Self-Regulated Learning in Inquiry-Based Education

Exploring Differences in SRL Skills Among Learners with Varying Competence Levels

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Abstract

In inquiry-based learning (IBL), students are expected to take ownership of their learning through planning, monitoring and reflecting, which are key components of self-regulated learning (SRL). While prior research suggests that SRL is essential for successful engagement in IBL, it remains unclear how these skills manifest among learners with different competence levels, particularly in primary education. This exploratory study examined which SRL behaviours are demonstrated by children with High, Average and Low competence levels during an individual, digital IBL task. Learners in their final year of primary school (N = 31) completed a simulation-based task while thinking aloud. Verbal data were analysed using an observation scheme based on Zimmerman's Cyclical Phases Model of SRL. Overall, SRL behaviours were observed most frequently during the investigation phase of the inquiry cycle, while the orientation and discussion phases elicited few observable SRL behaviours. When comparing competence groups, only a significant difference was found only for the behaviour of predicting, with average-competence students engaging in this more frequently than low-competence peers. These findings suggest that the relationship between competence level and SRL may be more complex than assumed and not easily captured through thinking-aloud data alone. Future research could benefit from incorporating complementary methods to better understand the nuances of SRL in IBL contexts. This study highlights the need to consider multiple factors beyond SRL when examining students' performance in inquiry-based learning.

Self-Regulated Learning in Inquiry-Based Education

Nowadays, it is essential for educational institutions to adapt to the evolving demands of society and equip students for the complexities of the modern world (Dilekçi & Karatay, 2023). As a result, there is an increasing emphasis on cultivating skills that go beyond the traditional transmission of knowledge. Today, education plays a critical role in fostering essential 21st-century skills such as communication, creativity, and collaboration. These competencies are closely intertwined with and foundational to the development of self-regulated learning (SRL). Self-regulatory skills including goal setting, monitoring, and reflective thinking are increasingly recognized as vital for academic achievement and long-term professional success (Khan et al., 2022; Setiani, 2023). Recent research suggests that, although supporting students' cognitive and personal development has long been a goal of education, there is now a more explicit focus on fostering metacognitive and self-regulatory skills in response to growing demands for lifelong learning, learner autonomy, and adaptability in a rapidly changing, knowledge-based society (Pintrich, 2004; Setiani, 2023; Zimmerman, 2002).

The emphasis on SRL has led to increasing attention toward pedagogical approaches that allow students to take an active role in directing and managing their own learning, such as through inquiry-based or constructivist learning environments (Lai et al., 2018). Inquiry-Based Learning (IBL) can serve as a pedagogical context in which self-regulated learning (SRL) is both required and potentially fostered, provided that adequate scaffolding and reflective support are in place (Lai et al., 2018; Vermunt, 2005; Zweers et al., 2019). SRL is an active and cyclical process in which learners set goals, plan strategies, monitor their understanding, and evaluate outcomes (Zimmerman, 2002). Due to the open-ended and often less structured nature of IBL, students are frequently required to take initiative in regulating their learning processes. This includes deciding how to approach a task, how to monitor progress, and when to adapt strategies (Lai et al., 2018; Vermunt, 2005). While these characteristics create opportunities for students to engage in SRL, research also emphasizes that IBL on its own does not automatically lead to the development of self-regulation. Without explicit guidance, students may struggle to manage their learning effectively in such contexts (Schunk & Ertmer, 2000; Zweers et al., 2019). Therefore, IBL holds potential for supporting SRL, but this depends largely on the intentional integration of instructional support and opportunities for reflection (Lai et al., 2018; Pintrich, 2004).

Studies have further indicated that IBL environments can contribute to the development of broader competencies such as problem-solving, creativity, and innovation, which are often linked to self-directed learning processes (Acar & Tuncdogan, 2018; Dilekçi & Karatay, 2023). While the successful implementation of IBL partially depends on students' existing self-regulatory capacities (Keselman, 2003; Vermunt, 2005), it may simultaneously provide a valuable context for supporting those skills, especially when appropriate scaffolding is present (Lai et al., 2018; Van Dijk et al., 2016). Given these considerations, IBL could serve as a promising framework for promoting SRL in educational practice.

On the contrary, in order to work well within IBL frameworks, the development of self-regulation is crucial for students, as this method inherently demands a high level of independence and initiative (Zweers et al., 2019). It is suggested that students who lack well-developed self-regulatory skills, may struggle with the less structured nature of IBL, potentially leading to frustration or disengagement (Vermunt, 2005). Conversely, students who possess strong self-regulation strategies are more likely to thrive in IBL environments, as they are able to plan their approach to the task, monitor their progress, and adjust their strategies when faced with obstacles (Lai et al., 2018).

Inquiry-Based Learning (IBL) is often considered a promising approach for promoting the development of students' self-regulated learning (SRL) skills, as it encourages learners to take ownership of their learning process by planning, monitoring, and evaluating their actions (Lai et al., 2018; Zimmerman, 2002). However, to engage effectively in IBL, students need to possess or develop such SRL skills. Without them, learners may struggle to navigate the less structured nature of inquiry tasks (Zweers et al., 2019).

In addition to SRL, students' cognitive ability levels appear to influence how successfully they engage with IBL. Research by Van Dijk et al. (2016) found that Dutch primary school students (aged 11-12) with higher cognitive abilities benefited more from IBL than their peers with average or lower abilities. These students also demonstrated more efficient inquiry processes. Similarly, Jiang and McComas (2015) reported that gifted students tend to interact more effectively with open-ended inquiry tasks, while less gifted students often require greater external structure and guidance.

Interestingly, Van Dijk et al. (2016) also found that the higher-ability students in their study made more frequent use of available support. This suggests that the relationship between competence level and SRL is not necessarily linear or straightforward. Although high-ability students often show greater self-regulation, they may also be more adept at recognizing when and how to use support effectively. This raises the question of whether SRL is solely a function of ability, or if other factors, such as help-seeking behaviour or prior experience, might play a mediating role.

While the relationship between cognitive ability and SRL during IBL is increasingly acknowledged, the understanding of how these two variables interact remains limited. High-ability students are often assumed to be more self-regulated, as they tend to demonstrate stronger metacognitive awareness and are more capable of managing their learning independently (Perry et al., 2002; Zimmerman, 2002). However, much of the existing research is based on general academic contexts or relies on self-report measures, which may not capture how self-regulation unfolds in the open-ended and less structured setting of inquiry-based learning. Furthermore, studies such as Van Dijk et al. (2016) show that even high-ability students actively use available support, suggesting that strong cognitive abilities do not always equate to fully autonomous learning. This indicates that the connection between competence and SRL may be more dynamic than previously assumed. Clarifying this relationship is essential for designing learning environments that provide appropriate support for students across competence levels, ensuring that instructional strategies are responsive to the specific self-regulatory needs of diverse learners (Perry et al., 2002; Van Dijk et al., 2016; Zimmerman, 2002).

Theoretical Framework

Inquiry-based Learning

To begin with, IBL can be described as a pedagogical approach that enables students to acquire knowledge through inquiry processes which closely resemble the methods used by scientists (Keselman, 2003). IBL provides students with the opportunity to engage deeply with complex topics and teaches them not only to acquire knowledge but also to actively apply it (Keselman, 2003). It does so by encouraging students to engage with questions and problems which challenge them to think critically, collaborate, and find solutions creatively (Qablan et al., 2024). Unlike traditional, teacher-centred approaches, IBL emphasizes learner autonomy and requires students to take responsibility for their learning journey (Spronken-Smith & Walker, 2010).

Increasingly, IBL takes place in digital environments such as online science labs, where students can conduct experiments, manipulate variables, and analyse data in simulated settings. These environments allow for immediate feedback and structured experimentation, making them especially suitable for educational research (Van Dijk et al., 2016).

According to Pedaste et al. (2015), a typical inquiry cycle consists of five stages. These stages mirror the scientific process, encouraging students to pose questions, design experiments, gather and analyse data, and ultimately reflect on and discuss their findings (Pedaste et al., 2015). In the orientation phase, the topic or theory is introduced by the teacher, instructor or prompts such as an instruction video. After that, the conceptualization phase starts, in which questions and potential hypotheses are being formed. Here, also a prediction can be requested from students. In this phase, it becomes clear to the students what needs to be known after completing the inquiry cycle. Thirdly, the investigation phase follows. Most action happens here, as data is being collected but also analysed and interpreted. Once the data is analysed, the conclusion phase starts, in which one's personal findings become clear and potential hypotheses are being confirmed or rejected. Lastly, the discussion phase is there to reflect on the whole process. In this study, students completed an IBL task using a digital lab environment based on Van Dijk et al. (2016), allowing for structured observation of their inquiry behaviour and self-regulation strategies.

Self-regulation Skills

In order to work well within the frameworks of IBL, the development of self-regulation is crucial for students (Lai et al., 2018). One way to describe self-regulation is the ability to generate thoughts, emotions, and behaviours that are planned and continuously adjusted to achieve personal objectives (Zimmerman, 2000). To be able to understand what objectives of self-regulation can be observed in an educational setting, Zimmerman (2000) introduced a model monitoring self-regulation: the Cyclical Phases Model. Firstly, there is a forethought. The way learners perform their task analysis, for example, by setting goals or plan their process, and express their self-motivation beliefs, indicates how well a learner masters those self-regulation skills. Observable behaviours of the forethought could be goal setting, strategic planning and talking about intrinsic interest with relation to the task. The second subprocess Zimmerman (2000) describes, is performance or "volitional" control. This subprocess can be split up in observing self-control, and self-observation. Lastly, there is the self-reflection subprocess, in which self-judgement and self-reaction come to play.

SRL Behaviours among Competence Level in Inquiry Learning

Research has shown that self-regulated learning (SRL) skills influence how students engage with IBL. However, it remains unclear whether and to what extent these skills are related to students' general competence levels (Lai et al., 2018; Van Dijk et al., 2016). Students with varying cognitive abilities are likely to approach inquiry tasks differently, particularly in how they connect new information to prior knowledge and assess its relevance and meaning (Wang et al., 2009). Highly capable students are generally considered better at independently solving problems and completing tasks, as they often prefer intellectually stimulating learning environments (Phillips & Lindsay, 2006; Reis & Renzulli, 2009). In contrast, students with lower ability levels tend to experience more difficulty with such tasks and benefit from a higher degree of structure to support their learning (Margolis & McCabe, 2003; Wang et al., 2009). These differences in cognitive abilities and learning preferences suggest that students' self-regulation capacities may also vary accordingly, emphasizing the need for differentiated support to foster SRL across diverse learner profiles.

Although SRL is relevant throughout the entire inquiry process, research suggests that certain phases of the inquiry cycle, like the investigation phase, may elicit more self-regulatory activity than others (Keselman, 2003; Pedaste et al., 2015). In addition, phases of inquiry such as orientation and discussion tend to require lower levels of observable SRL unless explicit scaffolding is provided (Lai et al., 2018; Qablan et al., 2024; Zweers et al., 2019). Understanding how SRL unfolds across the different phases of the inquiry cycle may help identify when students are most in need of support, and inform the design of learning environments that are responsive to their cognitive and metacognitive needs.

This Study

To summarize, research has shown that the extent to which learners possess self-regulation skills can influence how effectively they engage in IBL (Lai et al., 2018). Further, it is shown that learners' cognitive abilities may influence how effectively they self-regulate (Lai et al., 2018; Van Dijk et al., 2016). Although previous research has suggested a link between competence and SRL, it remains unclear how these skills manifest across learners with varying competence levels during actual IBL tasks (van Dijk et al., 2016). While it may seem intuitive that learners with higher competence are better able to self-regulate, there is limited empirical insight into how children with varying competence levels actually demonstrate these skills during IBL tasks. Gaining such insights is essential, as it would allow educators to provide more targeted support tailored to the needs of individual learners, particularly those who may struggle with self-regulation or require more structured guidance. Therefore, this study seeks to answer the following research questions:

"What is the relationship between children's competence level and the levels op SRL they use during a think-aloud inquiry-based learning task?"

"Which self-regulation skills do children with different competence levels show while performing an inquiry learning task?"

Methods

Participants

The study involved 31 elementary school students from the same group, aged 10 to 12 years (M = 11.7 , SD = 0.77) recruited from an elementary school in a mid-sized city in the Netherlands. The students were assigned to different competence groups; High (N = 12), Average (N = 10) and Low (N = 9). These competence levels are derived from the teacher's prior assessment of each student's general academic or scientific aptitude, based on his professional judgment, the primary's school secondary education recommendation, and the student's CITO test score.

Prior to participation, active informed consent was obtained from the students' parents or legal guardians through a physical letter distributed the week before the experiment. The letter, which first was approved by the Ethics Committee of the University of Twente, outlined the purpose of the study, the procedures involved, and the voluntary nature of participation.

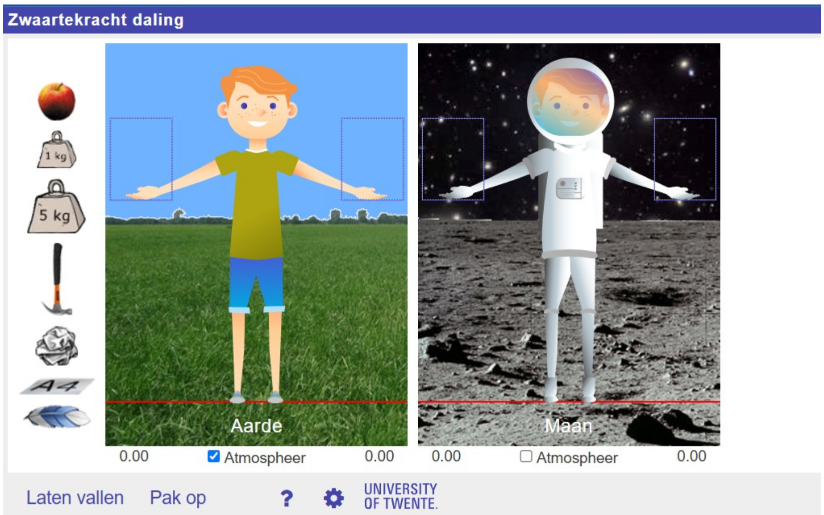
Materials

Inquiry Task

The inquiry task, originally developed by Van Dijk et al. (2016), was designed to guide students through the complete cycle of IBL within a digital simulation in the topic of gravity. The task engaged students in the five phases of the inquiry cycle as defined by Pedaste et al. (2015): orientation, conceptualization, investigation, conclusion and discussion. During the orientation phase, students were introduced to the concept of gravity. In the conceptualization phase, they were encouraged to formulate hypotheses about how object shape might influence gravitational behaviour on Earth and on the moon. The investigation phase involved experimenting with virtual objects under Earth and Moon gravity conditions, allowing students to gather and interpret data. As displayed in Figure 1, the students could choose different objects to drop simultaneously on Earth and on the Moon. The objects were an apple, a weight of 1 kilogram, a weight of 5 kilogram, a hammer, a paper ball, a piece of paper and a feather. Students could observe their chosen objects fall on both Earth and the Moon by clicking "laten vallen" (drop). Students were free to choose and test any number of objects and to repeat trials as they wish. This led to the conclusion phase, where learners evaluated their findings. At the final part of the task, students were asked to reflect on their experience by answering a question regarding their satisfaction with their performance and results, if they did not initiate the reflection themselves during the discussion phase.

Figure 1

Image of the Interactive Simulation used for the Experiment.



Script

To ensure consistency across all sessions and to support the think-aloud methodology, a scripted protocol was developed. This script aimed to standardize the interaction between the researcher and each participant, focusing on encouraging verbalization of thoughts without influencing the content. In addition, The script used age-appropriate language and relatable examples to introduce fundamental concepts, aiming to activate relevant prior knowledge and prepare students for the upcoming inquiry task. To ensure the language was age-appropriate, I explored popular educational and informative programs that children in this age group enjoy, using these as a reference point for tone and vocabulary. The script included a warm-up component designed to activate prior knowledge, aligning with the orientation phase of IBL as described by Pedaste et al. (2015). Open-ended questions were included such as “Do you know what gravity means?” to assess participants’ familiarity with key concepts relevant to the task. To support the think-aloud protocol, neutral prompts such as 'What are you thinking now?' or 'Why did you choose that object?' were used to encourage participants to verbalise their thought processes. These prompts provided insight into participants’ reasoning and self-regulated learning behaviours throughout the different phases of the inquiry cycle (Zimmerman, 2000). The number and type of questions were kept consistent across participants and were carefully formulates to avoid directing their strategies.

Procedure

Each participant was scheduled for a 15-minute long individual session. The task was conducted in a quiet, distraction-free environment within the school and was administered digitally on a laptop. Each session began with a standardized oral introduction, lasting approximately two minutes, delivered by the researcher in Dutch. During this introduction, students were asked to explain what they already knew about gravity and friction. Based on their responses, the researcher could supplement with additional information to ensure that all participants started the task with a similar baseline understanding.

Following the introduction, students were instructed to verbalize their thoughts throughout the activity using the think-aloud method. Students then engaged with the interactive digital simulation, which allowed them to test how the shape of various objects (e.g., an apple, paper ball, feather, or hammer) influenced gravitational behaviour on Earth and the Moon. Objects could be dragged into designated areas and dropped by clicking the “laten vallen” (drop) button. Students were free to select any number of objects, repeat trials, and explore different combinations and sequences without restriction. The primary task was to investigate and determine how the shape of an object affects its gravitational behaviour in different environments. For this part of the experiment, an unlimited number of trials was set, but a time limit of approximately 10 minutes was calculated.

At the end of the session, students were asked to reflect on their performance by selecting one of three satisfaction ratings (“Good,” “Average,” or “Bad”) and providing a brief justification for their choice. This subjective measure complemented the behavioural observations collected during the session. All sessions were conducted by the same researcher to ensure consistency in instruction, prompting, and data collection. During the activity, the researcher observed and recorded students' behaviours in real time using a structured observation scheme (see Figure 2). For each experiment including introduction and reflection in the end, a time limit of 15 minutes was set. Yet, the experiments did not take longer than 13 minutes, so this time limit has not been reached.

Data Analysis

Observation Scheme

An observation scheme was created to keep track of the different self-regulations behaviours that were performed by the students and is based on Zimmerman's Cyclical Phases Model (2000) of self-regulation (see Table 1).

The observable behaviours Goal Setting and Strategic Planning were used from the "Forethought Phase". The Self-Motivation Beliefs that are described in the model; Self-efficacy, Task interest and Goal orientation were not selected, because the behaviours did not seem to be observable, without interference of the researcher. As this was a think-aloud experiment, those behaviours did not therefore meet the criteria for being observable behaviours on their own.

Further, the behaviours Predicting (based on "Task strategies)", Following Instructions (based on "Self-instruction"), and Asking for help ("Help-seeking") were based on behaviours of the "Performance Phase". The behaviour Time management was not relevant here, as the researcher was in charge of managing time. Also the behaviours "Imagery", "Environmental structuring", "Interest incentives", "Metacognitive monitoring" and "Self-recording" were not used. The behaviour Redo Task (based on "Self-consequences") was added, to catch the process of students being aware of what they were doing.

Lastly, the behaviour Reflecting was based on the "Self-Reflection Phase" of Zimmerman's Cyclical Model, to see whether students were able to reflect on their own process during the experiment.

The observation scheme complemented the behavioural data gathered during the activity and captured self-regulation behaviours across five phases of scientific inquiry: orientation, conceptualization, investigation, conclusion, and discussion.

Table 1

Description and examples of the behaviours that were observed.

Behaviour	Description	Example
Goal Setting	Setting a specific objective or learning target for the task	"I want to discover what happens when I drop objects on the Earth and on the Moon."
Strategic Planning	Planning the steps or methods that will be used to accomplish their goal	"The weight and the paper sheet have different weights, so I want to see what happens on the Moon"
Predicting	Making a hypothesis or an explanation of what might happen previous to performing the task	"I think that the apple falls down faster than the feather."
Following Instructions	Attentively following task guidelines or researcher directions	Performing the task as explained by the researcher
Asking for Help	Seeking assistance when struggling	"How can I drop the objects now?"
Redo Task	Performing the same task twice or more frequent	Using the same objects twice (or more frequent).
Reflecting	Evaluating on their learning, strategies or outcomes of the task	Initiating the reflection by saying how they think the experiment went.

The observation scheme made it possible to generate a detailed mapping of SRL behaviours throughout the different phases of inquiry. To explore patterns in the data, descriptive statistics such as means, standard deviations and medians were calculated in RStudio for each SRL behaviour within each competence group (High, Average, Low). This provided insight into how frequently specific behaviours were observed among students with varying competence levels. Descriptive statistics were also calculated for each phase of the inquiry cycle within each competence group, in order to examine how SRL behaviours were distributed across the inquiry process.

Following this descriptive analysis, inferential statistical tests were used to assess whether observed differences between groups were statistically significant. Given the sample size ($N = 31$) and a non-normal distribution of the data, non-parametric tests were chosen. The Kruskal-Wallis test was conducted to examine group differences in each SRL behaviour and each inquiry phase. For behaviours or phases showing significant group effects, post hoc pairwise comparisons were performed, using the Mann-Whitney U test to determine where those differences occurred. This combined descriptive and inferential approach provided a comprehensive analysis of both the overall distribution and potential group-based differences in students' SRL behaviours throughout the inquiry process.

Results

Descriptive patterns of self-regulated learning per inquiry phase and competence level

A descriptive analysis of SRL behaviours across the five inquiry phases revealed the following patterns among the three competence groups (High, Average, Low). In total, the high-competence group ($N = 12$) exhibited 85 SRL behaviours. The majority of these occurred during the investigation phase ($n = 65$), with smaller proportions observed in the conceptualization phase ($n = 9$), the conclusion phase ($n = 9$), and single instances in both the orientation and discussion phases ($n = 1$ each).

Similarly, the average-competence group ($N = 10$) displayed 73 SRL behaviours, with 55 occurring during the investigation phase, followed by smaller counts in the conceptualization phase ($n = 10$), in the conclusion phase ($n = 7$), and in the orientation phase ($n = 1$). No SRL behaviours were recorded during the discussion phase for this group.

The low-competence group ($N = 9$) demonstrated a total of 48 SRL behaviours, predominantly during the investigation phase ($n = 39$), with smaller counts in the conceptualization phase ($n = 5$), the conclusion phase ($n = 3$), and the discussion phase ($n = 1$). No SRL behaviours were observed in the orientation phase for the low group.

Overall, the orientation and discussion phases elicited very few SRL behaviours across all groups. Only isolated instances were recorded: one behaviour each for the high-competence and average-competence groups in the orientation phase, and one behaviour each for the high-competence and low-competence groups during the discussion phase.

Notably, the investigation phase emerged as the most behaviourally active across all groups. This phase accounted for 76.5% of the total behaviours in the high-competence group, 75.3% in the average-competence group, and 81.3% in the low-competence group. This indicates that participants, regardless of group classification, concentrated the majority of their self-regulatory efforts during the hands-on exploration of the task.

Regarding specific SRL behaviours, “Predicting" was most prevalent during the investigation phase, especially in the average group, where it constituted 65.5% of behaviours within that phase. In contrast, this behaviour represented 41.5% and 43.6% of investigation-phase behaviours in the high-competence and low-competence groups, respectively.

In terms of broader behaviour trends, "Reflecting" appeared to be largely absent, with only a single instance each recorded in the high-competence and low-competence groups. Additionally, "Strategic Planning" was more commonly observed in the high-competence group (n = 15) and the average-competence group (n = 8) compared to the low-competence group (n = 5).

Differences in behaviour among the competence levels

Descriptive statistics for the observed SRL behaviours across the three competence levels (High, Average, Low) are presented in Table 2. Means, standard deviations, and medians were reported for each group and behaviour.

To see whether there were significant differences per behaviour among the groups, first the Kruskal-Wallis test was performed once for each behaviour, to compare the differences among the different competence levels (Table 3).

For the behaviour “Predicting”, the test showed a significant difference between the groups. Therefore, the Mann-Whitney U test was used to compare the High, Average, and Low competence groups across the seven SRL behaviours. The analysis revealed a statistically significant group difference for “Predicting” among the Average and Low competence groups. Further, the tests revealed no statistically group differences for the other SRL behaviours (Table 4).

Table 2

Descriptive statistics for SRL behaviours by competence level

Behaviour	Group	M	SD	Median
Goal Setting	High	0.17	0.40	0.00
	Average	0.10	0.32	0.00
	Low	0.00	0.00	0.00
Strategic Planning	High	1.25	1.82	0.00
	Average	0.80	1.23	0.50
	Low	0.56	1.13	0.00
Predicting	High	3.42	2.43	3.00
	Average	4.50	1.65	4.00
	Low	2.22	1.09	2.00
Following Instructions	High	1.08	1.38	1.00
	Average	0.80	0.92	1.00
	Low	2.00	1.58	2.00
Asking for Help	High	0.42	0.79	0.00
	Average	0.70	0.67	1.00
	Low	0.22	0.44	0.00
Redoing the Task	High	0.67	1.30	0.00
	Average	0.40	0.70	0.00
	Low	0.22	0.44	0.00
Reflecting	High	0.08	0.29	0.00
	Average	0.00	0.00	0.00
	Low	0.11	0.33	0.00

Table 3

Results of the Kruskal Wallis Test comparing SRL behaviours between competence levels

Behaviour	**H**	**Df**	**p**
Goal Setting	1.583	2	.453
Strategic Planning	1.103	2	.576
Predicting	7.687	2	.021*
Following Instructions	4.820	2	.090
Asking for Help	3.125	2	.210
Redoing the Task	0.260	2	.878
Reflecting	1.105	2	.592

Note * $p<.05$

Table 4

Results of Mann-Whitney U Tests comparing SRL behaviours between two competence groups at a time

Behaviour	Comparison	W	p	r
Goal Setting	High vs. Average	56.0	1.000	.094
	High vs. Low	63.0	.705	.274
	Average vs. Low	49.5	1.000	.387
Strategic Planning	High vs. Average	58.0	1.000	.031
	High vs. Low	65.5	1.000	.213
	Average vs. Low	54.5	1.000	.207
Predicting	High vs. Average	83.0	.393	.329
	High vs. Low	68.5	.309	.230
	Average vs. Low	80.0	.012*	.672
Following Instructions	High vs. Average	54.0	.1.000	.093
	High vs. Low	31.0	.277	.376
	Average vs. Low	21.5	.145	.463
Asking for Help	High vs. Average	76.5	.690	.264
	High vs. Low	57.5	1.000	.073
	Average vs. Low	63.0	.303	.387
Redoing the Task	High vs. Average	59.5	1.000	.009
	High vs. Low	58.5	1.000	.093
	Average vs. Low	49.5	1.000	.110
Reflecting	High vs. Average	55.0	1.000	.195
	High vs. Low	52.5	1.000	.046
	Average vs. Low	40.0	1.000	.242

Note. *p<.05

Differences in behaviours during the phases of inquiry

Descriptive statistics for the investigated phases of the inquiry cycle across the three competence levels (High, Average, Low) are presented in Table 5. Means, standard deviations, and medians were reported for each group and phase of inquiry.

Table 5

Means, standard deviations and medians for phases of inquiry learning by competence group

Phase	Group	M	SD	Median
Orientation	High	0.08	0.29	0.00
	Average	0.10	0.32	0.00
	Low	0.00	0.00	0.00
Conceptualization	High	0.75	0.87	1.00
	Average	1.00	0.82	1.00
	Low	0.56	0.73	0.00
Investigation	High	5.42	2.81	5.00
	Average	5.50	1.90	6.00
	Low	4.33	2.00	5.00
Conclusion	High	0.75	0.75	1.00
	Average	0.70	0.68	1.00
	Low	0.33	0.50	0.00
Discussion	High	0.08	0.29	0.00
	Average	0.00	0.00	0.00
	Low	0.11	0.33	0.00

To see whether there were potential differences among the different phases of the inquiry cycle, the Kruskal Wallis test was performed in total fifteen times. No significant differences were present (see Table 6), therefore there was no further action taken.

Table 6

Results of the Kruskal Wallis Test comparing the phases of the inquiry cycle between competence groups

Phase	H	Df	p
Orientation	0.871	2	.647
Conceptualization	1.704	2	.427
Investigation	1.417	2	.492
Conclusion	2.104	2	.349
Discussion	1.049	2	.592

Discussion

The purpose of this study was to investigate how primary school students with different competence levels demonstrate SRL skills during a think-aloud IBL task. While previous research has established that SRL plays a key role in supporting effective learning in IBL environments (Lai et al., 2018; Zweers et al., 2019), and that students with higher competence levels may benefit more from such tasks (Van Dijk et al., 2016), less is known about how SRL actually manifests across different competence levels during task performance. By examining both the frequency and nature of SRL behaviours displayed by students during an IBL activity, this study aimed to provide insight into the specific strategies used by learners with difference competence levels. These findings may help inform the design of targeted instructional support that aligns with learners' individual needs, ensuring more equitable engagement in IBL settings.

Summary of Findings and Connections to the Literature

Looking at the behaviours shown in the different phases of inquiry, the results show that the investigation phase of the inquiry cycle elicited the highest number of SRL behaviours across all groups. This suggests that students concentrated the majority of their regulatory efforts during the active engagement stage of the inquiry cycle, supporting previous findings that this phase is cognitively demanding and promotes SRL (Keselman, 2003; Pedaste et al., 2015; Qablan et al., 2024).

When comparing the SRL behaviours between competence groups, there were no statistically significant differences found for most behaviours, despite expectations grounded in earlier research (Phillips & Lindsay, 2006). The only exception was the behaviour of Predicting, for which a significant difference was recorded between the Average- and Low-competence groups. This finding is particularly striking, as it was anticipated that high-competence students would engage most frequently in predictive behaviours, given their advanced cognitive and metacognitive skills (Reis & Renzulli, 2009; Zimmerman, 2000). One possible explanation is that average-competence students, while possessing a basic conceptual grasp of the task, may have felt a greater need to anticipate outcomes in order to structure their learning process effectively. Predictive behaviour may thus have served as a compensatory strategy to manage uncertainty or incomplete understanding. This phenomenon can occur especially in complex IBL tasks, where learners are often required to navigate open-ended problems without predetermined pathways (Margolis & McCabe, 2003; Pedaste et al., 2015). This is consistent with findings from Keselman (2003), who notes that learners with developing conceptual models often benefit from prediction as a means of forming causal inferences and refining their understanding.

In contrast, low-competence students may have lacked not only the conceptual clarity but also the metacognitive awareness required to engage in predictive reasoning, which can inhibit their ability to benefit fully from IBL (Jiang & McComas, 2015; Lai et al., 2018). Their limited use of prediction could reflect a more reactive approach to learning, relying on immediate task cues rather than forward-thinking strategies. Interestingly, high-competence students did not exhibit significantly higher predictive behaviour than average-competence peers. This may be due to their greater familiarity with the subject matter or their ability to internalize and automate SRL processes, making such behaviours less visible during observation (Schunk & Ertmer, 2000; Zimmerman, 2002). Moreover, as Acar and Tuncdogan (2018) argue, the effectiveness of IBL depends not only on cognitive abilities but also on how students perceive and respond to uncertainty and innovation within the learning environment. High-competence students may have approached the task with greater confidence, reducing their need to explicitly engage in predictive behaviour.

Taken together, these findings suggest that the relationship between competence level and predictive SRL strategies may be mediated by students' cognitive strategies, task perceptions, and degree of metacognitive engagement. Understanding these nuances is essential for designing differentiated scaffolding in IBL contexts, ensuring that students at varying competence levels are equally supported in developing effective self-regulatory practices.

Although no statistically significant differences were found, the descriptive data revealed that students in the High- and Average-competence groups exhibited comparable patterns of SRL In particular, students in the high-competence group demonstrated slightly more frequent use of strategic planning and goal-setting behaviours. While these differences did not reach significance, the observed patterns align with prior research suggesting that high-performing or gifted students tend to engage more readily in self-directed, independent learning processes (Jiang & McComas, 2015; Van Dijk et al., 2016). These trends are reported here not as definitive outcomes, but as potentially meaningful observations that may warrant further investigation. It is important to note that the current study did not examine students' task performance or learning outcomes. Further, the absence of significant findings could be attributed to sample size limitations or variability within groups, but the descriptive trends nonetheless offer insight into how SRL behaviours may manifest across competence levels in inquiry-based settings.

The descriptive results showed that while high-competence students tended to engage more frequently in behaviours, such as strategic planning and goal setting, these patterns were not statistically significant. Interestingly, average-competence students demonstrated relatively high engagement in predictive behaviours, and low-competence students showed limited use of SRL strategies overall. These findings partly support the argument that students' SRL capabilities may relate to their competence level (Wang et al., 2009), but also suggest that these differences may be more complicated than often assumed. The observation that average- and even low-competence learners engaged in key SRL behaviours when provided with an IBL context, indicates that such environments may help activate latent self-regulatory skills across competence levels. This underscores the importance of designing inclusive learning tasks that support and scaffold SRL, not only for high-performing students, but for all learners. Moreover, the findings highlight the need to look beyond performance alone and consider how instructional design can shape observable learning behaviours.

The dominance of SRL behaviours during the investigation phase reinforces the idea that IBL environments can promote self-regulatory processes across varying levels of academic competence (Furtak et al., 2012; Kausar et al., 2024). This aligns with earlier findings suggesting that IBL tasks, particularly when they are well-structured, can act as scaffolds that guide learners through complex learning processes and activate SRL behaviours, even in students who may not typically demonstrate them (Keselman, 2003; Spronken-Smith & Walker, 2010). In the present study, the use of a think-aloud protocol within a relatively open-ended task may have introduced additional cognitive load, potentially influencing how students engaged with SRL strategies. According to Keselman (2003), structured support within inquiry activities helps reduce such demands, allowing learners to focus more effectively on metacognitive regulation and strategic planning.

However, some expected behaviours such as Reflecting and Goal Setting were infrequently observed across all groups. This observation aligns with findings from Vermunt (2005), who noted that younger students often lack mature metacognitive strategies. It also highlights a possible instructional shortcoming, suggesting that reflection and planning may not occur spontaneously in primary-aged learners unless these behaviours are explicitly taught and supported.

Limitations and Directions for Future Research

Several limitations should be acknowledged. First, the relatively small sample size (N = 31) limited the statistical power of the analyses and restricts the generalizability of the findings. Second, while behavioural coding offered insight into observable SRL behaviours, SRL is fundamentally an internal process. Even with the use of think-aloud protocols, which aim to make internal processes more visible, it is not possible to fully capture all aspects of self-regulation. To gain a more complete picture of SRL, it is recommended for future studies to combine think-aloud protocols with other qualitative methods, such as stimulated recall interviews or reflective journals, to access students' internal reasoning more thoroughly. Further, future research could benefit from larger and more diverse samples relating to variation in age, educational background, and cultural context in order to examine whether the findings apply across different learner groups and settings.

Another consideration is the cognitive demand of think-aloud protocols, particularly in open-ended tasks. These demands may affect how students engage in SRL during the activity. Future studies could compare these open-ended inquiry tasks with more structured formats, such as guided inquiry tasks that include instructional prompts or partially completed data tables. While increased support may support students with lower competence levels by reducing cognitive load, it could also result in less observable SRL behaviours, as students may not need to make as many autonomous decisions. Therefore, it raises an educational dilemma in how a task can be designed that supports students when needed, but still allows them to practise and demonstrate SRL behaviours. Additionally, the relatively limited behaviours observed during the orientation and discussion phases highlights the need to explore how these stages can be more effectively supported through instructional support. Future research could examine whether targeted support across all inquiry phases promotes more consistent and meaningful engagement in SRL.

Building on these findings, the observed variation in students' SRL engagement across different phases of the inquiry cycle highlights the importance of instructional support that extends beyond isolated phases such as investigation. Previous research has shown that IBL can promote SRL processes (Furtak et al., 2012; Kausar et al., 2024; Zimmerman, 2002), but effective implementation depends on how well each phase of inquiry is structured (Keselman, 2003; Pedaste et al., 2015). The limited behavioural activity during the orientation and discussion phases in the current study may indicate that students require more targeted scaffolding during these stages to foster deeper engagement (Qablan et al., 2024; Setiani, 2023). Moreover, while the think-aloud protocol used here offered valuable insights into students' regulatory behaviours, it may also have posed cognitive demands that reduced spontaneous engagement, particularly in the earlier or reflective phases of inquiry (Acar & Tuncdogan, 2018; Spronken-Smith & Walker, 2010). Future research might explore how different task structures and supportive strategies can help all learners, including those with lower academic competence, benefit more equally from inquiry-based environments (Margolis & McCabe, 2003; Wang et al., 2009; Zweers et al., 2019).

In conclusion, the results indicate that in order to get a deeper understanding of children's self-regulatory processes, a focus on alternative qualitative measures would be recommended. Furthermore, to improve the effectiveness of IBL on children, additional research about other influences than self-regulation skills would be beneficial.

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