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Digitally Enhanced Reflection to Support Primary School Pupils' Self-Regulated Learning

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Abstract

Self-regulated learning (SRL) is a critical skill that should be fostered from the early stages of education. The ability to metacognitively reflect plays a central role in supporting SRL, yet its practical implementation in primary education remains underexplored. This case study explores how structured reflection can support SRL in primary education during a phenomenon-based study module. Reflection was prompted in different phases of the SRL process using a learning management system that provided question prompts and learning analytics visualisations. Pupils' written answers to reflection prompts were first analysed using a qualitative content analysis. Three specific reflection profiles were identified using a latent class analysis: Reluctant, Nascent and Active reflectors. Differences between the profiles were found in the goal setting and monitoring phases. The associations between the profiles and study grades were analysed using a Chi-square test. Pupils with the lowest grades were more likely to belong to the Reluctant reflectors profile. These findings suggest that as primary pupils' skills to reflect their SRL are heterogeneous and this may also contribute to learning outcomes in primary education, the design of the reflection support is critical.

Keywords: e-learning; self-regulated learning; reflection; primary school pupils; learning analytics

Introduction

Self-regulated learning (SRL) is a crucial 21st-century skill essential for lifelong learning (Taranto & Buchanan 2020; van de Oudeweetering & Voogt 2018), that should be recognized and supported already at primary school (Dignath et al. 2008; Kontturi 2016; Panadero 2017). Additionally, as primary schools increasingly adopt digital and student-centred learning approaches, such as phenomenon-based learning (see e.g. Symeonidis & Schwarz 2016) students need to develop new competencies, including SRL (Segedy, Kinnebrew & Biswas 2016). Moreover, research has established that there is a positive association between SRL skills and study success (Ha et al. 2023; Zimmerman & Kitsantas 2005).

However, being able to self-regulate is a challenging task (Bjork et al. 2013) and it has generally been found that students' skills are inadequate (Baars et al. 2018; Baars & Viberg 2022). Accordingly, there is great heterogeneity in primary pupils' SRL skills and the need for continuous support (Heirweg et al. 2020; Kontturi 2016). It has therefore been suggested that SRL should be regarded more as a learning object and competence (Baars & Viberg 2022) – a competence that is consciously practised already at primary school. However, teachers are not knowledgeable enough to facilitate primary school pupils' SRL (Dignath & Veenman 2021; van de Oudeweetering & Voogt 2018). Following this, students are rarely taught how to apply metacognitive regulating skills (e.g. Dignath & Veenman 2021).

Given the importance of SRL in contemporary education, there is a growing need to identify solutions to support students in fostering their SRL (Panadero 2017; van de Oudeweetering & Voogt 2018). Previous studies have shown that supporting SRL digitally can improve SRL behaviours (e.g. Palalas & Wark 2020; Wong et al. 2019). Metacognitive activities, such as reflection, have been proven especially effective in enhancing SRL (e.g. Braad et al. 2022; Guo 2022). Research is mainly conducted in university settings (Palalas & Wark 2020), although it has already been acknowledged that providing awareness of primary education is needed (Rodríguez-Triana et al. 2017). This study explores primary school pupils' metacognitive reflection on different phases of an SRL process when the reflection is digitally enhanced through reflective prompts and LA and if this is connected to study success. The findings of this study further illustrate the implementation of supporting the phases of SRL digitally in primary school.

Self-regulated learning

SRL combines the cognitive, metacognitive, behavioural, motivational and emotional aspects of learning to describe how students regulate their learning (Panadero 2017; Zimmerman 2002). In SRL processes, students regulate their learning by setting goals, choosing learning strategies, monitoring their progress and reflecting on the outcomes (Panadero 2017;

Zimmerman & Schunk 2011). According to Zimmerman's model, three phases are repeated in the SRL processes: forethought, performance and reflection (Zimmerman 2002).

First, during the forethought phase, students analyse the learning task, activate their prior knowledge and set goals for their learning (Zimmerman 2002). According to Schunk and Swartz (1993), goals that include learning skills and competencies lead to better self-regulation. However, not all of the goals that students set have a positive impact on learning as students may also set avoidance goals (Panadero & Alonso-Tapia 2014).

Second, during the performance phase, self-regulated learners monitor their learning (Zimmerman 2002). Monitoring means that they systematically activate and sustain their thoughts, feelings, motivation and actions to attain their goals (Schunk & Greene 2018). This requires learners to become metacognitively aware of their learning. Metacognitive monitoring processes are important parts of the SRL as those inform subsequent processes of controlling and regulating (Baars & Viberg 2022). Baars and Viberg (2022) suggest that if monitoring is not accurate it may negatively impact the regulation of learning.

Third, in the self-reflection phase, self-regulated learners judge their work and provide an explanation for their results. To do so, they need to be able to self-evaluate and reflect on their learning (Zimmerman 2002). Judgments, reactions and explanations made at this point will impact future learning situations (Panadero & Alonso-Tapia 2014). Finally, although different phases of the SRL process are represented as separated and following each other in a linear order, in practice those usually are entwined as the process is cyclical (Heirweg et al. 2020; Zimmerman 2002).

Pupils of primary school age are aware of their learning and therefore capable of using different SRL strategies (Järvenoja et al. 2019; Kontturi 2016) and benefit from SRL interventions (Dignath & Büttner 2008). However, research has outlined that pupils in primary school age have heterogeneous skills to regulate their learning (Heirweg et al. 2020; Kontturi 2016). Pupils with stronger skills have better motivation (Kontturi 2016) and they use more various learning strategies (Heirweg et al. 2020; Kontturi 2016).

Reflection

Reflection refers to the self-monitoring of one's own goals, plans, process, experience and outcomes and making judgments of learning performance (cf. Mezirow 1991; Moon 2004; Zimmerman 2002). Since reflection is a time-consuming process that does not always come naturally, students usually need a reason or at least encouragement to reflect (Gustafson & Bennett Jr. 2002). Therefore, reflection should be embedded into the learning design and encouraged throughout the learning process (Leinonen et al. 2016). Written reflections are considered extremely beneficial when enhancing metacognitive skills and SRL as they require students to stop and think (Fernsten & Fernsten 2005).

To understand the development of reflection, different categorising models are made, such as the models of Mezirow (1991) and Fleck and Fitzpatrick (2010). Generally, in the lower levels of reflection, students describe their learning actions and the content learned (Fleck & Fitzpatrick 2010; Mezirow 1991). As they proceed to the higher levels of reflection, they are

generally more able to describe what aspects influenced their learning, make comparisons and see things from various perspectives (Fleck & Fitzpatrick 2010; Mezirow 1991). The highest levels of reflection are achieved when students are capable of changing their actions or thoughts based on their analytical reflections and, finally, critically connecting their thinking to wider moral and ethical issues (Fleck & Fitzpatrick 2010). Higher levels of reflection build on previous levels as reflection grows deeper (Fleck & Fitzpatrick 2010). Accordingly, research shows that the quantity of reflection usually delineates the level of reflection (Moon 2004).

Overall, research states that students who reflect on their learning perform better in school (Guo 2022; Perels et al. 2009) as higher achieving pupils tend to self-evaluate their learning more cyclically (e.g. Heirweg et al. 2020). The majority of the research on reflection has focused on the learning content. Fewer studies have revealed the effectiveness of reflection on primary school pupils' skills, such as SRL. Accordingly, research on reflection has mainly focused on older students. It should be noted that reflection skills can be learned at an earlier stage, as reflection is a developmental process (Gustafson & Bennett Jr. 2002) and metacognitive skills start to appear as early as the first years of primary school (Alvi & Gillies 2021).

Supporting SRL through digitally enhanced reflection

Research has highlighted the synergy of students' metacognitive activities to enhance SRL (e.g. Braad et al. 2022; Greene 2020; Guo 2022). Interventions have illustrated the crucial importance of metacognitive support (Braad et al. 2022; Dignath & Büttner 2008; Theobald 2021) since being able to metacognitively reflect on different phases of the SRL process is vital for the enhancement of SRL skills (Baars et al. 2018; Baars & Viberg 2022; Dignath & Büttner 2008). Metacognitive skills, such as monitoring and self-reflection are powerful processes in supporting SRL phases (Ha et al. 2023) as those produce feedback loops helping students to recognize the need for support or change of behaviour or goals. As students' reflection is prompted repeatedly on different phases of a self-regulated learning process (cf. Baars & Viberg 2022), it stimulates students to make otherwise implicit metacognition concrete. Consequently, it improves their metacognitive knowledge and guides them to reflect on their ways of learning. Repeated reflections can help students eventually scrutinize reflection on SRL as a metacognitive habit (cf. de Boer et al. 2018).

Encouraging results have been shown in supporting metacognitive reflection through technology (Fleck & Fitzpatrick 2010; Guo 2022; Kori et al. 2014). Technical tools providing guidance such as prompts or guiding questions can improve metacognition (Braad et al. 2022), give reflection structure, encourage the students to consider their learning more carefully, deepen their thinking and guide reflection to a higher level (Fleck & Fitzpatrick 2010; Kori et al. 2014; Leinonen et al. 2016). In a meta-analysis, Guo (2022) exhibited that digital metacognitive prompts significantly enhanced SRL activities.

Accordingly, tools for LA have increasingly been developed for digital learning environments to meet the need for more personalised learning support (Schumacher & Ifenthaler 2021). As the LMS captures the actions (for example searching for help, checking goals) of the learning

process, LA based on these learning actions could reveal more of the strategies and self-regulative processes that students face (Schunk & Greene 2018). In addition, LA dashboards allow students to visually monitor their progress, making the reflection more data based.

Consequently, the impact of regular digital reflection on study success is demonstrated in different contexts, such as online maths courses (Choi et al. 2017), and science classes (Pei et al. 2020) in primary school. However, not all reflection has a positive effect on reflection (Kori et al. 2014) as students might just copy and paste to get the “right” answers (Furberg 2009) or be overwhelmed by continuous over-prompting (Papadopoulos et al. 2009; Väisänen 2022). Accordingly, some students might not see the importance of reflection (Braad et al. 2022). More research is needed to understand what makes digitally enhanced reflection effective and suitable for younger learners (Rodríguez-Triana et al. 2017).

The aim of this study

Research on primary education pupils’ SRL and reflection, especially in digitally supported learning contexts, is still scarce. The purpose of this study was to explore primary school pupils (5th and 6th year) digitally enhanced reflection in different phases of an SRL process and to examine the associations to study success. Research findings in this field help us to understand the facilitation of reflection in digitally enhanced SRL processes to foster self-regulation. In this study, we use the term pupils when referring to the target group and students to refer to learners more generally.

The specific research questions were as follows:

RQ1: What kind of reflection do primary school pupils describe during the different phases of the digitally enhanced SRL process?

RQ2: What distinct profiles of pupils can be identified based on the various categories of reflection?

RQ3: What is the relationship between the reflection profiles and the pupils’ study success at the end of the digitally enhanced SRL study module?

Methods

Research context and procedures

A specific study module to support SRL through reflection was created for the purpose of this study in a digital LMS. Pupils used the LMS to study the learning materials, make learning tasks and reflect on each phase of the SRL process. The pupils worked actively on the LMS using their tablets. The context of the study was a phenomenon-based (Symeonidis & Schwarz 2016) study module on outer space. The study module consisted of five topics, each of them comprising two 45-minute lessons. The learning context was blended as the pupils worked in a classroom and were able to collaborate with their peers, ask for help and use the LMS with their tablets.

The LMS was facilitated to support the phases of self-regulated learning (Zimmerman 2002). Regular reflection to support SRL was embedded as open-ended questioning prompts that led the pupils to reflect in the SRL phases pre-knowledge, goals, monitoring, reflection and assessment. Accordingly, the LMS collected LA data on pupils’ behavioural actions and

pupils could follow and reflect on their progress through LA visualisations on their “Own Progress” -page (For further information on the LMS, see Väisänen et al., 2022) Using the LMS, LA and an effective learning design, pupils' reflection was systematised, and the learning process was cyclical.

At the end of the study module, study success was assessed by the class teachers with a final course assignment in the form of a written essay. In the final assignment, the pupils were asked to think about the three most important phenomena of outer space that affected their lives. Evaluation of the assignments was based on a school-specific grading scale, comprising four levels ranging from “emerging” (O) to “advanced” (E). The intermediate levels included “developing” (K) and “good” (H). The grading of the final assignment was based on the objectives of the study module, such as understanding outer space phenomena and how these affect people's lives.

Participants

The study module was conducted in a Finnish research and development-oriented teacher training school. The 5th and 6th-year pupils were accustomed to using their tablets for learning. A total of 89 pupils participated in the study module, 5th (n=30) and 6th (n = 22) year, aged 11–13 years. Participation in the research was optional. Of the pupils involved, 51 of them agreed to participate in the study, and their parents also agreed.

The research design was approved by the University of Eastern Finland institutional review board (IRB) for research ethics (11/2020). The research process followed the EU General Data Protection Regulation (GDPR 2016/679), the National Data Protection Act (1050/2018) and the national ethical principles of research with human participants.

Data collection

During the study module, authentic learning data was gathered through the LMS. To understand how pupils reflect and to answer research questions one and two, we used data from the LMS tasks in which the pupils reflected on their learning in different phases of the SRL process (pre-knowledge, goals, monitoring, reflection and assessment, cf. Zimmerman 2002). In each of the five topics of the study module, the same reflective open-ended questioning prompts were used, presented in Table 1.

Phases of the study module	Reflection tasks
Pre-knowledge	Have you ever wondered what’s inside the Earth? Write down what you already know.
	What does the Universe mean? How was it born? Which are the components of the Universe? Write down your answer.
Goals	Write down your own goals in this theme. What are you especially interested in?

Monitoring and reflection	Assess your own learning. Did you manage to answer the questions? Which questions were easy? Which questions were hard and need more practice?
Assessment and judgment	Assess your learning during this learning theme. How were you able to achieve the objectives of this theme? Which tasks were easy? Which tasks were hard?

Table 1: Reflection Prompts During Different Phases of the Study Module

The reflection tasks were an essential part of the study module, i.e. the pupils needed to complete the reflection tasks to continue with the LMS tasks. The pupils reflected a total of 16 times during the study module. The completion of the reflection tasks was conscientious as 92% (749/816) of the reflection tasks were carried out. The pupils' answers remained relatively short. The word count in the reflections for the whole module per pupil varied from 17 to 258 words, the average number being 94.7 words.

To answer research question 3, final course assessments were collected from the LMS data. At this point, some data loss occurred as we were able to get the final grades for 42 participants.

Analysis

To explore the pupils' reflections and to answer (RQ1), a qualitative content analysis (Elo & Kyngäs 2008) of the pupils' written reflections was conducted to find the characteristics of the reflections in each phase. The reflection data was collected according to the SRL phases pre-knowledge, goals, monitoring, reflection and judgment. Before the analysis, the data was structured according to these phases. To understand the meaningful connection of a single reflection text to the learning process and SRL phase, reflections were interpreted within the context of the precise reflection task, for example, the texts coded as judgments were made in the assessment phase.

We first started reading through the pupils' reflections several times to gain an overall understanding. In code creation, we used the qualitative analysis software Atlas.ti (version 22.1). Subcodes emerged from the data inside each SRL phase. At this point, we also analysed the depth of pupils' reflections according to the reflection levels presented by Fleck and Fitzpatrick (2010). Consequently, a total of 24 codes were identified (see Table 2).

In the second cycle of coding, the codes were combined into ten categories presented in Table 2 - Pre-knowledge relevant, No goals, General goals, Specific goals, Monitoring, Higher reflection, Non-purposeful reflection, Negative judgment, Easy judgment and Positive judgment. The coding was conducted by the first author. To enhance the reliability, the coding was discussed and negotiated in detail with the other authors in the second cycle of coding, and a few minor adjustments were made.

SRL categorization (SRL phases)	Codes after the first cycle of coding	Final categories based on data
Pre-knowledge	Pre-knowledge irrelevant	-
	Pre-knowledge relevant	Pre-knowledge relevant
Goals	No goals	No goals
	Task orientation General goals Grade orientation	General goals
	Skill orientation Specific goals	Specific goals
Monitoring	Monitoring challenges Monitoring easy General monitoring	Monitoring
Reflection	No monitoring Negative interest Frustration Avoidance No reflection	Non-purposeful reflection
	Purposeful reflection: Analysing Purposeful reflection: Future aspect Purposeful reflection: Outcomes Purposeful reflection: Process	Higher reflection
Judgment	Negative judgment	Negative judgment
	Easy judgment	Easy judgment
	Positive judgment OK judgment	Positive judgment

Table 2. Codes and Categories in the Different Phases of Qualitative Content Analysis

In the second phase of the study, we aimed to address the heterogeneity in students' reflection (RQ2) by identifying distinct reflection profiles based on the SRL reflection categories identified in the previous qualitative content analysis. As a pre-processing step, the qualitative categories were transformed into numeric data by counting the number of times each category was present in pupils' reflection responses. For the detection of SRL profiles, we conducted latent class analysis (LCA). LCA enables the detection of latent or unobserved patterns (clusters) within observed data (Hagenaars & McCutcheon 2002; Weller et al. 2020). Specifically, we used the R library glca (Kim & Chung 2020) to estimate the SRL reflection profiles. We estimated the number of clusters ranging from 2 to 10. We selected 3 as the optimal number of clusters based on fit indices such as information criteria (AIC and BIC) and entropy. To confirm that the detected profiles were well separated, we conducted a

Kruskal-Wallis non-parametric analysis of variance test to compare the presence of each of the coded categories between the clusters. To interpret and describe the implications of cluster membership for practice, we qualitatively reviewed students' reflections for each of the identified profiles.

In the final phase of the study, we examined the association between the SRL reflection profiles and study module grades (RQ3). The proportion of grades per cluster was analysed using a Chi-square test and plotted using a mosaic plot, which displays the association in the pattern of residual shading.

Results

RQ1: What kind of reflection do primary school pupils describe during the different phases of the digitally enhanced SRL process?

Qualitative analysis of the pupils' reflections exhibited heterogeneous ways to reflect during the different phases of the SRL process. In the category pre-knowledge, pupils expressed misunderstandings such as "The Universe was born when human life began" or they simply answered that they had not thought about it. The sub-category *Pre-knowledge relevant* illustrates the pupils' ability to connect and express prior knowledge meaningful to the context.

In the category *Goals*, three sub-categories occurred: *No goals*, *General goals* and *Specific goals*. In the sub-category *No goals*, the pupils were unable or reluctant to set any learning goals. The common answers pupils gave when asked to reflect on their goals were: "Nothing" or "I don't know". In the sub-category General goals, the pupils set very general goals for their learning. These were mostly on learning the content on an overall level such as "Learn something new" or "Learn everything". Accordingly, some task-oriented goals, for example, "Find the correct answers to tasks", or grade-oriented goals occurred. Contrary to these two previous categories, the sub-category *Specific goals* show the pupils setting specific goals for their learning regarding the content or skills to be learned. These were usually content-specific such as "My goal is to learn about the universe" but there were also some skills-oriented goals, such as "I will try to concentrate". Still, most of the pupils seemed to struggle to set goals for their learning; a lot of uncertainty was felt during this phase of the study module and the goals mostly remained on a general level.

The reflections of the SRL phase *Monitoring* show the pupils' ability to describe and specify their actions during their learning sessions. Generally, the pupils described which of the tasks they had found easy and which difficult, such as "It was easy to watch the videos and answer the questions" and "Writing was hard".

In the category *Reflection* two controversial sub-categories emerged: *High reflection* and *Non-purposeful reflection*. *High reflection* refers to pupils' ability to give explanations of their learning actions. They are analysing the reasons for their goal achievement such as "I was able to meet my goals and I was interested in this" or the lack of achievements: "I didn't succeed because I forgot to read about the structure of the Earth". Some pupils also specified their ways of studying, returned to their own goals when reflecting and also

understood what they needed to do in the future to achieve their goals. Controversially, the category *Non-purposeful* reflection refers to reflections with signs of avoidance, negative interest and frustration, with examples such as “Jsosksksk” or “Not interested”.

The category *Judgment* refers to pupils' self-evaluations at the end of each learning theme. Generally, the judgments pupils made were highly positive and gave the impression that learning had been easy and that they were satisfied with their learning process. In the sub-category *Positive judgment*, the pupils stated that they were satisfied with their learning process, such as “I succeeded in all my goals”, and “I did well”. In the sub-category *Easy judgment*, pupils reflected that learning had been easy for them, using expressions such as: “Everything was easy!”. Controversially, in the sub-category *Negative judgment*, the pupils made negative judgments of their learning performance such as “Bad” or “Nothing was easy”.

The mean values of the different categories expressed in Table 3 show the variation of reflection indicators in the pupils' reflections. The most common reflection indicator with the highest mean was *Positive judgment* (Mean = 5.39). whereas *High reflection* (Mean = 3.49) and *Monitoring* (Mean = 3.53) occurred equally often. The least frequently mentioned sub-category was Negative judgment with the lowest mean value (Mean = 0.22). Also, *No goals* (Mean = 1.12) and *Non-purposeful reflection* (Mean = 1.12) had low values. The pupils' reflections varied the most in the *High reflection* (SD = 4.09) and *Monitoring* categories (SD = 3.97). This indicates the variation in the pupils’ ability to reflect.

Category	*Mean*	*SD*
Easy judgment	3.000	2.441
General goals	1.765	2.036
Higher reflection	3.490	4.091
Monitoring	3.529	3.972
Negative judgment	0.216	0.879
No goals	1.118	1.762
Non-purposeful reflection	1.118	2.026
Positive judgment	5.392	3.007
Pre-knowledge relevant	1.373	0.937
Specific goal	2.588	2.202

Table 3. Descriptive Statistics of the SRL Categories per Pupil

RQ2: What distinct profiles of pupils can be identified based on the various categories of reflection?

Three distinct profiles (clusters) were identified in the latent class analysis, performed based on the categories made in the previous qualitative content analysis. The mean standardized value of each category in each of the clusters is shown in Figure 1.

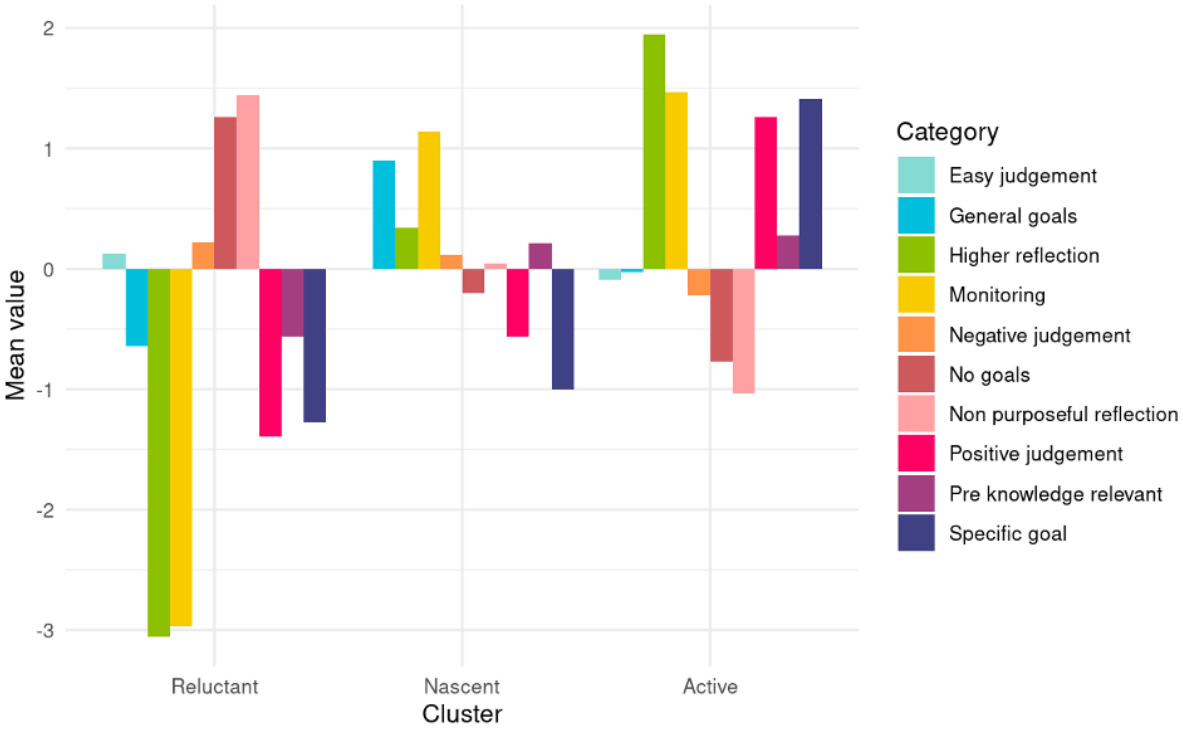

Figure 1. Mean Values of Each Category per Profile

The largest cluster was ***Active reflectors*** (N=23, 45.1%) showing a high occurrence of *Monitoring* (1.47 SDs higher than the overall mean) and *High reflection* (1.94***). Active reflectors*** are the only cluster in which *Specific goals* (1.41) and *Positive judgment* (1.26) are above the average. Within this cluster, *No goals* (-0.77) and *Non-purposeful reflection* (-1.03) are substantially below the mean. The second largest cluster was ***Reluctant reflectors*** (N=16, 31.4%). Contrary to ***Active reflectors***, this cluster shows a strong absence of Monitoring (-2.97 SDs lower than the mean) and *High reflection* (-3.05) as well as *Specific goals* (-1.28) or *General goals* (-0.64) and *Positive judgment* (-1.39). Instead, there is a strong presence of *No goals* (1.26) and *Non-purposeful reflection* (1.44). This is the only cluster in which *Easy judgment* (0.12) is marginally above the mean. The smallest cluster was ***Nascent reflectors*** (N=12, 24%). This cluster differs from the others with the highest value on *General goals* (0.9 SDs higher than the mean). *Monitoring* (1.14) is also significantly over average whereas *Specific goals* (-1) is largely below the mean.

As Table 4 shows, the three clusters showed statistically significant differences in the presence of all the qualitative categories, except for *Easy Judgment*, according to the Kruskal-Wallis tests performed for each category. Pairwise post-hoc analyses revealed that most of the differences exist between the **Active** and **Reluctant** clusters. The presence of High reflection was statistically significantly different among the three pairs of variables. *Monitoring* was significantly lower in the **Reluctant** cluster compared to the other two

clusters. In turn, *Non-purposeful* reflection was significantly lower in the **Active** cluster, whereas *Specific goals* were significantly higher in the other two clusters.

Category	Rank sum	p	Pairwise
Easy judgment	0.03	0.99	
General goals	6.40	0.04 *	Nascent - Reluctant
Higher reflection	27.64	0.00 ***	Nascent - Reluctant, Active - Reluctant, Active - Nascent
Monitoring	25.12	0.00 ***	Nascent - Reluctant, Active - Reluctant
Negative judgment	7.97	0.02 *	Active - Nascent
No goals	14.80	0.00 ***	Active - Reluctant
Non-purposeful reflection	16.96	0.00 ***	Active - Reluctant, Active - Nascent
Positive judgment	7.58	0.02 *	Active - Reluctant
Pre-knowledge relevant	9.55	0.01 **	Active - Reluctant
Specific goal	17.05	0.00 ***	Active - Reluctant, Active - Nascent

Table 4. Differences Between Clusters in Each Category (N = 51, df = 2)

Reluctant reflectors

The qualitative data for Reluctant reflectors (n=16) show the pupils struggling to reflect with their SRL process. Typically, they struggle to set goals for their learning, reflecting merely: “I don’t know” or “Everything”. Accordingly, Reluctant reflectors are generally not activating their pre-knowledge at the beginning of the learning process. These two aspects consequence that the important phases at the beginning of the learning process to regulate one’s learning remain unutilized. Still, pupils in this cluster are generally satisfied with their learning while making judgments. They reflect that their learning process had simply been easy and that they managed to do it well, typical answers being: “Everything was easy” and “It went well”.

Conclusively, the level of reflection in this cluster remains at a very low level. The answers remain very short, and the main goal seems to be getting learning tasks done and to mark those completed. The average quantity of words is 49.94 words in total in 16 reflection tasks, the range of variation being 24–104. Reluctant reflectors usually do not explicate which aspects of learning had been easy and which aspects they may have struggled with. All in all, they are very reluctant to reflect on their learning process. This leads to a lack of monitoring and a low level of reflection, typical aspects of this cluster.

In addition, some pupils in this profile express a strong negative attitude towards their learning, showing frustration, avoidance and not answering the reflection tasks, such as “Jsosksksksk” and “Something”. This high amount of *Non-purposeful* reflection can rather

harm the learning process than support it. Some pupils were also frustrated about repeated reflection tasks.

Nascent reflectors

The qualitative analysis of reflections in the second cluster, called Nascent reflectors (n=12) highlights the pupils with nascent skills towards higher levels of reflection. Typical for this cluster is the pupils' ability to set general goals. The term general here refers to goals not being exact or context-related, as the following examples explicit: "My goal is to learn everything", and "To learn something new". Nascent reflectors are able to express and utilise their pre-knowledge to some extent. These two abilities combined conclude that the starting point for the SRL process is already more advanced than in the first cluster.

Nascent reflectors seem to monitor their learning process. The qualitative data show that pupils can specify which parts of the learning were easy and which parts were hard: "It was easy to watch the videos and difficult to answer the questions". Being able to go back and report things that happened can be seen as a sign of reflection skills evolving. Interestingly, the pupils' advanced ability to critically reflect and monitor their learning seems to suggest that they reflect even more on the challenges they have faced. Criticality seems to stay throughout the learning process as pupils in this cluster rarely made positive judgments.

Advanced metacognitive monitoring enables higher reflection. Nascent reflectors seem to have the nascent ability to analyse aspects affecting their learning. For example, they can specify the learning strategies they have used and how they have managed to attain their goals. The nascent ability to produce more reflection is also seen in the quantity of reflection. The average number of words per pupil in this cluster is 94 words out of a total of 16 reflection tasks, the range of variation being 56–203 words.

Active reflectors

The third cluster (n=23) called Active reflectors typically shows active pupils engaged in reflecting on their learning process, showing the ability to effectively monitor and reflect and still being satisfied when assessing their learning process. To differentiate from the other clusters, typical for Active reflectors is their ability to set specific goals. Pupils in this cluster generally set content-specific goals such as "My goal is to learn how the rotation of the Earth affects the seasons". Being able to set specific goals indicates that the pupils have a deeper understanding of what they are supposed to learn, and they have also found their points of interest. The pupils in the Active reflectors cluster can also better utilise their pre-knowledge as a starting point for the learning process. The time and thinking spent at the beginning of the learning process seem to also benefit them positively later in their learning process.

As Active reflectors are typically highly monitoring and reflecting pupils their answers to reflection tasks are significantly longer; the average number of words per pupil in this cluster is 126.43 words in a total of 16 reflection tasks, the range of variation being 62–258 words. According to the qualitative analysis, they can monitor both the challenges and successes of their learning. Although they note that everything is not easy and they sometimes struggle, they still feel satisfied and positive about their learning process. "I think that I managed to attain the goals well. It was easy to make the group task. Hard was writing with own words".

Overall, contrary to other clusters, Active reflectors make more *positive judgments* related to their learning. They also provide justifications for positive judgments. Active reflectors can make significantly deeper reflections related to their learning process compared to other

clusters. They can, for example, make comparisons between their learning outcomes and their learning goals and specify which aspects affected their learning. This indicates a higher level of reflection.

Additionally, the qualitative analysis also reveals that understanding the necessity of practice and hard work is a typical feature of Active reflectors. Although pupils belonging to this profile are satisfied with their learning, they also understand the importance of practice and future learning tasks. They see learning as a continuous process; “I managed to do well but you can always make things better.”

RQ3: What is the relationship between the reflection profiles and the pupils' study success at the end of the digitally enhanced SRL study module?

Finally, we studied the association between membership in the reflection clusters to the grades given at the end of the study module. The grading followed the school's four-level grading system E= Advanced, H= Good, K= Developing, O= Emerging. Table 5 shows a contingency table containing the distribution of grades between clusters. The results of a Chi-square test showed that the differences were overall not statistically significant: X2 (6, N = 42) = 9.9054, p = .1287. However, a residual analysis, as shown in the shading of the mosaic plot (Figure 2), revealed that the relationship between the Reluctant cluster and the O grade was individually significant. In other words, pupils who obtained an O grade (the lowest grade) were more likely to belong to the Reluctant cluster. According to these results, a high level of reflection did not seem to necessarily guarantee academic success, but pupils with lower levels of success tend to have a low level of reflection.

Otherwise, the findings are in line with previous research on SRL and reflection, suggesting that the ability to reflect and regulate one's own learning increases the likelihood of enhanced study performance. The pupils in the Active reflectors cluster achieved more advanced or good grades and only a minority of them nearly failed the final assignment. The pupils in the Nascent reflectors cluster with varying abilities to set meaningful goals and monitor their learning achieved mostly intermediate-level grades H (Good) and K (Developing).

Cluster	E	H	K	O
Reluctant	2	3	3	6
Nascent	2	3	3	1
Active	7	8	3	1
Total	11	14	9	8

Table 5. Number of Pupils with Each Grade Level per Cluster

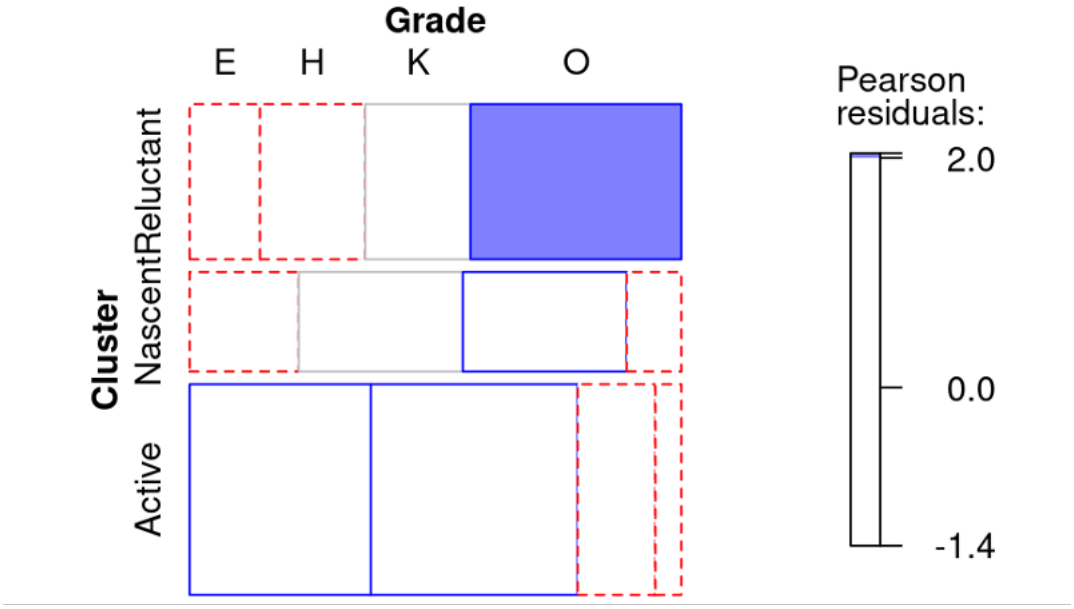

Figure 2. Mosaic Plot Showing the Association Between the Pupils' Reflection Profiles and their Grades

Discussion

This study aimed to explore digitally enhanced reflection among primary school pupils (5th and 6th year), outlining the profiles of the pupils based on their reflections and investigating the connections to study success. The LMS used was designed to facilitate and support reflection and pupils' SRL process with reflective questioning prompts and LA visuals.

Pupil distribution in the different reflection profiles demonstrates that primary school pupils can benefit from digitally enhanced reflection, i.e. LA visuals and questioning prompts. With almost half of the pupils belonging to the Active reflectors cluster, the results resonate with previous research (Kontturi 2016). Additionally, the distribution indicates that most of the pupils of this age are already capable of digitally monitoring and reflecting on their learning. Because the support for pupils' metacognitive understanding of their learning process enables better regulation of learning (cf. Braad et al. 2022; Greene 2020; Guo 2022), digitally enhanced reflective practices can be seen as a way to promote SRL in primary schools.

However, the findings also confirm the results of the previous studies (Guo 2022; Kontturi 2016) that primary school pupils exhibit significant differences in their ability to regulate their learning. The three reflection profiles identified were Reluctant reflectors, Nascent reflectors and Active reflectors. Differences were observed especially in the phases of setting goals, monitoring and reflecting. Furthermore, the ability to reflect in one phase of SRL seems to connect with the other phases. This supports the idea of previous research that when implementing practices to support SRL, each SRL phase should be considered as SRL is a cyclical process, each phase affecting the others (Baars & Viberg 2022). Overall, the results of this study revealed that especially monitoring and a higher level of reflection were deeply intertwined processes, monitoring being a requirement for reflection to occur. The close

relationship between monitoring and other phases of SRL in primary school is supported by Heirweg et al. (2020).

Contributing to previous research (Guo 2022; Perels et al. 2009), the analysis of correlations between reflection profiles and study success revealed only a weak correlation between the final grades of the study module and the reflection profiles. However, the strongest connection found between the Reluctant reflectors and the lowest grades suggests that the unwillingness to reflect might harm the whole learning process. Consistent with previous research by Väisänen et al. (2022), the present study indicates that especially setting goals for learning remains a challenging task for 5th and 6th year pupils. Since well-defined goals prompt learners to guide their learning in the subsequent phases when they monitor and evaluate their performance (cf. McCardle et al. 2017), this phase should not be overlooked.

This study offers promising results on digitally enhancing SRL in primary schools. Digitally enhanced reflection can make reflection a systematic part of the learning process and help to automatise the metacognitive skills required in SRL processes. Together with direct instruction of learning strategies (Dignath & Veenman 2021), this could be a powerful tool to support self-regulated learning in primary schools. Accordingly, Kontturi (2016) highlights the importance of more holistic support for SRL considering aspects such as learning design, physical learning environment and social interaction.

However, this study confirms that pupils with lower metacognitive skills are less likely to utilize digital support for metacognitive reflection in SRL (cf. Braad et al. 2022). Repeated reflection also caused frustration and avoidance in the lower-reflecting pupil profiles. Reluctant reflectors struggled with goal-setting and monitoring, often engaging in non-purposeful reflection. Overall, they expressed minimal interest in reflective practices and failed to recognize the value of reflection (cf. Braad et al. 2022). As this inadequate reflection appeared to correlate with diminished learning outcomes, this could also be attributed to motivational factors (Järvenoja et al. 2019). Consequently, we must critically evaluate the extent to which technology can replace human interaction in metacognitive reflection within primary schools. Human guidance remains valuable for providing alternative perspectives and fostering critical thinking (Kori et al. 2014). The findings of this study align with previous studies, suggesting that due to the heterogeneous nature of SRL skills in primary school, some pupils still require teacher assistance (So et al. 2019) or personalized support (Braad et al. 2022) for their SRL processes.

Limitations and future research

In the context of this study, the learning design was very structured. Future research could investigate reflection when the learning context is more complex, requiring advanced skills such as collaboration. As the effects of LA for reflection writings were not separately investigated in this study, future studies would presumably gain a holistic understanding by combining learning analytics log data with qualitative methods.

This study is not without limitations. First, as the research data are limited to one specific school cohort, the findings of this study may not be generalisable to other contexts. Second, as the first phase of the data analysis employed manual coding techniques for qualitative content analysis, it may be subject to limitations such as researcher bias. Third, it must be acknowledged that the clustering analysis in this study was based on a limited amount of

data, which may have impacted the accuracy and reliability of the clustering results. Larger datasets may be necessary to confirm the findings.

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