Journal of Applied Research in Memory and Cognition 9 (2020) 186–203

Contents lists available at ScienceDirect

Journal of Applied Research in Memory and Cognition

journal homepage: www.elsevier.com/locate/jarmac

Empirical article

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

Felicitas Biwer*, Mirjam G.A. oude Egbrink, Pauline Aalten, and Anique B.H. de Bruin

Maastricht University, The Netherlands

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.

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 2-h 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.

Keywords: Desirable difficulties, Learning strategies, Intervention program, Metacognitive knowledge, University students

Author Note.

* Correspondence concerning this article should be addressed to Felicitas Biwer, Department of Educational Development and Research, FHML, Maastricht University, Universiteitssingel 60, 6229 ER Maastricht, Postbus 616, 6200 MD Maastricht, The Netherlands.

E-mail address: f.biwer@maastrichtuniversity.nl (F. Biwer).

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 1).

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 and 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, 2019; 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

Table 1
Overview of 10 commonly used learning strategies, ordered in their effectiveness for long-term learning (based on Dunlosky, Rawson, Marsh, Nathan, & Willingham, 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

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 (2019) 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 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. ($M \pm SD$); 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

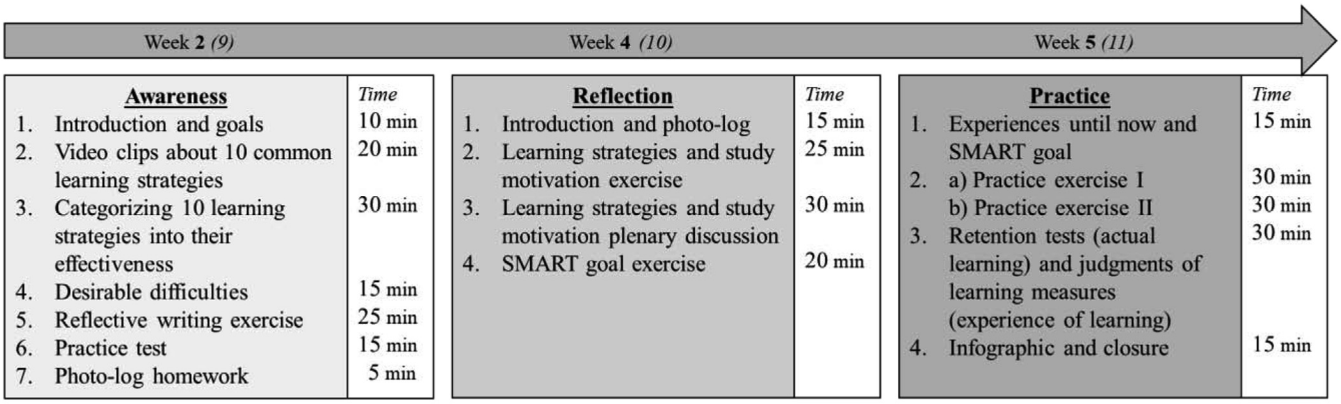

Figure 1. Overview of the 'Study Smart' intervention program.

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 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 2 h 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 1 for an overview of the learning strategies targeted in the intervention.

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 s 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; Nunes & 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 behavior 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 min, 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-h 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 $\kappa = .86$ in the pretest and Cohen's Kappa $\kappa = .90$ 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 $\alpha = .82$) and the item "I use summaries written by somebody else" (new Cronbach's $\alpha = .59$) 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). The focus group sessions lasted 60–90 min. 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

The study procedure is illustrated in Figure 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 min. 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

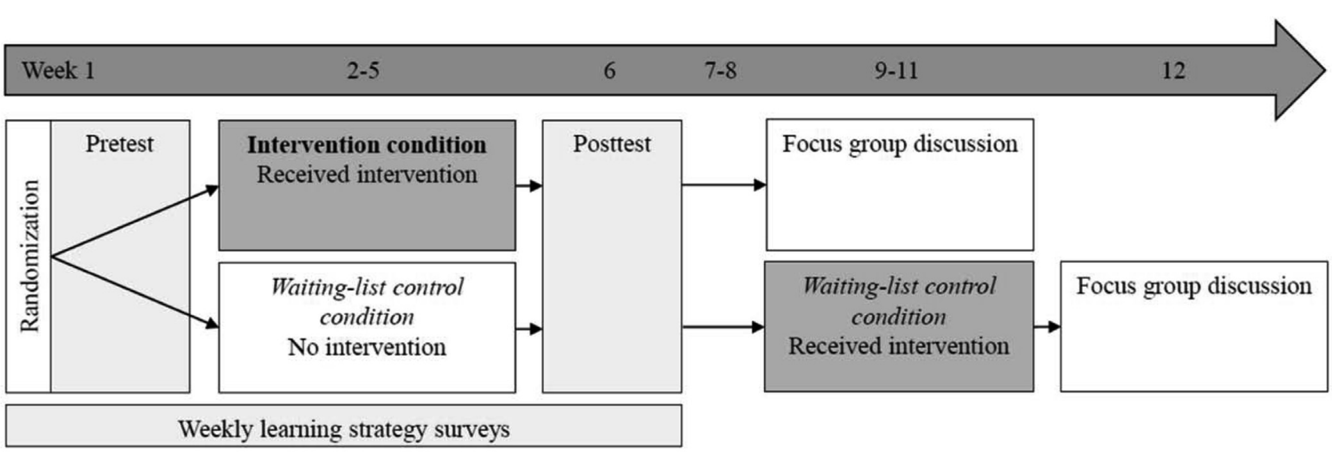

Figure 2. Overview of the study procedure, in which the Study Smart program represents the intervention.

Table 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 $*p < .05$; $**p < .01$; $*** p < .001$.

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.

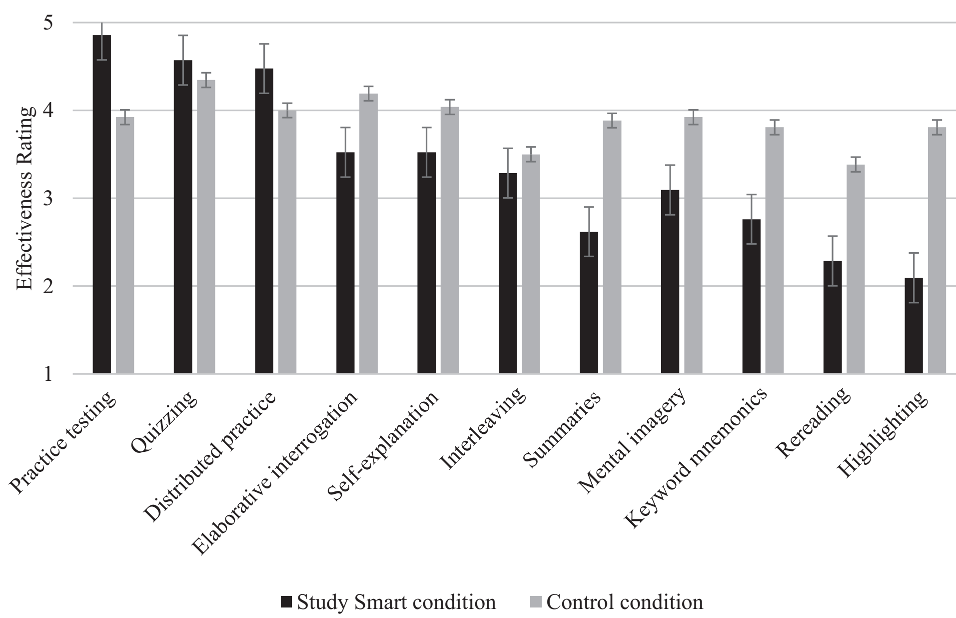

Figure 3. Average posttest ratings of to what extent students think the strategies are effective for long-term learning, from 1 (not at all effective) to 5 (extremely effective). Strategies are ordered in their (approximate) effectiveness for long-term learning from left (highly effective) to right (less effective); see Table 1 for more detail. Error bars represent standard errors of the mean.

Both time, $F(11, 35) = 5.89$, $p < .001$, $\eta_p^2 = .65$, and the time × 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 3 for an overview of the posttest ratings for both conditions.

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 3.

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.

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 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 $(SD)_{\text{post}} = 1.88$ (1.02).

Effects on Use of Effective Learning Strategies

With regard to the extent of use of the learning strategies, we conducted an 11 (strategies) × 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 4.

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 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 6 shows the differences in strategy use between conditions using the posttest ratings.

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 × 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 5.

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

Table 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 $^*p < .05$; $^{**}p < .01$; $^{***}p < .001$.

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 7 and depicts the interpretation of the qualitative data.

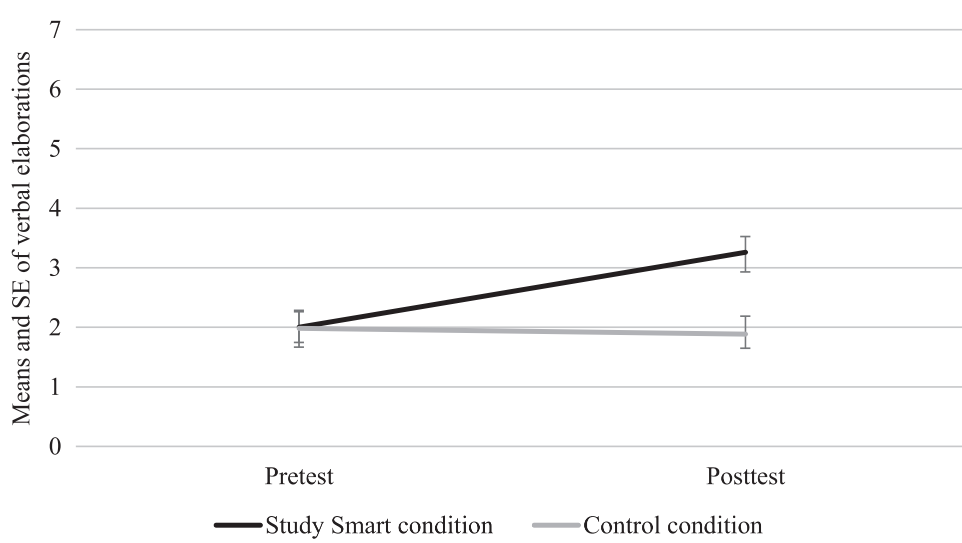

Figure 4. Average pre- to posttest elaboration scores on scenario ratings, from 0 (no correct explanation) to 7 (correct explanations for all seven scenarios). Error bars represent standard errors of the mean.

Table 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 $^*p < .05$; $^{**}p < .01$; $^{***}p < .001$.

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.

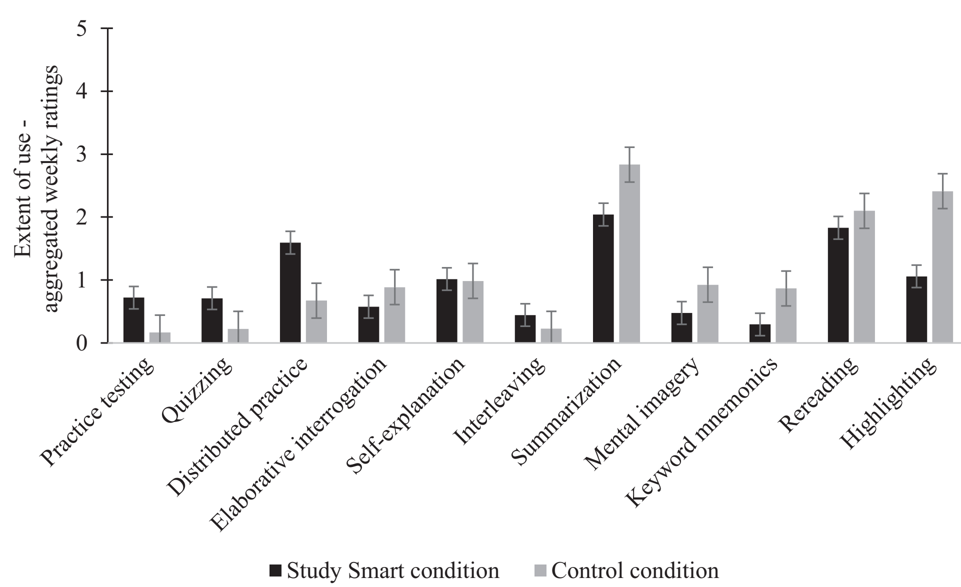

Figure 5. Average aggregated weekly ratings of to what extent students used the learning strategies, according to the weekly learning strategy surveys, from 0 (never used) to 5 (very often), indicated per condition. Strategies are ordered in their (approximate) effectiveness for long-term learning from left (highly effective) to right (less effective); see Table 1 for more detail. Error bars represent standard errors of the mean.

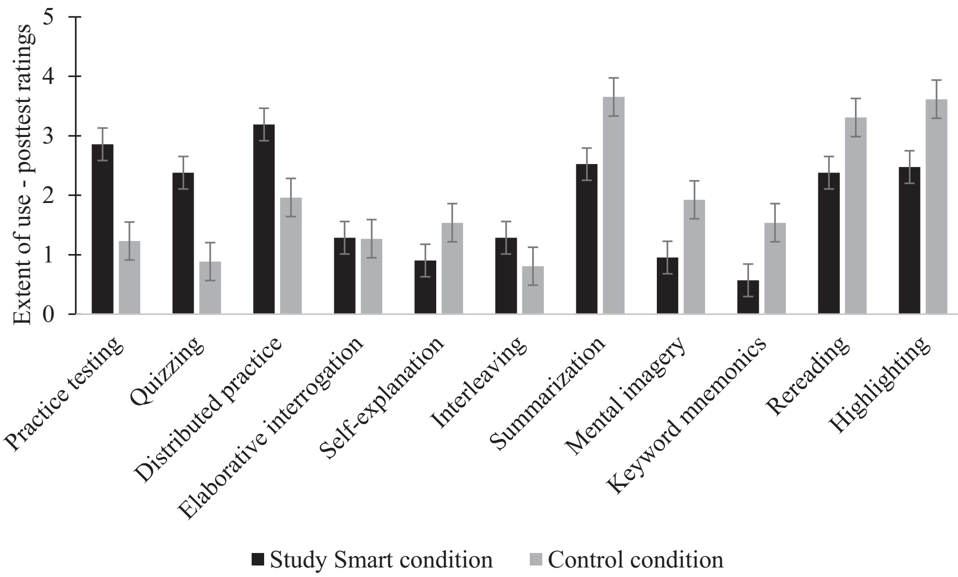

Figure 6. Average posttest ratings of to what extent students used the learning strategies, from 0 (never used) to 5 (very often), indicated per condition. Strategies are ordered in their (approximate) effectiveness for long-term learning from left (highly effective) to right (less effective); see Table 1 for more detail. Error bars represent standard errors of the mean.

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

Table 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 $*p < .05$; $**p < .01$; $***\ p < .001$.

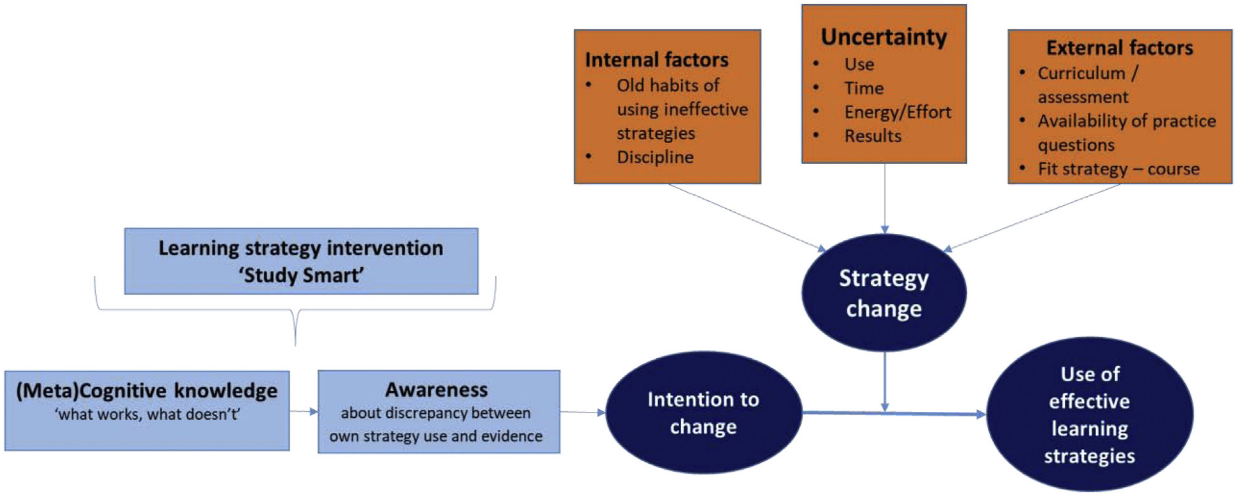

Figure 7. Barriers and facilitators in using effective learning strategies.

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 toward 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 Figures 5 and 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.

Conflict of Interest Statement

The author has no conflict of interest in relation to this paper.

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.

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

Session	Goals	Exercises and activities	Time
Awareness	Creating a good atmosphere in the group	**1. Introduction and goals of the session**	10 min
	Creating awareness about different learning strategies and own strategy use	**2. Video clips about 10 common learning strategies** - Students watch short video clips (30 s) 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	**3. 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	**4. 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 and 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
	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	**5. 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	**6. 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	**7. 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	**1. Introduction and Photolog** - Students are sharing their photologs with each other	15 min
	Reflection on own learning strategies, barriers and facilitators, and study motivation	**2. 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

Session	Goals	Exercises and activities	Time
	Becoming aware about how to implement effective learning strategies	**3. 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	**4. 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	**1. 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
	Practicing one effective and one ineffective learning strategy and experiencing the ‘experienced-learning-versus-actual-learning’ paradox	**2. (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 min 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	**3. 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-h session and that this exercise is more about experiencing the effort while using a different learning strategies	30 min
		4. 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 et al., 2016).

B.1. 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 10 min, 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 10 min, and then are asked to study the passage again for another 10 min. After one week, all students are asked to recall as much of the text as they can remember in a short-answer test.

B.2. 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.

B.3. 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 h each day studying the different statistical methods. Student B starts studying two days before the exam and goes over all learning material for 7 h on Wednesday and 7 h on Thursday. Both students spend the same total amount of hours (14 h).

B.4. 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 1 h for this course in each of the seven weeks before the exam.

B.5. 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.

B.6. 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.

B.7. 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
(1) I think tutorial A is better for learning, because if you write things down, you can better remember them.	0
(2) 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
(3) With writing down you ask yourself to reproduce what you just read. Only study is in my opinion not enough	0.5
(4) 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

References

Adesope, O. O., Trevisan, D. A., & Sundararajan, N. (2017). Rethinking the use of tests: A meta-analysis of practice testing. *Review of Educational Research*, *87*, 659–701. http://dx.doi.org/10.3102/0034654316689306

Ariel, R., & Karpicke, J. D. (2017). Improving self-regulated learning with a retrieval practice intervention. *Journal of Experimental Psychology: Applied*, *24*, 43–56. http://dx.doi.org/10.1037/xap0000133

Bartoszewski, B. L., & Gurung, R. A. R. (2015). Comparing the relationship of learning techniques and exam score. *Scholarship of Teaching and Learning in Psychology*, *1*, 219–228. http://dx.doi.org/10.1037/stl0000036

Bjork, E. L., Little, J. L., & Storm, B. C. (2014). Multiple-choice testing as a desirable difficulty in the classroom. *Journal of Applied Research in Memory and Cognition*, *3*, 165–170. http://dx.doi.org/10.1016/j.jarmac.2014.03.002

Bjork, R. A. (1994). Memory and metamemory considerations in the training of human beings. In J. Metcalfe, & A. Shimamura (Eds.), *Metacognition: Knowing about knowing* (pp. 185–209). Cambridge, MA: MIT Press.

Bjork, R. A., Dunlosky, J., & Kornell, N. (2013). Self-regulated learning: Beliefs, techniques, and illusions. *Annual Review of Psychology*, *64*, 417–444. http://dx.doi.org/10.1146/annurev-psych-113011-143823

Blasiman, R. N., Dunlosky, J., & Rawson, K. A. (2017). The what, how much, and when of study strategies: Comparing intended versus actual study behaviour. *Memory*, *25*, 784–792. http://dx.doi.org/10.1080/09658211.2016.1221974

Brandmark, A., Byrne, M., O'Brien, K., Hogan, K., Daniel, D. B., & Jakobsen, K. V. (2020). Translating for practice: A case study of recommendations from the wakeful rest literature. *Teaching of Psychology*, *47*, 92–96. http://dx.doi.org/10.1177/0098628319889268

Braun, V., & Clarke, V. (2006). Using thematic analysis in psychology. *Qualitative Research in Psychology*, *3*, 77–101. http://dx.doi.org/10.1191/1478088706qp063oa

Cepeda, N. J., Pashler, H., Vul, E., Wixted, J. T., & Rohrer, D. (2006). Distributed practice in verbal recall tasks: A review and quantitative synthesis. *Psychological Bulletin*, *132*, 354–380. http://dx.doi.org/10.1037/0033-2909.132.3.354

Cohen, J. (1988). *Statistical power analysis for the behavioral sciences* (2nd ed.). Hillsdale, NJ: Lawrence Erlbaum Associates.

Delaney, P. F., Verkoeijen, P. P. J. L., & Spirgel, A. (2010). Spacing and testing effects: A deeply critical, lengthy, and at times discursive review of the literature. In B. H. Ross (Ed.), *Psychology of learning and motivation* (Vol. 53) (pp. 63–147). Academic Press.

Dembo, M. H., & Seli, H. P. (2004). 'Students' resistance to change in learning strategies courses. *Journal of Developmental Education*, *27*, 2–11.

DeWinstanley, P. A., & Bjork, E. L. (2004). Processing strategies and the generation effect: Implications for making a better reader. *Memory & Cognition*, *32*, 945–955. http://dx.doi.org/10.3758/bf03196872

Dolmans, D. H., De Grave, W., Wolfhagen, I. H., & van der Vleuten, C. P. (2005). Problem-based learning: Future challenges for educational practice and research. *Medical Education*, *39*, 732–741. http://dx.doi.org/10.1111/j.1365-2929.2005.02205.x

Donker, A. S., de Boer, H., Kostons, D., Dignath van Ewijk, C. C., & van der Werf, M. P. C. (2014). Effectiveness of learning strategy instruction on academic performance: A meta-analysis. *Educational Research Review*, *11*, 1–26. http://dx.doi.org/10.1016/j.edurev.2013.11.002

Doran, G. T. (1981). There's a S.M.A.R.T. way to write managements's goals and objectives. *Management Review*, *70*.

Dresel, M., Schmitz, B., Schober, B., Spiel, C., Ziegler, A., Engelschalk, T., . . ., & Steuer, G. (2015). Competencies for successful self-regulated learning in higher education: Structural model and indications drawn from expert interviews. *Studies in Higher Education*, *40*, 454–470. http://dx.doi.org/10.1080/03075079.2015.1004236

Dunlosky, J., & Rawson, K. A. (2012). Overconfidence produces underachievement: Inaccurate self evaluations undermine students' learning and retention. *Learning and Instruction*, *22*, 271–280. http://dx.doi.org/10.1016/j.learninstruc.2011.08.003

Dunlosky, J., Rawson, K. A., Marsh, E. J., Nathan, M. J., & Willingham, D. T. (2013). Improving students' learning with effective learning techniques: Promising directions from cognitive and educational psychology. *Psychological Science in the Public Interest*, *14*, 4–58. http://dx.doi.org/10.1177/1529100612453266

Ebbinghaus, H. (1913). *Memory: A contribution to experimental psychology*. New York: Teachers College, Columbia University.

Elliot, A. J., & McGregor, H. A. (2001). A 2 × 2 achievement goal framework. *Journal of Personality and Social Psychology*, *80*, 501–519.

Fishbein, M., & Ajzen, I. (2011). *Predicting and changing behavior: The reasoned action approach*. New York: Psychology Press.

Foerst, N. M., Klug, J., Jostl, G., Spiel, C., & Schober, B. (2017). Knowledge vs. Action: Discrepancies in university students' knowledge about and self-reported use of self-regulated learning strategies. *Frontiers in Psychology*, *8*, 1288. http://dx.doi.org/10.3389/fpsyg.2017.01288

Gurung, R. A. R., & Burns, K. (2019). Putting evidence-based claims to the test: A multi-site classroom study of retrieval practice and spaced practice. *Applied Cognitive Psychology*, *33*, 732–743. http://dx.doi.org/10.1002/acp.3507

Hadwin, A. F., Winne, P. H., Stockley, D. B., Nesbit, J. C., & Woszczyna, C. (2001). Context moderates students' self-reports about how they study. *Journal of Educational Psychology*, *93*, 477–487. http://dx.doi.org/10.1037/0022-0663.93.3.477

Hartwig, M. K., & Dunlosky, J. (2012). Study strategies of college students: Are self-testing and scheduling related to achievement? *Psychonomic Bulletin & Review*, *19*, 126–134. http://dx.doi.org/10.3758/s13423-011-0181-y

Huck, S. W., & McLean, R. A. (1975). Using a repeated measures ANOVA to analyze the data from a pretest-posttest design: A potentially confusing task. *Psychological Bulletin*, *82*, 511–518. http://dx.doi.org/10.1037/h0076767

Karpicke, J. D., Butler, A. C., & Roediger, H. L. (2009). Metacognitive strategies in student learning: Do students practise retrieval when they study on their own? *Memory*, *17*, 471–479. http://dx.doi.org/10.1080/09658210802647009

King, N. (2004). Using templates in the thematic analysis of text. In C. Cassell, & G. Symon (Eds.), *Essential guide to qualitative methods in organizational research* (pp. 256–270). SAGE Publications Ltd.

Koriat, A., & Bjork, R. A. (2006). Mending metacognitive illusions: A comparison of mnemonic-based and theory-based procedures. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *32*, 1133–1145. http://dx.doi.org/10.1037/0278-7393.32.5.1133

Kornell, N., Rhodes, M. G., Castel, A. D., & Tauber, S. K. (2011). The ease-of-processing heuristic and the stability bias: Dissociating memory, memory beliefs, and memory judgments. *Psychological Science*, *22*, 787–794. http://dx.doi.org/10.1177/0956797611407929

Leppink, J. (2019). When negative turns positive and vice versa: The case of repeated measurements. *Health Professions Education*, *5*, 76–81. http://dx.doi.org/10.1016/j.hpe.2017.03.004

McCabe, J. (2011). Metacognitive awareness of learning strategies in undergraduates. *Memory & Cognition*, *39*, 462–476. http://dx.doi.org/10.3758/s13421-010-0035-2

Morehead, K., Rhodes, M. G., & DeLozier, S. (2016). Instructor and student knowledge of study strategies. *Memory*, *24*, 257–271. http://dx.doi.org/10.1080/09658211.2014.1001992

Nunes, L. D., & Karpicke, J. D. (2015). Retrieval-based learning: Research at the interface between cognitive science and education. *Emerging Trends in the Social and Behavioral Sciences: An Interdisciplinary, Searchable, and Linkable Resource*, 1–16.

Oppenheimer, D. M. (2008). The secret life of fluency. *Trends in Cognitive Sciences*, *12*, 237–241. http://dx.doi.org/10.1016/j.tics.2008.02.014

Roediger, H. L., & Karpicke, J. D. (2006). Test-enhanced learning: Taking memory tests improves long-term retention. *Psychological Science*, *17*, 249–255. http://dx.doi.org/10.1111/j.1467-9280.2006.01693.x

Roediger, H. L., & Pyc, M. A. (2012). Inexpensive techniques to improve education: Applying cognitive psychology to enhance educational practice. *Journal of Applied Research in Memory and Cognition*, *1*, 242–248. http://dx.doi.org/10.1016/j.jarmac.2012.09.002

Rohrer, D., & Taylor, K. (2007). The shuffling of mathematics problems improves learning. *Instructional Science*, *35*, 481–498. http://dx.doi.org/10.1007/s11251-007-9015-8

Rowland, C. A. (2014). The effect of testing versus restudy on retention: A meta-analytic review of the testing effect. *Psychological Bulletin*, *140*, 1432–1463. http://dx.doi.org/10.1037/a0037559

Smith, B. L., Holliday, W. G., & Austin, H. W. (2010). Students' comprehension of science textbooks using a question-based reading strategy. *Journal of Research in Science Teaching*, *47*, 363–379. http://dx.doi.org/10.1002/tea.20378

Soderstrom, N. C., & Bjork, R. A. (2015). Learning versus performance: An integrative review. *Perspectives on Psychological Science*, *10*, 176–199. http://dx.doi.org/10.1177/1745691615569000

Tullis, J. G., Finley, J. R., & Benjamin, A. S. (2013). Metacognition of the testing effect: Guiding learners to predict the benefits of retrieval. *Memory & Cognition*, *41*, 429–442. http://dx.doi.org/10.3758/s13421-012-0274-5

van Peppen, L. M., Verkoeijen, P. P. J. L., Heijltjes, A. E. G., Janssen, E. M., Koopmans, D., & van Gog, T. (2018). Effects of self-explaining on learning and transfer of critical thinking skills. *Frontiers in Education*, *3* http://dx.doi.org/10.3389/feduc.2018.00100

Winne, P. H., & Jamieson-Noel, D. (2002). Exploring students' calibration of self reports about study tactics and achievement. *Contemporary Educational Psychology*, *27*, 551–572.

Xie, K., Heddy, B. C., & Vongkulluksn, V. W. (2019). Examining engagement in context using experience-sampling method with mobile technology. *Contemporary Educational Psychology*, *59*, 101788. http://dx.doi.org/10.1016/j.cedpsych.2019.101788

Yan, V. X., Bjork, E. L., & Bjork, R. A. (2016). On the difficulty of mending metacognitive illusions: A priori theories, fluency effects, and misattributions of the interleaving benefit. *Journal of Experimental Psychology: General*, *145*, 918–933. http://dx.doi.org/10.1037/xge0000177

Yan, V. X., Clark, C. M., & Bjork, R. A. (2017). *Memory and metamemory considerations in the instruction of human beings revisited: Implications for optimizing online learning From the laboratory to the classroom: Translating science of learning for teachers*. pp. 61–78. New York, NY, US: Routledge/Taylor & Francis Group.

Yan, V. X., Thai, K.-P., & Bjork, R. A. (2014). Habits and beliefs that guide self-regulated learning: Do they vary with mindset? *Journal of Applied Research in Memory and Cognition*, *3*, 140–152. http://dx.doi.org/10.1016/j.jarmac.2014.04.003

Received 16 December 2019;
received in revised form 30 March 2020;
accepted 30 March 2020
Available online 20 May 2020