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Kikas, Eve

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Evaluating the Efficacy of a Teacher-Guided Comprehension-Oriented Learning Strategy Intervention Among Students in Grade 4

Kikas, E.[1], Mädamürk, K.[1,2], Hennok, K.[1], Sigus, H.[1], Talpsep, T.[1], Luptova, O.[1] & Kivi, V.[1]

[1]School of Natural Sciences and Health, Tallinn University, Estonia

[2]Faculty of Educational Sciences, Department of Education, University of Helsinki, Finland

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Author note

Eve Kikas,

School of Natural Sciences and Health, Tallinn University, Narva mnt. 25, 10120 Tallinn, Estonia; Email: eve.kikas@tlu.ee.

Current themes of research:

Children's development and learning in kindergarten and school. The role of individual characteristics and contextual factors (e.g., teaching practices, parental support) in students' learning. Assessing and supporting learning to learn skills.

Most relevant publications in the field of Psychology of Education

Kikas, E., Mädamürk, K., & Palu, A. (2019). What role do comprehension-oriented learning strategies have in solving math calculation and word problems at the end of middle school? British Journal of Educational Psychology. https://doi.org/10.1111/bjep.12308

Soodla, P.; Tammik, V.; Kikas, E. (2019). Is part-time special education beneficial for children at risk for reading

Kikas, E. & Tang, X. (2019). Child-perceived teacher emotional support, its relations with teaching practices, and task persistence. European Journal of Psychology of Education, 34, 359-374. DOI: https://doi.org/10.1007/s10212-018-0392-y

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Jõgi, A.-L, Kikas, E. (2016). Calculation and word problem-solving skills in primary grades – Impact of cognitive abilities and longitudinal interrelations with task-persistent behaviour. British Journal of Educational Psychology, 86, 165-181.DOI:10.1111/bjep.12096

Kikas, E., Peets, K., and Hodges, E. (2014). Collective Student Characteristics Alter the Effects of Teaching Practices on Academic Outcomes. Journal of Applied Developmental Psychology, 35, 273–283

Kikas, E. (2004). Teachers' conceptions and misconceptions concerning three natural phenomena. Journal of Research in Science Teaching, 41, 432–448.

Kaja Mädamürk

School of Natural Sciences and Health, Tallinn University, Estonia

Faculty of Educational Sciences, Department of Education, University of Helsinki, Finland
E-mail: kaja.madamurk@tlu.ee

Current Themes of Research:

The development of math skills and motivation. The role of individual characteristics (cognitive skills, motivation) and contextual factors (teaching practices) in students' learning.

Most Relevant Publications:

Kikas, E., Mädamürk, K., & Palu, A. (2019). What role do comprehension-oriented learning strategies have in solving math calculation and word problems at the end of middle school? British Journal of Educational Psychology. https://doi.org/10.1111/bjep.12308.

Mädamürk, K., & Kikas, E. (2019). Developmental trajectories of goal orientations and math skills from grades 7 to 9. European Journal of Psychology of Education, 34, 147-167. https://doi.org/10.1111/bjep.12308.

Mädamürk, K., Kikas, E., & Palu, A. (2018). Calculation and word problem-solving skill profiles: relationship to previous skills and interest. Educational Psychology, 38, 1239-1254. https://doi.org/10.1080/01443410.2018.1495830.

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Liis Hennok

School of Natural Sciences and Health, Tallinn University, Estonia E-mail: liis.hennok@tlu.ee

No previous publications

Hardi Sigus

School of Natural Sciences and Health, Tallinn University, Estonia E-mail: hardi.sigus@tlu.ee

No previous publications

Teri Talpsep

School of Natural Sciences and Health, Tallinn University, Estonia E-mail: terita@tlu.ee

No previous publications

Olga Luptova

School of Natural Sciences and Health, Tallinn University, Estonia E-mail: olga.luptova@gmail.com

No previous publications

Valentina Kivi

School of Natural Sciences and Health, Tallinn University, Estonia E-mail: velorivelori@gmail.com

No previous publications

Evaluating the Efficacy of a Teacher-Guided Comprehension-Oriented Learning Strategy Intervention Among Students in Grade 4

Abstract

This study examined the effects of a teacher-led learning-strategy intervention program on fourth-grade students' reported use and perceived effectiveness of rehearsal and comprehension-oriented learning strategies. During 18 program units, teachers taught about learning and various learning strategies, including visualisation, elaboration and categorisation. Strategies were practised in math, language and science classes. Participants were comprised of 82 fourth-grade students in the intervention group and 387 fourth-grade students in the control group. Students' reported use and perceived effectiveness of learning strategies were assessed before and at least four months after intervention using a web-based word-memorisation task and associated reflection questions. The intervention group tended to use more comprehension-oriented learning strategies in post-tests, and the intervention group also showed an increase in perceived effectiveness of comprehension-oriented learning strategies. Still, rehearsal was evaluated as the most effective strategy in both the control group and the intervention group. Explanations for these findings and possible future directions are discussed.

Keywords: comprehension-oriented learning strategy; rehearsal; intervention; primary school

The importance of helping students become self-regulated learners is widely acknowledged (Bjork, Dunlosky and Kornell 2013; Dent and Koenka 2016). One way learners regulate their cognition is by selecting and applying cognitive learning strategies (LS; also called memory or memorisation strategies), which are defined as goal-oriented activities that support acquiring, organising and transforming information (Dent and Koenka 2016; Dunlosky, Rawson, Marsh, Nathan and Willingham 2013; Weinstein, Acee and Jung 2011). While some strategies (e.g., rehearsal) only promote simple memorisation, others (e.g., elaboration) foster comprehension and flexible future use of learnt knowledge (Dent and Koenka 2016; Weinstein et al. 2011). The latter type are currently emphasised in modern curricula (Council of the European Union 2018).

Despite what is taught in school, findings indicate that many students tend to use and value ineffective LS (Bjork et al. 2013; Dunlosky et al. 2013). Thus, schools should more comprehensively support students' ability to understand and apply comprehension-oriented learning strategies. Prior studies have shown that many teachers lack sufficient knowledge about LS (Glogger-Frey, Deutscher and Renkl 2018) and seldom teach or talk about LS explicitly and systematically (Dignath and Büttner 2018; Ornstein, Coffman, Grammer, San Souci and McCall 2010). This may indicate that teachers need help in supporting students' LS.

LS interventions have been carried out for decades in experimental classroom and medical settings (Bjorklund, Miller, Coyle and Slawinski 1997; Dehn 2010; Gaskill and Murphy 2004). However, further research is needed for LS interventions to be widely applicable in school. When interventions are implemented separately from ordinary classroom practises, students may have difficulty applying learnt strategies in non-experimental contexts (Hattie, Biggs and Purdie 1996). Similarly, strategies learnt during specific lessons (for math, see Barbieri, Rodrigues and Jordan 2020) may be difficult to generalise to other lessons.

So far, less attention has been paid to supporting metacognitive awareness of LS. However, analyses indicate that, in addition to teaching LS, teachers should emphasise how, when and why to apply each LS, especially among younger students and low achievers (Dignath, Büttner and Langfeldt 2008). Lastly, many interventions are carried out by researchers, and while these interventions tend to be more effective in the short term than those implemented by teachers (de Boer, Donker and van der Werf 2014), teacher talk and teacher practises have a long-term effect on students' learning (Coffman et al. 2019). Therefore, it is important to educate teachers so that they can support students' LS during classroom lessons.

To overcome these shortcomings, the 'Learning With Understanding' intervention program was designed to help primary school teachers teach, practise and raise metacognitive awareness of comprehension-oriented learning strategies (COrLS). The program is based on sociocultural and constructivist learning theories that emphasise the learner's active role in constructing his/her knowledge, the importance of the learner's preliminary knowledge and skills, and teacher support throughout the process (Chi and Wiley 2014; Vygotsky 1978). Based on Estonian national curriculum and earlier research on LS interventions (e.g., Dignath et al. 2008; Fiorella and Zhang 2018), we selected three interrelated COrLS: elaboration of new information with known material and daily practise; organisation of material into categories; and elaboration and organisation of information with visual aids. The aim of this pilot study was to examine the effects of intervention on fourth-grade students' reported use and perceived effectiveness of LS. The study included two groups (intervention and control) in a pre- and post-testing design.

Learning strategy interventions and their effectiveness

Numerous LS strategy interventions have been carried out with primary school children in experimental situations (Bjorklund et al. 1997; Gaskill and Murphy 2004) and in specific lessons (for reading, see Souvignier and Mokhlesgerami 2006; for math, Barbieri et al. 2020). However, these types of interventions may not support flexible application of learnt strategies in different lessons and tasks (Hattie et al. 1996). A growing number of interventions have tapped student strategies related to working memory and executive functions (Colmar, Davis and Sheldon 2016; Dias and Seabra 2017). Interventions that exclusively tap working memory have not shown strong effects on academic skills (Sala and Gobet 2017), while those that also aim to raise metacognitive awareness have shown stronger effects not only on working memory but also on academic skills (Cornoldi, Carretti, Drusi and Tencati 2015).

A meta-analysis by Dignath et al. (2008) confirmed that interventions with a specific cognitive focus have low effects, while interventions that are integrative and incorporate different aspects of learning — including cognitive, metacognitive and motivational aspects — are most effective. Their analysis further suggested that, in addition to teaching about LS, teachers should also stimulate metacognitive awareness by providing knowledge about strategy application and associated benefits (see also Dehn 2010; Dignath and Büttner 2008). Young children, specifically, have difficulty accurately evaluating their memory functioning and recognising when strategies may be helpful (Clerc, Miller and Cosnefroy 2014). It is also important to practise strategies in different contexts, which promotes automatization, helps reduce cognitive load related to monitoring new strategies, and helps to overcome utilisation deficiency (Bjorklund et al. 1997; Clerc et al. 2014).

Interventions focused on learning through visualisation indicate that creating drawings or schemas to elaborate learnt material is a constructive activity that leads to deep learning

(Ainsworth, Tytler and Prain 2020). A meta-analysis by Fiorella and Zhang (2018) showed that, when compared to only reading or using text-focused strategies, drawing leads to better comprehension, regardless of the amount of teacher support. However, when compared to viewing ready-made illustrations, the effects of drawing are mixed and depend on the quality of drawing and amount of teacher support.

In general, findings indicate that interventions tend to be more effective when implemented by researchers than by teachers (de Boer et al. 2014; Dignath et al. 2008; Hattie et al. 1996). Possible disadvantages of teacher-led interventions include lower teacher motivation, knowledge, skills and expectations of success (Abrami, Poulsen and Chambers 2004; Datnow and Castellano 2000; Steinbach and Stoeger 2016). However, studies have shown that teacher-led interventions are more effective when teachers are included in the co-construction of the intervention at all stages (Datnow and Castellano 2000). To raise teachers' skills and expectations, it is also important to educate teachers in areas related to intervention (Abrami et al. 2004).

Developing the 'Learning With Understanding' program

Selecting implementers and school level. Although earlier studies have shown that researcher-led interventions tend to be more effective than teacher-led interventions, researchers only work with students for short periods of time. Teachers, on the other hand, have daily interaction with students, which has a long-term effect on students' learning and development (Coffman et al. 2019). Teachers may also use learnt knowledge and skills in future lessons. For these reasons, we chose primary school teachers as implementers. Drawing on prior research, we

educated teachers on learning, memorising and LS, and we included teachers as much as possible throughout the process (Abrami et al. 2004; Datnow and Castellano 2000). Primary school class teachers were chosen as they give all main subject lessons and can thus practise the newly learnt strategies in different lessons.

Selecting targeted strategies. It is well documented that, at the beginning of school, children use rehearsal as a primary memorisation strategy (Ornstein et al. 2010; Schleepen and Jonkman 2012). Rehearsal involves repeating new information, but it does not presume transforming knowledge or moving beyond what is learnt (Weinstein et al. 2011). Rehearsal is useful for short-term retention and memorisation of factual information, but it leads to superficial, restricted learning (Dunlosky et al. 2013; Weinstein et al. 2011).

Compared to rehearsal, COrLS are more time-consuming and cognitively demanding, requiring good content-specific knowledge and a strong working-memory capacity (Schleepen and Jonkman 2012). Primary school students can learn about and use these strategies (Schleepen and Jonkman 2012), but students need help maintaining motivation and overcoming utilisation deficiency (Clerc et al. 2014). As earlier studies have emphasised the benefits of interventions with integrative and multidimensional learning (Dignath et al. 2008), we selected three interrelated COrLS as targets of the intervention: elaboration of new information with known material and daily practise; organisation of material into categories; and elaboration and organisation of information with visual aids.

Elaboration creates associations between new material and prior knowledge, thereby facilitating understanding, consolidation and subsequent retrieval (Weinstein et al. 2011). By creating associations between learned material and personal experiences, learners understand how new knowledge is related to daily life. This, in turn, supports motivation (see value

components in expectancy-value theory; Eccles and Wigfield 2020). Elaboration integrates new knowledge into a broader framework of interrelated concepts, impacting both semantic and episodic memory (cf. Bjork et al. 2013).

Abstract categorisation involves recognising and grouping information according to meaningful, hierarchical categories. The supportive effect of semantic categorisation has been shown in learning complex topics (for math, see Hardiman, Dufresne, & Mestre 1989; Kikas et al., 2020). Studies have shown utilisation deficiency when children use categorisation strategies spontaneously after learning about them (Clerc et al. 2014; Miller 2000). However, it is also possible to support categorisation in primary school children (e.g., Gaskill and Murphy 2004; Grammer et al. 2013). For instance, Gaskill and Murphy (2004) taught categorisation strategies to second graders and, immediately after the teaching session, the researchers found time by group interaction effects on strategy use, performance (word-list memorisation) and self-efficacy (predictions of success on a memorisation task).

Visualisation involves active reorganisation and elaboration of new material through the creation of visual representations like diagrams, drawings and maps (Tippett 2016; Van Meter and Garner 2005). Effective visualisation requires integration of information from different modalities and includes both elaboration and organisation of learnt material. Using self-constructed visual representations may support memorisation and understanding, but students need help building representations and understanding their usefulness (Ainsworth et al. 2020; Tippett 2016; Van Meter and Garner 2005). Although most visualisation research has focused on scientific texts, some studies have investigated the effects of visualisation on solving math word problems (Van Essen and Hamaker 1990). Researchers have also indicated that visualisation benefits metacognitive awareness of the learning process (Fiorella and Zhang 2018).

Practising learnt knowledge in different lessons and raising metacognitive awareness. Studies have shown that teaching strategy use when learning material in regular classes is more effective than teaching strategy use in extracurricular settings with artificially created problems (Hattie et al. 1996). Practising also helps to reduce cognitive load and overcome utilisation deficiency (Bjorklund et al. 1997; Clerc et al. 2014). During our program, teachers encouraged the use of LS in math, language and science lessons.

Applying LS effectively presumes good metacognitive awareness — i.e., not just the mere knowledge of a strategy, but why it is effective and when to use it (Dehn 2010; Grammer et al. 2013; Weinstein et al. 2011). Between kindergarten and middle school, students learn more about memory functioning and LS' usefulness (Schneider 2008). Still, young children often have difficulty evaluating their memory functioning and performance, which may also be one cause of strategy transfer problems (Clerc et al. 2014). Younger children also tend to have misbeliefs about the efficacy of different strategies (Daugherty and Ofen 2015). To overcome these problems, Dehn (2010) listed the following key aspects of metacognition-supportive instruction: 1) understanding how human memory works; 2) recognising the trainee's memory strengths and weaknesses; 3) conditional knowledge about LS; and 4) self-monitoring of learning and LS. Thus, we also incorporated these topics into our program lessons.

The present study

The teacher-led 'Learning With Understanding' intervention program was developed to enhance students' understanding and application of three COrLS (elaboration, categorisation and visualisation) in subject lessons. The program was designed to be used in primary school, where students tend to use rehearsal but are generally ready to learn about and use COrLS that presume

deep information processing (Schleepen and Jonkman 2012). The aim of the present study was to test the effects of intervention on the reported use and perceived effectiveness of LS (i.e., COrLS and rehearsal) using a word list memorisation task with follow-up questions (Kikas & Jõgi, 2016). We compared intervention and control groups using a pre- and post-test design in Grade 4. In Estonia, fourth grade is the last year when teachers teach all main subjects, thus allowing teachers to encourage students to apply newly learnt strategies in different lessons. Our research questions and hypotheses were as follows.

First, does reported use of COrLS and rehearsal differ between intervention and control groups in pre- and post-tests? In pre-tests, we expected no difference in reported use of COrLS. In post-tests, we expected more students in the intervention group to report using COrLS.

Second, are there differences in how students perceive the effectiveness of LS between intervention and control groups before and after intervention? We expected that, before intervention, students would perceive the effectiveness of rehearsal higher than COrLS, and that this perception would not differ between intervention and control groups (cf. Kikas & Jõgi, 2016). In contrast, we expected that only the intervention group would have a higher perceived effectiveness of COrLS in post-tests. The intervention program emphasised the advantages of COrLS in learning, including simple word learning. As the program did not specifically deal with rehearsal, we did not expect changes or differences in perceived effectiveness of rehearsal.

Third, how effective are students at memorising words? We expected that students in the intervention group would show higher word-recognition scores in post-tests.

Fourth, do students who use rehearsal versus COrLS differ in their ability to memorise words, and are there differences between intervention and control groups? We expected that students who reported using COrLS would have higher word-recognition scores, and that the

effect would be more visible after intervention in the intervention group. Studies have shown that information organised during learning is better recalled later on (Dehn 2010). However, the effect might not be strong due to possible utilisation deficiency (Clerc et al. 2014) and because we assessed word recognition, not free recall.

Method

Participants

The intervention group included 82 participants (38 boys) from two schools (6 classrooms; 10–19 students per classroom). The control group was drawn from the fourth-grade participants of a larger project focusing on developing tools to assess learning to learn competence (Kikas et al., 2018). It consisted of 387 participants (182 boys) from nine schools (21 classrooms; 17–25 students per classroom). All schools were mainstream schools from different parts of Estonia.

The mean age of children during pre-tests was 10.42 years in the intervention group (range: 9.76–11.89) and 10.42 years in the control group (range: 9.76–11.89). The intervention and control groups did not differ significantly in gender composition [χ^2 (1) = 0.01, p = .91] or age [t (1, 467) < 0.001, p > .99].

Materials

The ‘Learning With Understanding’ program is a theory-driven, manualised intervention developed for use in primary schools. The program was developed for teachers and designed by

a multidisciplinary team of researchers and teachers. The intervention's classroom-based approach relies upon cognitive, developmental and educational psychology research on memory, learning and LS. The teacher manual provides detailed instructions, and student worksheets include tasks to be used.

A detailed structure of the program, units (parts of lessons) and activities is provided in the Appendix. The program comprises three parts. It begins with a theoretical background of strategies (memory, memorising and individual differences in memorising). The second part includes learning about three COrLS: visualisation, elaboration and categorisation. After each lesson about a specific strategy, the strategy is applied in three main subject lessons: math, language and science. The last two units aim to support students' metacognitive awareness of these strategies by discussing the strengths and weaknesses of each strategy and student's own skills in applying each strategy.

Measures

The intervention was evaluated using a word-list memorisation task with follow-up questions (Kikas & Jõgi, 2016; Kikas et al., 2008, 2020). Word-list memorisation tasks have been widely used in experimental studies (Gaskill and Murphy 2004; Yu et al. 2018) and in clinical work to support children with memory problems (e.g., Dehn 2010, pp. 239–240). Word-list memorisation is a specific learning task that can be solved using different strategies and, as such, is more suitable for assessing knowledge and reported application of LS than questionnaires with broadly wordeditems and Likert-type scales (Samuelstuen and Bråten 2007). Such questionnaires presume generalisations across times and conditions and are specifically confusing for young children

(Richardson 2004; Veenman 2011). The advantage of this task over the *Motivated Strategies for Learning Questionnaire MSLQ* (e.g., Pintrich, Smith, Garcia, and McKeachie 1993) has been shown for middle school students (Kikas & Jõgi, 2016). Word-list memorisation tasks have been previously used in Estonia to assess knowledge and reported application of LS in Grades 2–9.

Findings indicate that perceived effectiveness and reported application of COrLS are higher in Grade 9 than in earlier grades (unpublished data). Studies also show that perceived effectiveness and application of COrLS are related to higher math and language skills (for Grades 7 and 9, see Kikas & Jõgi, 2016; Kikas et al., 2020).

Students were asked to memorise 21 nouns from three broad categories: sports equipment (e.g., ball, ski), weather conditions (e.g., snow, storm) and vegetables (e.g., tomato, beet). Each noun was 3–6 letters long and commonly used in everyday language. All nouns were displayed together in a random layout on a computer screen. Students had 90 seconds to memorise the words, after which the words disappeared from the screen. Students were neither informed of the categories nor about the possibility of using any memorisation strategy. Next, students were shown 35 words (21 learnt and 14 new) and instructed to mark the learnt words. A *word-recognition score* was calculated as the sum of marked learnt words plus unmarked additional words (maximum 35).

After completing these tasks, students were shown six LS (see Table 1) and asked to choose the one they had used to memorise the target words. Strategies were selected from earlier studies with students from Grades 2–9 (Kikas & Jõgi, 2016; Kikas et al., 2008). These studies asked an open question on strategy use, and the most frequent answers formed our selected choices. Students could also describe a strategy in their own words. Several of these descriptions were later categorised underone of the given strategies; those which were not intelligible were considered ‘other’ (Table 1)

and not included in subsequent analyses. According to reported strategy use, students were divided into two groups. Two strategies tapped rehearsal, and students who marked these formed the *rehearsal group*. Four strategies tapped elaboration, organisation and visualisation (i.e., COrLS), and students who marked these formed the *COrLS group*.

Finally, the same six LS were shown again, and students were asked to evaluate the effectiveness of each strategy when memorising the target words. A five-point Likert-type scale was used. Students were asked to mark one of five shaded circles (from *very bad* to *very good*). Exploratory factor analysis was carried out using Mplus 8.2 (Muthén and Muthén 1998–2017) to determine the number of factors. Results indicated a two-factor model with good fit [χ^2 (4) = 4.10, p = .39]. Two scores were calculated: the *perceived effectiveness of rehearsal* (calculated via the mean of two rehearsal categories' evaluations) and the *perceived effectiveness of COrLS* (calculated via the mean of four COrLS categories' evaluations). Internal reliability was acceptable for the two rehearsal strategy statements (in the pre- and post-tests, Cronbach's α = .69 and .64, respectively) and good for COrLS (Cronbach's α. ≥ 71 at both time points).

Intervention fidelity

Two fidelity measures were used. First, each teacher was asked to fill out a *diary log* after each lesson. Second, *student worksheets* were collected and reviewed to determine the number of tasks each student completed in each unit. Because of incomplete diary logs, we combined the logs and student worksheets to determine the number of lessons completed. Analysis of the logs and student worksheets indicated that all 18 lessons were taught in five classes, while the categorisation strategy was not applied in one science class. In the third meeting, teachers confirmed they had implemented units according to the manual. The stated reason for not

applying the categorisation strategy in science lessons was that the ordinary lesson plan did not allow for practising the learnt strategy.

The average number of minutes required to complete each lesson was taken from completed logs. The mean duration was 24.14 minutes (range: 17–30 minutes).

Procedure

To ensure clarity, the procedure will be described separately for each group.

Intervention group

Two schools were invited to participate in an intervention program called ‘Learning With Understanding’. An invitation letter that described the aims of the intervention program was sent to the school principals. After the principals had agreed, teachers were contacted and asked for their consent to participate. Participation was voluntary, but all invited teachers agreed to participate. Teachers then contacted parents and sent informed consent letters. All students participated in the intervention as it was a part of ordinary school lessons, but only students with parental permission completed tests.

Pre- and post-testing. All participating students were tested twice using the same tests — once before and again at least four months after completion of the intervention program. All measures were administered as group tests during regular schooldays. Assessments were carried out in computer labs. Trained research assistants or teachers provided the instructions and any

necessary support in understanding the instructions. It took about 45 minutes to complete the whole test. Only tasks assessing LS were used in this study.

Educating and supporting teachers. The intervention program was divided into two parts to avoid overwhelming teachers with too much new information at once. Prior to implementation, researchers gave all participating teachers a two-day course on memory, learning and LS. Before the course, teachers received the materials for the first seven units of the program (see Appendix) and were asked to familiarise themselves with the materials. The materials introduced the ideas and principles of the program. All materials were discussed in detail, and teachers were encouraged to provide feedback about how to improve the program and tasks. However, no modifications were made. Teachers then carried out the program in their classes.

Halfway through the intervention, the materials of the second part of the program were sent to teachers and a second meeting was held. This meeting gave teachers the opportunity to: 1) discuss problems and challenges they faced when implementing the program; 2) ask questions from researchers; and 3) give suggestions for improving the program. During the meeting, the materials and procedure for the last 11 units were discussed in detail. Researchers emphasised the importance of the final two units, where teachers were meant to discuss individual differences and the strengths and weaknesses of all three LS. These units were meant to raise students' metacognitive awareness of LS. After instruction and discussion, teachers proceeded with the program. After completing the program, a final meeting was held to discuss challenges and future directions.

All meetings took place in teachers' home schools. When needed, researchers provided teachers with additional support, either through personal discussion or via email. After each lesson, teachers completed an online diary log to assess the program's effectiveness, strengths

and weaknesses. The aim of these measures was to support teachers' motivation, knowledge and efficacy, and thus, to raise the fidelity of the intervention program. This information also gave ideas for further improvement of the program.

Control group

The control group was drawn from the fourth-grade participants of the larger project (Kikas et al., 2018). An invitation letter that described the aims was sent to schools across Estonia. After the school principals had agreed, teachers were contacted and asked for their consent to participate in the assessment. Participation was voluntary, but all invited principals and teachers agreed to participate. Teachers then contacted parents and sent informed consent letters. Only students with parental permission completed tests. All participating students were tested twice using the same test and conditions as the intervention group. The timespan between testing was also the same.

After the first assessment, participating teachers were given a workshop on the assessment tool and learning competence, including LS. After the second testing, teachers were given feedback on the student results from their classes. Teachers were also provided a training course about how to interpret the results.

Data analysis

Chi-square tests were used to study between-group differences in reported use of COrLS. Factorial univariate analyses of variance (ANOVA) with repeated measures were used to study

the effects of intervention on perceived effectiveness of COrLS, rehearsal and word memorisation. Partial η^2 was used as a measure of effect size and interpreted similarly to Cohen's guidelines (.01 = small; .06 = medium; .14 = large; see Richardson 2011). ANOVA was also used to examine differences in word-recognition scores.

Results

Reported use of strategies

Chi-square tests were used to answer the first research question and to examine between-group differences in reported use of COrLS. In pre-tests, 16% of the intervention group and 11% of the control group reported using a COrLS (see Table 1); this difference was nonsignificant, χ^2 (1) = 1.52, p = .22. In post-tests, 24% of the intervention group and 13% of the control group reported using COrLS; this difference was statistically significant, χ^2 (1) = 8.24, p = .004.

Perceived effectiveness of LS

To answer the second research question and to study the effect of intervention on perceived effectiveness of COrLS and rehearsal, we carried out a 2 (time: pre- and post-test) x 2 (strategy: perceived effectiveness of COrLS and rehearsal) x 2 (group: intervention and control) factorial univariate analysis of variance (ANOVA) with repeated measures for the first two factors. The ANOVA revealed significant main effects of strategy, F (1, 467) = 532.82, p < .001, η^2 = .53, and group, F (1, 467) = 30.57, p < .001, η^2 = .06. Significant interactions were found between strategy and group, F (1, 467) = 29.44, p < .001, η^2 = .06; strategy and time, F (1, 467) = 18.45, p < .001, η^2 = .04; and time, strategy and group, F (1, 467) = 10.12, p = .002, η^2 = .02. We then

checked group differences in perceived strategy effectiveness. Students in the intervention group evaluated COrLS higher than students in the control group both in pre-tests ($p < .001$; $\eta^2 = .03$) and post-tests ($p < .001$; $\eta^2 = .11$). The groups did not significantly differ in perceived effectiveness of rehearsal (p = .44 for pre-tests and p = .61 for post-tests).

Subsequent analyses were carried out separately for each group. First, we checked for differences in perceived strategy effectiveness over time. Although analyses indicated that the perceived effectiveness of rehearsal did not change in the intervention group ($p = .08$) and decreased in the control group ($p = .01$), the effect sizes were similarly low ($\eta^2 = .04$). Perceived effectiveness of COrLS increased in the intervention group ($p < .001$, $\eta^2 = .15$) but decreased in the control group ($p < .001$; $\eta^2 = .08$). Second, we checked for differences in perceived effectiveness of rehearsal and COrLS at both time points. Differences in strategy evaluation revealed that, at both time points and in both groups, students perceived rehearsal to be more effective than COrLS ($p < .001$). Effect sizes were high both for the control group ($\eta^2 = .62$ for pre-tests; $\eta^2 = .57$ for post-tests) and for the intervention group ($\eta^2 = .57$ for pre-tests; $\eta^2 = .27$ for post-tests). Results are illustrated in Figure 1.

Word memorisation

To answer the third research question and to examine group differences in memorising words in pre- and post-tests, we carried out a 2 (group: intervention and control) x 2 (time: pre- and post-test) repeated measures ANOVA. Only the main effect of time, F (1, 464) = 56.09, $p < .001$, $\eta^2 = .11$, was significant. In both groups, word-recognition scores were higher in post-tests (see also Table 2). Thus, the intervention did not have a significant effect on word memorisation.

To answer the fourth research question and to examine the effect of reported strategy use on word-recognition efficiency, we carried out a 2 (group: intervention and control) x 2 (reported strategy use: COrLS and rehearsal) ANOVA with the word-recognition score as a dependent variable. None of the effects were significant. Thus, students who reported using COrLS did not show significantly better performance in the word-recognition task than students who reported using rehearsal; this finding was consistent between pre- and post-tests.

Discussion

Teachers in this study implemented the 'Learning With Understanding' intervention program to support better use and awareness of the effectiveness of different LS. The study aimed to examine the effects of the program on fourth-grade students' reported use and perceived effectiveness of rehearsal and COrLS, and to investigate the effects of the program on word memorising efficiency. The study used a pre- and post-test design with two groups (intervention and control). We also assessed the effects of the intervention 4–5 months later in order to gauge the long-term effects of the program. Results showed that the program impacted reported use and perceived effectiveness of COrLS.

Reported use of LS. Both before and after intervention, a minority of students reported using COrLS to memorise words. A similar intervention at the end of middle school also showed a preference for rehearsal over COrLS (Kikas & Jõgi, 2016; Kikas et al., 2020). Several reasons may explain this preference for rehearsal. First, rehearsal is the first LS many children use because rehearsal places low demands on working memory and presumes lower subject- and LS-related knowledgethan COrLS (Dehn 2010; Ornstein et al. 2010; Schleepen and Jonkman 2012). In a time-limited

learning task, students may select the most familiar and low-effort strategy that has proven effective for short-term retention of factual information (Dunlosky et al. 2013; Weinstein et al. 2011).

Specific strategies chosen by students are also informative (Table 1), showing that over 50% of students chose reading. Reading includes repetition without any changes to the sequence of words and is the easiest strategy with the lowest demands on working memory. Visualisation was the most frequently reported COrLS in pre-tests. However, it is impossible to infer how detailed these visualisations might be. Studies have shown that simple representations are less effective for learning than figures that organise information (Krawec 2014; Weinstein et al. 2011). Therefore, benefits of visualisation may differ in relation to the complexity of the visualisation. We were surprised to find the first-letter strategy was chosen the least often. We expected that first-letter mnemonics may be taught at school in early grades (see Test and Ellis 2005) or that students may recall vocabulary terms written in alphabetical order from textbooks.

As expected and in line with earlier experimental intervention studies (Gaskill and Murphy 2004; Grammer et al. 2013), intervention had positive effect on reported use of COrLS. However, despite the fact that more students in the intervention group reported using COrLS in post-tests, this percentage was still low (25%). Similar to pre-tests, more than half of students in post-tests reported simply reading the words. Thus, we can conclude that students in the intervention group learnt about the effectiveness of some COrLS. Although students practised LS via a word-list memorisation task (Topic 6, Unit 13; see Appendix) — where the advantages of COrLS were demonstrated and discussed — and although students also practised COrLS in subject lessons, students did not acquire the ability to transfer and apply COrLS within different contexts.

Students in the intervention group also reported using strategies that presume finding relations and reorganising learnt words. These strategies were explicitly taught and practised in relation to word memorisation during the intervention program. However, as reported use of COrLS was not related to higher word-recognition scores, students may have remembered that these are good strategies and may have reported their use despite not actually use them during testing (i.e., social desirability).

Perceived effectiveness of LS. Both before and after intervention, students evaluated rehearsal as more effective than COrLS. A similar intervention at the end of middle school also showed a preference for rehearsal (unpublished data). As stated, rehearsal places lower demands on working memory and persistence than COrLS (Dehn 2010; Schleepen and Jonkman 2012), which may give the impression of effectiveness. Rehearsal is also effective for short-term memorisation of factual information (Dunlosky et al 2013), thus students have likely experienced its effectiveness in school. Moreover, rehearsal may be the most effective strategy if students cannot find associations and groups.

Due to its simplicity, teachers and parents may value rehearsal as well. Executive functions are still developing during primary school (Crone and Steinbeis 2017), and metacognitive awareness of memory and LS is low at this age (Schneider 2008), thus students may need additional hints or support when analysing tasks and choosing an appropriate strategy (cf. Gaskill and Murphy 2004). The tests in the present study did not offer such hints. Observation studies in ordinary classrooms have shown that discussion of learning and memorisation are typically rare (Ornstein et al. 2010).

Our hypothesis related to the effect of intervention on perceived effectiveness of COrLS was also confirmed. Throughout the intervention program, students did not practise or talk about

rehearsal, thus it is no surprise that evaluations remained high. As previously stated, in addition to being easy to use, rehearsal strategies are effective for some tasks and contexts (Dunlosky et al. 2013; Weinstein et al. 2011).

Effects of intervention and reported use of COrLS on word recognition. Students' word-recognition scores were higher in post-tests, but, differently from findings by Gaskill and Murphy (2004), this effect was not related to the intervention. This suggests that 18 units may be insufficient to teach primary school students how to use COrLS. The use of COrLS presumes high subject- and learning-related knowledge, working memory and effort (Schleepen and Jonkman 2012). The finding that reported use of COrLS was not high or effective likely refers to utilisation deficiency (Clerc et al. 2014). However, the difficulties and cognitive processes behind this deficiency may be different (cf. Miller 2000).

Students in the intervention group who used COrLS may have invested too much effort into thinking about strategies and searching for associations, thus depriving them of time to memorise the target words. Students specifically stated using sentence compiling and grouping, both of which presume a strong understanding of relations between target words. Target words were common, but trying to integrate information and identify associations might overload working memory and decrease productivity (cf. Clerc et al. 2014). Another reason reported use of COrLS did not impact word-memorisation could be due to the use of a word-recognition score rather than a word-recalling score (as has been used in previous studies; Kikas & Jõgi, 2016).

Avoidance or ineffective use of COrLS may result from a lack of teacher knowledge and skills in applying these strategies. While earlier studies have revealed teachers' LS-related misconceptions (Glogger-Frey et al. 2018), a three-day course may not be sufficient to override long-held beliefs. For instance, during the first seminar, teachers in the intervention group

reported use of ready-made drawings or models. However, this is not a visualisation strategy that students can use independently (Tippett 2016; Van Meter and Garner 2005).

Other researchers have noted similar misconceptions (e.g., Glogger-Frey et al. 2018). During the final seminar, teachers in the intervention group reported that visualisation was the most difficult strategy to teach. This suggests challenges in overcoming earlier preferences for ready-made drawings and/or the complexity of composing drawings and models (Ainsworth et al. 2020). In the current study, visualisation was also the first strategy to be taught, and teachers' uncertainty may have been heightened.

Limitations

First, a word-list memorisation task is only one way to assess LS. This time-limited task may have unintentionally encouraged rehearsal.

Second, the computer-based tests used in the intervention required students to select a strategy from six forced-choice options. Thus, student reports on strategy use might differ from the strategy they actually used. While students were given the option to write a strategy using their own words, only minority used this option. Students in the intervention group may have chosen a strategy they remembered to be effective, even if they did not actually use it. In the future, researchers should observe student behaviour during testing to validate student responses.

Third, we did not examine the effect of intervention on use of LS in different subject areas or with regard to subject-specific skills. Future studies should examine these effects.

Fourth, we did not account for teacher variability in terms of individuals skills and interests. Following suggestions from prior research, we educated teachers, asked for frequent feedback, developed the program together and worked closely throughout the intervention. Through such

engagement, we hoped to enhance teacher motivation, knowledge and efficacy, the absence of which could inhibit successful teaching (Abrami et al. 2004; Steinbach and Stoeger 2016). However, some teachers may have been more engaged than others, thereby influencing their behaviour and results. In the future, observations should be carried out to ensure fidelity.

Future research should also account for the Hawthorne Effect, as teachers in the intervention group received more attention from researchers. Teachers may have, in turn, exaggerated their interest and satisfaction levels while minimising their problems and difficulties. In addition, teachers' prior knowledge about memory, learning and LS may have impacted the program. We did not assess teacher knowledge before or after the intervention.

Conclusions, implications and future directions

This study showed that primary school students prefer rehearsal strategies over COrLS and thus need support in understanding the benefits of different LS and practising their application. We found some effects of teacher-led intervention on students' reported use and perceived effectiveness of COrLS, but we also recognise that some modifications to the program are needed. Modifications may include more practise with different tasks, a longer duration of the intervention program and reductions on working memory load during lessons.

In the future, more attention should be paid to rehearsal. Rehearsal is the most widely used strategy and effective for some tasks, but it is not the best strategy for understanding and applying learnt material (Dunlosky et al. 2013). To overcome students' preference for rehearsal, its advantages and disadvantages should be discussed. Prior studies have shown that students prefer rehearsal even at the end of middle school (Kikas & Jõgi, 2016; Kikas et al., 2020), thus future studies may want to apply this intervention in later grades, when topics become more complicated and tasks

presume the application of effective learning strategies. Starting the intervention later is justified as executive functions develop during adolescence, thereby allowing for more efficient use of LS (Yu et al. 2018).

As visualisation is the most complex learning strategy (Van Meter and Garner 2005; Tippett 2016), the program could be rearranged so that visualisation is taught after elaboration and categorisation. Future research should also include a variety of tasks, including subject-specific tasks that are easier to use with COrLS (e.g., math tasks that can be solved by composing schemas; science tasks that presume semantic categorisation).

Finally, future studies should also carry out person-oriented analyses to examine the impact of intervention on students with different knowledge levels, skills and motivation. Additional analyses are also necessary to study the role of teacher characteristics like motivation, knowledge and skills.

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Table 1. Percentages of reported strategies in Pre- and Post-test

Strategy	Time1		Time 2	
	Intervention	Control	Intervention	Control
Reading the words several times	55	53	54	55
Repeating the words several times	28	34	20	29
Visualizing objects according to the words and memorizing the visualization	10	6	5	4
Forming sentences from the words and memorizing	2	4	9	4
Grouping the words by the first letter and memorizing them as groups	0	0	1	1
Grouping the words by their meaning and memorizing them as group	4	1	10	4
Other	1	2	2	4
Rehearsal strategies	**83**	**87**	**74**	**84**
Comprehension-oriented strategies	**16**	**11**	**25**	**13**

Table 2. Descriptive statistics

		Intervention			Control			Bivariate Pearson correlations					
Measure	Min-max	M	SD	ICC	M	SD	ICC	1	2	3	4	5	6
1. PE of COrLS T1	1−5	2.89	0.96	.03	2.42	0.93	.02		.05	.05	.33*	-.09	-.05
2. PE of rehearsal T1	1−5	4.32	0.87	.00	4.25	0.80	.03	.08		.20*	-.02	.26*	.10*
3. Word recognition T1	13−35	25.39	4.78	.02	25.59	5.08	.04	-.04	.23*		.10*	.06	.43*
4. PE of COrLS T2	1−5	3.32	0.88	.09	2.42	0.98	.01	.36*	.12	.09		.03	.05
5. PE of rehearsal T2	1−5	4.09	0.90	.13	4.15	0.91	.04	.11	-.09	.00	-.04		.17*
6. Word recognition T2	13−35	27.68	4.28	.01	27.82	4.43	.07	-.02	.34*	.46*	.31*	-.14	

Note. PE = perceived effectiveness, COrLS = comprehension-oriented learning strategies, T1 = time 1, T2 = time 2, M = mean, SD = standard deviation, ICC = intraclass correlation. Pearson correlations below diagonal are for intervention group and above diagonal for control group, * $p < .05$

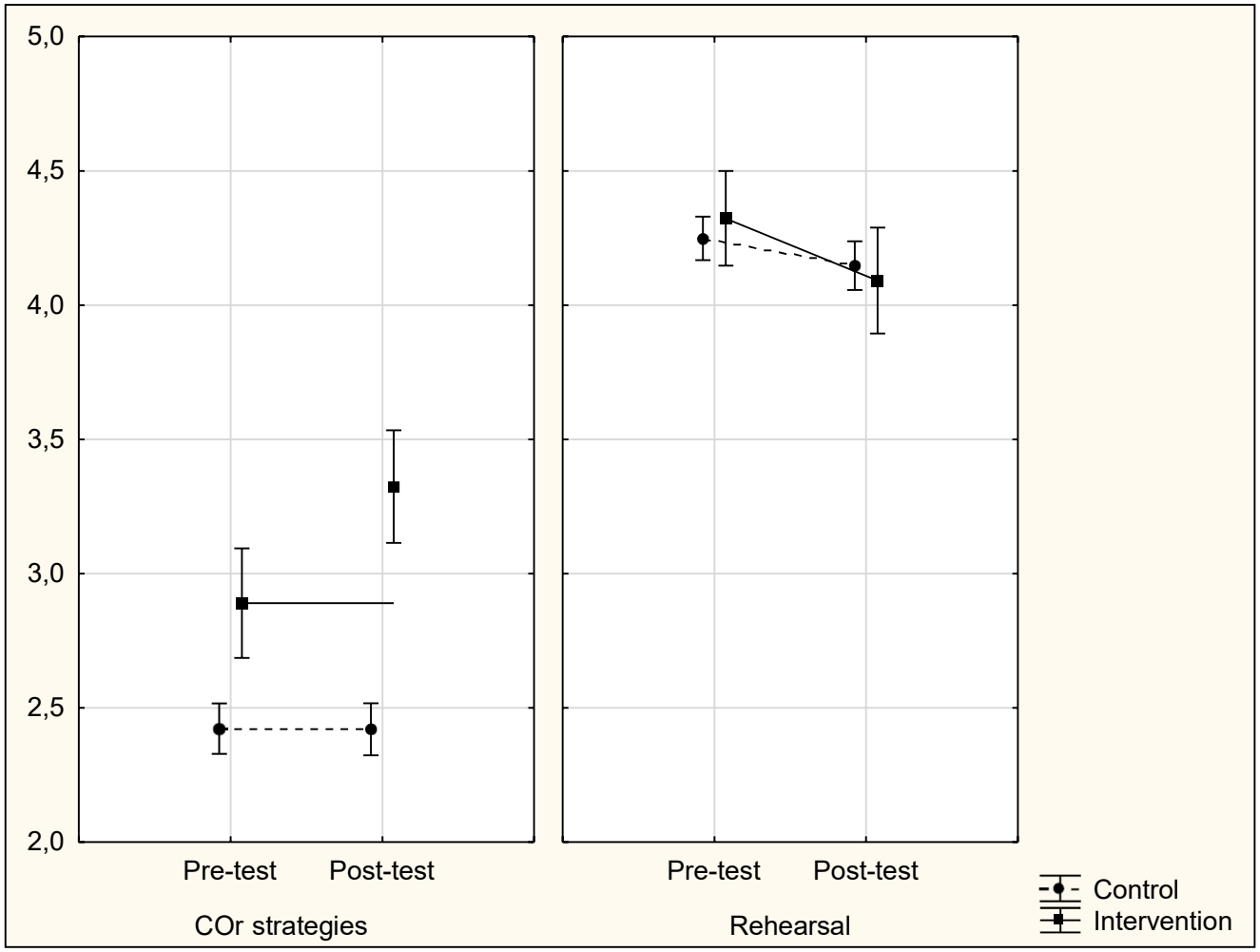

Figure 1. Perceived effectiveness of rehearsal and comprehension-oriented strategies (COr) in intervention and control groups in pre- and post-tests

Appendix

The structure and content of topics and units.

Topic (T) and unit (U)	**Content**	**Examples of tasks**
T1U1 Memory systems	The process of learning, the relationship between memory and learning. Discussions on how via seeing, hearing, touching, and practicing, information is perceived, encoded, and stored in memory.	Homework: students have to describe how they learned when completing an ordinary homework task (i.e., which processes they used for remembering). The work is discussed the next day when checking ordinary homework.
T2U2 Thinking and memory	Memorizing information by actively thinking about it, finding associations between current and new information, and breaking larger amounts of information into smaller units.	The teacher reads aloud a rather complicated sentence that students certainly cannot remember. After listening, students write down what they remembered. How much information they remembered from the sentence is then checked. Next, the teacher groups the sentence into smaller units so that students can remember more information. Students compare the amount of information they remembered the first and second time. Classroom discussion is held on how previous knowledge and breaking larger amounts of information into smaller units helps remembering.

T3U3 Individual differences in memorizing	Recapitulation of learned knowledge about memory and memorization, exploring individual differences in memorizing. Showing and practicing ways to improve one's memorization skills.	Students are asked to memorize 12 objects from pictures which are shown on a computer screen for 30 seconds. Before seeing the objects, students are asked to guess how many objects they think they will remember. After writing down the names of remembered objects, students compare their guess to the actual result. Classroom discussion is held on which strategies students used for memorizing and which strategies are better or worse for each student.
T4U4 Visualization strategy	Showing and explaining how drawings, images, and models support learning, and how to use them to solve problems and to improve understanding of learned information.	The teacher reads aloud sentences that represent objects in an illogical sequence: "The balloon is above the table. Below the balloon is a tablecloth, and below the tablecloth is a vase." Students are asked to write down the sequence of objects. In a second part of the task, the teacher reads another sentence representing objects in an illogical sequence, but additionally asks student to draw the objects while listening to the sentences. After listening to the sentence, students once again write down the correct order of the objects. Classroom discussion is held on how drawing helps remembering.

T4U5 Applying visualization in math	Showing and practicing drawing to solve math problems. Discussions on how modelling the task helps to better solve problems, and how to creating simple, abstract (not necessarily visually-nice) drawings. The unit is modified to be in accordance with the level of the problems students learn in ordinary classes.	Students are asked to solve a word problem by making a drawing: "There were 15 people in the bus. At the bus stop, 5 people left and 2 came on the bus. How many people are in the bus now?"
T4U6 Applying visualization in language	Showing and practicing drawing to better understand and interpret written text. Discussions on which illustrations are more suitable. The unit is modified to be in accordance with the level of the texts students learn in ordinary classes.	Students have to read a text, divide texts in smaller parts, and make drawings for each part that help better understand and remember the text. Classroom discussion is held to analyze different ways of making drawings and to explain how drawing helps learning.
T4U7 Applying visualization in science	Showing and practicing making drawings to understand science texts. Discussions on which illustrations are more helpful and supportive for memorizing and understanding important information. The unit is modified to	After reading about the day-night cycle, students are asked to illustrate the movements of the Earth and the Sun in a garden and from far away in space. Two drawings are compared, and the benefits of the second drawing in understanding the day-night cycle are discussed.

	be in accordance with the topics students learn in ordinary lessons.	
T5U8 Elaboration strategy	Review of how information is stored in memory, including associations between information held in memory and new information, and the importance of elaborating on and using personal information to enhance the probability of memorizing and retrieving new information (self-reference effect).	Students are given a keyword (e.g. garage) and asked to provide as many words as possible that are related to that word. Classroom discussion is held regarding why these related words are remembered and why they help in the remembering new information.
T5U9 Applying elaboration in math	Showing and practicing how to use personal experiences and associations to understand math. Discussions on how academic math is used outside of school. The unit is modified to be in accordance with the topics students learn in ordinary lessons.	Topic: *Fractions*. On their worksheet, students are asked to mark half of an object (pizza, chocolate bar, cookie, etc.). Classroom discussion is held on the meaning of half in everyday life and in the context of academic math.
T5U10 Applying elaboration in language	Showing and practicing how to use personal experiences and associations in learning to better understand written texts. Practice making connections between	Students read a poem, mark unknown words, and try to guess the meaning of these words. Then, the teacher provides the correct meaning of all new words and asks students to discuss how to best memorize unknown words. Finally,

	semantic knowledge and personal experience to enhance understanding and the application of learned knowledge. The unit is modified to be in accordance with the topics students learn in ordinary lessons.	students form sentences related to their life using the new words.
T5U11 Applying elaboration in science	Showing and practicing how to use personal experiences and associations to better understand science. Practice making connections with learned topics and personal experiences. The unit is modified to be in accordance with the topics students learn in ordinary lessons.	Students are asked to memorize the names of continents using acronyms and to identify associations with information they already know (the shape of the continent, famous person living there, animal/bird/plant native to the area).
T6U12 Categorization strategies I	Learning to categorize words in different ways, explaining the reasons for each category and discussing their value and usefulness in learning.	Students are asked to categorize the words "potato, beet, turnip, strawberry, bilberry, dogberry" in three ways and to explain their reasons for categorizing. Classroom discussion is held on why and how different ways of categorization (on the basis of visible or more abstract characteristic) are useful to support learning.

T6U13 Categorization strategies II	Review of memorization strategies tapped in previous lessons. Exploring possible ways of memorization. Introducing and practicing categorization as a memorization strategy. Discussions on how and why forming categories could be efficient and when to use categorization strategies.	Students are instructed to memorize 12 words in two different ways — repeating them in the exact same order as they are displayed, and trying to form groups that make sense to them. After each trial, students write down the words they remember. Classroom discussion is held to compare the results and explain why different numbers of words were remembered. Students are also asked to recall all learned words in the next unit to see which strategy promoted long-term learning.
T6U14 Applying categorization in math	Showing and practicing the use of different categorization strategies in math. Different ways to form groups are reviewed, and the reasons why some of them are more useful than others are discussed. The unit is modified to be in accordance with the topics students learn in ordinary lessons.	Categorizing word problems. Students are given four problems, including 1) two multiplication problems and two division problems; 2) two including the phrase “times more” and two including the phrase “times less.” Students are asked to categorize four tasks into two groups in two different ways and to name the groups. Classroom discussion is held to analyze the groupings and their effectiveness in helping to solving math problems.
T6U15 Applying	Showing and practicing the use of categorizing in learning language. Discussion of which grouping(s)	Categorizing texts. Students are given four texts (two poems, two riddles; two with authors, two in bold) and asked to group these texts into two

categorization in language	could be useful and how categorizing can be used when learning language. The unit is modified to be in accordance with the topics students learn in ordinary lessons.	groups in two different ways and to name the groups. Classroom discussion is held to analyze which groupings effectively support language learning.
T6U16 Applying categorization in science	Showing and practicing the use of categorizing in learning science. The usefulness of grouping is discussed, and different categorizing strategies to better understand the topic are practiced. The unit is modified to be in accordance with the topics students learn in ordinary lessons.	Topic: *Models and plans.* Students are asked to form 1) three and 2) two groups of photos (globe, town-plan, model of solar system, photos of town, the Earth, the Sun). Students form teams and compare each of their groupings. Each student explains the reasons for their own groupings.
T7U17 Strengths and challenges of cognitive learning strategies	Review of topics on learning strategies and practice implementing these strategies in different situations and tasks. Discussions about how to use strategies adaptively and efficiently.	Pairs of students are asked to teach the teacher how to solve a math problem. Students have to think about and write down the best strategy to solve the problem. Classroom discussion is held to explain and analyze all given strategies.
T8U18 Strengths and challenges of	Review of the learned material. Individual differences in memory and learning, and how to improve	Students are asked to recall learning strategies and to fill out a table which describes how comfortable they are using each strategy.

each student in applying learning strategies	learning skills. Students are encouraged to reflect about their own strengths and weaknesses in using different learning strategies in different situations and tasks.	Students are also asked to give examples of how and when they have used each strategy.