our results would not have an impact had they not been presented or shared with others openly and regularly. Studies included in this dissertation can be accessed via published open-access manuscripts (Chapters 2, 4, 6) or are intended to be published in the near future (Chapters 3, 5) in open-access scientific journals that address a broad audience in the field of educational and cognitive psychology as well as medical and health sciences education.

All studies were presented as research paper, workshop, symposium or poster presentation at national and international scientific conferences: at the European Research Association for Learning and Instruction (EARLI) in 2019 and 2021, the

Junior researchers network of EARLI (JURE) in 2018 and 2019, the Special Interest Group for Metacognition (SIG 16) in 2018 and 2020, the International Cognitive Load Theory Conference (ICLTC) in 2019 and 2021, the American Educational Research Association Annual Meeting (AERA) in 2020, the Dutch Education Days (ORD) in 2019 and 2020, the annual meeting of the international association for medical education (AMEE) in 2019, and the annual meeting of the Dutch Association for Medical Education (NVMO) in 2019 and 2020.

In addition, I presented our findings to research colleagues during the ICO (Interuniversity center for educational sciences) conferences, the School of Health Professions Education (SHE) academies in 2018, 2019, and 2021 and other departmental meetings, such as lunch lectures in 2018 and 2020 and the Research Meet at EDLAB, the Maastricht University Institute for Educational Innovation. Moreover, I presented our research findings and implications to students in regular lectures during the well-being week at Maastricht University, or at external institutes, such as Binus University in Indonesia. I also guided a discussion about effective learning during a 'Student Meet' at EDLAB. In the last year of my PhD project, I was selected as one of 12 'Faces of Science' of the KNAW (the Royal Dutch Association of Science). I got the possibility to share my insights and views on science in general and on current topics of the learning sciences, as well as my thoughts on educational themes in blog-posts for young students (https://www.nemokennislink.nl/facesofscience/wetenschappers/felicitas-biwer/).

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Summaries

ENGLISH SUMMARY

In **chapter 1** of this thesis, we introduce the importance of supporting students' self-regulated use of effective learning strategies in higher education. While research in cognitive psychology has demonstrated the effectiveness of so-called 'desirably difficult' learning strategies for long-term learning (e.g., practice testing), many students still struggle to implement these strategies in their daily practice. This might be due to inaccurate knowledge and misleading experiences during learning, but also to a lack of direct strategy instruction or support in practicing the use of these strategies.

Five studies were conducted to determine how students can be supported in their self-regulated use of effective learning strategies following three approaches. First, by directly addressing metacognitive knowledge and beliefs about learning strategies; second, by supporting students' practice in their self-study activities; and third, by addressing the role of resource management strategies in adapting to online learning. These five studies are reported in chapters 2-6. The four guiding research questions were:

1) How does a direct learning strategy intervention addressing awareness, practice, and reflection affect students' metacognitive knowledge, use of effective learning strategies, and academic performance (Chapters 2 and 3)?
2) What are the prerequisites and challenges in implementing a learning strategy intervention on a large scale? (Chapter 4)
3) What are the effects of stimulating retrieval practice by answering self-generated practice questions compared to answering provided questions or rereading on long-term retention? (Chapter 5)
4) How did students adapt their resource management strategies to emergency remote education? (Chapter 6)

Chapter 2 aimed to gain an understanding about the effects of a direct learning strategy intervention ('Study Smart'). This intervention addresses awareness about, practice with, and reflection on effective learning strategies, especially on students' metacognitive knowledge and use of learning strategies. We tested the effects of the intervention in a pre-post waiting-list control group design with 47 undergraduate students, followed up with focus group discussions on perceived barriers and challenges. We found that the training helped students to gain more accurate metacognitive knowledge about the effectiveness of different learning strategies. Students reported using more practice testing and relied less on rereading and highlighting after having attended the training. In focus group discussions, we dove further into facilitators and barriers of a learning strategy change. Students described that the Study Smart program made them aware about which strategies are (in)effective and that a potential discrepancy with their current own strategy use motivated them to change their study behavior. Nevertheless, several factors hindered their strategy change: internal factors, such as lack of discipline or strong old habits, external factors, such as the lack of available practice questions or lack of external support, and uncertainty about the specifics of the use of a new learning strategy.

In **chapter 3**, we investigated the effect of the adapted Study Smart program in a different student population; the program was implemented for all 110 first-year students in a pharmacology curriculum. Pre-post comparisons showed that students gained more accurate metacognitive knowledge and reported to use more effective strategies, such as interleaved practice, elaboration and distributed practice, and less ineffective strategies, such as highlighting or rereading. Compared to the previous cohort, which did not receive any learning strategy instruction, students in the Study Smart cohort improved their academic performance throughout the year; differences between the top, middle, and bottom students were significantly reduced at the time of the final exam. These results suggest that a direct intervention and continuous support on use of learning strategies, especially for lower achieving students, can support students' academic success in their first year. Note that here the 20% lowest scoring students on the first midterm exam also received extra support regarding their learning strategies.

Chapter 4 describes the results of a three-year long educational design research process, in which we examined challenges in implementing the direct learning strategy intervention on a larger scale. Based on data from evaluations, focus group discussions with students and teachers, and observations and insights from train-the-trainer sessions, we distilled five common challenges of implementation. First, learning strategy instruction about evidence-based learning strategies should be provided to all first-year students. However, it is not a one-size fits all approach, but needs to take individual differences and needs in the self-regulated use of effective learning strategies into account. Second, the instruction should be provided as early as possible to facilitate effective strategy use from the beginning of a study program. One should realize that students often do not see the relevance of changing their strategies. Third, there will be resistance from students to accept the scientific information due to strong idiosyncratic ideas and naïve theories about learning strategies. Fourth, sustained practice of effective learning strategies is challenging. Behavior change processes take time and need further context-specific support, possibly inspired by habit formation interventions. Fifth, not only students, but also teachers need to learn how to implement principles of effective learning strategies in their teaching in order to practice what they preach.

In **chapter 5**, we focused on supporting practice of effective learning strategies by zooming in on one problem students often encounter when aiming to apply retrieval practice during self-study: the lack of available practice questions. In two between-subjects experiments, we examined whether answering self-generated questions would lead to a similar testing effect as answering provided questions, with a rereading control condition. We did not find a benefit of generating and answering self-generated questions over rereading. Answering provided questions was more effective for long-term learning than both answering self-generated questions and rereading, but only when students could seek feedback after initial retrieval. Both the quality of the generated questions and the level of topic overlap with posttest questions appeared to be positively related with learning outcomes when practicing retrieval with self-generated questions. We conclude that instructors should provide relevant practice questions to their students to enhance the learning effect of retrieval practice.

In **chapter 6**, we investigated the role of resource management strategies in supporting students' self-regulated use of effective learning strategies in the context of emergency remote education during the COVID-19 pandemic. One thousand eight hundred students completed a questionnaire on their resource-management strategies and indicators of (un)successful adaptation to emergency remote learning. In general, students reported experiencing more difficulties in managing time, regulating their attention and effort, and feeling less motivated than before the crisis, but they spent more time and effort in their self-study. By using a person-centered approach (cluster analysis), we identified nuanced differences between four groups of students, described as adaptation clusters: the 'overwhelmed', the 'adapters', the 'maintainers', and the 'surrenderers'. While the majority of students experienced great difficulties in their resource management because of distractions, lack of social support and feelings of isolation, students in the 'adapter' profile managed to thrive and successfully apply effective learning strategies during online education. Students' responses to open-answer questions on their educational experiences, which were coded using a thematic analysis, were consistent with the quantitative profiles. These results stress the importance of tailored interventions to support students adapting to online education and self-regulated learning.

Chapter 7 synthesizes the main findings presented in this thesis and elaborates on theoretical and practical implications. We discuss our research in light of existing self-regulated learning training programs and elaborate on the importance of combining theory-based methods (i.e., directly instructing students on the effectiveness of different learning strategies) with experience-based methods (i.e., letting students experience the benefits of different strategies) and support in practice (i.e., guiding students in their practice with learning strategies). The Study Smart program, which was central to this dissertation, can be seen as an important first step in teaching students self-regulated learning skills by adding the specifics of desirable difficulties. We discuss different routes of practical support: learning how to learn is not only a metacognitive issue, but also an issue of behavior change. As a next step, training sessions on self-regulation skills should be integrated longitudinally into curricula, and combined with professional development of teachers. Lastly, embracing heterogeneity and more person-centered approaches could advance future support of self-regulated use of effective learning strategies, and guide new research initiatives on this topic.

NEDERLANDSE SAMENVATTING

In **hoofdstuk 1** van dit proefschrift introduceren we het belang van zelfregulerend leren, en meer specifiek, de zelfregulatie van effectieve leerstrategieën in het hoger onderwijs. Onderzoek in de cognitieve psychologie heeft de effectiviteit van leerstrategieën die veel moeite kosten maar een positief effect op leren voor de lange termijn hebben (‘*desirable difficulties*’) aangetoond, bijvoorbeeld door het maken van oefentoetsen. Maar veel studenten hebben nog steeds moeite om deze strategieën zelfstandig toe te passen. Dit kan te wijten zijn aan gebrekkige kennis en misleidende ervaringen tijdens het leren, maar ook aan een gebrek aan directe instructie over effectieve leerstrategieën of ondersteuning bij het oefenen met deze strategieën.

Voor dit proefschrift werden vijf studies uitgevoerd om te onderzoeken hoe studenten ondersteund kunnen worden in het zelfregulerend gebruik van effectieve leerstrategieën; daarbij werd gebruik gemaakt van drie verschillende benaderingen. Ten eerste door direct aandacht te besteden aan metacognitieve kennis over en overtuigingen ten aanzien van leerstrategieën; ten tweede door de manier waarop studenten hun zelfstudieactiviteiten uitoefenen te ondersteunen; en ten derde door in te gaan op de rol van het reguleren van aandacht en energie (‘*resource management strategieën*’) bij het aanpassen aan online leren. Over deze vijf studies wordt gerapporteerd in de hoofdstukken 2-6. De vier leidende onderzoeksvragen waren:

1) Wat is de invloed van een directe interventie gericht op leerstrategieën, waarin aandacht wordt besteed aan bewustwording, oefening en reflectie, op de metacognitieve kennis, het gebruik van effectieve leerstrategieën en de academische prestaties van studenten? (Hoofdstukken 2 en 3)
2) Wat zijn de voorwaarden en uitdagingen bij het implementeren van een leerstrategie-interventie op grote schaal? (Hoofdstuk 4)
3) Wat zijn de effecten van oefentoetsen waarin zelfgemaakte oefenvragen beantwoord worden in vergelijking met het beantwoorden van aangeboden vragen of het opnieuw lezen van een tekst op het lange termijn leren? (Hoofdstuk 5)

4) Hoe hebben studenten hun resource management strategieën aangepast aan een plotselinge overgang naar onderwijs op afstand? (Hoofdstuk 6)

Hoofdstuk 2 had als doel om inzicht te krijgen in de effecten van een directe leerstrategie interventie (*'Study Smart'*). Deze interventie richt zich op bewustwording van, oefening met, en reflectie op effectieve leerstrategieën. In het bijzonder richt het zich op de metacognitieve kennis en het gebruik van leerstrategieën in de praktijk. We testten de effecten van de interventie in een pre-post wachtlijst controlegroep design met 47 bachelor studenten, gevolgd door focusgroep discussies over ervaren barrières en uitdagingen. We zagen dat de training studenten hielp om meer accurate metacognitieve kennis te verwerven over de effectiviteit van verschillende leerstrategieën. Studenten gaven zelf aan dat ze na het volgen van de training vaker oefentoetsen gebruikten en minder vertrouwden op herlezen en markeren van tekst. In focusgroep discussies gingen we verder in op wat een verandering van leerstrategie faciliteert of hindert. Studenten vertelden dat het Study Smart programma hen bewust maakte van welke strategieën (in)effectief zijn en dat een mogelijke discrepantie met hun huidige eigen strategiegebruik hen motiveerde om hun studiegedrag te veranderen. Desondanks was ook sprake van verschillende factoren die de verandering van hun leerstrategieën belemmerden: persoonlijke factoren zoals een gebrek aan discipline of sterke oude gewoontes, externe factoren zoals een gebrek aan beschikbare oefenvragen of aan externe ondersteuning, en onzekerheid over de specifieke kenmerken van het gebruik van een nieuwe leerstrategie.

In **hoofdstuk 3** onderzochten we het effect van het aangepaste Study Smart programma in een andere studentenpopulatie; het programma werd geïmplementeerd in een farmacologie curriculum voor alle 110 eerstejaars studenten. Pre-post vergelijkingen toonden aan dat studenten meer accurate metacognitieve kennis hadden opgedaan en dat ze vaker effectieve strategieën gebruikten, zoals gemengd leren en gespreid leren, en minder ineffectieve strategieën, zoals markeren of herlezen. Vergeleken met het voorgaande cohort, dat geen instructie kreeg over leerstrategieën, verbeterden de studenten in het Study Smart cohort hun academische prestaties gedurende het jaar; de verschillen tussen

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de studenten die het best, gemiddeld en het minst presteerden waren significant verminderd op het moment van het laatste examen. Deze resultaten suggereren dat een directe interventie en voortdurende ondersteuning bij het gebruik van leerstrategieën voor lager presterende studenten hun academisch succes in het eerste jaar kan verbeteren. Van belang is hier dat de 20% laagst scorende studenten op het eerste examen daarna extra ondersteuning kregen met betrekking tot hun leerstrategieën.

Hoofdstuk 4 beschrijft de resultaten van een drie jaar durend ontwerponderzoek (*educational design research*), gericht op de uitdagingen tijdens het implementeren van de directe leerstrategie interventie op een grotere schaal. Op basis van gegevens uit evaluaties, focusgroep discussies met studenten en docenten, en observaties en inzichten uit train-de-trainer sessies, distilleerden we vijf vaak voorkomende uitdagingen in het implementatie proces. Ten eerste, de instructie over effectieve leerstrategieën zou moeten worden aangeboden aan alle eerstejaars studenten. Het is echter geen 'one-size-fits-all' aanpak; er moet rekening worden gehouden met individuele verschillen en behoeften bij het leren gebruiken van effectieve leerstrategieën. Ten tweede zou de instructie zo vroeg mogelijk in het eerste jaar gegeven moeten worden om effectief strategiegebruik vanaf het begin van een studieprogramma te bevorderen. Daarbij moet men zich realiseren dat studenten vaak niet meteen de relevantie van het veranderen van hun leerstrategieën inzien. Ten derde moet rekening gehouden met weerstand vanwege sterke idiosyncratische ideeën en naïeve gedachten over leerstrategieën. Ten vierde is het volhouden van oefenen met effectieve leerstrategieën een uitdaging. Gedragsveranderingsprocessen vergen tijd en hebben extra contextspecifieke ondersteuning nodig, mogelijk geïnspireerd door interventies gericht op gedragsverandering. Ten vijfde zouden niet alleen studenten, maar ook docenten moeten leren hoe ze principes van effectieve leerstrategieën in hun onderwijs kunnen verwerken ('*practice what you preach*').

In **hoofdstuk 5** hebben we ons gericht op het ondersteunen van het oefenen met effectieve leerstrategieën door in te zoomen op een probleem waar studenten vaak tegenaan lopen als ze oefentoetsen zouden willen toepassen tijdens hun zelfstudie: het gebrek aan beschikbare oefenvragen. In twee experimenten onderzochten we of het beantwoorden van zelfgemaakte vragen over een bestudeerde tekst tot een vergelijkbaar toetsingseffect zou leiden als het beantwoorden van aangeboden vragen; het herlezen van de tekst diende als controle conditie. We vonden geen voordeel van het zelf maken en beantwoorden van vragen ten opzichte van het herlezen. Het beantwoorden van aangeboden vragen bleek effectiever voor lange termijn leren te zijn dan het beantwoorden van zelfgemaakte vragen of het herlezen van de tekst, maar alleen wanneer studenten na het beantwoorden feedback op hun antwoorden kregen. Bij het oefenen met zelfgemaakte vragen bleken zowel de kwaliteit van de zelfgemaakte vragen als de mate van thematische overlap met de vragen in de uiteindelijke toets positief gerelateerd te zijn aan het resultaat op die toets. We concluderen dat docenten relevante oefenvragen aan hun studenten zouden moeten aanbieden om het leereffect van oefentoetsen te vergroten.

In **hoofdstuk 6** onderzochten we de rol van resource management strategieën in het ondersteunen van het zelfregulerend gebruik van effectieve leerstrategieën in de context van de plotselinge overgang naar online onderwijs tijdens de COVID-19 pandemie. Duizend-achthonderd studenten vulden een vragenlijst in over hun resource management strategieën en over hoe ze zich aanpasten aan onderwijs op afstand. In het algemeen gaven studenten aan meer moeite te hebben met tijdsmanagement en het reguleren van hun aandacht en energie; ook voelden ze zich minder gemotiveerd dan voor de crisis. Met behulp van een persoonsgerichte aanpak (clusteranalyse) identificeerden we verschillen tussen vier groepen studenten, aangeduid als de volgende vier clusters: de 'overweldigden', de 'aanpassers', de 'volhouders', en de 'opgevers'. Terwijl de meerderheid van de studenten grote moeite had met online studeren ten gevolge van afleiding, een gebrek aan sociale steun en gevoelens van isolatie, slaagden studenten in het 'aanpassers'-profiel erin om effectieve leerstrategieën toe te passen tijdens het online onderwijs. De antwoorden van studenten op open vragen over hun onderwijservaringen, die werden gecodeerd met behulp van een thematische analyse, waren consistent met de kwantitatieve profielen. Deze resultaten benadrukken het belang van op maat gesneden interventies om studenten bij de aanpassing aan online onderwijs en zelfregulerend leren goed te kunnen ondersteunen.

Hoofdstuk 7 geeft een gecombineerde samenvatting van de belangrijkste bevindingen in dit proefschrift en gaat in op theoretische en praktische implicaties. We bespreken ons onderzoek in het licht van bestaande trainingsprogramma's voor zelfregulerend leren en gaan in op het belang van het combineren van op theorie gebaseerde methoden (d.w.z. studenten direct instrueren over de effectiviteit van verschillende leerstrategieën) met op ervaring gebaseerde methoden (d.w.z. studenten de voordelen van verschillende strategieën laten ervaren) en ondersteuning in de praktijk (d.w.z. studenten begeleiden in het oefenen met leerstrategieën). Het Study Smart programma, dat centraal stond in dit proefschrift, kan gezien worden als een belangrijke eerste stap in het aanleren van zelfregulerende leervaardigheden aan studenten door de specifieke kenmerken van 'desirable difficulties' toe te voegen. We bespreken verschillende routes van praktische ondersteuning: leren hoe te leren is niet alleen een metacognitieve kwestie, maar ook een kwestie van gedragsverandering. Als volgende stap moeten trainingen in zelfregulatievaardigheden over de breedte geïntegreerd worden in curricula, en gecombineerd met professionaliseringsactiviteiten voor leerkrachten. Ten slotte zou het omarmen van diverse en meer persoonsgerichte benaderingen de toekomstige ondersteuning van zelfregulerend gebruik van effectieve leerstrategieën kunnen bevorderen, en richting kunnen geven aan nieuwe onderzoeksinitiatieven over dit onderwerp.

DEUTSCHE ZUSAMMENFASSUNG

In **Kapitel 1** dieser Dissertation stellen wir die Bedeutung des selbstregulierten Lernens vor und erklären, wie wichtig es ist, Studierende im Gebrauch effektiver Lernstrategien zu unterstützen. Forschungen in der kognitiven Psychologie haben die Wirksamkeit von Lernstrategien gezeigt, die zwar einen hohen Aufwand erfordern, sich aber positiv auf das langfristige Lernen auswirken („*desirable difficulties*"). Ein Beispiel einer „erwünscht schwierigen" Lernstrategie ist das aktive Abrufen von Information aus dem Gedächtnis durch Übungstests. Vielen Studierenden fällt es jedoch schwer, diese Strategien selbstständig anzuwenden. Dies kann auf unzureichendes Wissen und irreführende Erfahrungen beim Lernen zurückzuführen sein, aber auch auf fehlendes Strategietraining oder mangelnde Unterstützung beim Üben dieser Strategien.

Im Rahmen dieser Dissertation wurden fünf Studien durchgeführt, um zu untersuchen, wie Studierende bei der selbstgesteuerten Anwendung effektiver Lernstrategien unterstützt werden können. Als erstes wurde die direkte Instruktion zu metakognitivem Wissen und Überzeugungen über die Effektivität von verschiedenen Lernstrategien untersucht. Als zweites wurden Studierende beim Üben der Lernstrategien unterstützt. Als drittes wurde die Rolle von Ressourcenmanagementstrategien bei der Anpassung an das Online-Lernen erforscht. Über diese fünf Studien wird in den Kapiteln 2-6 berichtet. Die vier leitenden Forschungsfragen lauteten:

1) Welchen Effekt hat ein direktes Lernstrategietraining auf das metakognitive Wissen, den Gebrauch effektiver Lernstrategien und die akademischen Leistungen von Studierenden? (Kapitel 2 und 3)?
2) Was sind die Voraussetzungen und Herausforderungen bei der Umsetzung eines Lernstrategietrainings in großem Maßstab? (Kapitel 4)
3) Welchen Lerneffekt haben Abrufübungen beim Beantworten selbst erstellter Übungsfragen im Vergleich zum Beantworten vorgegebener Fragen oder zum wiederholten Lesen? (Kapitel 5)

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4) Wie haben Studierende ihre Ressourcenmanagementstrategien an den plötzlichen Übergang zum Distanzunterricht angepasst? (Kapitel 6)

In **Kapitel 2** wurde der Effekt eines direkten Lernstrategietrainings (‚Study Smart') untersucht. Das Training hat zum Ziel Studierende über die Effektivität verschiedener Lernstrategien bewusst zu machen und sie in der Anwendung davon durch Übung und Reflexion zu unterstützen. Wir untersuchten den Effekt des Trainings auf das metakognitive Wissen und den Gebrauch effektiver Lernstrategien in einem Prä-Post Design mit Wartelisten-Kontrollgruppe mit insgesamt 47 Bachelor-Studierenden. Nach dem Posttest organisierten wir Fokusgruppendiskussionen über erfahrene Herausforderungen bei der Anwendung effektiver Lernstrategien. Wir fanden heraus, dass das Training den Studierenden half, genaueres metakognitives Wissen über die Wirksamkeit verschiedener Lernstrategien zu erlangen. Die Studierenden berichteten, dass sie nach dem Training mehr Übungstests benutzten und weniger passive Lernstrategien benutzten, wie z.B. Texte mehrmals lesen oder unterstreichen. In den Fokusgruppendiskussionen berichteten die Studierenden, dass das Study Smart Programm sie bewusst darübergemacht hat, welche Strategien (in)effektiv sind, und dass es sie motivierte, ihr Lernverhalten zu ändern. Dennoch gab es mehrere Faktoren, die den Strategiewechsel behinderten: interne Faktoren, wie z.B. mangelnde Disziplin oder starke alte Gewohnheiten, externe Faktoren, wie z.B. der Mangel an verfügbaren Übungsfragen oder der Mangel an externer Unterstützung, und Unsicherheit über die spezifische Anwendung einer neuen Lernstrategie.

In **Kapitel 3** untersuchten wir die Wirkung des überarbeiteten Study Smart Trainings in einer anderen Studentenpopulation. Das Training wurde für alle 110 Erstsemester eines Pharmakologie-Studiengangs eingeführt. Prä-Post-Vergleiche zeigten, dass die Studierenden genaueres metakognitives Wissen erwarben und angaben, effektivere Strategien wie verschachteltes Lernen (‚Interleaved Practice'), Selbsterklärungen und verteiltes Lernen (‚Distributed Practice') und dabei weniger ineffektive Strategien wie Unterstreichen oder wiederholtes Lesen zu verwenden. Im Vergleich zur vorigen Kohorte, die kein Lernstrategietraining erhielt, verbesserten die Studierenden der Study Smart Kohorte ihre akademischen Leistungen im Laufe des Jahres. Die Unterschiede zwischen den besten, mittleren und schlechtesten Studierenden waren zum Zeitpunkt der Abschlussprüfung deutlich geringer. Diese Ergebnisse deuten darauf hin, dass ein direktes Lernstrategietraining und kontinuierliche Unterstützung bei der Anwendung von Lernstrategien, insbesondere für leistungsschwächere Studierende, deren akademische Leistungen verbessern kann.

In **Kapitel 4** werden die Ergebnisse eines dreijährigen Designforschungsprozesses (‚*Educational Design Research*') beschrieben, in dem wir die Herausforderungen bei der Umsetzung des Lernstrategietrainings in größerem Maßstab untersucht haben. Auf der Grundlage von Daten aus Evaluierungen, Fokusgruppendiskussionen mit Studierenden und Dozenten sowie Beobachtungen und Erkenntnissen aus den Dozent-Trainingen haben wir fünf Herausforderungen ausgearbeitet. Als erstes sollte allen Studienanfängern ein Lernstrategie-Training über evidenzbasierte Lernstrategien angeboten werden. Es handelt sich dabei jedoch nicht um einen Einheitsansatz, sondern es müssen die individuellen Unterschiede und Bedürfnisse beim selbstregulierten Gebrauch effektiver Lernstrategien berücksichtigt werden. Als zweites sollte das Training so früh wie möglich stattfinden, um Studierende von Beginn des Studiums an so gut wie möglich zu unterstützen. Man sollte sich hierbei darüber im Klaren sein, dass Studierende oft die Relevanz einer echten Verhaltens- und Strategieveränderung (noch) nicht erkennen. Als drittes muss man beachten, dass sich Studierende mit starken idiosynkratrischen Vorstellungen und naiven Theorien über Lernstrategien weigern, die wissenschaftliche Information direkt zu akzeptieren. Als viertes ist die dauerhafte Anwendung effektiver Lernstrategien eine Herausforderung. Nachhaltige Verhaltensänderung braucht Zeit und weitere kontextspezifische Unterstützung. Als fünftes müssen nicht nur Studierende, sondern auch Dozenten lernen, wie sie die Prinzipien effektiver Lernstrategien in ihrem Unterricht umsetzen können, um das zu praktizieren, was sie predigen.

In **Kapitel 5** haben wir uns darauf konzentriert, die Anwendung effektiver Lernstrategien zu unterstützen. Wir haben dabei ein Problem näher beleuchtet, auf das Studierende häufig stoßen, wenn sie während ihres Selbststudiums Übungstests verwenden möchten: den Mangel an verfügbaren Übungsfragen. In zwei Experimenten wurde untersucht, ob die Beantwortung selbst erstellter Fragen zu einem ähnlichen Testeffekt führen würde wie die Beantwortung vorgegebener Fragen. Die Kontrollbedingung war das Wiederlesen der Texte. Wir konnten keinen Vorteil des Erstellens und Beantwortens selbst erstellter Fragen gegenüber dem Wiederlesen feststellen. Die Beantwortung vorgegebener Fragen schien für das langfristige Lernen effektiver zu sein als die Beantwortung selbst erstellter Fragen oder das erneute Lesen des Textes, allerdings nur, wenn die Studierenden nach der Beantwortung Feedback zu ihren Antworten erhielten. Beim Üben mit selbst erstellten Fragen wurde festgestellt, dass sowohl die Qualität der selbst erstellten Fragen als auch der Grad der thematischen Überschneidung mit den Fragen im endgültigen Test positiv mit dem Ergebnis des Tests zusammenhängt. Zusammenfassend sollten Dozenten ihren Studierenden relevante Übungsfragen zur Verfügung stellen, um den Lerneffekt der Abrufübungen zu erhöhen.

In **Kapitel 6** untersuchten wir die Rolle von Ressourcenmanagement-Strategien bei der Anpassung an plötzlichen Distanzunterricht während der COVID-19-Pandemie. Eintausendachthundert Studierende füllten einen Fragebogen zu ihren Ressourcenmanagementstrategien und Indikatoren für eine (un)erfolgreiche Anpassung an den Distanzunterricht aus. Im Allgemeinen berichteten die Studierenden über größere Schwierigkeiten beim Zeitmanagement und bei der Regulierung ihrer Aufmerksamkeit und Energie; sie fühlten sich auch weniger motiviert als vor der Pandemie. Mithilfe eines personenzentrierten Ansatzes (Clusteranalyse) konnten wir Unterschiede zwischen vier Gruppen von Studierenden feststellen: die „Überforderten", die „Anpassungsfähigen", die „Durchhalter" und die „Aufgeber". Während die Mehrheit der Studierenden aufgrund von Ablenkung, mangelnder sozialer Unterstützung und Gefühlen der Isolation große Schwierigkeiten hatte, gelang es den Studierenden des Profils der „Anpassungsfähigen", während des Distanzunterrichts erfolgreich effektive Lernstrategien anzuwenden. Die Antworten der Studierenden auf offene Fragen zu ihren Lernerfahrungen, die mithilfe einer thematischen Analyse ausgewertet wurden, stimmten mit den quantitativen Profilen überein. Diese Ergebnisse machen deutlich, wie wichtig maßgeschneiderte Interventionen sind, um

Studierende bei der Anpassung an Distanzunterricht und im selbstregulierten Lernen passend zu unterstützen.

Kapitel 7 fasst die wichtigsten Ergebnisse dieser Arbeit zusammen und geht auf theoretische und praktische Implikationen ein. Wir erörtern unsere Forschungsergebnisse vor dem Hintergrund bestehender Trainingsprogramme für selbstreguliertes Lernen und erläutern, wie wichtig es ist, theoriegestützte Methoden (d. h. durch direktes Lernstrategietraining) mit erfahrungsgestützten Methoden (d. h. Studierende die Vorteile verschiedener Strategien erfahren zu lassen) und Unterstützung in der Praxis (d. h. Studierende bei der Anwendung von Lernstrategien anzuleiten) zu kombinieren. Das Study-Smart-Programm, das im Mittelpunkt dieser Dissertation stand, kann als ein wichtiger erster Schritt bei der Vermittlung von Fähigkeiten zum selbstregulierten Lernen an Studierende angesehen werden, indem es die Besonderheiten der ‚*desirable difficulties*' berücksichtigt. Wir erörtern verschiedene Wege der praktischen Unterstützung: Lernen, wie man lernt, ist nicht nur eine metakognitive Frage, sondern auch eine Frage der Verhaltensänderung. Als nächster Schritt sollten Trainingseinheiten zu Selbstregulationsfähigkeiten langfristig in die Lehrpläne integriert und mit der beruflichen Weiterbildung von Dozenten kombiniert werden. Zudem könnten stärker personenzentrierten Ansätze die künftige Unterstützung des selbstregulierten Gebrauchs effektiver Lernstrategien fördern und neue Forschungsinitiativen zu diesem Thema anleiten.

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Appendices

ACKNOWLEDGMENTS / DANKWOORD / DANKWORT

There are many people who contributed to this dissertation. I want to thank all students, teachers, mentors, and course coordinators who shared their experiences and put time and effort in participating in this research. Without you, this work would not have been possible.

To my wonderful supervisor team: Anique, Mirjam, and Wisnu. Thank you for all your support, energy, critical thoughts, discussions and always open doors (or zoom-rooms). I am very grateful for your supervision and your guidance.

Anique, je belde me nog op de avond van mijn sollicitatiegesprek dat ik was aangenomen voor de PhD-positie. Ik wilde er toch eerst nog even over nadenken en had nog wat vragen, maar ik ben ontzettend dankbaar dat ik deze en zo veel andere kansen van jou heb gekregen. Wat had mijn leven er nu anders uit gezien! Ik heb heel veel van jou als begeleider en mentor mogen leren. Dank je wel voor alle kansen die je mij geeft en je vertrouwen.

Mirjam, ik gun iedereen die promoveert een promotor zoals jij in het team. Je hield altijd overzicht, zelfs als ik het even kwijt was, en tegelijkertijd had je het nodige oog voor details in mijn manuscripten. Dank voor je enthousiasme, je ondersteuning en positieve blik. Dit deed altijd goed.

Wisnu, what a lucky person I am that you joined our team. Unfortunately, your time in Maastricht was limited, but as we found out along the way, it did not make any difference that you were at the other side of the globe. I enjoyed our weekly meetings, learned a lot from your critical view and scientific thinking and hope we will continue working together!

Pauline, het eerste jaar van mijn promotietraject heb jij als copromotor een belangrijke rol gespeeld in het opstarten van het project. Ik denk met veel plezier

terug aan onze gezamenlijke workshop in Wageningen en je enthousiasme over Study Smart. Dank je wel.

To all SRL lab members: Sanne R., Luotong, Lucy, Jonas, Erdem, Héctor, Louise, and Tian, a big thank you for all your input, critical thoughts and fun discussions. I always looked forward to our bi-weekly meetings, picnics in the park and coffee-walks, and I learned a lot from all your projects, ideas and perspectives.

To all Study Smart project members from the first hour. Thank you for all the opportunities and your support in implementing and doing research in all different faculties. In het speciaal dank aan Walter, voor je rust, je organisatietalent en je ondersteuning in het hele project.

Sanne S., ik ben heel blij dat je deel maakte van het Study Smart team. Het was heel fijn om samen met jouw enthousiasme het Study Smart programma verder te ontwikkelen, bij de universiteit én on tour. Dank je wel!

Yoka, dank je wel voor je ondersteuning en onze wekelijkse meetings over Study Smart, ik kon veel van jou leren en samen met je aanpakken.

Harm, Stella, and Matthijs: thank you for the fruitful collaboration on the UM.online project, your openness and your support in getting to know how 'our' students deal with online learning.

To the members of the EFG 3 monitoring and regulation of effort group: I learned a lot from our exchange and discussions and I am grateful for being part of such a diverse, social and smart group of researchers. Thank you.

Besonders möchte ich auch Alexander Renkl für die gute Lehre und Ausbildung bedanken und dass Sie mich nach Maastricht empfohlen haben.

An die AG6 Multiple Repräsentationen am IWM in Tübingen. Katharina, danke, dass ich eure Forschungsgruppe besuchen durfte, ich habe viel gelernt über Experimentdesign und Forschung in Deutschland. Emely, danke dass du mich so herzlich aufgenommen und mir alles gezeigt hast. Ich hoffe, dass wir in der Zukunft noch viel zusammenarbeiten können!

To all great O&O and SHE colleagues, thank you for the warm and open atmosphere in our department. I felt welcome from the first minute and am thankful for all opportunities I got. Grote dank aan het geweldige Doc-Prof team Herma, Pascal, Wilma, Lianne, Maarten, Karen, Ruth, Astrid, Sophie en Cintha voor alles wat ik bij jullie mocht leren. Thank you Maryam for organizing the SHE journal club together. Onmisbaar en altijd een open deur voor alle vragen die ik had waren Nicky, Hennie, Lilian, Audrey, Eveline, Maurice, Ruud, en Joost; dank jullie wel voor jullie ondersteuning.

A big thanks to all fellow SHE PhD colleagues, internal and external, past and present. Serge, Koos, Jolien, Derk, Stephanie, Anique, HQ, Guy, Tiuri, Emmaline, Suzanne, Cindy, Joy, Andrea, Lorette, Eveline, Yuanyuan, Hao, Fury, Fatemeh, Fengyuan: thank you for the PhD-platforms, the coffee and lunch walks, the PhD trips to Brussels, Antwerp, and Nijmegen, the conference visits, the 'ambtenaren-carnaval', the daily chat's and the 'gezelligheid'. Lianne, dank je wel voor de koffie-dates, naai- en haakadvies en je altijd open deur! Carolin, danke für die vielen gemeinsamen Spaziergänge und Gespräche in 'Deutsch-Niederländischem Kauderwelsch' was keiner so gut versteht wie du. Michelle, je vrolijkheid en enthousiasme is aanstekelijk, dankjewel voor je luisterend oor en de gezelligheid!

Thank you to all my friends for checking in, thinking along, and for celebrating small and large successes together. Danke, Corinna, Lea, und Maria fürs Mitfiebern, zusammen wandern, reisen, und endlos quatschen. Danke Anne, Martin und Marlen fürs Zuhören und Erzählen, gemeinsame Chorerlebnisse und Ausflüge, und besonders für ganz viel Gemütlichkeit und Gesellschaft in meiner Zeit in Tübingen. Danke Jakob, Bene, Daniel, Hannah, Jana, und Michi für unsere

alljährliche Weihnachtsfeier und das Teilen der großen Meilensteine im Leben. Dank aan Raoul en Maud voor de gezellige etentjes en vrolijkheid!
And to the best university choir of Maastricht: a special thanks to Wim, Noah, Menno, Daan, Anne, Clara, Philipp, Philibert, Lucie, Saskia, Anne-Charlotte and Charles. Taking my mind off from work when singing made me for sure more productive and happy in the end!

Mijn lieve kamergenoten die nog zo veel meer zijn geworden dan alleen maar kamergenoten: Sam en Juliët. Sam, je verwelkomde me zo hartelijk op onze kamer, je leerde mij Nederlands en verbetert mij nog steeds (waarvoor dank!), je introduceerde de Nederlandse cultuur als niemand anders en je bent in de loop van de jaren een heel dierbare vriendin geworden. Juliët, jij had vrij snel door dat ik toch niet zo'n 'serieuze Duitse vrouw' was en ik ben je heel dankbaar voor het samen zingen, lachen, praten, en boomstammen stelen. Wat ben ik blij dat jullie altijd, en op de dag van mijn verdediging zelfs letterlijk, achter mij staan.

Mijn lieve schoonfamilie, Annemieke, Joep, Daan, Matthijs, Irene, en Lotte, jullie maken dat ik me thuis voel in het mooie Limburg. Heel veel dank voor alle zondag-diners, wandelingen, familie-weekendjes, naai-acties, spel-avonden en altijd luisterend oor.

Liebe Oma, auch konntest du dir nicht so genau vorstellen was ich eigentlich in meinem PhD mache, du warst immer interessiert. Danke für die Maultaschen und Spätzle, die warmen Socken und Handschuhe und deine lieben Berichte die so manche kalten Tage fröhlicher gemacht haben.

Liebe Anne Sophie, lieber Johannes. Ohne eure Hilfe bei der Lastminute Bewerbung wäre ich wahrscheinlich gar nicht nach Maastricht gekommen, und was hätte ich da verpasst! Danke, dass ihr mich aus der Ferne unterstützt. Auch sehen wir uns viel zu selten, weiß ich, dass ihr immer für mich da seid. Ich bin sehr stolz und dankbar, dass ich die Patentante von Charlotte sein darf.

Und meine lieben Eltern, die immer für mich da und meine größte Unterstützung sind. Lieber Papa, danke für die Diskussionen und Gespräche (ohne dich wäre meine wissenschaftliche Karriere bestimmt nicht so schnell begonnen), dein Interesse und Begeisterung in alles was ich mache. Liebe Mama, dir kann ich alles erzählen und unsere täglichen Telefongespräche sind mir unglaublich wichtig. Du bist immer für mich da und auch aus der Ferne weißt du immer die richtigen Worte zu finden. Danke für eure Liebe, die unendliche Unterstützung und das warme Zuhause.

Lieber Caspar, je bent mijn steun en toeverlaat, de beste quarantaine-buddy, partner in crime, mon bon mari en beste vriend die ik me kan voorstellen. Dank je wel voor je ondersteuning, dat je onze tuin zo mooi hebt gemaakt terwijl ik zat te schrijven, dat je mij de nodige afleiding gaf, mij regelmatig hebt uitgelaten en dat je zo trots op me bent. Ik kijk heel erg uit naar onze toekomstige avonturen.

ABOUT THE AUTHOR

Felicitas Biwer was born on May 5, 1992 in Bonn, Germany. After attending high school in Trier, she moved to Freiburg im Breisgau to study Psychology. She holds a Bachelor's degree in Psychology and a Research Master's degree in Cognitive and Educational Psychology from Albert-Ludwigs-Universität Freiburg, Germany. During her Master studies, Felicitas spent one year at Carleton University, Ottawa, where she became interested in connecting applied and fundamental education research. She specialized in her master thesis in educational psychology and graduated in 2017. Felicitas began her research for her PhD project in 2017 at the School of Health Professions Education.

In her PhD research, Felicitas investigated how to support students using effective study strategies for long-term learning. During her PhD trajectory, Felicitas was project member of the Study Smart team at Edlab, Maastricht University's institute for educational innovation. In her role as trainer, she gave workshops, train-the-trainer sessions and program sessions in and outside the university. She also obtained her University Teaching Qualification and started teaching and mentoring in health sciences, biomedical sciences, and the Master of Health Professions Education. She is member of the Emerging Field Group Monitoring and Regulating Effort, by the Jacobs Foundation. Felicitas has been invited to present her research at various international conferences and symposia. In 2021, she went for a research visit at the Leibniz Institut für Wissensmedien in Tübingen, Germany, at the research group for multiple representations led by Prof. dr. Katharina Scheiter. Felicitas has been recently selected as one of 12 'faces of science' by the Royal Dutch Association of the Sciences (KNAW) and aims to communicate her research to enthousiast high school students for science.

Felicitas is currently working as a post-doc researcher at SHE, Maastricht University, and combines her research on effort regulation with her project work on implementing and further developing the Study Smart program.

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Biwer, F., de Bruin, A., Aalten, P., & oude Egbrink, M. (2018). Study smart – How to improve students' learning strategies in higher education. *Poster session, JURE 2018,* Antwerp, Belgium.

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Awards and nominations

2021	Selected for 'Face of Science 2021', Royal Dutch Society of Science
2021	Selected for participation at the PULSE 2021 symposium for early career researchers
2020	Nomination for the best practice paper award at NVMO conference online
2019-present	Member of the EARLI Emerging Field Group "Unifying cognitive load and self-regulated learning research: monitoring and regulation of effort"
2018	Nomination for the best post award at SIG 16 Metacognition conference, Zurich, Switzerland

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