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Selbstregulation beim Lernen junger Lernender: Einflussfaktoren und Herausforderungen bei der Erfassung

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Zusammenfassung

Selbstregulation beim Lernen (SRL) beschreibt die Fähigkeit von Lernenden, ihre Lernprozesse gezielt zu steuern, um Lernziele zu erreichen (Winne & Perry, 2000). SRL wird dabei als ein dynamischer Prozess mit verschiedenen Phasen beschrieben, welcher kognitive, metakognitive, motivationale, emotionsregulierende und ressourcenorientierte Strategien umfasst, die es ermöglichen, das eigene Lernen zu überwachen, anzupassen und zu optimieren (Boekaerts, 1999; Winne & Hadwin, 1998; Zimmerman, 2000). In Bildungskontexten spielt SRL eine zentrale Rolle: Studien zeigen, dass Lernende mit ausgeprägten SRL-Kompetenzen nicht nur bessere schulische Leistungen erbringen, sondern auch motivierter sind (Dent & Koenka, 2016; Pintrich & De Groot, 1990).

In der SRL-Forschung werden verschiedene Instrumente verwendet, die in sogenannte Online- und Offline-Methoden unterteilt werden (Veenman & van Cleef, 2019). Online-Methoden erfassen SRL während des Lernprozesses und betrachten SRL als situativen Strategieeinsatz, während Offline-Methoden Lernende oder Dritte abseits des direkten Lernenprozesses zu SRL-Verhalten befragen und SRL als stabile Fähigkeit ansehen (Rovers et al., 2019; Winne & Perry, 2000). Die Erfassung von SRL steht vor mehreren Herausforderungen, darunter die Sicherstellung der Validität von Messinstrumenten, die angemessene Operationalisierung der vielfältigen und dynamischen SRL-Prozesse, sowie die Detailliertheit bei der Messung (Veenman, 2011; Winne & Perry, 2000). Bei jungen Lernenden ist die Erfassung von SRL besonders herausfordernd, da klassische Methoden wie Selbstbeurteilungsfragebögen durch soziale Erwünschtheit, sprachliche Fähigkeiten und retrospektive Verzerrungen beeinflusst werden (Veenman & van Cleef, 2019). Daher wird in der aktuellen SRL-Forschung verstärkt ein multimethodischer Ansatz gefordert, in welchem sich ergänzende Methoden kombiniert werden (Callan & Cleary, 2018).

In den theoretischen Modellen zu SRL werden zwar einige potenzielle Einflussfaktoren auf die SRL-Kompetenzen Lernender beschrieben (Boekaerts, 1999; Pintrich, 2000; Winne & Hadwin, 1998; Zimmerman, 2000), jedoch wurden diese bisher nur unzureichend empirisch untersucht. Während der Einfluss von motivationalen Faktoren, wie der allgemeinen Selbstwirksamkeitsüberzeugung (z.B. J.-L. Berger & Karabenick, 2011), bereits gut belegt ist, fehlt es an Studien die weitere kontextuelle, kognitive und motivationale Einflussfaktoren erforschen. Insbesondere für die Entwicklung von Interventionen und zur Identifizierung von Gruppen mit besonderem SRL-Förderbedarf ist dieses Wissen jedoch von besonderer Relevanz.

Ausgehend von diesen Forschungslücken hat diese Dissertation zum Ziel (1) Erfassungsmethoden von SRL bei jungen Lernenden zu entwickeln und zu erproben und (2) mögliche Einflussfaktoren auf die SRL-Kompetenzen von Lernenden im Grundschulalter zu erforschen.

In Beitrag I wird die im Rahmen der Dissertation entwickelte digitale „Train Track Task“ (TTT) als innovatives Instrument zur Erfassung von SRL bei 85 jungen Lernenden der 2. bis 5. Klasse vorgestellt und evaluiert. Die digitale TTT wurde aufbauend auf der TTT als Beobachtungsmethode (Bryce & Whitebread, 2012) entwickelt und kombiniert Log-Daten und Laut-Denken-Protokolle, um insbesondere metakognitive Prozesse sichtbar zu machen. Die Forschungsfragen untersuchten die Operationalisierung von *Monitoring*- und *Control*-Prozessen in Log-Daten, Unterschiede in den metakognitiven Prozessen von Lernenden zwischen einfachen und komplexen Aufgaben, sowie die Zusammenhänge zwischen Log-Daten und Laut-Denken-Protokollen. Metakognitive Handlungen wurden theoriebasiert kodiert und mittels eines Finite State Machine (FSM)-Ansatzes analysiert. Die Ergebnisse zeigten zehn metakognitive Prozesse, deren Häufigkeit und Dauer je nach Aufgabenkomplexität variierten. Bei komplexeren Aufgaben traten *Monitoring*- und *Control*-Prozesse häufiger und länger auf. Zudem ergaben sich Unterschiede in den Sequenzen der metakognitiven Verhaltensweisen sowie signifikante Korrelationen zwischen den in den Log-Daten und den Laut-Denken-Protokollen erfassten metakognitiven Prozessen. Die digitale TTT bietet damit eine innovative Möglichkeit zur Untersuchung metakognitiver SRL-Prozesse. Beitrag I trägt somit zur Reproduzierbarkeit von SRL-Erfassung bei und zeigt Potenzial für die wissenschaftliche und praktische Anwendung der TTT in der Beurteilung von SRL-Kompetenzen junger Lernender.

Beitrag II untersucht, inwieweit Lernende mit ungleichen Bildungsvoraussetzungen Unterschiede in der Nutzung von SRL-Strategien und ihrem metakognitiven Wissen zeigen. Dabei wurden drei Risikobereiche betrachtet: (1) Sozioökonomische Faktoren (Internationaler Sozioökonomischer Index des beruflichen Status (ISEI), Bildungsabschluss der Eltern), (2) migrationsbezogene Faktoren (Migrationshintergrund, Sprache zu Hause) und (3) entwicklungsbedingte Faktoren (Lern- und Aufmerksamkeitsstörungen, Unterstützungsbedarf bei Hausaufgaben). Dabei wurde erwartet, dass höhere Risiken mit geringerer SRL-Strategienutzung und niedrigerem metakognitiven Wissen einhergehen. Insgesamt nahmen 141 Lernende der 2. bis 5. Klasse und ihre Eltern an der Studie teil. Die Erfassung der SRL-Strategienutzung und des metakognitiven Wissens erfolgte über Selbstbeurteilungsfragebögen, Elternbeurteilungen und Szenario-Tests. Die Risikofaktoren wurden als dreistufige Variablen

gebildet, die jeweils das Ausmaß des sozioökonomischen, migrationsbezogenen oder entwicklungsbezogenen Risikos widerspiegelten. Je nach Erfassungsmethode unterscheiden sich die Ergebnisse. Die Befunde weisen darauf hin, dass Kinder mit einem hohen sozioökonomischen Risikofaktor eine geringere SRL-Strategienutzung im Elternrating zeigten. Entgegen der Hypothese berichteten Kinder mit hohem migrationsbezogenem Risiko eine höhere SRL-Strategienutzung im Selbstbeurteilungsfragebogen. Eltern von Kindern mit Lernschwierigkeiten schätzten deren SRL-Strategienutzung niedriger ein. Keiner der Risikofaktoren zeigte signifikante Zusammenhänge mit dem metakognitiven Wissen erfasst durch Szenario-Tests. Die Ergebnisse verdeutlichen die Bedeutung individueller Risikofaktoren für SRL. Zudem verweist die Studie auf den Bedarf nach weiterer Forschung, um die erhöhte SRL-Strategienutzung in den Selbstbeurteilungsfragebögen bei Kindern mit migrationsbezogenem Risiko besser zu verstehen.

Beitrag III bezieht sich auf die Emotionsregulation (ER) beim Lernen, bei welcher interne und externe Faktoren überwacht, kontrolliert und verändert werden, um die emotionale Erregung an die jeweilige Situation anzupassen und dadurch bestimmte Ziele zu erreichen (Gross & Thompson, 2007). ER kann dabei als wichtiger Bestandteil von SRL gesehen werden, welcher die schulische Leistung von Lernenden beeinflusst (Ben-Eliyahu, 2019; Wong et al., 2023). Beitrag III untersucht die Nutzung von ER-Strategien bei Lernenden der 2. bis 5. Klasse und die Rolle von Erwartungs- und Wertüberzeugungen als Einflussfaktoren auf die ER junger Lernender. Zentrale Fragestellungen der Studie betrafen die Variation der ER-Strategien je nach Erfassungsmethode und Kontext, die Zusammenhänge zwischen den Methoden sowie mögliche Unterschiede abhängig von Alter und Geschlecht. Zudem wurde analysiert, ob Erwartungs- und Wertüberzeugungen hinsichtlich ER-Strategien den Einsatz von ER-Strategien vorhersagen. An der Studie nahmen 82 Kinder zwischen 7 und 12 Jahren und ihre Eltern teil. Die ER-Strategien wurden mittels Selbstbeurteilungsfragebogen, Elternbeurteilungen, Interviews und Laut-Denken-Protokollen erfasst. Erwartungs- und Wertüberzeugungen wurden durch Fragebögen und eine induktive Kodierung der Interviews erfasst. Die Ergebnisse zeigen, dass Kinder verschiedene ER-Strategien anwenden, wobei die Strategien aus dem Bereich Situationsmodifikation und Aufmerksamkeitsumlenkung am häufigsten genutzt wurden. Strategien der Kognitive Umbewertung wurde hingegen in allen Erfassungsmethoden selten berichtet. Die verschiedenen Instrumente erfassten unterschiedliche Aspekte der ER, wobei nur das Interview alters- und geschlechtsspezifische Unterschiede in

der Nutzungshäufigkeit zeigte. Erwartungs- und Wertüberzeugungen beeinflussten die ER-Nutzung gemessen mit dem Selbstbeurteilungsfragebogen und dem Interview, nicht jedoch in der Elternbeurteilung oder bei der Erfassung mit Laut-Denken-Protokollen. Die Studie unterstreicht die Bedeutung methodischer Unterschiede bei der Erfassung von ER und weist auf einen möglichen Trainingsbedarf für kognitive Umbewertung als wichtige ER-Strategie (John & Gross, 2004) hin. Die Ergebnisse liefern wertvolle Erkenntnisse für die Entwicklung von ER-Interventionen und die multimethodische Erfassung von ER bei jungen Lernenden.

In der studienübergreifenden Diskussion werden die verschiedenen Befunde der Beiträge in Zusammenhang gebracht. Während Beitrag I die metakognitiven SRL-Strategien fokussierte, wurden in Beitrag III die ER von Lernenden untersucht und in Beitrag II verschiedene Strategiebereiche von SRL betrachtet. Anknüpfend an die aktuelle Diskussion zur Erfassung in der SRL-Forschung, wurde SRL in allen Beiträgen multimethodisch, durch Kombinationen aus SRL-Selbstbeurteilungsfragebögen, Elternbeurteilungen, Interviews, Laut-Denken-Protokollen, Log-Daten und Szenario-Tests, erfasst. Während sich in Beitrag I und II signifikante Korrelationen zwischen den Ergebnissen basierend auf den verschiedenen genutzten Erfassungsmethoden für SRL zeigten, wurden in Beitrag III für die Erfassung von ER-Strategienutzung keine Zusammenhänge zwischen den verschiedenen gezeigt. Sowohl in den Einzelbeiträgen als auch in der zusammenfassenden Diskussion der Dissertation werden die Ursachen für Gemeinsamkeiten und Unterschiede in den verschiedenen Erfassungsmethoden, wie beispielsweise die zugrundeliegende Operationalisierung von SRL in den Erfassungsmethoden (Winne & Perry, 2000), diskutiert. Dabei werden die spezifischen Potenziale und Herausforderungen der einzelnen Methoden herausgearbeitet. Insbesondere zeigt sich, dass sich Online- und Offline-Methoden, wie beispielsweise Log-Daten und Laut-Denken-Protokolle, bei der Erfassung von SRL sinnvoll ergänzen. Insgesamt unterstreichen die Befunde die Relevanz eines bewussten, zielgerichteten und multi-methodischen Einsatzes von SRL-Erfassungsmethoden. Darüber hinaus stellt die Dissertation innovative Methoden zur Erfassung von SRL bei jungen Lernenden vor. Aufbauend auf der Diskussion zu SRL-Erfassungsmethoden und den empirischen Befunden der Beiträge wurde in der zusammenfassenden Diskussion eine systematische Übersicht der gängigen SRL-Erfassungsmethoden vorgenommen, welcher versucht die Methoden in den erfassten Aspekten von SRL zu differenzieren.

In Bezug auf die bisher nur wenig untersuchten Einflussfaktoren auf SRL wurden in Beitrag II und III Zusammenhänge zwischen kontextuelle, kognitiven, sowie motivationalen Faktoren

und SRL-Kompetenzen untersucht. In Beitrag II wurden Zusammenhänge zwischen sozioökonomischem Status, Migrationshintergrund, sowie Lernschwierigkeiten und der SRL-Strategienutzung gefunden, jedoch nicht mit metakognitivem Wissen. In den Beiträgen II und III zeigte sich zudem ein Zusammenhang mit Alter und Geschlecht, wobei Mädchen und ältere Lernende höhere SRL-Kompetenzen zeigten. Beitrag III hebt die Bedeutung motivationaler Faktoren hervor. Dabei zeigte sich ein positiver Zusammenhang zwischen Erwartungs- und Wertüberzeugungen für die Anwendung von SRL-Strategien und den SRL-Kompetenzen von Lernenden. Im Rahmen der Diskussion in den einzelnen Beiträgen, sowie auch in der zusammenfassenden Diskussion wurden die Befunde theoretisch eingeordnet und mit der bisherigen empirischen Forschung in Zusammenhang gebracht. Basierend auf den empirischen Befunden und theoretischen Annahmen in den SRL-Modellen wurde auch hier eine vereinfachte Übersicht der Einflussfaktoren erstellt.

Diese Dissertation erweitert die existierende SRL-Forschung, indem neue Methoden zur Erfassung von SRL bei jungen Lernenden entwickelt und erprobt wurden. Zudem geben die Ergebnisse Aufschluss über Zusammenhängen zwischen unterschiedlichen Einflussfaktoren und der SRL-Kompetenzen junger Lernender. Durch die potenzielle Weiternutzung und -entwicklung der Erfassungsmethoden, das Potenzial mit diesen interindividuellen Unterschieden, beispielsweise basierend auf Risikolagen zu erfassen, und den Einsatz der in der Dissertation entwickelten Übersichten in der zukünftigen Forschung kann ein wichtiger Beitrag zur Erforschung und Förderung von SRL in der schulischen Praxis geleistet werden.

Abstract

Self-regulated learning (SRL) refers to learners' ability to actively control their learning processes in order to achieve learning goals (Winne & Perry, 2000). SRL is described as a dynamic process consisting of multiple phases and encompassing cognitive, metacognitive, motivational, emotion-regulating, and resource-oriented strategies that enable learners to monitor, adjust, and optimize their learning (Boekaerts, 1999; Winne & Hadwin, 1998; Zimmerman, 2000). To engage in SRL, learners require metacognitive knowledge, including an understanding of different SRL strategies (Pintrich, 2000). SRL plays a crucial role in educational contexts. Research has shown that learners with strong SRL skills not only achieve better academic outcomes but are also more motivated, engaged, and persistent when facing challenges (Dent & Koenka, 2016; Pintrich & De Groot, 1990).

In SRL research, different instruments are used to measure SRL, which are generally categorized into online and offline methods (Veenman & van Cleef, 2019). Online methods assess SRL during the learning process and view SRL as a situational use of strategies, whereas offline methods collect data from learners or third parties outside of the learning process and consider SRL as a more stable ability (Rovers et al., 2019; Winne & Perry, 2000). Measuring SRL presents several challenges, including ensuring the validity of measurement instruments, adequately operationalizing the multifaceted and dynamic nature of SRL processes, achieving a sufficient level of detail in measurement, and capturing the contextual and dynamic aspects of SRL (Veenman, 2011; Winne & Perry, 2000). Assessing SRL in young learners is particularly challenging, as common methods such as self-report questionnaires can be influenced by social desirability, language abilities, and retrospective biases (Veenman & van Cleef, 2019). Therefore, recent SRL research increasingly emphasizes the need for a multimethod approach that combines complementary measurement methods (Callan & Cleary, 2018).

Although theoretical models of SRL describe various potential influencing factors on learners' SRL competencies (Boekaerts, 1999; Pintrich, 2000; Winne & Hadwin, 1998; Zimmerman, 2000), empirical research on these factors remains limited. While the impact of motivational factors, such as general self-efficacy beliefs (e.g., J.-L. Berger & Karabenick, 2011), is well established, there is a lack of studies examining further contextual and demographic, cognitive and neural, motivational and emotional influences. However, understanding these influencing factors is particularly relevant for the development of interventions and for identifying learner groups with specific SRL support needs.

Based on these research gaps, this dissertation aimed to (1) develop and evaluate SRL measurement methods for young learners and (2) investigate potential influencing factors on SRL competencies in primary school-aged children. Study I introduces and evaluates the digital "Train Track Task" (TTT) as an innovative instrument for assessing SRL in young learners from second to fifth grade. The digital TTT was developed based on the observational TTT method (Bryce & Whitebread, 2012) and combines log data with think-aloud protocols to make metacognitive processes more visible. The research questions focused on the operationalization of monitoring and control processes in log data, differences in learners' metacognitive processes when working on simple versus complex tasks, and the relationships between log data and think-aloud protocols. A total of 85 learners from second to fifth grade participated in the study. The digital TTT included two tasks during which log data and think-aloud protocols were collected. Metacognitive actions were coded based on theoretical frameworks and analyzed using a Finite State Machine (FSM) approach. The results identified ten metacognitive processes whose frequency and duration varied depending on task complexity. More complex tasks were associated with more frequent and prolonged monitoring and control processes. Additionally, differences in metacognitive behavior sequences and significant correlations between metacognitive processes captured with log data and think-aloud protocols were found. The digital TTT thus provides an innovative, theory-based method for investigating metacognitive SRL processes. By transparently operationalizing metacognitive processes in log data, this study contributes to the reproducibility of SRL assessments and highlights the potential of the digital TTT for both scientific and practical applications in evaluating young learners' SRL competencies.

Study II examined the extent to which learners with unequal educational backgrounds differ in their use of SRL strategies and their metacognitive knowledge. Three risk domains were considered: (1) socioeconomic factors (ISEI, parental education), (2) migration-related factors (migration background, family language), and (3) developmental factors (learning and attention difficulties, need for homework support). It was hypothesized that higher levels of risk would be associated with lower use of SRL strategies and reduced metacognitive knowledge. A total of 141 learners from second to fifth grade and their parents participated in the study. SRL strategy use and metacognitive knowledge were assessed through self-report questionnaires, parent ratings, and scenario-based tests. Risk factors were categorized into three levels, reflecting the extent of socioeconomic, migration-related, or developmental risk. The

results varied depending on the SRL measurement method. Findings indicated that children with high socioeconomic risk showed lower SRL strategy use in parent ratings. Contrary to expectations, children with high migration-related risk reported higher SRL strategy use in self-report questionnaires. Parents of children with learning difficulties rated their children's SRL strategy use lower. None of the risk factors showed significant associations with metacognitive knowledge as measured by a scenario-based test. These findings highlight the importance of individual risk factors in SRL and suggest that targeted interventions may be beneficial. For example, learners with learning difficulties particularly benefit from structured SRL support (Azevedo et al., 2023; Dignath et al., 2008). Furthermore, the study underscores the need for additional research to better understand the increased self-reported SRL strategy use among children with migration-related risk.

Study III focuses on emotion regulation (ER) in learning, which involves monitoring, controlling, and modifying internal and external factors to adjust emotional arousal according to the learning situation and achieve goals (Gross & Thompson, 2007). ER is considered an essential component of SRL that influences learners' academic performance (Ben-Eliyahu, 2019; Wong et al., 2023). The central research questions addressed the variation in ER strategies depending on the measurement method and context, the relationships between different methods, and possible differences based on age and gender. Additionally, the study examined whether expectancy and value beliefs regarding ER strategies predict the use of ER strategies. A total of 82 children aged 7 to 12 years and their parents participated in the study. ER strategies were assessed using self-report questionnaires, parent ratings, interviews, and think-aloud protocols. Expectancy and value beliefs were measured through questionnaires and an inductive coding of the interviews. The results indicate that children employ various ER strategies, with situation modification and attentional deployment being the most frequently used. In contrast, cognitive reappraisal was rarely reported across all assessment methods. The different instruments captured distinct aspects of ER, with only the interview revealing age- and gender-related differences. Expectancy and value beliefs influenced ER usage as measured by the self-report questionnaire and the interview but not in parent ratings or task-based assessments using think-aloud protocols. The study highlights the significance of methodological differences in ER measurement and suggests a potential need for training in cognitive reappraisal as a crucial ER strategy (John & Gross, 2004). The findings provide valuable insights for the development of ER interventions and the multimethod assessment of ER in young learners. The overarching discussion integrates the various findings from the

different studies. While Study I focused on metacognitive SRL strategies, Study III examined learners' ER, and Study II addressed all strategy domains of SRL.

In line with the ongoing debate on measurement in SRL research, SRL was assessed with multiple methods in all studies through a combination of SRL self-report questionnaires, parent ratings, interviews, think-aloud protocols, log data, and scenario-based tests. While Studies I and II revealed significant correlations between the results obtained from different SRL assessment methods, Study III did not show any relationships between the different ER measurement approaches. Both the individual studies and the overall discussion of the dissertation explore the reasons for similarities and differences among the various assessment methods, such as the underlying operationalization of SRL in these methods (Winne & Perry, 2000). The specific potentials and challenges of each method are outlined, emphasizing that online and offline methods, such as log data and think-aloud protocols, can meaningfully complement each other in assessing different aspects of SRL. Overall, the findings underscore the importance of a deliberate, targeted, and multimethod approach to assess SRL. Furthermore, the dissertation introduces innovative methods for assessing SRL in young learners. Building on the discussion of SRL assessment methods and the empirical findings of the studies, a systematic overview of commonly used SRL assessment methods was developed in the overall discussion, aiming to differentiate the methods based on the aspects of SRL they capture.

With regard to the previously underexamined influencing factors on SRL, Studies II and III investigated the relationships between contextual and demographic, cognitive and neuronal, as well as motivational factors and SRL competencies. Study II identified associations between socioeconomic status (SES), migration background, and learning difficulties with SRL strategy use, though not with metacognitive knowledge. Moreover, both Studies II and III found relationships between age and gender, with girls and older learners displaying higher SRL competencies. Study III highlights the importance of motivational factors, demonstrating a positive relationship between expectancy and value beliefs and the application of SRL strategies as well as learners' SRL competencies. Within the discussions of the individual studies and the overall dissertation, these findings are theoretically contextualized and linked to existing empirical research. Based on the empirical findings and theoretical assumptions from SRL models, a simplified overview of influencing factors was also created.

This dissertation extends existing SRL research by developing and testing new methods for assessing SRL in young elementary school learners. Additionally, the results provide

insights into the relationships between various contextual and demographic, cognitive and neural, as well as motivational and emotional influencing factors and young learners' SRL competencies. By enabling the further use and development of the developed methods, offering the potential to capture interindividual differences (e.g., based on risk factors), and employing the overviews developed in the dissertation in future research, this work contributes significantly to the investigation and promotion of SRL in educational practice.

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Diskussion

1 Einleitung

Der technologische Fortschritt und speziell der vielfältige Einsatz von künstlicher Intelligenz, transformieren derzeit grundlegend nahezu alle Bereiche unserer Gesellschaft, insbesondere unsere Bildungssysteme (Martin et al., 2024; Zhang & Aslan, 2021). Dabei haben sich die Räume, die Vorgehensweise, die Zeit und die Geschwindigkeit in welcher Informationen für uns zugänglich sind und verarbeitet werden können maßgeblich verändert. Das stellt neue Anforderungen an Lernende, da sie sich in einer dynamischen, informationsreichen Umgebung orientieren, Wissen gezielt verarbeiten und ihre Lernprozesse flexibel anpassen müssen. Gleichzeitig hat die COVID-19-Pandemie viele Lernende vor neue Herausforderungen gestellt und gezeigt, wie wichtig es ist, das Lernende dazu fähig sind ihr eigenes Lernen zu organisieren und zu planen, sich selbst für das Lernen zu motivieren und ihre Emotionen auch in herausfordernden Situationen zu regulieren (F. Berger et al., 2021; Carter et al., 2020; Huber & Helm, 2020). In einer sich dementsprechend rasant wandelnden Gesellschaft ist die Selbstregulation beim Lernen (SRL), gekennzeichnet durch die Fähigkeit, den Lernprozess zu planen, zu steuern und zu kontrollieren (Pintrich, 2000; Zimmerman, 2000), daher entscheidender denn je. SRL gilt daher als eine wichtige Grundlage für das lebenslanges Lernen (OECD, 2018; Usher & Schunk, 2018) und als ein Prädiktor für den Lernerfolg (Dent & Koenka, 2016).

Die SRL-Kompetenzen von Lernenden variieren allerdings stark, wobei einige Lernende erhebliche Schwierigkeiten aufweisen (Wigfield et al., 2011; Winne, 2005). Im Zusammenhang mit der COVID-19-Pandemie zeigen sich deutliche Lerndefizite bei Lernende der Grund- und Sekundarstufe (Betthäuser et al., 2023) während derzeit allgemein große Leistungsunterschiede zwischen Lernenden in vergleichenden Bildungsstudien sichtbar werden (Betthäuser et al., 2023; Lewalter et al., 2023; McElvany et al., 2023; OECD, 2023). Diese können beispielsweise auch im Kontext der gestiegenen Anforderungen zur SRL im Rahmen des Fernunterricht während der COVID-19-Pandemie und damit verbundenen Schwierigkeiten bei einigen Lernenden gesehen werden (F. Berger et al., 2021).

Zur Identifikation von SRL-Defiziten und zur Erforschung der interindividuellen Unterschiede in der SRL bei Lernenden benötigt es allerdings verlässliche, effiziente Erfassungsmethoden. Trotz umfangreicher Forschung stellt die Erfassung von SRL weiterhin eine große Herausforderung dar (Panadero et al., 2016; Rovers et al., 2019). Die Beurteilung der SRL-Kompetenzen von Lernenden basiert in der bisherigen Forschung häufig auf

Selbstberichten, welche anfällig für Verzerrungen sind und die zudem vor allem bei älteren Lernenden eingesetzt und evaluiert wurden (A. Roth et al., 2016; Veenman & van Cleef, 2019). Für jüngere Lernende fehlen innovativen und altersgerechte Instrumente, die nicht nur auf retrospektiven Selbsteinschätzungen basieren, sondern die tatsächliche SRL-Strategienutzung abbilden und somit Defizite und Förderbedarfe zuverlässig aufdecken können (Koivuniemia et al., 2021; Whitebread et al., 2009). Die Weiterentwicklung von geeigneten Erfassungsmethoden von SRL ist somit eine wichtige Grundlage für die zukünftige Forschung zur Förderung von SRL.

Die bisherige Forschung konnte bereits zeigen, dass SRL-Trainings wirkungsvoll sind und das speziell Lernende mit erhöhtem Förderbedarf von diesen profitieren (Azevedo et al., 2023; Berkeley & Larsen, 2018; Boer et al., 2018; Dignath et al., 2008; Theobald, 2021). SRL-Kompetenzen, wie die Verwendung von SRL-Strategien und metakognitiven Fähigkeiten, entwickeln sich zwar mit zunehmendem Alter (Perry et al., 2018; Wesarg-Menzel et al., 2023), jedoch wird diese altersbedingte Entwicklung maßgeblich durch soziale Prozesse, Übung und Erfahrungen beeinflusst (Perry & VandeKamp, 2000; Wesarg-Menzel et al., 2023). Um eine gezielte Förderung von SRL zu ermöglichen, ist es allerdings ebenso notwendig zu verstehen, welche Einflussfaktoren Unterschiede und Defizite in den SRL-Kompetenzen bei Lernenden bedingen und welche Zielgruppen besonders von SRL-Fördermaßnahmen profitieren könnten. Während die Bedeutung von SRL für den Lernerfolg bereits vielfach empirisch untersucht und belegt wurde (Dent & Koenka, 2016), fehlt es bisher an Forschung, welche die Ursachen für die Unterschiede in der SRL-Kompetenz von Lernenden untersucht. Bislang ist nur wenig darüber bekannt, welche Faktoren den Einsatz von SRL-Strategien oder das Wissen über SRL-Strategien von Lernenden beeinflussen (Dong et al., 2024).

Hinzukommend hat die Forschung zur Emotionsregulation (ER) beim Lernen, als ein Teilbereich von SRL, zunehmend an Bedeutung gewonnen (Ben-Eliyahu, 2019; Zheng et al., 2023). Dennoch mangelt es an empirischen Studien, die sich spezifisch mit der ER junger Lernender im Grundschulalter, geeigneten Erfassungsmethoden für diese Zielgruppe und den Einflussfaktoren auf die Emotionsregulation im Lernkontext befassen.

Mit dieser Dissertation soll ein Beitrag zur empirischen Beforschung von SRL bei Lernenden im Grundschulalter geleistet werden, indem Methoden zur Erfassung von SRL entwickelt und erprobt und mögliche Einflussfaktoren auf die SRL-Kompetenzen von jungen Lernenden erforscht werden.

2 Theoretischer Hintergrund

Zur Kontextualisierung der Arbeit und Herleitung der Forschungslücken werden im Folgenden zunächst theoretische SRL-Modelle und verschiedene Komponenten von SRL erläutert. Anschließend werden die spezifischen Herausforderungen in der Erfassung von SRL bei Lernenden beschrieben. Zuletzt wird ein Überblick über einige der bisher untersuchten Einflussfaktoren auf SRL gegeben.

2.1 Selbstregulation beim Lernen

2.1.1 Definition und Relevanz von Selbstregulation beim Lernen

Als ein umfangreiches Konstrukt bietet SRL die Möglichkeit, Komponenten erfolgreichen Lernens zu erklären und zu erforschen (Boekaerts, 1999). SRL kann dabei als individueller, aktiver Prozess definiert werden, bei dem Lernende die eigenen Gedanken, Gefühle und das Verhalten während des Lernens beobachten und anpassen, um ein selbstgesetztes oder vorab definiertes Ziel zu erreichen (Pintrich, 2000; Zimmerman, 2000). Selbstregulierte Lernende setzten sich dementsprechend aufgabenbezogene Ziele, nutzen effektive Strategien, um diese zu erreichen, sind dazu fähig ihren Lernprozess, falls notwendig, flexibel anzupassen und die Stärken und Schwächen ihres Vorgehens zu evaluieren (Boekaerts, 1996; Zimmerman, 1990).

Als ein übergeordnetes theoretisches Konzept vereint SRL so verschiedenen Konstrukte, wie beispielsweise Lernstrategien, Metakognition, Selbstkonzept, volitionale Strategien und Selbstkontrolle, welche wiederum auf verschiedene Forschungsdisziplinen und -historien gründen und mit jeweils eigenen Paradigmen und Fachbegriffen einhergehen (Boekaerts et al., 2000; Paris & Paris, 2001; Schunk & Greene, 2018). Dies verdeutlicht die Komplexität des SRL-Konstrukts, aus der sich vielfältige konzeptionelle und praktische Definitionen ergeben haben (Boekaerts & Corno, 2005). Seit der Einführung erster theoretischer Konzepte zu SRL vor etwa 50 Jahren (Schunk & Greene, 2018) wurden stetig theoretische Modelle (weiter)entwickelt und potenzielle Zusammenhänge und Effekte von SRL empirisch erforscht.

Die Relevanz von SRL für erfolgreiches Lernen wurde bereits mehrfach durch meta-analytische Untersuchungen gestützt, die darauf hinweisen, dass SRL positiv mit der akademischen Leistung von Lernenden zusammenhängt (Broadbent & Poon, 2015; Dent & Koenka, 2016; Dignath et al., 2008; Dignath & Büttner, 2008; Xu et al., 2023). Verschiedene

empirische Studien und Übersichtsartikel konnten zeigen, dass selbstregulierte Lernende eine bessere Leistung in Lesen und Schreiben (Harding et al., 2019; Varier et al., 2021), im Problemlösen (Hatala et al., 2023; Paquette et al., 2021), beim Lernen in digitalen Lernumgebungen (z.B. Xu et al., 2023) und bessere mathematische Fähigkeiten (Desoete et al., 2001; Tzohar-Rozen & Kramarski, 2017) zeigen. Hinzukommend weisen empirische Studien darauf hin, dass ausgeprägte SRL mit einer höheren Lernmotivation und mit höheren Selbstwirksamkeitsüberzeugungen bei Lernenden (Bai & Guo, 2021; Lim & Yeo, 2021; Schunk & Ertmer, 2000) und zum Beispiel einem geringeren Risiko für einen frühzeitigen Schulabbruch verbunden ist (Meyers et al., 2013).

Zunächst wurde angenommen, dass sich SRL-Kompetenzen erst im Schulalter, etwa im Alter von acht Jahren, entwickeln (Veenman et al., 2006). Mittlerweile konnte jedoch gezeigt werden, dass bereits bei jungen Lernenden, im Alter zwischen drei und fünf Jahren, erste metakognitive Verhaltensweisen beobachtet werden können und sich SRL-Kompetenzen mit zunehmendem Alter weiterentwickeln (Bryce & Whitebread, 2012; Metcalfe & Finn, 2013). Die Forschung mit jüngeren Kindern im Vorschulalter konzentriert sich häufig auf die Selbstregulierung (SR) über den Lernkontext hinaus, welche als die domänenunspezifische Fähigkeit beschrieben wird, Emotionen, Verhaltensweisen und Kognition in verschiedenen Kontexten zu regulieren (Inzlicht et al., 2021; Wesarg-Menzel et al., 2023). Somit beschreiben SR und SRL ähnliche Fähigkeiten und Prozesse, SRL kann allerdings als eine spezifischeres Konstrukt gesehen werden, welches sich konkret auf den Lern-Kontext bezieht (Dinsmore et al., 2008).

Ein zentrales Ziel der SRL-Forschung ist es, zu verstehen, wie Lernende ihre eigenen Lernprozesse steuern. Zur Erklärung und Erforschung des SRL-Prozess wurden Theorien und Modelle entwickelt, die das SRL-Konstrukt in einzelne Komponenten und Phasen unterteilen. Die folgenden Abschnitte bieten einen Überblick über zentrale Theorien und deren gemeinsamen sowie differenzierenden Merkmale.

2.1.2 Komponenten von Selbstregulation beim Lernen

SRL umfasst den Regulationsprozess von Lernenden in verschiedenen Bereichen, wie zum Beispiel von Gedanken und dem Prozess der Informationsverarbeitung, der Motivation zu lernen, dem Verhalten während des Lernens, der Lernumgebung, sowie den eigenen Gefühlen während des Lernens (Ben-Eliyahu, 2019; Boekaerts, 1999; Pintrich, 2000; Zimmerman, 2000). Dabei kommen diverse SRL-Strategien zum Einsatz (Boekaerts, 1996), für deren Anwendung Lernende metakognitives Wissen benötigen (Weinstein et al., 2000) und deren Nutzung mit

Hilfe von übergeordneten metakognitiven Prozessen überwacht und angepasst werden kann (Pintrich, 2000; Zimmerman, 2000). Metakognition spielt dabei eine zentrale Rolle, da sie die Grundlage zur Überwachung und Steuerung eigener Lernprozesse darstellt.

Metakognition. Metakognition, als ‚Denken über das Denken' (Flavell, 1979), beschreibt einen übergeordneten Prozess und umfasst das Bewusstsein von Lernenden über ihre Fähigkeiten, die verfügbaren Ressourcen zur Bewältigung von Aufgaben und ihr Wissen darüber, wie sie ihr Vorgehen steuern können, um Lernprozesse und -ergebnisse zu verbessern (Winne & Perry, 2000). Das Konstrukt Metakognition kann dabei noch weiter differenziert werden. Am häufigsten wird dabei in metakognitives Wissen und metakognitive Fähigkeiten oder Strategien unterschieden (Efklides, 2008; Veenman et al., 2006). Metakognition ist dabei eng mit SRL verbunden und kann als eine Vorrausetzung für SRL gesehen werden (Gascoine et al., 2017).

Metakognitives Wissen. Metakognitives Wissen umfasst das Wissen über die Aufgabe, die eigenen Fähigkeiten und Strategien (Flavell, 1979). Zur effektiven Anwendung von SRL-Strategien benötigen Lernende metakognitives Strategie-Wissen über ein Repertoire von SRL-Strategien (Pintrich, 2000). Lernende müssen die grundlegende Definition und Beschreibung von Strategien kennen (deklaratives Wissen), wissen, wie diese Strategien angewandt werden können (prozedurales Wissen) und unter welchen Bedingungen, welche Strategie am geeignetsten ist (konditionales Wissen) (Händel et al., 2013; Weinstein et al., 2011).

Metakognitive Fähigkeiten bzw. Strategien. Metakognitive Fähigkeiten bzw. Strategien können als übergeordnete SRL-Strategien betrachtet werden, die dazu dienen den Lernprozess und den Strategieeinsatz zu überwachen und anzupassen (Boekaerts, 1999; Pintrich, 1999). Metakognitive Strategien umfasseb die Planung und Zielsetzung des Vorgehens und des Strategieeinsatzes, das Überwachen des Lernfortschritts und die Evaluation des eigenen Vorgehens während des Lernens (Pintrich, 1999). Die metakognitiven Prozesse und darin angewandten Strategien werden als ein Zusammenspiel aus *Monitoring* und *Control* beschrieben (Nelson & Narens, 1994). *Monitoring*, als Beobachten und Überwachen, kann dabei als eine der wichtigsten Grundlagen für SRL gesehen werden, ohne welche eine zielgerichtete Regulation des Lernprozesses nicht möglich ist (Butler & Winne, 1995; Winne & Perry, 2000). *Monitoring* umfasst die kontinuierliche Beobachtung und Beurteilung des Vorgehens, des Aufgaben-Verständnisses, des Fortschritts und der Strategien, welche die Lernenden während der Aufgabenbearbeitung anwenden (Nelson & Narens, 1994). *Control*

beschreibt daran anknüpfend die Strategien und Maßnahmen, die auf der Grundlage des *Monitoring*-Prozesses ergriffen werden (Nelson & Narens, 1994).

SRL-Strategien. Um die verschiedenen Bereiche regulieren zu können, nutzen Lernende neben den beschrieben metakognitiven Strategien weitere vielfältige Strategien. SRL-Strategien bezeichnen zielgerichtete, selbstgesteuerte Handlungen, die darauf abzielen, sich neue Informationen oder Fähigkeiten anzueignen, die Wahrscheinlichkeit für Lernerfolg erhöhen und dabei helfen herausfordernde Aufgaben erfolgreich zu bewältigen (Weinstein et al., 2000; Zimmerman & Martinez-Pons, 1986). Sie stellen daher bewusst gewählte Vorgehensweisen dar, bei denen Lernende aus einem Repertoire an Methoden diejenigen auswählen, die sie für eine spezifische Herausforderung oder Aufgabe als am geeignetsten erachten (Zimmerman, 2000).

Einige SRL-Theorien, wie beispielsweise das Drei-Schichten-Modell von Boekaerts (1999) fokussieren sich auf die Beschreibung der verschiedenen SRL-Strategiebereiche als wichtige Komponenten von SRL. Den Kern des Drei-Schichten-Modells (Boekaerts, 1999) machen die kognitiven Lernstrategien zur Informationsverarbeitung aus. In einer zweiten Schicht sind diese wiederum von verschiedenen metakognitiven Strategien umgeben, mit Hilfe welcher der Einsatz dieser kognitiven Strategien und der gesamte Lernprozess gesteuert, überwacht, evaluiert und angepasst wird. Die äußerste Schicht des Modells veranschaulicht Strategien zur Regulation des Selbst, zum Beispiel durch die Anpassung der Ressourcen und motivationsregulierende Strategien.

Kognitive SRL-Strategien. Zur effizienten Aufnahme und Verarbeitung von Informationen und zum Erreichen von Lernzielen nutzen selbstregulierte Lernende kognitive Strategien (Boekaerts, 1996). Kognitive SRL-Strategien können wiederum in Wiederholung, Organisation und Elaboration differenziert werden (Weinstein et al., 2011). Zu den kognitiven SRL-Strategien gehören beispielweise das Auswendiglernen, das Erstellen von Mind-Maps, Paraphrasieren und Zusammenfassen von Lerninhalten.

Motivationsregulierende SRL-Strategien. Ein weiterer wichtiger Bestandteil von SRL sind motivationale Prozesse, die Lernende dazu nutzen, ihre Motivation zu lernen zu initiieren und aufrechtzuerhalten (Boekaerts, 1996; Wolters, 2003). Zu den motivationsregulierenden SRL-Strategien gehören beispielsweise selbstkonsequente Gedanken, wie das Versprechen einer Belohnung, bestärkende Selbstgespräche oder die aktive Steigerung des Interesses an der Aufgabe (zum Beispiel dadurch, dass man sie spielerisch gestaltet) (Wolters, 2003).

Emotionsregulierende SRL-Strategien. In den neueren Forschungen rücken verstärkt Emotionen und deren Regulation als wesentliche Komponente von SRL in den Fokus (Zheng et al., 2023). Emotionen können den Lernprozess beeinträchtigen und fördern (Camacho-Morles et al., 2021; Pekrun et al., 2023). Um negative Emotionen zu bewältigen und den Fokus auf den Lernzielen beizubehalten, können Lernende auf Emotionsregulations-Strategien zurückgreifen. Diese umfassen beispielsweise die Umbewertung einer emotional belastenden Situation oder den Einsatz von Strategien zur direkten Regulation der aufkommenden Emotionen (Gross, 2015).

SRL-Strategien zur Regulation der Ressourcen und der Umgebung. In vielen der theoretischen SRL-Modelle tauchen zudem noch ressourcenorientierte Strategien auf, welche darauf abzielen die Lernumgebung anzupassen (Pintrich, 1999), wie beispielsweise die Gestaltung eines ablenkungsarmen Lernortes. Neben der Anpassung der Lernumgebung werden hier beispielsweise auch die Unterstützung durch Eltern, Mitlernende und Lehrkräfte, als Ressource verortet.

Die verschiedenen Komponenten von SRL bilden die Grundlage dafür, wie Lernende ihren Lernprozess steuern, überwachen und anpassen. Diese Komponenten und die mit dem SRL-Konstrukt in Verbindung stehenden vielfältigen Fähigkeiten, Anforderungen und das strategische Vorgehen können zusammengenommen als SRL-Kompetenzen beschrieben werden (Wirth & Leutner, 2008). Um ein umfassendes Verständnis von SRL zu gewinnen, ist es entscheidend, nicht nur die einzelnen Komponenten zu betrachten, sondern auch den dynamischen Prozess, in dem diese miteinander interagieren. Im folgenden Kapitel wird dieser SRL-Prozess daher näher beleuchtet.

2.1.3 Der Prozess der Selbstregulation beim Lernen

Neben der Identifikation und Differenzierung der einzelnen SRL-Komponenten, haben Forschende seit dem Ende des 20. Jahrhunderts verschiedene theoretische Modelle entwickelt, um den komplexen SRL-Prozess besser verstehen und erforschen zu können (Panadero, 2017; Tinajero et al., 2024; Wirth & Leutner, 2008). Zu den am häufigsten zitierten Prozess-Modellen gehören die von Zimmerman (2000), Winne und Hadwin (1998) und Pintrich (2000) (Panadero, 2017; Tinajero et al., 2024).

In dem zyklischen Phasenmodell von Zimmerman (2000) wird der SRL Prozess anhand von drei aufeinanderfolgenden Phasen beschrieben: Die *Forethought-Phase* (Phase der Vorüberlegungen) dient dazu Ziele für den Lernprozess zu setzen, das (strategische) Vorgehen

zu planen und umfasst zudem motivationale Prozesse in Vorbereitung auf die Bearbeitung der Aufgabe. Die anschließende tatsächliche *Performance-Phase* (Handlungs-Phase) bezieht sich auf die Prozesse, die sowohl die Handlungen als auch die Motivation während des Lernens betreffen. Dabei überwachen Lernende ihren Fortschritt und nutzen verschiedene SRL-Strategien, um kognitiv engagiert und motiviert zu bleiben. Die Phase der *Self-reflection* (Selbstreflexions-Phase), im Anschluss an die Aufgabenbearbeitung, beschreibt die kognitiven und motivationalen Reaktionen im Zusammenhang mit der individuellen Evaluation der Lernerfahrung. Die Ergebnisse der Selbstreflexions-Phase stellen wiederum die Grundlage für die erneute Forethought-Phase des nachfolgenden Lernzyklus dar, woraus sich ein iterativer Prozess ergibt.

Winne und Hadwin (1998) beschreiben den SRL Prozess in ihrem COPES (*Conditions, Operations, Products, Evaluations und Standards*) Modell anhand von vier Phasen. Die erste Phase des SRL Prozess unterteilen sie in (1) Aufgabenorientierung und (2) Zielsetzung und Planung. Während der Aufgabenorientierung, erschließen sich die Lernenden das Material, überprüfen ihr eigenes Verständnis und Bedingungen der Aufgabe, beispielsweise die Zeitvorgaben, aber auch interne Bedingungen wie das Vorwissen, Motivation und Überzeugungen. In dem zweiten, daran anschließenden Stadium des SRL Prozess, der Zielsetzung und Planung, setzen sich die Lernenden im Hinblick auf ihr Lernergebnis, ihre eigenen Gedanken, ihres Vorgehens und ihrer Motivation Ziele. Zur Erreichung dieser Ziele werden Strategien und Vorgehensweisen geplant. In der anschließenden dritten Phase, der (3) Ausführung der Aufgabe und dem Einsatz von Strategien, wird das Vorgehen kontinuierlich anhand der selbstgesetzten Ziele überprüft. Das daraus resultierende interne Feedback, aber auch externe Rückmeldungen, dienen dazu das eigene Vorgehen oder sofern nötig auch die selbstgesetzten Ziele, anzupassen und zu überwachen. In der vierten daran anschließenden Phase der (4) Reflexion evaluieren Lernende das eigene Vorgehen und ihren Einsatz und die Effektivität von Strategien während des Lernprozesses.

Pintrich (2000) entwickelte ein SRL-Modell, welches sowohl die Phasen als auch die in 2.1.2 beschriebenen, verschiedenen Komponenten von SRL in einer Tabelle vereint. Auch sein Modell umfasst vier Phasen. Im Gegensatz zu Winne und Hadwin (1998) unterteilt er nicht die Phase der Vorbereitung, sondern differenziert in der Phase der Aufgabenbearbeitung bzw. des Lernens spezifisch zwischen *Monitoring* und *Control* als eigenständigen Stadien innerhalb des SRL-Prozesses. Neben den so vier ausdifferenzierten Phasen (1. *Forethought, planning and activation* (Vorüberlegung, Planung und Aktivierung), 2. *Monitoring* (Überwachen), 3. *Control*

(Kontrolle), *4. Reaction and Reflection* (Reaktion und Reflexion)), beschreibt er darüber hinaus vier verschiedene Bereiche der Selbstregulation: Kognition (1), Motivation und Emotion (2), Verhalten (3) und Kontext (4). Je nach Phase und Bereich werden innerhalb des tabellarischen Modells Prozesse und Strategien definiert, die zum Einsatz kommen bzw. welche von Lernenden aktiviert werden.

Basierend auf diesen klassischen Modellen wurde eine Vielzahl von weiteren SRL-Prozess-Modellen entwickelt. In diesen neueren Modellen wurde die SRL-Theorie weiter ausdifferenziert und zum Beispiel ein Fokus auf die Regulation von bestimmten Bereichen, wie Emotionen (Ben-Eliyahu, 2019; Efklides, 2011) oder Motivation (Miele & Scholer, 2018), oder auch der Regulation in sozialen Kontexten gesetzt (Järvelä & Hadwin, 2013).

Die verschiedenen SRL-Prozess Modelle unterscheiden sich in ihrem Fokus, teilen jedoch überwiegend die Konzeptualisierung von SRL als einen dynamischen Prozess in unterschiedlichen Phasen (Panadero, 2017). Basierend auf den aufgeführten verschiedenen theoretischen Konzeptualisierungen von SRL als ein dynamischer Prozess und den verschiedenen SRL-Komponenten ergeben sich unterschiedliche Operationalisierungen und eine Vielzahl von Erfassungsmethoden (Wirth & Leutner, 2008).

2.2 Erfassung von Selbstregulation beim Lernen

In der SRL Forschung wird eine Vielzahl von Instrumenten eingesetzt (Gascoine et al., 2017; Panadero et al., 2016). Dabei wird grundsätzlich zwischen Online- und Offline-Methoden unterschieden (Veenman & van Cleef, 2019). Online-Methoden zielen darauf ab SRL während des tatsächlichen Lernprozesses oder der Bearbeitung einer Aufgabe zu erfassen und betrachten SRL dementsprechend als ein Ereignis bzw. situativen Strategieeinsatz (*event*) innerhalb des Lernprozesses (Bannert et al., 2014; Winne & Perry, 2000). Bei Offline-Methoden hingegen werden Lernende oder Dritte (z.B. Eltern) außerhalb der direkten Bearbeitung von Lernaufgaben zu dem Lernverhalten und der Verwendung von SRL-Strategien befragt (Rovers et al., 2019; Veenman, 2011). SRL wird in diesen Methoden meist auf eine situationsunabhängige Weise und als eine stabilere Fähigkeit (*aptitude*) operationalisiert (Winne & Perry, 2000). Darüber hinaus wird in der Erfassung von SRL oft zwischen der Erfassung auf dem Makro- oder Mikro-Level unterschieden (Greene & Azevedo, 2009). Makroprozesse beziehen sich auf übergeordnete Komponenten oder Phasen von SRL, wie beispielsweise der allgemeinen Strategienutzung oder der Planung. Mikroprozesse hingegen

umfassen spezifischere Aktivitäten bzw. Strategien innerhalb dieser Phasen oder Komponenten, wie etwa die Zielsetzung innerhalb der Phase der Vorüberlegungen. In diesem Zusammenhang wird zudem oft auf die Granularität, dem Detailierungsgrad in dem SRL-Prozesse mit den verschiedenen Erfassungsmethoden gemessen werden, verwiesen (Rovers et al., 2019). Im Folgenden werden die gängigsten Methoden zur Erfassung von SRL kurz beschrieben und die Vorteile und Kritikpunkte erläutert, um die spezifischen Herausforderungen in der Erfassung von SRL herauszuarbeiten.

2.2.1 Offline-Erfassungsmethoden

Offline Methoden umfassen verschiedene Instrumente, welche SRL als eine tendenziell stabile Fähigkeit erfassen (Winne & Perry, 2000). Zudem erfassen diese Methoden SRL eher auf einem Makro-Level und geben wenig detaillierte Informationen (Rovers et al., 2019).

Selbstbeurteilungsfragebogen. Selbstbeurteilungsfragebögen sind die vorherrschende Methode in der SRL-Forschung und erfassen SRL als globales Maß für den Einsatz von SRL-Strategien über verschiedene Lernkontexte hinweg (Winne & Perry, 2000). Ihr Vorteil liegt in der effizienten Anwendung bei großen Stichproben und der bewährten Beurteilung des globalen SRL-Niveaus (Rovers et al., 2019). Allerdings wird ihre ausschließliche Verwendung zunehmend kritisiert. Der retrospektive Einsatz von SRL-Strategien ist oft ungenau und anfällig für sozial erwünschte Antworten sowie Verzerrungen (Panadero et al., 2016; A. Roth et al., 2016). Zudem ist SRL ein kontextabhängiger Prozess und variiert je nach Aufgabe, weshalb Selbstbeurteilungsfragebögen nicht für die Erfassung dieser kontextabhängigen Veränderungen geeignet sind (Winne, 2017).

Beurteilungen durch Erwachsene. In den Beurteilungen der SRL-Strategienutzung durch Erwachsene werden Eltern, Lehrkräfte oder andere Bezugspersonen gebeten, die Selbstregulation von jungen Lernenden einzuschätzen (McCoy, 2019). Eltern und Lehrkräfte stehen täglich in engem Kontakt mit Lernenden und können somit die SRL während des alltäglichen Lernens beobachten und einschätzen (Chen et al., 2015). Aufgrund ihrer zeiteffizienten Nutzung können Beurteilungen durch Erwachsene bei der Erfassung von SRL junger Lernender daher von Vorteil sein (Chen et al., 2015; McCoy, 2019). Dennoch sind SRL-Beurteilungen durch Erwachsene in mehrfacher Hinsicht limitiert. Die Einschätzungen sind in hohem Maße subjektiv, und insbesondere die Beurteilung durch Eltern wird ebenso wie Selbstbeurteilungen durch soziale Erwünschtheit beeinflusst (McCoy, 2019). Zudem lassen sich mit Hilfe der Beurteilungsfragebögen für Erwachsenen nur die SRL Prozesse einschätzen, welche von außen beobachtbar sind (McCoy, 2019).

Szenario-Tests. Zur Erfassung des metakognitiven Wissens kommen häufig Szenario-Tests zum Einsatz, in welchen Lernende verschiedene Vorgehensweisen zu unterschiedlichen Szenarien beurteilen sollen (Händel et al., 2013). Je nach Alter können die Szenarien sowohl aus dem Lernkontext als auch aus dem außerschulischen Alltag stammen (Lockl et al., 2016). Nach der Beschreibung eines Szenarios werden dem Lernenden mehrere Antwortoptionen mit verschiedenen Strategien präsentiert (Händel et al., 2013). Basierend auf Expert*innen-Ratings wird vorab die relative Nützlichkeit der Strategien bewertet, wodurch eine Einstufung der Antworten möglich sind (Neuenhaus et al., 2011). Ähnlich wie Fragebögen haben Szenario-Tests den Vorteil, dass sie effizient in der Anwendung sind (Dörrenbächer-Ulrich et al., 2021). Im Vergleich zu anderen Offline-Methoden beziehen sich Szenario-Tests zudem auf bestimmte Kontexte. Allerdings ist die Anwendung von Szenario-Tests sehr stark vom Alter der Lernenden abhängig und die Konstruktion der lebensnahen Szenarien und der verschiedenen Antworten stellt eine besondere Herausforderung dar (Händel et al., 2013).

Interviews. In Interviews werden den Lernenden offene Fragen zu ihrem Einsatz von SRL-Strategien gestellt. SRL-Interviews können so gestaltet werden, dass die Lernenden sowohl retrospektiv als auch prospektiv zu den Strategien und ihrer Anwendung oder zu ihrem Vorgehen in bestimmten Situationen befragt werden (Spörer & Brunstein, 2006). SRL-Interviews variieren dabei zwischen narrativen Interviews, halbstrukturierten Interviews und strukturierten Interviews (Winne & Perry, 2000). Der Vorteil von Interviews besteht darin, dass die Strategieverwendung nicht nur anhand von vordefinierten Strategien erfasst wird, sondern Lernende in ihren Beschreibungen Aufschluss über das individuelle Repertoire an Strategien geben, über das sie verfügen und das sie verwenden (Zimmerman & Martinez-Pons, 1986). Somit können SRL-Interviews einen vertieften Einblick in die SRL-Strategienutzung von Lernenden geben, wobei Interviews durch die sprachlichen Fähigkeiten, potenzielle Unsicherheiten und die Motivation der Lernenden limitiert sein können (Spörer & Brunstein, 2006).

Lerntagebücher. Eine weitere Methode zur Erfassung von SRL, die stärker in den Lernprozess eingebettet ist, sind Lerntagebücher. Bei diesen werden Lernende aufgefordert, ihr Lernverhalten zu mehreren Messzeitpunkten meist über einen längeren Zeitraum hinweg zu berichten. Als strukturiertes Instrument zum Beispiel mit Fragen vor und nach der Lernaufgabe können Lerntagebücher die verschiedenen Phasen des gesamten SRL-Prozess erfassen (Panadero et al., 2016). In Anlehnung an das Prozessmodell von Zimmerman werden Fragen

zur Planung vor, Fragen zur Überwachung während und der Beurteilung nach dem Lernen gestellt (Klug et al., 2011). Der Einsatz von standardisierten Lerntagebüchern zur Bewertung von SRL ist bereits für Lernende in der Grundschule praktikabel (Dörrenbächer-Ulrich et al., 2021; Spörer & Brunstein, 2006).

Selbstberichte, insbesondere solche, die über einen längeren Zeitraum geführt werden müssen, wie z. B. Lerntagebücher, sind stark von der Motivation abhängig (Spörer & Brunstein, 2006). In der Erfassung von SRL mit Selbstberichten vermischen sich zudem möglicherweise verschiedenen Komponenten von SRL wie das metakognitive Wissen, die retrospektive Beurteilung der Strategienutzung aber auch Überzeugungen (Cleary et al., 2012; Rovers et al., 2019; Spörer, 2004). Daher wird mittlerweile zunehmend argumentiert, dass diese Methoden nicht dazu geeignet sind die tatsächlichen SRL-Strategienutzung zu erfassen (Rovers et al., 2019).

2.2.2 Online-Erfassungsmethoden

Im Gegensatz zu den oben aufgeführten Offline-Erfassungsmethoden zielen Online-Methoden darauf ab, SRL als zeitlich begrenztes Ereignis zu messen, das sich auf einen bestimmten Kontext, zum Beispiel eine gerade ausgeführte Aufgabe, bezieht (Winne & Perry, 2000). Diese Methoden sind daher stark auf die Konzeptualisierung von SRL als Prozess ausgerichtet und zielen darauf ab, den tatsächlichen, aufgabenbezogenen Regulationsprozess von Lernenden zu erfassen (Azevedo, 2014).

***Beobachtungen*.** Beobachtungen erfassen die SRL von Lernenden während laufender Lernprozesse oder Aufgabenbearbeitungen (Winne & Perry, 2000). Dabei können verschiedene Schwerpunkte gesetzt werden (Boekaerts & Corno, 2005). Beobachtungsmethoden liefern umfangreiche Daten zu verbalen und nonverbalen Verhaltensweisen, die mit Kodierungsschemata sowohl qualitativ als auch quantitativ ausgewertet werden können (Whitebread et al., 2009). Ein Vorteil dieser Methode ist, dass sie tatsächliches Verhalten während einer spezifischen Aufgabe erfasst, anstatt sich auf Erinnerungen oder Selbstberichte zu stützen (Winne & Perry, 2000). Besonders bei jungen Lernenden helfen Beobachtungen, Verzerrungen durch soziale Erwünschtheit oder Sprachprobleme zu vermeiden (Whitebread et al., 2009; Winne & Perry, 2000). Sie können zudem im natürlichen Umfeld durchgeführt werden. Ein Nachteil ist, dass Beobachtungen nur das äußere Verhalten erfassen und nicht die zugrundeliegenden Gedankenprozesse, die möglicherweise verhindern, dass ein Lernender eine Strategie anwendet (McCoy, 2019). Darüber hinaus ist die Datenerhebung und -analyse zeit- und ressourcenintensiv (Marulis et al., 2016; Veenman & van Cleef, 2019).

Laut-Denken-Protokolle. Bei der Methode des Laut-Denkens werden Lernende dazu aufgefordert ihre Gedanken während des Lernprozesses zu verbalisieren (Veenman & van Cleef, 2019). Diese Erfassungsmethode ermöglicht es, Einsichten in die kognitiven und metakognitiven Prozesse der Lernenden zu gewinnen, wie etwa die Planung, Überwachung und Anpassung ihrer Lernstrategien (Veenman, 2011). Der Vorteil dieser Methode liegt darin, dass sie direkten Zugang zu den mentalen Prozessen der Lernenden bietet, die durch Beobachtungen oder retrospektive Selbstberichte schwerer zugänglich sind (Greene & Azevedo, 2009). Ein Nachteil ist jedoch, dass auch Laut-Denken-Protokolle nicht immer ein vollständiges Bild des inneren Denkprozesses liefern (Boekaerts & Corno, 2005; Ridgley et al., 2020). Zudem liefert auch diese Methode umfangreiche Daten, die in der Aufbereitung und Analyse ressourcen- und zeitaufwändig sind (Veenman & van Cleef, 2019).

Log-Data. Bei der Erfassung von SRL durch Log-Daten wird das Verhalten der Lernenden in digitalen Lernumgebungen aufgezeichnet (Veenman & van Cleef, 2019; Winne, 2014). Diese Daten umfassen detailliert die Interaktionen, wie Klicks, Verweildauer auf bestimmten Aufgaben oder Seiten, woraus sich die Häufigkeit und Art der genutzten SRL-Strategien ableiten lassen (Azevedo, 2014; Du et al., 2023). Log-Daten bieten objektive, kontinuierliche und oft in Echtzeit erfasste Einblicke in das Lernverhalten der Lernenden, was sie besonders nützlich für die Analyse von SRL-Prozessen in digitalen Kontexten macht (Siadaty et al., 2016). Ein Vorteil dieser Methode ist das Potenzial, ein umfangreiches und detailliertes Bild des Lernverhaltens zu liefern, ohne die Lernenden direkt zu stören (Veenman & van Cleef, 2019). Dabei können auch längere Zeitspannen ressourcenschonend nachgezeichnet werden. Ein möglicher Nachteil besteht darin, dass Log-Daten nur das äußere Verhalten erfassen und keine Informationen über die zugrundeliegenden mentalen Prozesse der Lernenden bieten (Fan et al., 2023). Dementsprechend stellt die Interpretation von Log-Daten zur Identifikation von SRL-Kompetenzen eine große Herausforderung dar (Roll & Winne, 2015; van Laer & Elen, 2018). Dabei müssen beispielsweise klare Operationalisierungen und Indikatoren für SRL in den spezifischen Log-Daten entwickelt werden. Bei der ausschließlichen Erfassung durch Online-Methoden wie Log-Daten gehen jedoch potenzielle Informationen verloren, wie beispielsweise Überzeugungen der Lernenden oder nicht-beobachtbares oder schwer zu operationalisierendes SRL-Verhalten (Jansen et al., 2020; Winne, 2017).

Hinzukommend werden weitere neue Methoden wie Eye-Tracking-Daten, Messungen der Gehirnaktivierung, der Hautleitfähigkeiten und andere bio-physiologische Indikatoren zur Erfassung von SRL erprobt (Azevedo & Gašević, 2019; Reimann et al., 2014).

Die Vielfalt an Online- und Offline-Erfassungsmethoden zeigt, dass jede Methode spezifische Stärken und Grenzen hat. Während Online-Methoden, wie Log-Daten, präzise Prozessdaten liefern, aber die kognitiven Prozesse nur indirekt erfassen, bieten Offline-Methoden, wie Fragebögen, Einblick in subjektive Einschätzungen, sind jedoch anfällig für Verzerrungen (Vandevelde et al., 2013; Winne & Perry, 2000). Insbesondere bei jungen Lernenden stellt die Erfassung von SRL aufgrund von sprachlichen Fähigkeiten, Verzerrungen durch soziale Erwünschtheit und der retrospektiven Beurteilung eine Herausforderung dar (Azevedo, 2009; Perry & VandeKamp, 2000). Um ein umfassenderes Bild von SRL zu erhalten, gewinnt der multimethodische Ansatz an Bedeutung. Im Folgenden wird die Kombination verschiedener Methoden kurz diskutiert.

2.2.3 Multimethodische Erfassung

Die Kombination von verschiedenen Methoden zur Erfassung von SRL ermöglicht eine umfassendere und genauere Analyse der Lernprozesse, da unterschiedliche Perspektiven und Datenquellen sich ergänzen und Nachteile einzelner Methoden nivellieren können (Azevedo & Gašević, 2019; Järvelä & Bannert, 2021). Durch die Kombination beispielsweise von Selbstberichten, Beobachtungen, Laut-Denken-Protokollen und Log-Daten können Forschende sowohl die inneren Gedankenprozesse der Lernenden, als auch ihr tatsächliches Verhalten in unterschiedlichen Kontexten und über verschiedene Zeiträume hinweg erfassen (Vandevelde et al., 2015). Multi-Modal-Ansätze gehen noch einen Schritt weiter, indem sie verschiedene Modalitäten der Datenerfassung kombinieren, wie zum Beispiel verbale, visuelle und physiologische Daten (Järvelä & Hadwin, 2013; Noroozi et al., 2020). Dies kann durch den Einsatz von Videoaufzeichnungen, Eye-Tracking-Technologien oder bio-physiologische Indikatoren geschehen (Azevedo & Gašević, 2019; Noroozi et al., 2020). Obwohl in der aktuellen Forschung immer wieder auf die Notwendigkeit hingewiesen wird, SRL multimethodisch zu erfassen, haben bisher nur wenige Studien einen solchen Ansatz verfolgt und Übereinstimmungen und Unterschiede zwischen den verschiedenen Erfassungsmethoden untersucht (Fan et al., 2022; Fan et al., 2023; Saint et al., 2020). Dies ist zum anderen durch die Herausforderungen in der Forschung mit Multi-Method- und Multi-Modal-Daten, wie beispielsweise die zeitliche Angleichung der verschiedenen Datenquellen, die aufwendige Aufbereitung der Daten und komplexe Auswertungsprozesse (Azevedo & Gašević, 2019)

begründet. Die wenigen Studien, in denen verschiedene Methoden zur Erfassung der SRL verwendet wurden, weisen zudem auf geringe Korrelationen zwischen den Online- und Offline-Methoden hin (Dörrenbächer-Ulrich et al., 2021; Spörer, 2004; Veenman & van Cleef, 2019). Dennoch bieten diese Ansätze einige Vorteile, wie die Reduktion der Verzerrungen, die mit der alleinigen Anwendung einer Methode verbunden sein können (Veenman, 2011). Multi-Modal-Ansätze können darüber hinaus genaue und differenziertere Analysen der verschiedenen Facetten von SRL ermöglichen, da sie das Lernverhalten in seiner ganzen Komplexität erfassen (Järvelä & Bannert, 2021). Die fortlaufende Weiterentwicklung und Evaluierung von Erfassungsmethoden und Studien, welche verschiedene Erfassungsmethoden kombinieren, liefern somit wichtige Erkenntnisse darüber, was genau mit den jeweiligen Methoden erfasst wird und ob es sich je nach Messmethode eventuell um verschiedene Aspekte der SRL handelt.

Die präzise Erfassung von SRL ermöglicht nicht nur Einblicke in den SRL-Prozess und dessen Komponenten, sondern auch in interindividuelle Unterschiede zwischen Lernenden. Diese Unterschiede können wiederum durch verschiedene Einflussfaktoren bedingt sein, die im Folgenden näher betrachtet werden.

2.3 Einflussfaktoren auf Selbstregulation beim Lernen

Im Vergleich zu der umfangreichen Forschung zu den Zusammenhängen zwischen SRL und schulischer Leistung (Dent & Koenka, 2016) existieren bislang nur wenige empirische Studien zu möglichen Prädiktoren von SRL. Dennoch wurden in theoretischen Modellen und ersten empirischen Untersuchungen bereits verschiedene Faktoren identifiziert, welche die SRL-Kompetenzen Lernender beeinflussen könnten.

Kontextuelle und demografische Faktoren. Einige der SRL-Theorien beschreiben verschiedene kontextuelle Faktoren, welche einen Einfluss auf die SRL von Lernenden haben könnten (Pintrich, 2000; Winne & Hadwin, 1998; Zimmerman, 2000). Dabei werden beispielsweise die Unterstützung durch Lehrkräfte und Eltern, die soziale und schulische (Lern-)Umgebung und spezifische Anforderungen der Aufgaben als Einflussfaktoren auf SRL benannt.

Metaanalysen und systematische Übersichtartikel konnten bereits den komplexen Einfluss von elterlichem Verhalten auf die allgemeine SR-Fähigkeiten in der frühen Kindheit und SRL-Kompetenzen im Schulalter herausarbeiten (Dermitzaki & Kallia, 2021; Pino-Pasternak & Whitebread, 2010; Wesarg-Menzel et al., 2023). So hängt beispielsweise die

Förderung der Autonomie durch die Eltern positiv mit SRL von Kindern zusammen (Dermitzaki & Kallia, 2021). Zudem gibt es eine Vielzahl von empirischen Studien, welche den Einfluss von Lehrkräften auf die SRL-Kompetenzen der Lernenden in ihren Klassen untersucht hat (Dignath & Veenman, 2021; Heirweg et al., 2021; Karlen et al., 2024). Hier zeigte sich beispielsweise, dass Lehrkräfte im Unterricht nur wenig SRL fördern, Lernende allerdings von einer expliziten SRL-Strategieförderung durch Lehrkräfte profitieren können (Dignath & Veenman, 2021).

Neben den in den SRL-Theorien angenommenen Zusammenhängen, wurden in empirischen Studien weitere potenzielle Zusammenhänge zwischen SRL und kontextuellen bzw. demografischen Einflussfaktoren exploriert. Obwohl sich ein Großteil der Studien auf die Entwicklung von SR in der frühen Kindheit bezieht (z.B. Sektnan et al., 2010), konnten einige empirische Untersuchungen bereits zeigen, dass ein eingeschränkter Zugang zu Ressourcen und unterstützenden Strukturen bei Familien mit niedrigerem sozioökonomischen Status (SÖS) auch mit niedrigerer SRL-Strategienutzung und geringerem metakognitiven Wissen in Zusammenhang stehen (Karlen et al., 2014; Pappas et al., 2003; Vandevelde et al., 2017). Die wenigen existierenden Studien zu Unterschieden in der SRL bei Lernenden mit Migrationshintergrund zeigen widersprüchliche Ergebnisse. Während einige Untersuchungen darauf hinweisen, dass Lernende mit Migrationshintergrund tendenziell weniger SRL-Strategien nutzen (z.B. Vandevelde et al., 2017), berichten andere, dass insbesondere Mädchen mit Migrationshintergrund mehr übergeordnete SRL-Strategien anwenden (z.B. Blom & Severiens, 2008).

Kognitive und neuronale Faktoren. Darüber hinaus werden in einigen SRL-Theorien kognitive Faktoren, wie das Vorwissen und das Strategiewissen als potenzielle Einflussfaktoren benannt (Boekaerts, 1996; Pintrich, 2000; Winne & Hadwin, 1998). Die empirische Forschung konnte bereits Zusammenhänge zwischen einem hohen metakognitiven Strategiewissen und der Nutzung von SRL-Strategien durch Lernende zeigen (z.B. Meneghetti & De Beni, 2010), weist aber auch auf Diskrepanzen zwischen dem metakognitiven Wissen und der tatsächlichen Nutzung von SRL-Strategien bei Lernenden hin (z.B. Foerst et al., 2017).

Basierend auf Forschung zu Zusammenhängen zwischen kognitiven Faktoren und schulischer Leistung (Arnold et al., 2020; Landerl et al., 2009; B. Roth et al., 2015). kann vermutet werden, dass auch weitere kognitive Faktoren mit SRL in Verbindung stehen, die in bestehenden SRL-Theorien noch nicht berücksichtigt wurden. Bei der Untersuchung des Zusammenhanges von SRL mit Intelligenz zeigten sich allerdings gemischte Ergebnisse, die

sowohl eine höhere (z.B. Zimmerman & Martinez-Pons, 1990) als auch geringere SRL-Strategienutzung (z.B. Sontag et al., 2012) im Zusammenhang mit einer höheren Intelligenz zeigten.

Ein bislang wenig erforschter, aber zunehmend relevanter Zusammenhang betrifft den Zusammenhang zwischen SRL-Kompetenzen und Lernschwierigkeiten bzw. diagnostizierten Lern- und Aufmerksamkeitsstörungen. Lernstörungen umfassen sowohl unerwartete schlechte schulische Leistungen, die nicht durch geringere kognitive Potenziale oder äußere Faktoren erklärbar sind, als auch spezifische Lernstörungen wie Legasthenie und Dyskalkulie (Büttner & Hasselhorn, 2011; World Health Organization [WHO], 2021). Die Aufmerksamkeitsdefizit-/Hyperaktivitätsstörung (ADHS) ist gekennzeichnet durch die Kernsymptome Unaufmerksamkeit, Hyperaktivität und Impulsivität oder eine Kombination dieser Symptome (WHO, 2021). Erste empirische Untersuchungen konnten zeigen, dass Lernende mit ADHS Schwierigkeiten in der Anwendung von SRL-Strategien zeigen (z.B. Bakracevic Vukman et al., 2013) und Kinder mit diagnostizierten Lernstörungen weniger metakognitive Verhaltensweisen und ein geringeres metakognitives Wissen aufweisen (Desoete et al., 2006; Tzohar-Rozen et al., 2021). Es herrscht jedoch Uneinigkeit in der Definition und Operationalisierung von Lernstörungen, da Diskrepanz-Kriterium zwischen IQ und Leistung häufig kritisiert wird und viele Kinder mit verschiedenen Lernschwierigkeiten dabei unberücksichtigt bleiben (Büttner & Hasselhorn, 2011; Kavale & Forness, 2000). Daher plädieren einige Forschende dafür, nicht nur diagnostizierte, sondern auch symptomatische Lernende ohne formale Diagnose in Studien zu schulischen Leistungsdefiziten einzubeziehen (Büttner & Hasselhorn, 2011; Loe & Feldman, 2007).

Darüber hinaus wird ein grundlegender Zusammenhang zwischen der Entwicklung von SRL-Kompetenzen und dem Alter angenommen (z.B. Veenman et al., 2006). Einige empirische Studien zeigen einen Zuwachs metakognitiver Fähigkeiten mit zunehmendem Alter (z.B. Annevirta & Vauras, 2006). Eine Zunahme in der SRL-Strategienutzung mit zunehmendem Alter der Lernenden wird zwar oft angenommen, empirische Studien kommen jedoch zu gemischten Ergebnisse. In einigen längsschnittlichen Studien wird berichtet, dass die Nutzung von SRL-Strategien mit zunehmenden Alter steigt (z.B. Meijs et al., 2009), während andere keine Entwicklung im Zusammenhang mit Alter finden (z.B. Leutwyler, 2009) oder sogar aufzeigen, dass beispielsweise die Nutzung von SRL-Strategien mit dem Übergang in die

weiterführende Schule sogar abnimmt (Bardach et al., 2023; Martinek et al., 2016; Mok et al., 2007; Theodosiou & Papaioannou, 2008).

In Bezug auf Zusammenhänge mit dem Geschlecht zeigen sich ebenfalls gemischte Befunde. Tendenziell zeigen Studien jedoch häufiger, dass Mädchen mehr übergeordnete SRL-Strategien anwenden als Jungen (Heirweg et al., 2019; Leutwyler, 2009; Schunk & Greene, 2018).

Motivationale Faktoren. Die meisten SRL-Theorien weisen auf motivationale Faktoren als zentrale Einflussfaktoren auf SRL hin (Boekaerts, 1996; Pintrich, 2000; Zimmerman, 2000). In den theoretischen Modellen wird beispielsweise ein Zusammenhang zwischen SRL und Selbstwirksamkeitsüberzeugungen, Interesse und Wert an dem Lerninhalt, Erwartungen hinsichtlich des Lernergebnisses und Zielorientierung angenommen. Die bisherige empirische Forschung bestätigt, dass motivationale Faktoren, wie Kontrollüberzeugungen, der zugesprochene Aufgabenwert, das Erleben von Selbstwirksamkeit und die Zielorientierung der Lernenden in einem positiven Zusammenhang mit der SRL von Lernenden stehen (J.-L. Berger & Karabenick, 2011; Lim & Yeo, 2021; Zimmerman & Kitsantas, 2007). Die spezifischen Überzeugungen von Lernenden hinsichtlich SRL-Strategien, wie beispielsweise die Selbstwirksamkeitsüberzeugungen, SRL-Strategien anwenden zu können, wurden bisher nur wenig untersucht, obwohl diese in manchen theoretischen Modellen als relevante Einflussfaktoren genannt werden (Zimmerman, 2000). Hinzukommend bietet die Erwartungs-Wert-Theorie nach Wigfield und Eccles (2000) eine fundierte theoretische Grundlage für diese Zusammenhänge. Die Theorie besagt, dass die Motivation und das Handeln von Lernenden durch zwei zentrale Faktoren beeinflusst wird: die Erwartung, mit der eine Person den Erfolg bei einer Tätigkeit antizipiert, und der Wert, den sie dieser Tätigkeit beimisst. Die Erwartungs-Wert-Theorie erklärt demnach, wie individuelle Erwartungen und Werte die Wahl von Aufgaben, die Anstrengung und die Ausdauer beeinflussen, die Lernende in ihre Aktivitäten investieren und lässt sich auch auf die Nutzung von SRL-Strategien übertragen. Erste Studien mit älteren Lernenden der Sekundarstufe weisen bereits auf einen positiven Zusammenhang zwischen den Selbstwirksamkeits- (Erwartung) (Joo et al., 2000) und Nützlichkeits-Überzeugungen (Wert) in Bezug auf SRL-Strategien von Lernenden und der SRL-Strategienutzung hin (Karabenick et al., 2021).

Trotz der umfangreichen Forschung zu SRL existieren wie aufgezeigt nach wie vor bedeutende Forschungslücken in der präzisen Erfassung von SRL sowie in der Untersuchung der vielfältigen Einflussfaktoren auf SRL. Die Weiterentwicklung und Evaluation der SRL-

Erfassungsmethoden und die Identifizierung und vertiefte Erforschung von möglichen Einflussfaktoren sind allerdings von zentraler Bedeutung, um ein besseres Verständnis für die Bedingungen und Voraussetzungen erfolgreicher selbstregulierter Lernprozesse zu erlangen und gezielte Interventionen zur Förderung von SRL zu entwickeln.

3 Ziele und Forschungsfragen

Die vorliegenden Forschungsarbeiten wurde im Rahmen des PuS-SeL Projektes (‚Problemlösen und Strategien – Selbstregulation beim Lernen') erstellt. Dabei leiteten zwei übergeordnete Fragestellungen das Forschungsprojekt:

1. Wie kann SRL bei jungen Lernenden erfasst werden?
2. Welche Faktoren beeinflussen die SRL-Strategienutzung und das metakognitive Wissen von jungen Lernenden und erklären diese Unterschiede in der SRL-Strategienutzung und dem metakognitiven Wissen?

Zur Beantwortung der ersten Fragestellung wurden im Rahmen des Forschungsprojektes verschiedene Methoden zur Erfassung von SRL bei jungen Lernenden der zweiten bis fünften Klasse entwickelt und erprobt. Ziel war es SRL nicht ausschließlich in Selbstbeurteilungsfragebögen zu erfassen, sondern darüber hinaus durch innovative Methoden sowohl den in den theoretischen Modellen ausformulierten SRL Prozess zu berücksichtigen, als auch auf die Kritik an der Validität von etablierten Fragebögen einzugehen. Als eine der entwickelten Erfassungsmethoden wurde die digitale Train Track Task (Bryce & Whitebread, 2012), eine digitale Problemlöse-Aufgabe, zur Erfassung von metakognitiven Strategie-Nutzung mit Log-Daten und Laut-Denken-Protokollen erprobt und evaluiert (Beitrag I). Darüber hinaus wurde ein Interview zur Erfassung von SRL-Strategien und insbesondere Emotionsregulationsstrategien für junge Lernende adaptiert und umgesetzt (Zimmerman & Martinez-Pons, 1986). Außerdem wurde die Emotionsregulation von Lernenden in Laut-Denken-Protokollen während der digitalen TTT identifiziert (weiterführende Analysen in Beitrag III). Darüber hinaus wurden SRL-Strategienutzung und das metakognitive Wissen mit bereits erprobten Selbstbeurteilungsfragebögen, Elternbeurteilungen und Szenario Tests erfasst (Beitrag II, weiterführende Analysen in Beitrag III).

In einem zweiten Schritt wurde untersucht, welche Faktoren Unterschiede in der SRL-Strategienutzung und dem metakognitiven Wissen von Lernenden erklären. Hierzu wurden die Zusammenhänge zwischen Risikofaktoren für Bildungsmisserfolg und SRL (Beitrag II) und

der Einfluss von Erwartungs- und Wertüberzeugungen hinsichtlich Emotionsregulationsstrategien auf die Nutzung von Emotionsregulationsstrategien durch Lernende (Beitrag III), sowie Zusammenhänge mit dem Alter und Geschlecht der Lernenden (Beitrag II und III) untersucht.

4 Zusammenfassung der Einzelbeiträge

Die kumulative Dissertation besteht aus einer theoretischen Arbeit, zwei empirischen Studien (Beitrag I und II) sowie einem Beitrag mit weiterführenden Analysen (Beitrag III). Die Datenerhebungen für alle drei Beiträge fanden im Rahmen des PuS-SeL Projektes statt und wurden in den Jahren 2021 und 2022 durchgeführt, in welchem die Schulen zum Teil durch die anhaltenden Restriktionen der COVID-19-Pandemie vorrübergehend geschlossen waren. Tabelle 1 gibt einen Überblick über die einzelnen Beiträge der Dissertation.

Tabelle 1: *Beiträge der kumulativen Dissertation*

Beitrag	Autorinnen	Titel	Zeitschrift
I	**van Berk, B.;** Kroehne, U. & Dignath, C.	On the right track: decoding self-regulated learning in young students' log data with the digital train track task.	Frontiers in Education
II	**van Berk, B.** & Dignath, C.	Risk factors for academic underachievement and young students' self-regulated learning.	Zeitschrift für Erziehungswissenschaften
III*	**van Berk, B.** & Dignath, C.	Take a deep breath or scream it all out: emotion regulation strategies of young learners.	Learning and Instruction

**Weiterführende Analysen. Beitrag befindet sich aktuell in Revision.*

4.1 Beitrag I: Die digitale Train Track Task

Theoretischer Hintergrund. Auf Grundlage des COPES (*Conditions, Operations, Products, Evaluations und Standards*) Modell von Winne und Hadwin (1998) wird SRL als ein dynamischer Prozess verstanden, der kognitive, metakognitive und motivationale Strategien umfasst. Dabei stellen metakognitive Prozesse, die durch die wechselseitige Interaktion von *Monitoring* und *Control* gekennzeichnet sind (Nelson & Narens, 1994; Winne & Nesbit, 2009),

eine zentrale Komponente des SRL Prozesses dar (Gascoine et al., 2017). Besonders im Kontext junger Lernender ist die Erfassung von SRL und speziell dieser metakognitiven Prozesse des *Monitoring* und der *Control* allerdings herausfordernd, da die klassischen Instrumente, wie Fragebögen, oft inakkurat, durch soziale Erwünschtheit oder bei retrospektiver Befragung auftretende Probleme, sich an das genaue Handeln zu erinnern, verzerrt sind (Veenman & van Cleef, 2019). Hinzukommend sind einige *Monitoring*- und *Control*-Prozesse nicht unmittelbar beobachtbar und daher nur eingeschränkt durch Fremdbeurteilungen oder Beobachtungen zu beurteilen (van Laer & Elen, 2018).

Log-Daten als eine innovative Erfassungsmethode eröffnet neue Möglichkeiten, um SRL während der Bearbeitung von Aufgaben und unabhängig von Selbsteinschätzungen zu erfassen (Roll & Winne, 2015; Winne, 2017). Trotz der vielfältigen Vorteile sieht sich die SRL-Forschung mit Log-Daten durch zahlreichen Herausforderungen konfrontiert. Dazu zählen die präzise Operationalisierung von SRL-Indikatoren in den diversen Log-Daten, die Entwicklung angemessener Lernumgebungen und technologiebasierten Aufgaben, der Umgang mit vielfältigen Störsignalen in den Log-Daten sowie Fragen der Transparenz, Validität und Replizierbarkeit (Azevedo, 2014; Du et al., 2023; Roll & Winne, 2015; Saint et al., 2020; van Laer & Elen, 2018).

Forschungsziel. Das Ziel dieser Studie war es, mit der digitalen "Train Track Task" (TTT) eine innovative Methode zur Erfassung von SRL bei jungen Lernenden zu entwickeln und zu evaluieren. Die digitale TTT wurde basierend auf einem bereits erprobten Beobachtungsinstrument, der TTT als Beobachtungsmethode nach Bryce und Whitebread (2012) entwickelt. In der Erfassung mit der digitalen TTT werden Log-Daten und Laut-Denken-Protokolle genutzt, um SRL, insbesondere metakognitive Prozesse, zu erfassen und so Einblicke in die SRL-Prozesse junger Lernender zu ermöglichen. Die Forschungsfragen dieser Studie umfassen:

1. Wie können *Monitoring*- und *Control*-Prozesse in den Log-Daten der digitalen TTT operationalisiert werden?
2. Welche Unterschiede zeigen sich in der Sequenz und Häufigkeit von *Monitoring*- und *Control*-Verhaltensweisen zwischen einer einfachen und einer komplexen digitalen TTT Aufgabe?

3. Wie korrelieren die aus Log-Daten extrahierten *Monitoring*- und *Control*-Verhaltensweisen mit den durch Laut-Denken-Protokolle erhobenen Daten der digitalen TTT?

Methode. Insgesamt nahmen 85 Lernende der 2. bis 5. Klasse (M = 10.2 Jahre, SD = 1.21 Jahre, 49% weiblich) an der Studie teil. In der digitalen TTT wurden die Lernenden dazu aufgefordert, einen in einem Plan dargestellten Schienenkreis mit einem vorgegebenen Set aus verschiedenen Schienen zu rekonstruieren. Die Teilnehmenden bearbeiteten dabei jeweils zwei digitale TTT-Aufgaben: eine einfache und eine komplexere Aufgabe. Alle Interaktionen, wie das Verschieben oder Drehen von Schienen und das Klicken auf integrierte Buttons, wurden mit Hilfe von Log-Daten erfasst. Simultan wurden während der Aufgabenbearbeitung Laut-Denken-Protokolle aufgezeichnet, um zusätzliche Einblicke in die SRL-Prozesse der Teilnehmenden zu gewinnen. Basierend auf den theoretischen SRL Modellen (Nelson & Narens, 1994; Winne & Hadwin, 1998) und bisheriger Forschung mit der originalen TTT als Beobachtungsmethode (Bryce & Whitebread, 2012; Spektor-Levy et al., 2017) wurden metakognitive Handlungen und Zustände operationalisiert und in einem Kodiersystem definiert und beschrieben. Zur Analyse der Log-Daten wurde ein Finite State Machine (FSM)-Ansatz verwendet, um SRL-bezogene Verhaltensweisen bzw. ‚*States*' anhand von definierten Log-events zu extrahieren. Um das Potenzial der digitalen TTT zu evaluieren, wurden die so identifizierten *Monitoring*- und *Control*-Prozesse während der einfachen und komplexen Aufgaben mit Hilfe von frequenzbasierten statistischen Analysen und Transitionsgraphen verglichen. Zusätzlich wurden die Log-Daten mit Laut-Denk-Daten während der Aufgabenbearbeitung verglichen, um Unterschiede und Gemeinsamkeiten in den beiden Datenquellen herauszuarbeiten und das Potenzial der Erfassung von metakognitiven Verhaltensweisen mit Hilfe der Log-Daten zu validieren.

Ergebnisse. Insgesamt konnten zehn verschiedene metakognitive Prozesse (z.B. technische Orientierung, Überprüfung des Plans, Überwachung und Korrektur von Fehlern) in den Log-Daten identifiziert und kodiert werden. Die Analysen zeigten signifikante Unterschiede hinsichtlich der Häufigkeit und der Dauer der *Monitoring*- und *Control*-Prozesse der Lernenden während der Bearbeitung der einfachen und der komplexen Aufgabe. Bei den komplexeren Aufgaben zeigten die Teilnehmenden häufigeres und längeres *Monitoring*- und *Control*-Verhalten, beispielsweise durch häufigeres Öffnen des Plans oder Korrekturverhalten. Darüber hinaus zeigten sich anhand der Transitionsgraphen Unterschiede in der Abfolge der verschiedenen metakognitiven Verhaltensweisen in den beiden Aufgaben. Die Übergänge

zwischen Zuständen wie dem neutralen Bauen und einem erneuten Prüfen des Plans oder einem Überwachen des Verständnisses und Korrigieren von Fehlern traten bei komplexeren Aufgaben beispielsweise häufiger auf. Zudem zeigten sich zwischen den aus den Log-Daten extrahierten SRL-bezogenen Zustände und den entsprechenden Kodierungen dieser in den Laut-Denken-Daten signifikante Korrelationen, was die Validität der Erfassung durch die Log-Daten der TTT unterstützt.

Schlussfolgerung. Die Studie stellt eine innovative Methode zur Erfassung der metakognitiven SRL-Prozesse junger Lernender mit Hilfe von Log-Daten vor. Die transparente, theoriebasierte Operationalisierung von SRL in Log-Daten in dieser Studie ermöglicht eine bessere Reproduzierbarkeit und Übertragung auf andere Zielgruppen. Korrelationen der erfassten metakognitiven Prozesse in den Log-Daten mit parallel erfassten Laut-Denken-Daten stützen die Validität der Methode. Die digitale TTT hat somit das Potenzial effizient zur Beurteilung von SRL-Kompetenzen von jungen Lernenden in der Wissenschaft und Praxis Anwendung zu finden.

4.2 Beitrag II: Risikofaktoren für Bildungsmisserfolg und SRL

Theoretischer Hintergrund. In empirischen Studien wurde wiederholt der negative Einfluss von verschiedenen Risikofaktoren für Bildungsmisserfolg, wie beispielsweise einem niedrigen sozio-ökonomischen Status, Migrationshintergrund oder auch Lern- und Aufmerksamkeitsschwierigkeiten auf die akademische Leistung gezeigt (Arnold et al., 2020; Kavale & Forness, 2000; OECD, 2023). Es wird angenommen, dass SRL-Kompetenzen den Zusammenhang zwischen individuellen und kontextuellen Faktoren und dem Lernerfolg beeinflussen könnten (Pintrich, 2000). Während die positiven Zusammenhänge zwischen SRL-Kompetenzen und der schulischen Leistung bereits vielfach untersucht wurden (Dent & Koenka, 2016), wurde bisher nur unzureichend erforscht inwieweit SRL-Strategienutzung und das metakognitive Wissen von Lernenden, ebenfalls mit individuellen oder kontextuellen Faktoren in Zusammenhang stehen. Die Identifikation von Zusammenhängen zwischen SRL und Risikofaktoren für Bildungsmisserfolg bietet das Potenzial, entscheidende Erkenntnisse zur Überwindung von Bildungsbarrieren zu gewinnen und durch gezielte Förderung von SRL den Einfluss von Risiken für Bildungsmisserfolg zu mindern.

Forschungsziel. In dieser Studie sollte untersucht werden, inwieweit Lernende mit ungleichen Bildungsvorrausetzungen Unterschiede in ihren SRL-Kompetenzen zeigen. Dazu

wurde untersucht, ob die Verwendung von SRL-Strategien und das metakognitive Wissen junger Lernender mit folgenden Faktoren zusammenhängen:

1. Sozioökonomische Faktoren (Internationaler Sozioökonomischer Index des beruflichen Status (ISEI) und Bildungsabschluss der Eltern)
2. Migrationsbezogene Faktoren (Migrationshintergrund und die Häufigkeit, mit der zu Hause Deutsch gesprochen wird)
3. Entwicklungsbedingte Faktoren (Lern- und Aufmerksamkeitsstörungen und Unterstützungsbedarf bei den Hausaufgaben).

Dabei wurde angenommen, dass Lernende mit einem erhöhten Risiko in dem jeweiligen Bereich eine niedrigere SRL-Strategienutzung und ein geringeres metakognitives Wissen zeigen.

Methode. Insgesamt nahmen 141 Lernende der 2. bis 5. Klasse (Alter M = 9.9 Jahre, SD = 1.25; 53% weiblich) und jeweils ein Elternteil an der Studie teil. Die SRL-Strategienutzung und das metakognitive Wissen der Lernenden wurde dabei multimethodisch mit Hilfe von Selbstbeurteilungsfragebögen, einem Elternbeurteilungs-Fragebogen und Szenario-Tests erfasst. Zur Untersuchung des Einflusses der verschiedenen potenziellen Risikofaktoren für Bildungsmisserfolg auf SRL wurden die Indikatoren eines Bereiches (Sozioökonomische Faktoren, Migrationsbezogene Faktoren, Entwicklungsbedingte Faktoren) jeweils in 3-stufige Faktorvariablen kombiniert. Kinder, deren Familien ein niedriger ISEI zugeordnet wurde und deren Eltern keinen tertiären Bildungsabschluss besitzen, erhielten einen hohen sozioökonomischen Risikoscore. Kinder, bei denen nur einer der beiden Faktoren zutraf, erhielten einen mittleren Risikoscore, während Kinder, auf die beides nicht zutraf, einen niedrigen Risikofaktor erhielten. Ebenso wurde bei der Kombination der Indikatoren in Risikoscore Variablen für Migration und Lernschwierigkeiten vorgegangen. Aufgrund der geringen Stichprobengröße wurden anschließend mehrere Regressionsmodelle durchgeführt und eine Bejamini-Hochberg-Korrektur (Benjamini et al., 2009) vorgenommen, um eine potenzielle Alpha-Fehler-Inflation zu reduzieren.

Ergebnisse. In korrelativen Analysen zeigten sich bereits signifikante Zusammenhänge zwischen den Daten aus dem Elternrating, dem Selbstbeurteilungsfragebogen, dem metakognitiven Wissen erhoben durch Szenario-Tests, dem Migrationshintergrund, und teilweise bei dem Unterstützungsbedarf bei den Hausaufgaben.

Die Regressionsanalysen mit den kombinierte Faktorvariablen zeigten im Anschluss, dass Kinder aus Familien mit einem höheren sozioökonomischen Risikofaktor niedrigere SRL-

Strategienutzung in der SRL-Elternbeurteilung zeigten. Zudem zeigte sich, entgegen der Hypothese, dass Lernende mit einem hohen migrationsbezogenen Risikofaktor eine höhere SRL-Strategienutzung im Selbstbeurteilungsfragebogen zeigten. Außerdem zeigte sich, dass Eltern die SRL-Strategienutzung von ihren Kindern mit einem höheren Risiko für Lernschwierigkeiten niedriger einschätzten. Die Analysen zeigten keine Zusammenhänge zwischen den verschiedenen kombinierten Risikofaktoren mit dem metakognitiven Wissen.

Schlussfolgerung. Die Studie liefert erste Einblicke in das Zusammenspiel von Risikofaktoren für Bildungsmisserfolg und SRL im schulischen Kontext junger Lernender, die sowohl für die Forschung als auch die Praxis von Bedeutung sind. Bei der Gestaltung von SRL-Trainings und in der schulischen Praxis sollte besonderes Augenmerk auf Lernende gelegt werden, die möglicherweise gezielte Unterstützung bei der Nutzung von SRL-Strategien benötigen, wie etwa Lernende mit Lernschwierigkeiten. Zudem ist weitere Forschung erforderlich, um die Gründe für die erhöhte Selbstbeurteilung der SRL-Strategienutzung bei Kindern mit einem erhöhten migrationsbezogenen Risiko für Bildungsmisserfolg zu untersuchen. Zur weiterführenden Erforschung der Auswirkungen von Risiken für Bildungsmisserfolg auf SRL sind zudem Studien notwendig, die innovative Erfassungsmethoden zur aufgabenbezogenen SRL-Strategieanwendung nutzen und untersuchen.

4.3 Weiterführende Analysen (Beitrag III): Emotionsregulation beim Lernen junger Lernender

Theoretischer Hintergrund. Emotionen, insbesondere Leistungsemotionen, die sich spezifisch auf Lernsituationen beziehen (Pekrun, 2006), beeinflussen die Motivation, Anstrengung und das metakognitive Vorgehen von Lernenden (Boekaerts, 2007; Efklides, 2011), sowie deren Lernprozesse und den schulischen Erfolg (Camacho-Morles et al., 2021; Pekrun & Linnenbrink-Garcia, 2014). Dabei zeigen sich insbesondere zwischen negativen Emotionen, wie beispielsweise Langeweile und Wut, und der Leistung von Lernenden negative Zusammenhänge (Camacho-Morles et al., 2021).

Emotionsregulation (ER), definiert als Überwachung, Kontrolle und Veränderung interner und externer Faktoren, um die emotionale Erregung situationsgerecht anzupassen und spezifische Ziele zu erreichen (Gross & Thompson, 2007), stellt dementsprechend eine wichtige Fähigkeit im Lernprozess dar. So konnte bereits gezeigt werden, dass ER einen

Einfluss auf die schulische Leistung hat (Wong et al., 2023). Neuere SRL-Theorien integrieren ER und betrachten Emotionen als eigenständige, zu überwachende und zu regulierende Komponente innerhalb des SRL-Prozesses (Ben-Eliyahu, 2019; Efklides, 2011).

Während der Zusammenhang zwischen Emotionen und akademischer Leistung bereits gut erforscht ist, gibt es noch wenig Erkenntnisse zur Nutzung von ER-Strategien, insbesondere bei Grundschulkindern, ihren spezifischen Herausforderungen und möglichen Ursachen für eine geringe Strategienutzung. Zudem wurden in der bisherigen Forschung, ähnlich wie in der SRL-Forschung, überwiegend Selbstbeurteilungsfragebögen zur Erfassung von ER genutzt (Ng et al., 2022). Das ERAS Modell (Harley et al., 2019) stellt den Prozess der Entstehung von Emotionen in Lernsituationen, Einflussfaktoren und die verschiedenen ER-Strategiebereiche dar. Dabei kommen je nach Zeitpunkt innerhalb des Entstehungsprozesses von Emotionen verschiedene ER-Strategien aus den fünf Bereichen Situationsauswahl, Situationsmodifikation, Aufmerksamkeitslenkung, kognitive Umbewertung und Reaktionsmodulation zum Einsatz (Gross, 1998, 2015). Die Erwartungs-Wert-Theorie (Wigfield & Eccles, 2000) bietet eine vielversprechende theoretische Grundlage zur Erforschung des Einflusses von Überzeugungen junger Lernender auf deren ER-Strategienutzung.

Forschungsziel. Ziel der Studie war es, die Nutzung von ER-Strategien bei Grundschulkindern sowie die Rolle von Erwartungs- und Wertüberzeugungen als mögliche Einflussfaktoren darauf zu untersuchen. Folgende Forschungsfragen leiteten die Studie:

1. Welche ER-Strategien verwenden junge Lernende gemessen mit den verschiedenen Erfassungs-Methoden und den verschiedenen Kontexten?
2. Inwieweit besteht ein Zusammenhang zwischen den verschiedenen ER-Erfassungsmethoden?
3. Wie unterscheiden sich junge Lernende in ihrer ER-Strategienutzung je nach Geschlecht und Alter?
4. Sagen die Erwartungs- und Wertüberzeugungen der Lernenden in Bezug auf ER-Strategien den Einsatz von ER-Strategien in den verschiedenen ER-Erfassungsmethoden voraus?

Methode. Insgesamt nahmen 82 Lernende im Alter von sieben bis zwölf Jahren (M = 10.16, SD = 1.24; 51% weiblich) und jeweils ein Elternteil an der Studie teil. Dabei wurde die ER-Strategienutzung der Lernenden multimethodisch mit Hilfe eines Selbstbeurteilungsfragebogens, eines Fragebogens zur Fremdbeurteilung durch die Eltern, eines szenariobasierten, halb-standardisierten Interviews und mit Laut-Denken während einer

spielerischen Problemlöse-Aufgabe erfasst. Die transkribierten Interview- und Laut-Denken-Protokolle wurden anhand eines Kodiersystems kodiert, welches auf theoretischen Modellen und bisherigen empirischen Erkenntnissen zur ER basiert. Anschließend wurden Häufigkeits-Scores für die verschiedenen ER-Strategiebereiche nach dem ERAS-Modell (Harley et al., 2019) errechnet.

Neben der ER-Strategienutzung wurden zudem die Selbstwirksamkeitsüberzeugungen hinsichtlich der Nutzung von spezifischen ER-Strategien (Erwartung) und die Nützlichkeitsüberzeugungen in Bezug auf die ER-Strategie (Wert) mit Hilfe von Fragebögen für die Lernenden erfasst und Erwartung- und Wertüberzeugungen in Bezug auf ER Strategien in den Interview Daten induktiv kodiert.

Ergebnisse. Die Analyse der Nutzung von Emotionsregulationsstrategien durch junge Lernende zeigte, dass sie eine Vielzahl von Strategien einsetzen und diese an unterschiedliche Aufgaben (unterschiedlich schwierige Problemlöseaufgaben) und Kontexte (Interviewszenarien) anpassen können. Besonders häufig wurden Situationsmodifikation und Aufmerksamkeitsumlenkung genutzt, während kognitive Umbewertung in allen Erfassungsmethoden am wenigsten genannt wird.

Korrelationsanalysen verdeutlichen den unterschiedlichen Charakter der vier verschiedenen ER-Erfassungsmethoden, welche verschiedene Aspekte der ER zu messen scheinen. Ein Zusammenhang der ER-Strategienutzung mit Alter und Geschlecht zeigte sich nur in der Erfassung durch das Interview. Hier berichteten ältere Lernende und Mädchen mehr ER-Strategienutzung. In den Analysen zeigte sich zudem, dass Erwartungs- und Wertüberzeugungen die Nutzung von ER-Strategien gemessen mit Selbstbeurteilungsfragebogen und dem Interview beeinflussen, jedoch nicht die aufgabenbasierte ER-Strategienutzung erfasst mit dem Laut-Denken und die Beurteilung durch die Eltern.

Schlussfolgerungen. Die geringe Nutzung von kognitiver Umbewertung deutet auf einen Trainingsbedarf hin, da diese Strategie in der Forschung als besonders wirkungsvoll gilt (John & Gross, 2004). Die Studie zeigt die Unterschiede in den Erfassungsmethoden, insbesondere in Bezug darauf, ob ER als stabile Fähigkeit oder eine kontextabhängige ER-Strategienutzung während einer Aufgabe gemessen wird. Abhängig von der Methode stand die Nutzung von ER-Strategien im positiven Zusammenhang mit den Erwartungs- und

Wertüberzeugungen der Lernenden. Diese Erkenntnisse sind besonders relevant für die Gestaltung von ER-Trainings.

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6 Beiträge der kumulativen Dissertation

6.1 Beitrag I: On the right track: decoding self-regulated learning in young students' log data with the digital train track task.

van Berk, B.; Kroehne, U. & Dignath, C. (2024). On the right track: decoding self-regulated learning in young students' log data with the digital train track task. Frontiers in Education (9) 1-20. Frontiers Media SA. https://doi.org/10.3389/feduc.2024.1388202

Beiträge der Autor*innen zu der Publikation:

Bernadette van Berk: Konzeption und Design der Studie, Literaturrecherche, Datenerhebung, Datenanalyse, Interpretation der Ergebnisse, Schreiben des Manuskripts, Überarbeitungen im Reviewprozess

Ulf Kröhne: Software, Schreiben des Abschnitts zur Software

Charlotte Dignath: Einwerbung von Forschungsfördermitteln, Konzeption und Design der Studie, Überprüfung und Feedback, Korrekturlesen und Endredaktion

Abstract

Assessing Self- regulated learning (SRL) – the interplay between monitoring and control behavior - remains challenging, particularly in young learners. The unobtrusive assessment with log data to investigate SRL offers a promising method to deepen the understanding of the SRL process of young students. Despite the significant potential of log data to enhance the measurement of SRL, recent research encounters new challenges of operationalization, transparency, generalizability, as well as validity and reproducibility. This study introduces an innovative instrument, the digital Train Track Task (TTT) for assessing SRL with log data in young learners, focusing on monitoring and control behavior. Log data of 85 primary school students (2^{nd} to 5^{th} grade, aged 7 to 13 years) performing one simple and one complex TTT were analyzed. As a novel method Finite State Machines (FSM) were applied to extract SRL-related actions and states from the log data. To evaluate and explore the potential of the digital TTT, monitoring and control behavior during simple and complex tasks were compared, employing frequency-based statistical analysis and transition graphs. Additionally, the log data was multi-methodically linked with think aloud data. The results revealed differences in monitoring and control behavior during the simple and the complex task regarding frequency, duration and transitions between the SRL related states. Extracted SRL related states from log data and corresponding think aloud data showed significant correlations. Adding to the growing body of log data research, this study offers an innovative task to validly assess metacognitive self-regulation processes of young learners during problem solving. The transparent, theory-based operationalization of SRL in this study, taking into account recent demands for SRL log data research, allows better reproducibility and transfer and adds to generalizability of findings from SRL log data research.

Introduction

Self-regulation in learning (SRL) is considered an important competence for lifelong learning in a constantly changing and demanding environment (Usher & Schunk, 2018), by enabling learners to proactive regulate their cognitive, metacognitive, and motivational processes, set goals, monitor their progress, and adapt strategies to achieve optimal educational outcomes (Zimmerman, 2000).Consequently, more and more educational researchers are focusing on the promotion of SRL and SRL is receiving increasing attention among school professionals. However, promoting SRL requires an understanding of the individual engagement of students in the SRL process and recognition of potential deficits in learners. To this end, a valid assessment of SRL that is not only based on the perception of learners, parents or teachers, but also represents learners' SRL approaches within the process, is crucial.

As the research of SRL evolves and new technical possibilities emerge, the assessment of SRL, especially in young learners, has been widely discussed in recent research, but remains a challenge (Du et al., 2023; Veenman & van Cleef, 2019). Besides validity as the central issue in SRL assessment, effectiveness, granularity and age-appropriateness of SRL assessment methods are also aspects that pose challenges to researchers (Rovers et al., 2019). Moreover, the question arise of how these SRL assessment methods can be simplified and effectively transferred from research to practice application on a long-term.

In light of technological development and the potential of learning analytics, considered as the assessment and analysis of diverse learner-produced data to understand and improve learning and learning environments (Khalil & Ebner, 2015), new emerging methods can be used to overcome the current challenges in SRL assessment and deepen the understanding of the complex SRL process (Roll & Winne, 2015; Winne, 2017).

Accordingly, an innovative way to assess SRL as a process is the analysis of log data. Log data has the potential to improve learning science by using it to explore individual learning approaches in detail, to predict learning outcomes but also to guide learning analytics to improve learning processes in real time (Winne, 2020). Despite the significant research using log data to capture SRL, new challenges are emerging that research will need to address (Du et al., 2023; Molenaar, 2014; Roll & Winne, 2015). Current research in the field of SRL using learning analytics is very diverse, using a wide variety of methods to analyze diverse data (van Laer & Elen, 2018; Winne, 2014). Consequently, studies are often difficult to replicate, cannot be transferred to other target groups or learning contexts and are therefore severely limited in their potential to generalize important findings across different areas (Azevedo, 2014; Du et al.,

2023; van Laer & Elen, 2018). Moreover, with the increasing use of digital technologies for educational purposes and assessment, many studies rely on an data-driven analysis of log data to describe the SRL process and neglect the theoretical basis (Reimann et al., 2014; van Laer & Elen, 2018). Therefore, actions and behaviors derived from log data and associated with SRL may not accurately reflect the actual presence of those behaviors.

In response to these deficits, some researchers have already created frameworks and best practice examples for the use of log data in SRL research (Saint, Whitelock-Wainwright, et al., 2020; Siadaty, Gasevic, & Hatala, 2016; van Laer & Elen, 2018). Nevertheless, most studies have focused on older students (Perry & VandeKamp, 2000; Viberg et al., 2020) although there is empirical evidence for the early development of SRL and the demand for early promotion (Dignath et al., 2008; Perry et al., 2018; Perry & VandeKamp, 2000). As a consequence, the development of innovative SRL assessment methods with young learners is lagging behind.

This study aims to address current challenges and demands in SRL assessment and introduce an innovative instrument for assessing SRL with log data in young learners. To assess young students' actual SRL and metacognitive activities in a task-based and procedural manner, we digitized the Train Track Task (TTT) (Bryce & Whitebread, 2012), by augmenting this assessment instrument with log data analyzes. The resulting log data reveal indicators for SRL behavior with a particular focus on monitoring and control. The central contribution of the study is to introduce the digital problem-solving task as an SRL assessment drawing on log data analyzes, taking into account the important steps from recent frameworks and protocols for working with this type of data (Saint, Gašević, et al., 2020; Siadaty, Gasevic, & Hatala, 2016; van Laer & Elen, 2018). The presented innovative assessment method aims to create a basis for simple and playful tasks for recording log data in order to assess SRL in research and is intended to provide a practical application for the diagnosis of SRL by practitioners in the long term.

As a novel approach, Finite State Machines (FSM) are described and applied to extract SRL-related states from the log data. To evaluate the potential of the digitized TTT to assess complex SRL processes, monitoring and control behavior across a simple and a complex digital TTT are compared.

Theoretical Background

SRL and Metacognition

When demonstrating self-regulated learning (SRL) students set themselves goals, select and use strategies or tactics to manage and keep track of their information processing, behavior, use of resources, motivation and emotions during learning (Winne & Hadwin, 1998; Zimmerman, 2000). SRL cannot be seen as a skill that learners either have or do not have, but rather as a dynamic process learners engage in to achieve their aims (Azevedo, 2009). Numerous studies have shown that SRL is a positive predictor of academic success (Dent & Koenka, 2016) and also of diverse non-academic outcomes (Anthonysamy et al., 2020; Robson et al., 2020). In particular, SRL can be beneficial while working on problem solving (Stillman & Mevarech, 2010) or in digital learning environments (Broadbent & Poon, 2015). Even if many students face deficits in SRL (Winne, 2005), several studies and meta-analyses highlight that students can be fostered in their SRL (Dignath & Büttner, 2008).

SRL as a Dynamic Process

Winne und Hadwin's (1998) COPES model of SRL explains the dynamic process students engage in while they regulate their learning during a specific task. The model describes a cyclical sequence of phases, starting with task definition and contextual analysis, where students evaluate and orientate themselves in the learning environment and identify task-relevant influencing factors and information (Winne, 2017; Winne & Hadwin, 1998). Relevant factors may include internal influences, such as task-related prior knowledge, and external conditions, such as the technical environment or the specified timeframe for the task. The subsequent phase involves goal setting and strategic planning. In this phase learners formulate standards for the products of their task performance according to which they plan their approach (Winne, 2017; Winne & Baker, 2013). The third phase of the COPES model, implementation, describes learners actual use of the chosen strategies. In this phase students consider feedback from diverse sources, like the learning environment, but also through self-reflection, like the satisfaction with their own performance (Winne, 2017). Following the completion of the task, students evaluate their approach and the effectiveness of their strategy use in a reflective phase (Winne & Hadwin, 1998). The COPES model highlights the iterative nature of self-regulation, as students continuously adapt and refine their approaches in response to feedback and emerging task demands. This iterative process of SRL leads to improved learning outcomes and problem-solving skills over time and is included in most SRL models (Panadero, 2017).

Monitoring and Control as Key Components of SRL

Within this complex SRL process, various metacognitive, cognitive and motivational strategies come into play (Boekaerts, 1996). One of the most important components of SRL is metacognition (Gascoine et al., 2017). Nelson und Narens (1994) have described metacognition as the interplay of monitoring and control. Monitoring behavior involves the active awareness and assessment of one's cognitive processes and the ongoing tasks. Learners continuously evaluate their understanding, progress and the strategies they apply during learning or problem-solving activities. Control refers to the strategies and actions taken based on the outcome of the monitoring process. Once individuals become aware of their cognitive states by monitoring, they can implement various control strategies. Control strategies can include adjusting the learning approach or changing study techniques. In essence, control mechanisms are the conscious, goal-directed efforts learners employ to enhance their performance. Learners, for instance, monitor discrepancies between their aims and their actions and use metacognitive control to adapt their behavior to their standards if necessary (Winne & Nesbit, 2009). These theoretical models (Winne & Hadwin, 1998; Winne & Nesbit, 2009) emphasizes the dynamic interplay between monitoring and control.

Accordingly, SRL is not necessarily a linear process with a clear order, but rather a repetitive interplay between monitoring and control. Therefore, SRL can be seen as sequence of events that occur during task performance, which offers a new perspective on metacognition and the whole SRL process (Azevedo, 2014). Based on this assumption, SRL can be interpreted as a successive sequence of states, with a clearly defined start and end point of each state (Winne & Baker, 2013). However, SRL and the occurrence of such events is a partially invisible process. Not all of the SRL activities of learners, in particular cognitive and metacognitive events, are directly visible. The covert nature of SRL can be described as a learner's dynamic SRL approach consisting of a sequence of observable behavioral events that indicate not directly observable states (van Laer & Elen, 2018). Accordingly, this conceptualisation of SRL is based on the assumption that meaningful insights into learners' latent behavioral states can be gained through a careful examination of ordered observable behavioral events or sequences (Molenaar & Järvelä, 2014). For example, when a learner is rereading the task instruction or the own written product, this could be an observable action or event, indicating metacognitive monitoring, a state difficult to identify without such indicators. However, rereading the own written product can also be interpreted as an indicator for evaluating, which demonstrates that

observable actions cannot always be objectively, uniquely assigned to one covert SRL state and highlights the need to take this into account when assessing SRL.

SRL Assessment

In order to examine the complexity of SRL, to identify deficits in SRL and to provide and evaluate effective SRL training, age-appropriate, valid and reliable measurement tools are crucial. However, the assessment of SRL and metacognition, especially with young learners, is challenging, and the validity and reliability of the variety of instruments has been repeatedly questioned (Veenman & van Cleef, 2019; Winne, 2010). A general distinction in SRL assessment can be made between 'on-line' (event based) and 'off-line' (aptitude based) methods (Veenman & van Cleef, 2019; Veenman et al., 2006). While in off-line assessment (e.g. self-report questionnaires, scenario tests) students are asked either before or after performing a learning task to report their learning behavior and strategy use, on-line measurements (e.g. observational methods, think aloud, log data) are conducted during the actual learning process or performance of a task (Reimann et al., 2014; Rovers et al., 2019; Veenman, 2011). Off-line methods are therefore based on the assumption that SRL is a static aptitude and independent of the direct learning context, whereas on-line methods capture SRL in a situated event-based manner (Greene & Azevedo, 2010; Winne & Perry, 2000). Even though many different SRL assessment methods have evolved over the last decade, researchers still face various challenges in SRL assessment, like poor validity, efficiency and granularity.

Validity of SRL Assessment Methods

Based on the common agreement to define SRL as a process with different phases (Panadero, 2017), the exclusive use of off-line measurements has often been criticized in recent SRL research (Veenman & van Cleef, 2019). The retrospectively reported use of SRL strategies in self-report questionnaires is often inaccurate and prone to socially desirable responses and to over- or underestimation (Panadero et al., 2016; Roth et al., 2016). Thus, the general validity of self-reports, especially for children, has frequently been questioned (Veenman & van Cleef, 2019; Whitebread et al., 2009). Instead of assessing what students recall or believe to do during learning, on-line measures attempt to assess what learners' actually do while working on a task. Therefore, these methods, are considered to be more objective, precise and valid than off-line measures (Greene & Azevedo, 2009; van Halem et al., 2020). However, as event based measurements are a rather recent development in SRL research, the psychometric properties of on-line measures are not yet as well documented as for off-line measurements, like self-reports

(McCoy, 2019). Nevertheless, studies show high correlations within on-line methods and between SRL on-line assessment and performance, which indicates validity for these methods (Veenman & van Cleef, 2019).

Applicability of SRL Assessment Methods

Despite the major concerns regarding validity, off-line methods have been the most common assessment method in SRL research for a long time, based on their time-efficient administration. Data of SRL self-report questionnaires and adult-ratings can be collected and analyzed easily in large samples (Chen et al., 2015; Gascoine et al., 2017; McCoy, 2019; Veenman, 2011). In contrast, on-line measurements, like observations, interviews or think aloud protocols, lead to an extensive database of verbal and nonverbal behaviors. The data collection, the transcription and analysis of this data is time consuming (Vandevelde et al., 2015; Veenman & van Cleef, 2019) and needs a lot of resources. In addition, some of these methods are intended for laboratory research and are impractical for applied, school-based research (Marulis et al., 2016; McClelland & Cameron, 2012). Furthermore, previous research has discussed the potential reactivity of the different assessment methods of metacognition, drawing attention to the relevance of task and person characteristic, and cues (Double & Birney, 2019). A meta-analysis suggests that general think aloud assessment is nonreactive, but that asking participants to verbalize or explain further details in addition, such as reasons for their behavior or thoughts, are positive reactive (Fox et al., 2011). Nonetheless, both methods are shown to increase task performance time.

Granularity of SRL Assessment Methods

When comparing and evaluating the validity of different instruments and considering the efficient analysis of SRL data, the granularity of the SRL assessment seems relevant (Bannert et al., 2014; Fan et al., 2022; Molenaar, 2014; Winne, 2010). Offline measures, like self-reports, assess SRL as a global measure of how an individual usually uses SRL strategies in learning by aggregating learning approaches across learning contexts, episodes and tasks (Winne & Perry, 2000). In contrast, within online measurements, granularity can vary substantially (Azevedo, 2014; Zhou et al., 2010). Greene und Azevedo (2009) describe the different types of granularity with the help of levels. For example, in think aloud protocols and log data, students' specific behaviors and mental processes are recorded resulting in micro-level data, that can also be encoded into macro-level categories of SRL (Greene & Azevedo, 2009;

Siadaty, Gasevic, & Hatala, 2016). Coding of log data, for example, can range from milliseconds and smallest mouse movements which are linked to specific SRL strategies to the general appearance of SRL behavior, by for example clicking on an URL link as a broad indicator for SRL (Winne, 2017).

SRL Assessment in Young Learners

Moreover, assessing SRL in young learners poses a major challenge (Whitebread et al., 2009). Overall, many instruments have been developed for older students. Most off-line methods, like strategy questionnaires, are highly dependent on student's literacy skills (Perry & VandeKamp, 2000; Whitebread et al., 2009). Being less dependent on language, some on-line methods, such as observations, are already suitable in pre-school age (Veenman & van Cleef, 2019; Whitebread et al., 2009; Winne & Perry, 2000). In addition, think aloud protocols have also proven to be a practical method for a more objectively assessment of SRL strategy use, also with young learners (Veenman, 2011). Despite the recent developments of SRL assessment methods, there is still a lack of research in the field of young learners.

Based on the paradigm shift, defining SRL as a series of events resulting in a complex and dynamic process, which develops over time (Molenaar, 2014), on-line measures seem to be the more valid option to capture SRL (Veenman & van Cleef, 2019). Nevertheless, self-reports are still frequently used because they are the most efficient option. Even if on-line SRL assessment methods are repeatedly discussed as being more valid, more sensitive to the process nature of SRL, and allow a finer-grained analysis, there is still a lack of instruments that can be administered and analyzed efficiently and in flexible contexts and especially with young students. With the increasing technical possibilities, computerized on-line assessment methods have received growing interest in SRL research (van Laer & Elen, 2018; Winne & Nesbit, 2009). In recent research, various forms of trace data are used to assess SRL, and consequently offer the potential to provide learners directly with feedback on their learning approach. Thus, learning analytics can serve to assess and to promote the SRL process.

SRL and Log Data

While learners work in any kind of learning environment, they create a large amount of data, whether unconsciously or on purpose, which is described as trace data (Khalil & Ebner, 2015). It can be collected in various ways, for example, in the form of simple notes and text highlighting, eye-tracking data or physical sensors, but also in the form of computerized log data that record detailed information about students actions during the learning processes or

task performance (Greene & Azevedo, 2010). In line with the idea of learning analytics, where students' various trace data is used to understand and improve learning processes (Khalil & Ebner, 2015), recent research in the field of SRL attempts to utilize the potential of this diverse data to describe, assess and promote the SRL process of learners (Roll & Winne, 2015). Task-based assessment of SRL with trace data is strongly oriented towards the conceptualization of SRL as a process and attempts to assess the actual regulatory behavior of students during the task performance (Winne, 2010; Winne & Perry, 2000). The aim of collecting this type of data is to make students' not directly observable mental processes during task performance visible in order to detect SRL (Winne, 2010). Although the terms 'trace data' and 'log data' are often used synonymously, it can be argued that log data refers more specifically to one type of trace data - individuals timestamped recorded activities in digital environments. Especially in digital learning environments and tasks, log data has the potential to reliably assess the engagement and interactions of students with the task material (Du et al., 2023). By gathering data automatically and unobtrusively across different settings, log data has the potential to overcome the current challenges of efficient but off-line SRL measurement (Fan et al., 2023; Rovers et al., 2019) and can also be collected efficiently in groups (Järvelä et al., 2019). Depending on the digital environment, different types of log data can be collected (Winne & Nesbit, 2009). Interactions with the features of the environment, like clicks on different buttons or opening a navigation menu, can be used to describe the process, while the information processing is recorded by for example opening, copying or rephrasing informative sources (Winne & Nesbit, 2009). In combination with time stamps, as another type of log data, this data has the potential to evaluate complex learning processes (Winne & Nesbit, 2009).

Despite the numerous advantages, research using log data to assess SRL faces several challenges: the operationalization of indicators for SRL in log data, developing suitable environments, filtering noises, transparency, validity and reproducibility (Du et al., 2023; Roll & Winne, 2015; Saint et al., 2022; van Laer & Elen, 2018; Winne & Baker, 2013).

Diversity of Subjects and Objectives

The actual areas of application of log data in SRL research are very diverse. For example, log data is used to assess SRL in reading and writing tasks (e.g. Fan et al., 2022; Rakovic et al., 2022), in context of hypermedia use (e.g. Kinnebrew et al., 2013) and in broad digital learning environments (e.g. Maldonado-Mahauad et al., 2018; Saint, Whitelock-Wainwright, et al., 2020). Previous research used log data, for instance, to investigate different

learning strategies and cluster different SRL approaches of students (e.g. Maldonado-Mahauad et al., 2018; Malmberg et al., 2014; Saint, Whitelock-Wainwright, et al., 2020). Other studies investigated the relation of SRL strategy use assessed with log data and the actual learning outcome (e.g. Maldonado-Mahauad et al., 2018; Rakovic et al., 2022). Using log data, several studies have already investigated the impact of interventions, such as prompting (e.g. Bannert & Reimann, 2012; Siadaty, Gašević, & Hatala, 2016).

Imbalance in the Target Group

Nevertheless, most of the above mentioned studies investigated SRL among secondary school students (e.g. Kinnebrew et al., 2013; Munshi et al., 2018), university students (e.g. Bannert & Reimann, 2012; Fan et al., 2022; Saint, Gašević, et al., 2020; Saint, Whitelock-Wainwright, et al., 2020), or adults (e.g. Siadaty, Gašević, & Hatala, 2016), whereas only few studies have examined SRL of young learners with the help of log data so far (e.g. Malmberg et al., 2014; Molenaar, 2014). A recent systematic review by Saint et al. (2022) indicated that merely 21% of the reviewed studies using on-line assessment focused on K-12 students, with only some of those investigated SRL in primary school students or in younger children. So far, multimedia learning environments such as gStudy (Winne et al., 2006) and Betty's Brain (Biswas et al., 2016) have been used to investigate upper primary school students' learning processes with different content focus.

Diversity of Log Data Analysis Methods

Various methods, like process mining (e.g. Bannert et al., 2014; Saint, Whitelock-Wainwright, et al., 2020), transition graphs (e.g. Malmberg et al., 2014; Saint, Gašević, et al., 2020; Siadaty, Gašević, & Hatala, 2016), cluster analysis (e.g. Maldonado-Mahauad et al., 2018), sequence analysis (e.g. Kinnebrew et al., 2013) and network analysis (e.g. Paquette et al., 2021; Saint, Gašević, et al., 2020), are used to analyze log data in order to detect SRL. To investigate the methodological potential of log data, only a few studies triangulated log data with different on-line measurements, like eye-tracking, to investigate the particular value of the different methods (e.g. Fan et al., 2022). Nevertheless, some studies have highlighted the potential of combining log data with other on-line or off-line SRL instruments, such as think aloud or self-reports (e.g. Fan et al., 2023; Jansen et al., 2020).

Challenges in Pre-processing and Operationalization

Despite progress in log data research, the structure and the pre-processing of raw log data for such analyzes are challenging, often not described in detail, and justification for

methodological decisions are often neglected (van Laer & Elen, 2018). In a first step, indicators in the form of log events have to be defined as meaningful actions (Zhou et al., 2010). In this context, distinctions from other related constructs as well as the theoretical explanations must be taken into account (Winne & Baker, 2013). Generating a sequence of meaningful actions from the raw log data, so that each action or sequence of actions corresponds to a strategy used by a learner, can be challenging. Non-strategic or irrelevant actions act as noise in the action stream and can lead to misinterpretations. For example, non-strategic actions might be deemed irrelevant, but they can also indicate latent processes that are relevant in the context of the complex SRL process. In addition, not all actions are unambiguous, which can lead to misinterpretations or subjective dependency of the extracted SRL behavior. Researchers often rely on statistical methods for the temporal and sequential analysis of the log data, but fail to argue theoretically why the sequences identified with the help of sequential analysis are meaningful and explanatory (van Laer & Elen, 2018; Zhou et al., 2010). This leads to a lack of transparency in previous SRL research with log data (van Laer & Elen, 2018) and to substantial differences in the quality and type of data, the granularity SRL is measured in and the actual operationalization of SRL (Azevedo, 2014). Overall, the numerous unique learning environments, the lack of transparency in pre-processing log data, and insufficient theoretical foundation make it difficult to replicate the studies and transfer methods and operationalisations.

Demands on Log Data Research

As a reaction, some researchers have started to develop frameworks to guide log data analysis (Saint, Whitelock-Wainwright, et al., 2020; Siadaty, Gasevic, & Hatala, 2016; van Laer & Elen, 2018). Three main steps can be distinguished in the work with log data: 1. pre-processing, 2. characterization and operationalization and 3. analysis. Within these general steps, the recently developed frameworks and protocols (Saint, Whitelock-Wainwright, et al., 2020; Siadaty, Gasevic, & Hatala, 2016; van Laer & Elen, 2018) highlight the relevance of theoretical foundation, transparent description and the pre-processing of the gathered data, followed by defining possible log events in libraries and transforming the data based on defined SRL actions. Only after having performed these important and yet often insufficiently described steps, it is possible to carry out analyzes. Besides the huge potential of the variety of analyzes, special attention should therefore be paid to data quality and the theory-driven processing of the mass of log data that is easily accessible.

Finite State Machines (FSM) for Processing of Log Data

SRL is not a linear process, but rather an iterative process with potentially repetitive loops of monitoring and control (Azevedo, 2009; Molenaar & Järvelä, 2014; Winne, 2014). According to that, this process involves a number of actions that represent SRL in their sequence and could result in certain metacognitive states during learning (Azevedo, 2014; Winne & Baker, 2013). Specific behavior, for example typing a text as a memo, could indicate that a learner is in a particular state, for instance, the state of planning or organizing information. Accordingly, events in the log data of learners, for instance events indicating key strokes in the memo, can be used as hints (probabilistic) or as evidence (deterministic) that the learner enters a particular state or remains in that particular state until different traceable behavior is observed. The diverse methodological approaches to analyze log data and to extract possible SRL indicators differ in how transparent the operationalization of the indicators are; i.e. how explicitly the observed behavior in digital environments that triggers log events is linked to the high-level inferences created using log data.

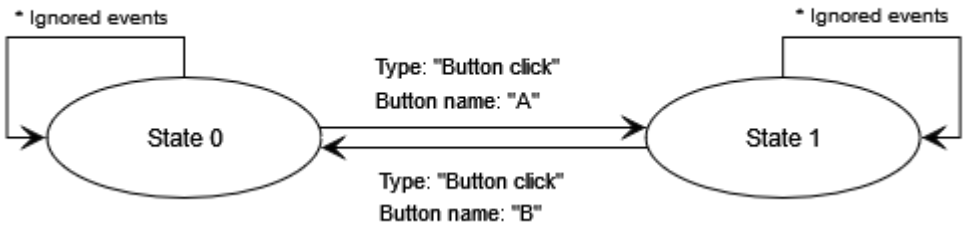
Extracting SRL Related States by Means of FSM

In the following, an analytical approach for the reconstruction of deterministic actions and states is briefly described. The approach aims to make the definition of so-called low-level features explicit and transparent. Low-level features are understood as the elementary pieces of evidence extracted from the log events, that either indicate an interpreted action (i.e. traceable behavior that occurs at a particular point in time) or a state (i.e. a temporary section of traceable behavior that starts and ends at identifiable time points in the log event data). Focusing on single events separately is not necessarily sufficient to extract these low-level features and unlock the full potential of information contained in the log event data. To effectively address the context in which events occur (referred to as contextual dependency, see Kroehne & Goldhammer, in press), algorithms like for example Finite State Machines (FSMs) can be utilized. FSMs are a formal way to define algorithms, which can be used to analyze log data by processing them event by event. These FSM algorithms defined a finite set of theoretically described and observed log events, resulting states and triggers for transitions (Kroehne & Goldhammer, 2018).

Actions and States as Low-level Features

To use FSMs, the log data is structured as individual events, and each event combines several information. First of all, a timestamp indicates when the event occurred. Moreover the

log data include a person identifier, indicating the individual participant, and a reference to the element of the computer-based instrument, for example the task name. In addition, different event types are recorded and defined based on the software used to computerize the assessment content. Beyond that, it is possible that the log data include additional event-specific data. Which event-specific data are available depends on the event type. For example, events of type "button click" directly provide the button's name as event-specific attribute. Events, such as "button click", may be interpreted directly, depending for example on the name of the clicked button. For instance, a click on a button to reset a task to the initial condition, would have the direct interpretation of an action as "Reset". An action only has a time stamp when it happened, but no time duration, although it would be possible to differentiate mouse or touch down and up events. In addition to actions, observed states can also be extracted from log data as low-level features. Clicking on a button "A" could, for example, open a pop-up window, which is visible until it is closed again via a click on button "B". The two events of type "button click" would identify a certain state "State 1", that has a duration: the time between the two events. In contrast to the previous example of the "Reset" button, not only the click on the button "A" has a certain interpretation, but also the time between these two events ("button click" on "A" and "B"), which represents a certain state as low-level feature.



BI - Figure 1: State Chart illustrating Differentiation of Observed States using Log-Events

Differentiating Observed States

As the arrows show in Figure 1, differentiating observed states is possible by identifying the transitions between these states with the available log events. For that purpose, events are distinguished by event type (e.g., "button click"), the provided element (e.g., the name of a task) and event-specific attributes (e.g., the name of a clicked button, provided by all events of type "button click"). Since log events typically have time stamps, the decomposition shown in Figure 1 automatically provides time measures for each state visit. The duration time for each

occurrence of "State 1" can be calculated by determining the time interval between the timestamps of the "button click" events for button "A" and button "B". Since potential off task events, that are not logged or not recognized as being relevant, may have occurred between these timestamps, it can also be described as maximum duration time of this state. Figure 1 illustrates that actions become labels for specific transitions and can be used to separate observed states using a FSM. However, the FSM visualized in Figure 1 is only one possible decomposition for a process into observed states based on log-events using FSMs.

Identifying Indicators for SRL

Using FSMs allows deriving timed low-level features, i.e., states with start and end time for computing the duration, and actions with a single timestamp. Based on these low-level features, process indicators can be extracted as aggregated values of the low-level features. These are variables at the person-by-task level with one value for each test-taker for each of the administered tasks. Depending on the desired process indicator, different low-level features can be extracted using additional FSMs. Not all log events have to be defined as meaningful actions. Log events that are not used to trigger transitions are absorbed by the self-transitions (marked as “*Ignored events” in Figure 1). Besides the documentation of log data, that describes when an event of a particular event type occurs and that provides details about the meaning of all event-specific attributes, the FSM operationalization of low-level features provides the opportunity to achieve transparency concerning log data analyzes and the extraction of observed states. It can also help to achieve replicability by providing additional description of the low-level features.

The aim of the study is to introduce the digital TTT as an innovative instrument to assess young students SRL. In order to enable the use of the newly developed task for future learning analytics, following research question guide the study:

1. How can monitoring and control be operationalized in the log data and extracted as theoretically defined low-level features?

2. To what extent do temporally ordered sequences of monitoring and control states extracted from log data differ in the simple TTT and the complex TTT?

3. To what extent do the log data and the think aloud data show similar frequencies of monitoring and control?

Materials and Methods

Sample and Procedure

The participating children were recruited throughout Germany for an online study. Due to COVID-19 pandemic the whole study was conducted remotely. In total, $N = 85$ students from 2nd through 5th grade, aged between 7 and 13, performed the digital Train Track Task (TTT) on their private computers at home. Of six students, demographic data is missing. The remaining 79 students of which information is available were on average $M = 10.2$ years old ($SD = 1.21$), and 49% of the participants were female (see BI Appendix - Table 3). The TTT was implemented in a digital learning platform (moodle). The participating families were informed in advance that they would need a computer with audio output and a mouse to complete the tasks. During the task processing, trained experimenters accompanied the students on the phone, initiated the task, and helped the children if technical difficulties occurred. The experimenters were not able to directly observe participants' performance during the task, and were explicitly instructed to offer only technical assistance, but no help to solve the task. The children were asked to inform the experimenter when they thought they had finished the task, but could always stop working on the tasks themselves.

The Digital Train Track Task

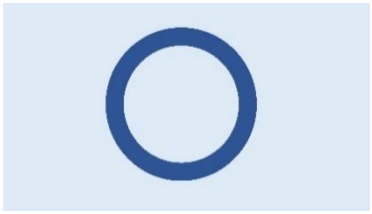
Originally, the TTT (Bryce & Whitebread, 2012) was developed as an observational instrument, that allows to capture young learners metacognitive strategy use in verbal and nonverbal behavior with the help of video data. The original TTT and its different age-related tasks has already been validated and tested in several studies with different age groups (Bryce & Whitebread, 2012; Spektor-Levy et al., 2017; Tzohar-Rozen et al., 2021). As an on-line assessment, the TTT offers numerous advantages. It is independent of language skills, exciting for children, relatively independent of culture and general school performance and can be varied in difficulty for different age groups (Bryce & Whitebread, 2012; Spektor-Levy et al., 2017). To use this potential in the context of learning analytics, the TTT was adapted and digitized as an innovative method to assess metacognition in primary school students. The digitized TTT can replace resource intensive video data with log data, which to some extent can be processed automatically.

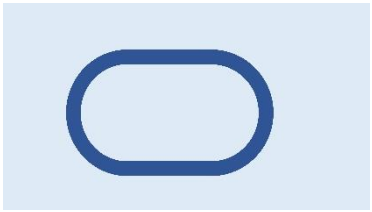
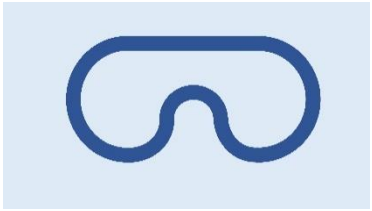
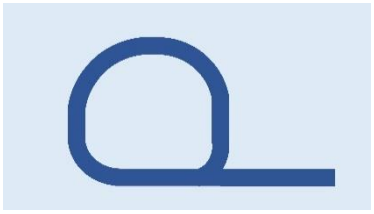
Development and Procedure of the Digital TTT

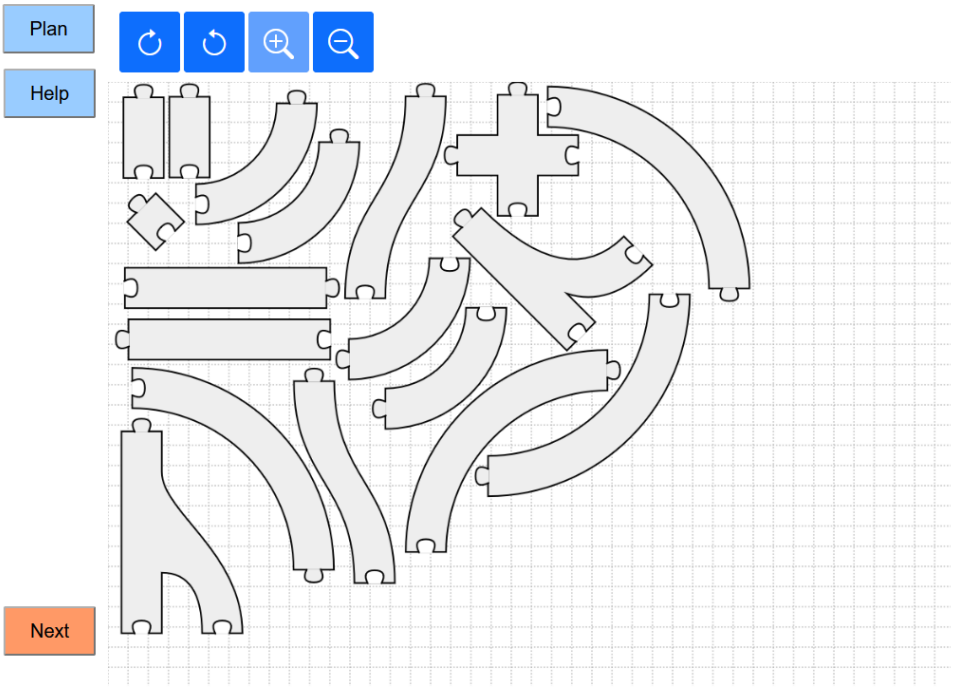
As in the original task, the digital TTT requires children to reconstruct a rail circle with a set of train tracks according to a plan. In our study, each child had to solve two different TTT. The digitized task starts by automatically opening a window that shows students a plan with a shape they have to rebuild. The train tracks are arranged in an unsorted way for each task. With the pointing device (mouse, touchpad or touch-screen) the tracks can be moved within the playing space. When two tracks are moved close to each other with matching connection spots and in the correct orientation, they automatically connect in the digital TTT. With specific buttons children can rotate the individual train tracks in two directions (clockwise and counterclockwise), can zoom in and out to enlarge the playing space, or take a closer look at a track or their current construction. Moreover, a help button offers the participants to (re)watch the explanatory video for the different features within the digital environment. With the ‘plan’ button, students can reopen the plan showing the shape they have to rebuild at any time while working on the task. The plan and help buttons are presented as so-called modal dialogs (see Kroehne, 2023b), and no interaction with the digitalized TTT was possible while either the ‘plan’ or ‘help’ window were visible on screen. Lastly, participants could jump to the next task or complete the task by clicking the 'next' button (see Figure 2).

After closing the plan window to start the task, the experimenter connected via telephone made the children aware of the help button, which included a video that introduces the different buttons in the digital environment and their function. As a first task, all students had to rebuild a simple circle shape. In the following task, participants received a more complex shape depending on their age. For this purpose, the shapes already evaluated in other studies (Bryce & Whitebread, 2012; Spektor-Levy et al., 2017) were utilized for the different age groups. Previous research with the TTT as observational instrument showed that the age is related to the development of SRL abilities (Spektor-Levy et al., 2017) and demonstrated individual differences in monitoring and control (Tzohar-Rozen et al., 2021).

BI - Table 1: *Shape Plans for the different Train Track Tasks*

Task 1: Simple task	
	**TTT_1** All students (2nd to 5th grade)

Task 2: Age related, more complex task			
	**TTT_2** 2nd grade students		**TTT_3** 3rd grade students
	**TTT_4** 4th grade students		**TTT_5** 5th grade students



BI - Figure 2: Digital Train Track Task Environment

Technical Setup

The digital Train Track Task was implemented in JavaScript/HTML5 as extension to be used with the CBA ItemBuilder (Kroehne, 2023b). In addition to the log events provided by the CBA ItemBuilder, the extension was implemented to provide additional replay-complete log data (see Kroehne & Goldhammer, 2018 for a definition) for all interactions within the digital TTT, allowing to create animated video-replays based on the log event data. Test deployment for online assessment was implemented using the IRTlib Software (Kroehne, 2023a), embedded into a learning management system (moodle) using LTI, with IRTlib functioning as an LTI tool provider serving the CBA ItemBuilder tasks including the digital TTT according to the study design (i.e., the age-related tasks as shown in BI - Table 1).

Data

Several researchers in the field of SRL and especially in the current development of log data assessment have emphasized the advantages of multimethod assessment for validation and evaluation (Saint et al., 2022). To assess metacognitive behavior with various data streams, think aloud data of students was gathered during performance of the digital TTT in addition to the log data.

Think Aloud Data

Participating children engaged in a think aloud procedure, where they were asked to verbalized their thoughts, feelings, and actions while performing the TTT. Participant were told once again that the experimenter, who gave the introduction on the phone, could not see what the children were doing. Before working on the task, participating children were trained to think aloud. When students remained silent, experimenters encouraged intensive think aloud with short standardized prompts, such as ‘please keep on thinking aloud’. Due to COVID-19 social distancing practices children's think aloud was recorded via telephone and subsequently transcribed. Transferring think aloud to a remote procedure is an innovative approach, nevertheless some researchers have already suggested the benefits of this novel approach from the participants' perspective (Alhejaili et al., 2022).

In order to identify indicators of monitoring and control, Bryce und Whitebread (2012) developed a coding scheme for analyzing observational data. The existing coding scheme has been extended by codes from think aloud research (Greene & Azevedo, 2009; Vandevelde et al., 2015) as well as by inductive codes in order to capture metacognition as comprehensive and as fine-grained as possible. Three coders were trained in an extensive training followed by an iterative coding process. In this process, sequences of audio data were discussed to achieve a shared understanding of the different codes and to develop potential inductive codes if necessary. Metacognitive statements were coded on a recurring basis. This implies that if a child made multiple statements about, for example, discovering errors during task execution, each statement was coded individually unless they were consecutive and referred to the same mistake within the same sentence. This led to an overall substantial agreement (Fleiss Kappa κ =.70) for all operationalized metacognitive behaviors coded in the think aloud. BI - Table 4 describes all codes, definitions and examples of think aloud protocols.

Log Data

The raw log data were provided by the IRTlib software as JSON files in a proprietary format containing a data structure for each raw log event. Log events from three difference sources (the deployment software / LTI tool provider IRTlib, the CBA ItemBuilder tasks and the digital TTT embedded as extension) were combined in post-processing into a flat and sparse log data table (see Kroehne et al., submitted for publication) using LogFSM. After processing, all log events contain the core attributes (in which timestamps, event types, element name / task

IDs), and additional event-specific attributes for events of a particular type. Event-specific attributes contain precise information on the moved track, coordinates of the moved tracks (start and end coordinates), directions of the rotations, connections between tracks, and a list of the track types in connected track groups were stored per individual and task. The data is sorted by anonymized ID and timestamps. In total, we obtained 19867 log events for all 85 participants and all tasks. BI - Table 2 shows the average performance time between the start event and the click on the 'NEXT' button to end the task, and the number of log events per task. Three children did not perform the simple TTT due to technical problems. No information was deleted from the database as all log events appeared to be relevant. Cases with very short or very long processing times, as outliers, were also not removed, as it was assumed that these children either had finished the task very quickly or took a long time to complete it.

BI - Table 2: *Total performance time and the number of log events per task*

	N	Median	SD	Min.	Max.
Time (minutes)					
TTT_1	82	3.17	3.05	0.05	14.52
TTT_2	13	2.9	8.65	0.89	30.58
TTT_3	25	12.67	8.17	0.27	35.12
TTT_4	14	18.37	12.58	2.13	38.95
TTT_5	33	6.97	6.14	0.32	25.93
Log_events (per student)					
TTT_1	82	30.5	37.71	4	229
TTT_2	13	50	91.67	16	333
TTT_3	25	181	160.79	5	658
TTT_4	14	254.5	230.97	44	713
TTT_5	33	122	124.21	13	613

Analysis

In order to introduce the digitized TTT and make it available for future research in the field of learning analytics, the analyzes and the detailed descriptions are guided by recent frameworks for log data research in the field of SRL (Järvelä et al., 2019; Roll & Winne, 2015; Saint, Whitelock-Wainwright, et al., 2020; Siadaty, Gasevic, & Hatala, 2016; van Laer & Elen,

2018; Winne, 2020). In a first step, the structure of the data was described. The SRL models introduced at the beginning (Nelson & Narens, 1994; Winne & Hadwin, 1998) served as the theoretical basis for the following analyzes. The analyzes of the think aloud and log data are based on the assumption of SRL as a process in various alternating and repeating phases. A distinction was made between three broad phases, described in the COPES model (Winne, 2014; Winne & Hadwin, 1998) and overlapping with other common SRL models (Panadero, 2017); namely orientation, performance and reflection. Based on the model of Nelson und Narens (1994), we distinguished between monitoring and control at the macro level and integrated different strategies and states as micro levels. First, the think aloud data was transcribed and coded as described above. In a second step, metacognitive behavior that may occur in the digitized TTT was operationalized using available log event data. Metacognitive states were described based on the theoretical model and on the coding scheme of the think aloud data. An action and a state library were defined, and actions and states were described. In a third step, actions and states were extracted as low-level features using algorithms formalized as FSM. Following the pre-processing, differences between the simple and complex tasks and relations between log data and think aloud were analyzed.

Results

Operationalizing SRL

Instead of a statistical approach, a theory-based approach based on previous research was chosen in order to operationalize potential indicators for metacognitive behavior in the log data. The coding schemes developed based on previous research and the think aloud data served as basis for the theory-driven identification of indicators of monitoring and control states in the log data of the digitized TTT. This approach was applied based on the assumption that SRL processes consist of a sequence of observable behavioral events and underlying unobservable states (van Laer & Elen, 2018). This procedure aimed to reduce the potential for misinterpretation of log events and to extract meaningful log events that reflected real-world metacognition.

Derivation of Meaningful Events in Log Data

In a first step, all possible log events within the digital environment were explored and meaningful actions were identified. The initial raw log data was made usable with the help of a video replay. The video replay visualizes the log data of an individual, showing the start and

end positions of train track movements, rotations, zooming and lists the log events of the buttons. To explore the log data, video replays of ten participants were recorded. Participants with different task processing times were selected, including some participants with particularly long task performance times and high metacognitive scores in think aloud coding, to investigate complex behavior and possibly less stringent monitoring and control behavior. ELAN computer software (version 6.7) (Max Planck Institute for Psycholinguistics, The Language Archive., 2023) (Lausberg & Sloetjes, 2009) was used to explore and analyze the selected cases. In this first step, a team of at least two trained research assistants separately coded one video and the underlying log data in an inductive manner and commented in ELAN which actions and metacognitive states could be derived from observable events or sequences of events. These preliminary indicators were discussed and initial operationalization for the metacognitive codes of the think aloud coding scheme were developed. This procedure was iteratively repeated for ten participants for a total of 20 tasks. Meaningful actions were extracted, developed definitions for metacognitive states and transitions were reviewed, adapted and optimized until a set of operationalized indicators was obtained. In addition, identified indicators were compared inter-individually to review if the present sequence could be interpreted differently in log data of other individuals. Through the use of video replay and extensive inductive exploration and development of indicators of metacognitive behavior, consistent with previous research and theory, an attempt was made to avoid misinterpretation of the raw log data. In addition, indicators were chosen that required minimal interpretation in order to remain as close as possible to participants' actual behavior and reduce subjective judgements. In total 14 distinguished meaningful actions were defined based on the log events. These relevant actions were based on clicks on the different buttons, rotations, movements, and the associated changes in the existing track connections.

BI - Table 3: *Action library*

	Actions	Description
1	PLAN_OPEN	Click on the ‘plan’ button, which opens the plan with the track shape
2	PLAN_CLOSE	Click on ‘close’ in the open plan window
3	HELP_OPEN	Click on the ‘help’ button, which opens the video with instruction for the technical environment
4	HELP_CLOSE	Click on ‘close’ in the open help window

5	ZOOM_IN	Click on the zoom button indicating a +
6	ZOOM_OUT	Click on the zoom button indicating a -
7	MOVE_SAME	Moving a track without changing connections
8	MOVE_PLUS	Moving a track and adding a new connections with that move
9	MOVE_MINUS	Moving a track and dissolve a connections with that move
13	MOVE_PLUS_MINUS	Moving a track and dissolve a connections and adding a new connection with that move
10	ROTATE_SAME	Rotate a track without changing connections
11	ROTATE_PLUS	Rotate a track and adding a new connections with that move
12	ROTATE_MINUS	Rotate a track and dissolve a connections with that move
14	NEXT	Click on ‘next’ Button to skip to the next task

During the data exploration with the help of the video replay, the frequency of same events occurring directly one after the other was also determined as a meaningful sequences of actions and indicator for transitions to the different states. Therefore, in addition to the 14 actions listed above, which are based on the initial events and the resulting connections, count indicators were generated. Count indicators were created for (a) the actions listed above, (b) the use of the individual tracks and (c) directions of rotation. If the same event type occurred several times in succession (e.g. move_minus), the count always increased by one. If a different action was executed within a sequence, the count started again at one. For (b) the individual tracks, a count indicator was created according to the same pattern, which counts how often the same track was used in succession. And (c) a count indicator was created for the direction of the rotations, counting how often the participant rotated the track in the same direction in direct succession.

The administration of a particular task always started with the plan window open, hence the action “PLAN_CLOSE” is the first action expected for each test-taker. As described above, the actions represent indicators for possible transitions into different metacognitive states. Based on the coding scheme of the think aloud data the state library shown in BI - Table 4 was developed. The state library includes eight metacognitive states on the micro level, which are assigned to monitoring and control on the macro level. In addition, three neutral, technical states are defined.

BI - Table 4: *State Library / Coding Scheme to extract metacognitive states from log data and think aloud data*

Macro Level	Micro Level	Description	Sample Think aloud	Actions in Log Data
Startstate		Start of the task; task starts by showing the child the plan; child closes the plan to start the task		PLAN_CLOSE
Endstate		End of the task by clicking on the next button		NEXT
Construction		Neutral state in which the child try's to reconstruct the given plan, moves different pieces or rotates to check if they fit, connect pieces to one another		MOVE_SAME; MOVE_PLUS
Monitoring	TECHNICAL_ ORIENTATION	*TAP:* *Log data:* Child directly opens the help video while in startstate	"I'll watch the help video again." "I zoom out, so that I can see the whole field."	HELP_OPEN
	CHECKING_PLAN	Looking at the shape plan *TAP:* child says it looks at the plan *Log data:* clicks on the plan button and closes the plan again	"I'll check the plan again."	PLAN_OPEN
	MONITORING_ UNDERSTANDING_ MISTAKE	Detection of a mistake or misunderstanding *TAP:* Child says that there might be something wrong *Log data:* The child removes the track piece and disconnects two or more tracks. Child rotates the same track piece at least three times in the same direction without connecting it to the construction	"Something's not right!" "I don't think I quite understand it yet." "I've just built something wrong." "I have to separate the pieces again."	ROTATE_MINUS; MOVE_MINUS; 3 x ROTATE_SAME in the same direction with the same track
	CHECK_ CONSTRUCTION	Review the construction,; comparison with the plan	"Wait, what does it look like so far?"	PLAN_OPEN

		TAP: Child compares the plan with the own construction or says that it will look at the entire construction again *Log data:* Re-opens the plan again, directly after checking the plan.	"I'll have a look at the plan and see if everything's right so far."	
Control	SEARCH_SORT_ MAKESPACE	Search for materials before and during the task. Organizing or grouping materials before and during the task. Moves tracks aside, to gain more space *TAP:* Child says it searches for a specific track piece, sorts the material or needs more space *Log data:* move three different tracks without connection to sort them or to make space; uses zoom to get more space	“Okay, I’ll search for all the tracks I will need.” "Huh, where are the straight rails?" "I'll pull the rails to the side first."	ZOOM_OUT, 3 x MOVE_SAME with three different tracks
	SEEKING_HELP	Seeking for help *TAP:* Child says it will open the help video again; asks adults (parents or interviewer) for help. *Log data:* Click on the help button	"I don't know what to do, I'll check help again" “I'll ask my mom for help."	HELP_OPEN
	CORRECT_MISTAKE	Trying to correct mistake *TAP:* Child says that it will try another track or found the right track *Log- data:* child connects a track to another after detecting a mistake (after state MONITORING_ UNDERSTANDING_MISTAKE) MISTAKE)	"This one might fit.” "Okay, now I have the right one.”	MOVE_PLUS; ROTATE_PLUS
	CHANGE_STRATEGY	Starts all over again; uses several different track pieces; change of track types *TAP:* Child says that it will need other track types or need to start all over	"No, I have to take the bigger curves." "I think I need to do that all over again."	2 x MOVE_MINUS

	Log data: Child takes at least two pieces apart again.

Feature Extraction Using LogFSM

To extract metacognitive features from the log data using FSM, we utilized the LogFSM R package (Kroehne & Goldhammer, 2018). The automated processing of log events implemented in the R package LogFSM processes the event data for each test-taker event by event, changing the observed state if a transition is defined for a particular event type (and possible event-specific additional attributes), and remains in the identical (current) observed state if no transition is defined. To extract the low-level features from the log data an algorithm was defined based on the action library and the state library (BI - Table 3 and B1 - Table 4). Actions were defined as triggers for transition in and out of defined states representing the micro level metacognition codes. In total 11 states were defined and extracted with the help of LogFSM, whereby eight states are SRL related. Two states are of technical nature and describe the task processing (startstate and endstate), while the construction state describes the continuous task performance in which monitoring and control behavior is not identified based on the defined indicators.

Differences Between the Simple and the Complex Task

Based on the definition of SRL as a dynamic process (Winne & Hadwin, 1998) and previous research (Iiskala et al., 2004; Malmberg et al., 2014) it can be assumed that students adapt their metacognitive behavior to the task type and difficulty. Guided by the second research question, to investigate to what extent the monitoring and control states extracted from the log data differ in the simple TTT and the complex, age related TTT, analyzes based on the frequency, duration and sequential occurrence of the metacognitive states in the log data were conducted. First, frequencies and duration of the different states are compared between the two task types. To take into account the process nature of SRL, in a second step transition graphs were used to explore and visualize differences in the process of the simple versus the complex task.

Comparison Based on Frequency and Duration

To examine variations in monitoring and control behavior between simple and complex digital TTT, we performed a descriptive statistical analysis, investigating differences in the frequency, duration, and associated proportions of each metacognitive state. With the help of the LogFSM, the total frequency and duration of each state for each participant was extracted. The frequency of each state was determined by counting its total occurrences. State duration represents the cumulative minutes students spent in the state, calculated based on the timestamp

information. Since the frequency and duration data were not normally distributed, we report the mean, median and the 25th and 75th percentile values. To compare the differences between the two tasks, Wilcoxon signed rank tests (with Bonferroni correction) were conducted for pairwise comparison.

BI - Table 5: *Descriptive statistics of the frequencies of metacognitive state entries extracted from the log data*

	Frequency											
	Simple TTT						**Complex TTT**					**WSR**
	Total (%)	***M***	**SD**	***Mdn***	**Q 1**	**Q 3**	**Total (%)**	***M***	**SD**	***Mdn***	**Q 1**	**Q 3**	***Z***
TECHNICAL_ ORIENTATION	49 (5.82)	0.6	0.49	1	0	1	5 (0.1)	0.06	0.24	0	0	0	[a]7.42*** [b]7.49***
CHECKING_PLAN	47 (5.58)	0.57	0.92	0	0	1	665 (13.93)	7.82	6.36	7	3	10	8.99*** [b]- 5.94***
MONITORING_ UNDERSTANDING _MISTAKE	161 (19.12)	1.96	2.79	1	0	2.75	1124 (23.55)	13.22	15.38	8	3	17	7.79*** [b]- 3.88***
CHECK_ CONSTRUCTION	3 (0.36)	0.04	0.19	0	0	0	54 (1.13)	0.64	1.29	0	0	1	4.78*** [b]- 4.52***
SEARCH_SORT_ MAKESPACE	101 (12)	1.23	1.66	1	1	1	374 (7.84)	4.4	4.56	3	1	7	6.19*** [b]3.41***
SEEKING_HELP	38 (4.51)	0.46	0.55	0	0	1	5 (0.1)	0.06	0.24	0	0	0	[a]5.70*** [b]5.99***
CORRECT_ MISTAKE	137 (16.27)	1.67	2.23	1	0	2	902 (18.9)	10.61	11.74	8	3	14	7.98*** [b]- 3.41***
CHANGE_ STRATEGY	10 (1.19)	0.12	0.46	0	0	0	171 (3.58)	2.01	3.84	1	0	2	6.57*** [b]- 6.11***
CONSTRUCTION	296 (35.15)	3.61	2.63	3	2	4	1473 (30.86)	17.33	14.78	13	8	23	[a]- 8.46*** [b]2.88**

Note. Statistical comparison was done with the use of the Wilcoxon signed rank tests for pair-wise comparison (use Bonferroni correction); Legend: [a] differences between total frequencies, [b] differences between relative frequencies (%); * $p < 0.05$; ** $p < 0.01$; and *** $p < 0.001$

The Wilcoxon signed-rank test revealed significant differences of the frequencies in the metacognitive states between the two tasks (see BI - Table 5). The negative Z-value indicates a consistent and significant increase in the occurrence of most of the states during the performance of the complex digital TTT. However, the SEEKING_HELP and the

TECHNICAL_ORIENTATION, both operationalized by clicking on the help button in different phases of the SRL process, occurred significantly less when working on the complex task. This seems reasonable, as the complex task was carried out directly after the simple task, and the children were therefore already familiar with the technical functions. The Wilcoxon signed-rank test on differences with regard to the relative frequencies also showed significant differences across all states. However, analyzes revealed a change in the direction for SEARCH_SORT_MAKESPACE and the neutral CONSTRUCTION state. Although overall these states occurred more frequently while the students were working on the complex task, they were more frequent in the simple task in relation to the total number of states. This indicates the sensitivity of the digital TTT to measure differences in monitoring and control behavior of young students during simple and more complex tasks.

BI - Table 6: *Descriptive statistics of the durations in the metacognitive states extracted from the log data*

	Duration (minutes)												
	Simple TTT						**Complex TTT**						**WSR**
	Total (%)	***M***	**SD**	***Mdn***	**Q1**	**Q3**	**Total (%)**	***M***	**SD**	***Mdn***	**Q1**	**Q3**	***Z***
TECHNICAL_ ORIENTATION	105.93 (26.75)	1.29	1.2	1.79	0	2.13	4.29 (0.45)	0.05	0.27	0	0	0	[a]7.64*** [b]7.49***
CHECKING_PLAN	10.41 (2.63)	0.13	0.21	0	0	0.21	126.77 (13.18)	1.49	1.25	1.31	0.65	1.98	[a]-8.79*** [b]-7.99***
MONITORING_ UNDERSTANDING _MISTAKE	35.01 (8.84)	0.43	0.83	0.15	0	0.35	199.18 (20.7)	2.34	2.85	1.32	0.47	3.42	[a]-7.06*** [b]-6.62***
CHECK_ CONSTRUCTION	0.56 (0.14)	0.01	0.04	0	0	0	12.61 (1.31)	0.15	0.29	0	0	0.16	[a]-4.79*** [b]-4.67***
SEARCH_SORT_ MAKESPACE	35.69 (9.01)	0.44	0.98	0.22	0.05	0.49	69.14 (7.19)	0.81	0.99	0.51	0.09	1.03	[a]-3.26** [b]0.62
SEEKING_HELP	66.01 (16.67)	0.81	1.03	0	0	1.83	3.08 (0.32)	0.04	0.21	0	0	0	[a]5.93*** [b]5.98***
CORRECT_ MISTAKE	14.27 (3.6)	0.17	0.24	0.07	0	0.27	72.67 (7.55)	0.85	0.87	0.53	0.23	1.34	[a]-7.19*** [b]-6.16***
CHANGE_ STRATEGY	0.57 (0.14)	0.01	0.03	0	0	0	13.88 (1.44)	0.16	0.31	0.03	0	0.19	[a]-6.58*** [b]-6.41***
CONSTRUCTION	127.54 (32.21)	1.56	1.32	1.25	0.73	1.83	460.57 (47.87)	5.42	4.11	4.28	2.22	7.95	[a]-7.62*** [b]-7.59***

Note. Statistical comparison was done with the use of the Wilcoxon signed rank tests for pair-wise comparison (use Bonferroni correction); Legend: [a] differences between total duration, [b] differences between relative durations (%); * $p < 0.05$; ** $p < 0.01$; and *** $p < 0.001$

In addition, Wilcoxon signed-rank tests also demonstrated a significant increase in duration in the states CHECKING_PLAN, MONITORING_UNDERSTANDING_MISTAKE, CHECK_CONSTRUCTION, SEARCH_SORT_MAKESPACE, CORRECT_MISTAKE, CHANGE_STRATEGY and CONSTRUCTION in the complex task compared to the simple task. Moreover, the comparison of duration showed that the children also spent more time in the states TECHNICAL_ORIENTATION and SEEKING_HELP during the simple task than during the complex task. The comparison of the proportional time spent in the different states between the two task types also revealed significant differences across nearly all of the metacognitive states, with the same pattern as in the comparison of the total duration. However, this analysis reveals a different pattern regarding the state SEARCH_SORT_MAKESPACE. In relation to the total duration, the participating children spent almost the same proportion of time on searching, sorting or making space in the two task types.

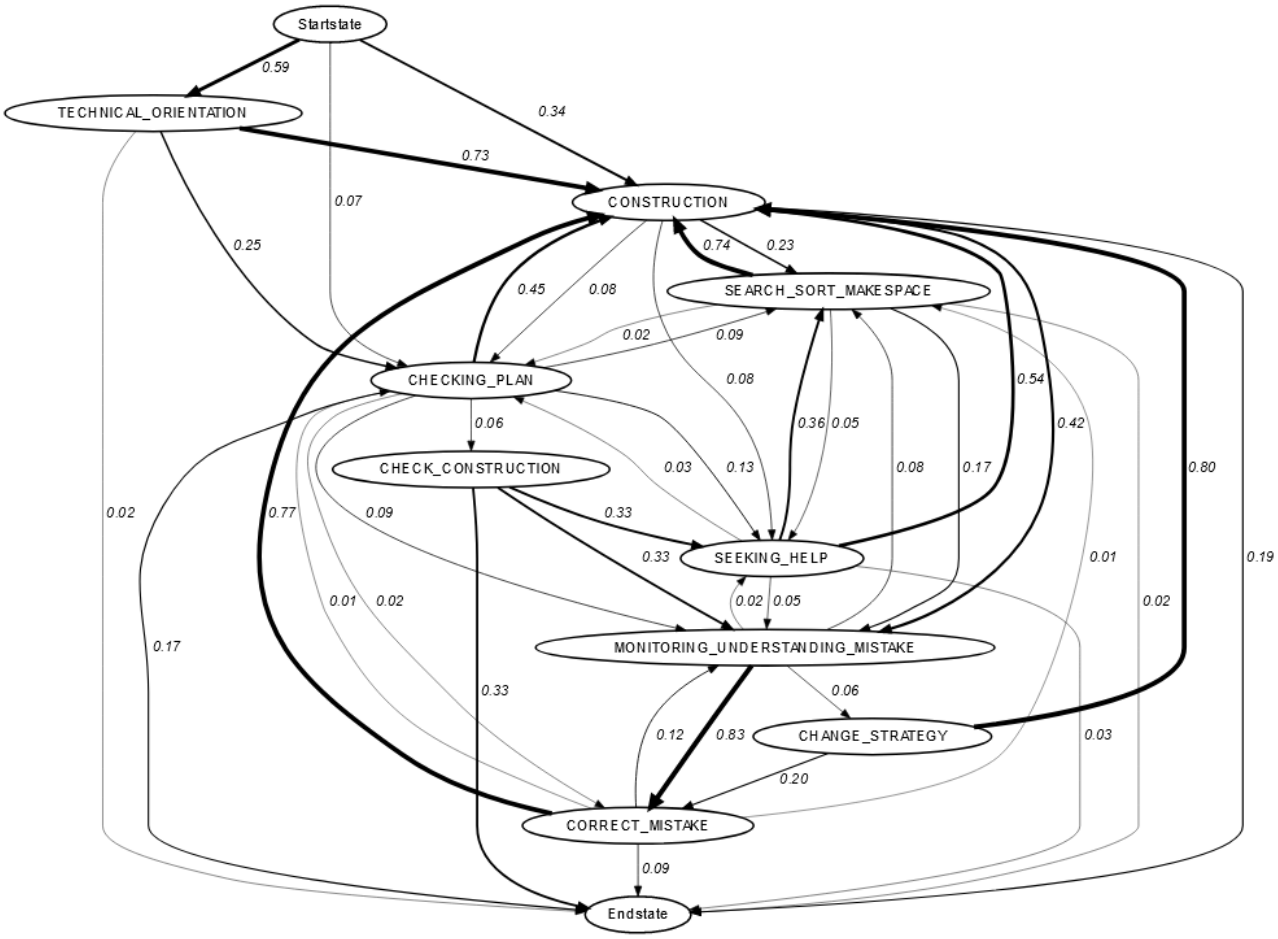
As BI - Table 6 illustrates, even the comparison of simple metrics like the proportional durations, give valuable insights into the SRL process and shows that children spend a higher percentage of time looking at the plan, monitoring and correcting mistakes in the complex task. All in all these findings underscore task-specific variations in children's metacognitive behavior and the potential of the introduced digitized TTT to measure such differences.

Comparison Based on Transition

Transition graphs were utilized to investigate differences in the sequential characteristics of the metacognitive processes during the simple and the complex TTT. They provide a helpful visualization to explore the data and identify meaningful patterns. DigrammeR package in R was used to create the generic visualization of the LogFSM results. The graph nodes were defined as the states, while transitions, displayed by arrows, showed the empirically observed transitions. The indicated weight of the path relates to the proportion (frequency of the transition divided by the total number of all transitions from this states). Accordingly, the sum of all outgoing path from one state node is 1.0. However, rounding of the independent probabilities for the transition paths may result in an inaccuracy of one per cent for the sum of all transitions (0.99 or 1.01 instead of 1).

As the analyzes of the frequency and the duration already suggested, the transition graph of the simple TTT shows the relevance of the states TECHNICAL_ORIENTATION in the orientation phase and SEEKING_HELP during task performance (see Figure 3). In more than half of the cases participating children opened the help video in the beginning of the task performance, while in 34% of the total transitions children changed directly to the

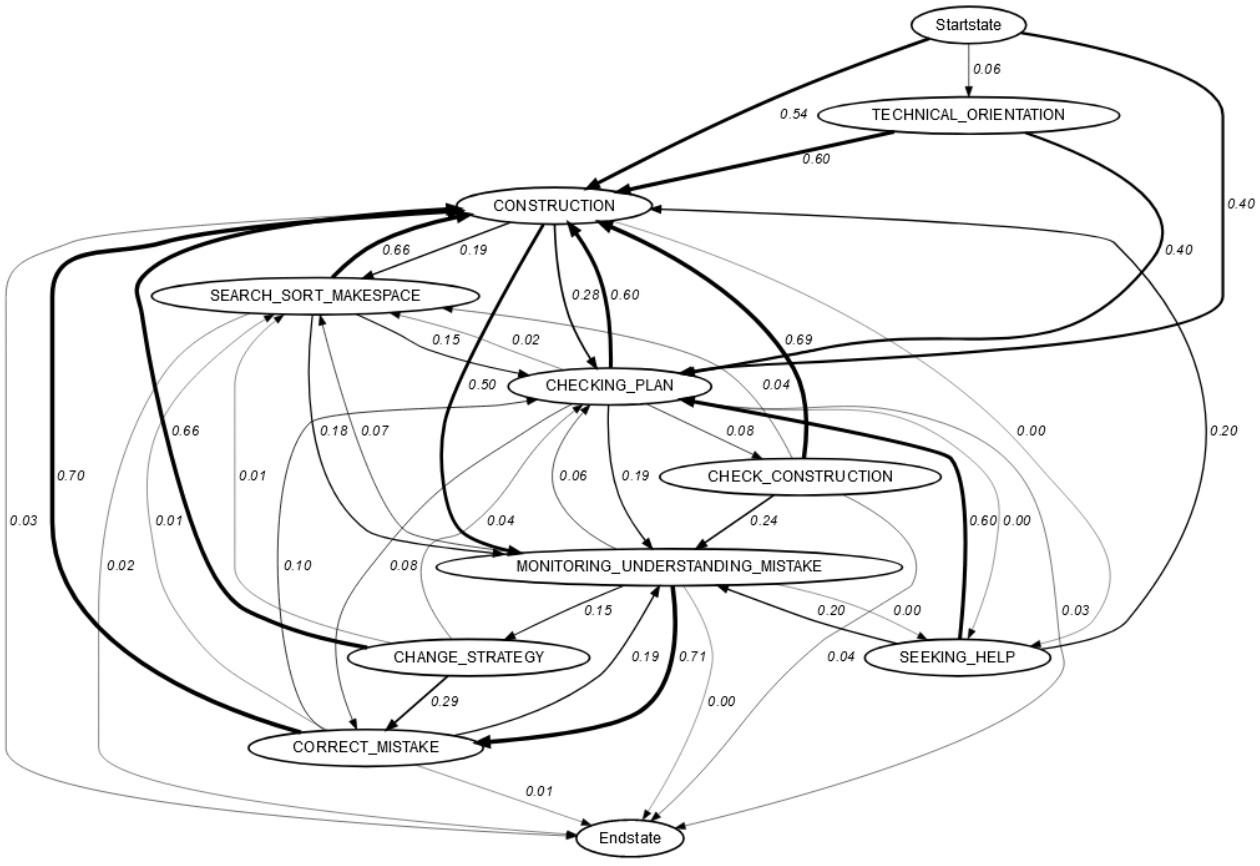
CONSTRUCTION state after starting the task performance. The simplicity of the shape is demonstrated by the fact that only 25% of the participant reopened the plan after TECHNICAL_ORIENTATION in the beginning of the task; only 7% did so directly after starting, and merely 8% of the transition from CONSTRUCTION lead to CHECKING_PLAN. Moreover, the transition graph visualize that in most cases CORRECT_MISTAKE directly followed the MONITORING_UNDERSTANDING_MISTAKE state (83%). Interestingly, a third of the transitions from CHECK_CONSTRUCTION were leading to the end state. This could be an indicator for evaluation of the own task performance, by, for example, comparing the own construction to the shape plan before finishing the task.



BI - Figure 3: Transition graph simple TTT

In comparison to the simple TTT, most children directly transferred to the CONSTRUCTION state after the start of the complex TTTs (see Figure 4). However, 40% of

all transitions from the start state in the complex TTTs are leading to CHECKING_PLAN, which suggests that the given shape was indeed more difficult in this tasks (see Figure 4). Compared to the simple task (42%), participating children changed more often from CONSTRUCTION state to MONITORING_UNDERSTANDING_MISTAKE in the complex tasks (50%). This also applies for the transition from CHECKING_PLAN to MONITORING_UNDERSTANDING_MISTAKE. While in the simple task only 9% of the transition from CHECKING_PLAN state are leading to the MONITORING_UNDERSTANDING_MISTAKE state, this appears in 19% of the cases in the complex tasks. All in all the transition graph of the complex TTTs visualizes the higher proportion of monitoring and control loops in these complex tasks compared to the simple digitized TTT.



BI - Figure 4: Transition graph complex TTTs

Relations Log Data and Think aloud Data

To evaluate the potential of the digital TTT to assess metacognitive behavior, relations between the monitoring and control behavior extracted from the log data and the think aloud data were investigated. To that end, frequency scores of the different extracted metacognitive states coded in the log data and the think aloud data were compared, and correlation analyzes were carried out. The frequency distributions provide a simple count-based measure of metacognitive behavior in the two different data streams. The analysis Wilcoxon signed rank tests and correlative analysis of this simple metric emphasizes the practical value while also showing their limitation.

Comparison of the average frequencies with which metacognitive behavior is extracted from the two data streams showed that most states of metacognitive behavior appeared more often in the log data than in the think aloud data (see BI Appendix - Table 1 and Table 2). Results of Wilcoxon signed rank (see BI Appendix - Table 1) show significant differences in all metacognitive behaviors, besides CHECK_ CONSTRUCTION and SEEKING_HELP. Although some operationalisation in the log data of metacognitive behavior could be questioned (e.g. change strategy as a more complex behavior), the code CHECKING_PLAN, for example, shows a very specific and clearly defined operationalisation (click on the “PLAN” button). Removing train tracks from an existing construction, as an indicator for MONITORING_UNDERSTANDING_MISTAKE in the log data, also provides a rather unambiguous interpretation. The differences therefore suggest incomplete reports of monitoring and control in the think aloud.

Despite differences in the frequencies, the validity of the extraction of the states SEARCH_SORT_MAKESPACE ($r = .25$, $p < .05$), CORRECT_MISTAKE ($r = .38$, $p < .01$), CHANGE_STRATEGY ($r = .44$, $p < .01$), CHECKING_PLAN ($r = .62$, $p < .01$) and MONITORING_UNDERSTANDING_MISTAKE ($r = .62$, $p < .01$) in the log data is strengthened by significant correlations between the two data streams (see BI Appendix - Table 2). However, different findings emerge for the three states TECHNICAL_ORIENTATION, CHECK_CONSTRUCTION and SEEKING_HELP. As indicators for TECHNICAL_ORIENTATION clicks on the “help” button at the beginning of the task (log data) and the coding of statements on task exploration and technical exploration in the beginning of the task (think aloud) were related. The think aloud data showed more statements on average and no significant correlation was found for TECHNICAL_ORIENTATION ($r =$

.07, p >.05) between these two assessment methods. This suggests that there might be more actions in the log data, which indicate task orientation and which have not yet been defined in the FSM or that it might be difficult to find indicators for students task orientation based on the exclusive log data. The non-significant correlation between CHECK_CONSTRUCTION (r = .18, p >.05) extracted from the log data and the think aloud data highlights challenges in the operationalization of this state. Compared to all states, CHECK_CONSTRUCTION was coded least frequently in the think aloud protocols and also appeared rather rarely in the log data. It seems possible that this state is generally more difficult to operationalize and therefore does not provide a good indicator for monitoring. SEEKING_HELP also occurred rather rarely. In this context, the various ways of seeking help by children during think aloud were reduced to asking adults for help or non-directed seeking for help. Nevertheless, the non-significant correlation (r = .09, p >.05) is intelligible, as in the think aloud protocols different strategies of seeking help are involved. BI Appendix Table 2 replays mean, standard deviation and correlation coefficients of all states extracted in the two data streams.

Discussion

The aim of this study was to introduce the digital TTT as an innovative instrument to assess young students' SRL in a multimethod way by drawing on think aloud and on log data. So far, only a few studies have analyzed log data from young learners on SRL (Saint et al., 2022).

Based on the models of Winne und Hadwin (1998) and Nelson und Narens (1994) and previous research with the original TTT and think aloud research (Bryce & Whitebread, 2012; Vandevelde et al., 2015), an action and a state library were developed to extract metacognitive behavior from the log data. Unlike earlier studies that mainly examined cognitive strategies like reading and note-taking based on log data (Malmberg et al., 2014; Munshi et al., 2018) to infer metacognitive processes (Kinnebrew et al., 2013), our study operationalized direct indicators of metacognitive behavior.

We found that similar metacognitive behaviors could be extracted from the digitized TTT as in studies with the original observational task (Bryce & Whitebread, 2012; Spektor-Levy et al., 2017; Tzohar-Rozen et al., 2021). Based on the pure log data, several of the monitoring behaviors also investigated in previous observation research could be operationalized (e.g. (technical) orientation, checking plan, check construction, monitoring mistakes), whereas some monitoring strategies (e.g. checking own, self-questioning, comment) (Bryce & Whitebread, 2012) were difficult to directly extract from the log data. In addition, it was possible to

operationalize and extract some of the control behavior assessed with the initial observational TTT (Bryce & Whitebread, 2012) for the analysis of log data.

However, a comparison of the developed state library with previous studies using the original TTT (Bryce & Whitebread, 2012) and other log data studies (Bannert et al., 2014; Saint, Gašević, et al., 2020) shows that the current digital implementation of the TTT does not allow for any direct indicators of planning, as an important SRL strategy. Our findings, in line with previous researchers (Roll & Winne, 2015; van Laer & Elen, 2018), underline the challenges to operationalize and extract all aspects of the complex SRL process. The extracted states in this study mainly belong to the orientation and performance phase of the common SRL models. This is in line with previous research and reviews like Viberg et al. (2020) pointing out that there is research from the field of learning analytics missing related to evaluation and reflection phase. Nevertheless, it seems possible to extract reflective and evaluation behavior from the TTT log data in future research, based on the states extracted in this study; for example by using additional FSMs or other statistical analysis methods. All in all, the operationalized monitoring and control states in this study show consistency with metacognitive behavior identified in other SRL log data research across diverse digital learning environments (Bannert et al., 2014; Du et al., 2023). Overall, log FSM proved to be a helpful tool for defining the indicators for state transitions and extracting the operationalized metacognitive states from the log data.

In the comparative analysis of the extracted metacognitive states in the simple and the complex TTT, significant differences emerged. These differences indicate that the digitized TTT has the potential to sensitively measure various SRL processes in young students, for example, depending on the difficulty of the tasks. The analyzes revealed that children exhibited monitoring and control behavior, both in total and relatively more frequently, during the complex TTT. This aligns with previous findings regarding differences in task performance (Iiskala et al., 2004) and gives new insights into intra-individual differences in students' strategy use investigated by other researchers (Malmberg et al., 2014). In addition to the comparison of frequency and duration, simple transition graphs were used to explore the sequential occurrence of monitoring and control. Even if this is a rather simple, explorative analysis of the SRL process, the comparison of the two graphs already provides insights into the different metacognitive processes during simple and complex tasks, suggesting a greater relevance of monitoring and checking the plan during the performance process of complex TTT.

As already demonstrated in other studies (Saint, Gašević, et al., 2020; Siadaty, Gašević, & Hatala, 2016), transition graphs have proven to be an insightful method for comparing and identifying differences in SRL processes.

The significant correlations between the think aloud data and the log data regarding a variety of operationalized metacognitive states support the validity of the digital TTT. However, the non-significant relation between TECHNICAL_ORIENTATION, CHECK_CONSTRUCTION, and SEEKING_HELP extracted in the log data and the think aloud data suggests that the operationalization of these states does not yet align well in the different datasets. Overall, the findings are consistent with previous studies that combined think aloud and log data, indicating both overlaps and potential for complementarity (Fan et al., 2023).

Limitations and Future Directions

While the present study contributes valuable and innovative insights into the assessment of SRL in young learners, it is important to acknowledge limitations that may impact the interpretation and generalizability of the findings. The study's sample size was relatively small, limiting the generalizability of the findings. Future research with larger samples could strengthen the comprehensive understanding of SRL processes in young learners. Moreover, the focus of the study was on primary school students, which may restrict the applicability of the findings to older age groups. Investigating SRL with the log data of the digitized TTT in a wider age range, for example secondary school students or preschool children, could elucidate developmental trajectories and differences in metacognitive abilities across different stages of childhood and adolescence. The rationale for the design of the different tasks was based on previous research using the TTT as an observation method and the track circles already evaluated in these studies (Spektor-Levy et al., 2017). However, the average performance time and the average log events of the five different tasks indicate that the digital TTT may not have reached an adjusted level of difficulty for each age group, in particular the 5th graders. Future research is needed to further evaluate the difficulty levels of different digital TTT tasks and the age-appropriate assessment of SRL with the digital TTT.

Despite the advantages of a simple and replicable task, the digital TTT may not fully capture the complexity of real-world learning situations. Even if a meta-analysis have strengthen the non-reactivity of think aloud (Fox et al., 2011), standardized short prompts were used and efforts were made to ensure the validity and reliability of the measurement of the

digitized TTT, inherent limitations, like uncontrolled environmental variables, may affect the accuracy of the data collected.

Future research could employ additional measures (like eye tracking) and evaluate the digital TTT in a more controlled surrounding to strengthen the robustness of the findings, in particular the interpretation of log events into real world metacognitive behavior. In addition, further research is needed to investigate the effects of the different modes of think aloud (face to face vs. remote/telephone).

Furthermore, as a limitation this study did not include assessment of participants' cognitive resources, such as cognitive load, which have been shown to be relevant in the context of SRL and metacognition (Wang & Lajoie, 2023). In addition, participants' spatial reasoning (Rimbatmojo et al., 2017), executive functions (Roebers, 2017), verbal and non-verbal cognitive abilities (Bohlmann et al., 2015; Tzohar-Rozen et al., 2021) might impact students' cognitive load during performance of the digital TTT and also the assessed metacognitive behavior with the recorded log data. Future studies and replications should therefore integrate the assessment of these constructs in order to control for cognitive abilities and provide an accurate explanation of inter- and intra-individual differences in SRL measured with the digital TTT.

In addition, collaborating with educators and implementing the use of the digital TTT in school to assess and promote SRL could bridge the gap between theory and practice. The analyzes presented here aimed to introduce and evaluate the task, but do not take into account the full potential of additional data streams, such as the corresponding think aloud data to elucidate influences such as beliefs or external circumstances on the SRL approach during task processing. As argued by several researchers, the exclusive use of on-line measures may be missing possible explanatory context factors or reasons for the observed behavior (Fryer & Dinsmore, 2020; Winne, 2010, 2020). Given the challenge that actions recorded with log events might not be unambiguous (Roll & Winne, 2015), the exclusive use of log data from the digital TTT to explore its potential to measure SRL cannot guarantee the absence of misinterpretations of log events. Even though a comprehensive approach was used to extract the most objective indicators of metacognitive behavior, some operationalized log events might not represent metacognitive states in reality, or some actual metacognitive behaviors of students' were missed altogether. Further data triangulation, with additional data streams, like think aloud, will offer insights into the underlying beliefs, strategies, reasons and external factors influencing

individuals' problem-solving approaches. This strengthens the need for multi-method research to further explore the influence of additional factors, which are hard to assess with log data solely (Fryer & Dinsmore, 2020; Winne, 2020).

Implications and Applications

The research using log data to assess SRL is currently experiencing rapid development. While technology now enables easy and efficient collection of log data, an increasing number of analytical methods are being explored, providing exciting insights into the complex SRL process. However, as with the majority of SRL assessment methods, there has been a strong focus on older students in current log data research (Saint et al., 2022). The present study offers an innovative method for capturing SRL using log data already created by young learners. The application of FSMs for the extraction of SRL-related states presented in this study is only a first, simplified approach that can be further extended. For example, by using further FSMs that build on each other, additional states can be extracted. Future research using FSM for SRL research could therefore contribute to better representation of the interconnected SRL processes. Additionally, by transparently presenting the task, providing a methodological approach for simple extraction of metacognitive states using FSM, along with making the task available for interested researchers, we provide a replicable assessment method.

The task has the potential to be supplemented by more complex tasks for older students, thus capturing developments in metacognitive abilities beyond elementary school. Refined operationalization or additional technical features (e.g. additional buttons) can also allow an even finer-grained analysis of SRL processes. As pointed out by a review of Viberg et al. (2020), there is still research missing on the implementation of learning analytics to support students' SRL. The digital TTT has the potential to advance SRL assessment of young students and provide a digital environment for transferable research. Future automatic real-time evaluation of task performances could also be made useful for teachers to identify SRL deficits. The task also offers the potential to implement direct feedback, thus promoting children's metacognition (e.g., reminding them to check the plan or to review the construction again) in line with learning analytics. Moreover, the task has the potential to be applied in various flexible contexts, at home, at school or in the laboratory research with additional promising measurements such as eye tracking.

All in all, the study presents an innovative task to assess SRL, in particular metacognitive behavior, of young students with the help of log data. The development of the digital TTT and the transparent and clear operationalization for the corresponding log data is a promising tool

for uncovering patterns of SRL in log data and shows the transformative potential of learning analytics in the field of SRL assessment.

Conflict of Interest

The authors declare that the research was conducted in the absence of any commercial or financial relationships that could be construed as a potential conflict of interest.

Author Contributions

BvB: Conceptualization, Formal analysis, Investigation, Writing – original draft, Writing – review & editing, UK: Software, Writing – review & editing; CD: Conceptualization, Funding acquisition, Supervision, Writing – review & editing

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Availability of data

Additional data documentation, CBA Itembuilder items of the digital TTT, an example dataset of the log data and a exampleanalysis code are available on an OSF repository under the following link: https://osf.io/f7d4v/.

BI Appendix

BI Appendix - Table 1: *Results Wilcoxon-Mann-Whitney Test comparison log data and think aloud data*

	Z
TECHNICAL_ ORIENTATION	-3.35***
CHECKING_PLAN	6.06***
MONITORING_ UNDERSTANDING_MISTAKE	4.20***
CHECK_ CONSTRUCTION	-0.74
SEARCH_SORT_ MAKESPACE	4.46***
SEEKING_HELP	0.16
CORRECT_ MISTAKE	7.39***
CHANGE_ STRATEGY	3.74***

Note. Statistical comparison was done with the use of the Wilcoxon signed rank tests for pair-wise comparison (use Bonferroni correction); Legend: differences between total frequencies; * $p < 0.05$; ** $p < 0.01$; and *** $p < 0.001$

BI Appendix - Table 2: *Means, standard deviations, and correlations with confidence intervals*

Variable	*M*	*SD*	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1. Technical Orientation (TAP)	1.13	0.99															
2. Checking Plan (TAP)	3.06	2.97	.18 [-.05, .39]														
3. Monitoring Understanding and Mistakes (TAP)	6.90	6.90	.36** [.15, .54]	.58** [.41, .71]													
4. Check Construction (TAP)	0.66	0.99	-.06 [-.28, .16]	.15 [-.07, .37]	.31** [.09, .50]												
5. Search, Sort and Make Space (TAP)	2.66	2.34	.48** [.29, .64]	.56** [.38, .70]	.39** [.18, .56]	-.03 [-.25, .20]											
6. Seeking Help (TAP)	0.88	1.46	.33** [.11, .51]	.01 [-.21, .23]	.26* [.04, .46]	.14 [-.09, .35]	.04 [-.19, .26]										
7. Correct Mistake (TAP)	2.94	3.29	.28* [.07, .48]	.70** [.57, .80]	.73** [.60, .82]	.18 [-.04, .39]	.54** [.36, .68]	-.02 [-.24, .21]									
8. Change Strategy (TAP)	0.58	0.94	.16 [-.07, .37]	.28* [.06, .47]	.54** [.36, .68]	.29* [.07, .48]	.13 [-.10, .34]	.16 [-.07, .37]	.27* [.05, .46]								
9. Technical Orientation (Log data)	0.62	0.51	.07 [-.16, .29]	-.09 [-.31, .14]	-.13 [-.35, .09]	-.12 [-.34, .10]	-.04 [-.26, .18]	-.06 [-.28, .17]	-.05 [-.27, .18]	-.06 [-.28, .17]							
10. Checking Plan (Log data)	8.68	6.77	.18 [-.05, .39]	.62** [.45, .74]	.49** [.30, .64]	.28* [.06, .48]	.32** [.10, .51]	.23* [.01, .43]	.41** [.20, .58]	.26* [.04, .46]	-.24* [-.44, -.02]						
11. Monitoring Understanding and Mistakes (Log data)	15.64	16.04	.24* [.01, .44]	.41** [.21, .58]	.62** [.45, .74]	.21 [-.01, .42]	.18 [-.04, .39]	.37** [.16, .55]	.36** [.15, .54]	.53** [.35, .67]	-.18 [-.39, .05]	.67** [.53, .78]					
12. Check Construction (Log data)	0.71	1.34	.01 [-.22, .23]	.37** [.16, .55]	.31** [.09, .50]	.18 [-.04, .39]	.10 [-.13, .32]	.14 [-.09, .35]	.19 [-.04, .40]	.22 [-.01, .42]	-.29** [-.48, -.07]	.68** [.54, .79]	.40** [.19, .57]				

13. Search, Sort and Make Space (Log data)	5.77	5.07	.16 [-.06, .37]	.30** [.08, .49]	.47** [.28, .63]	.22 [-.01, .42]	.25* [.03, .45]	.13 [-.10, .34]	.33** [.12, .52]	.44** [.24, .61]	-.06 [-.28, .17]	.38** [.18, .56]	.54** [.37, .68]	.20 [-.03, .41]			
14. Seeking Help (Log data)	0.60	0.80	-.02 [-.24, .21]	-.03 [-.26, .19]	-.00 [-.22, .22]	-.02 [-.25, .20]	-.03 [-.25, .19]	.09 [-.13, .31]	-.04 [-.26, .19]	-.07 [-.29, .16]	-.60** [-.73, -.43]	.17 [-.06, .38]	.14 [-.09, .35]	.15 [-.08, .36]	.16 [-.06, .37]		
15. Correct Mistakes (Log data)	12.66	12.29	.26* [.04, .46]	.44** [.24, .61]	.59** [.43, .72]	.22 [-.01, .42]	.20 [-.03, .40]	.37** [.16, .55]	.38** [.17, .56]	.49** [.30, .64]	-.16 [-.37, .07]	.69** [.55, .79]	.99** [.98, .99]	.40** [.19, .57]	.47** [.28, .63]	.11 [-.11, .33]	
16. Change Strategy (Log data)	2.23	4.02	.26* [.04, .46]	.36** [.14, .54]	.55** [.37, .69]	.19 [-.03, .40]	.21 [-.02, .41]	.38** [.17, .56]	.27* [.05, .47]	.44** [.24, .61]	-.24* [-.44, -.01]	.58** [.41, .71]	.87** [.80, .92]	.34** [.12, .52]	.33** [.12, .52]	.09 [-.14, .31]	.84** [.76, .90]

Note. *M* and *SD* are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. The confidence interval is a plausible range of population correlations that could have caused the sample correlation (Cumming, 2014). * indicates $p < .05$. ** indicates $p < .01$.

BI Appendix - Table 3: *Descriptive Statistics Gender*

	N	**Female**	**Male**	**Missing**
Grade 2	13	6	4	3
Grade 3	25	9	12	4
Grade 4	14	5	9	0
Grade 5	33	16	12	5
Total	85	36	37	12

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6.2 Beitrag II: Risk factors for academic underachievement and young students' self-regulated learning.

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Beiträge der Autorinnen zu der Publikation:

Bernadette van Berk: Konzeption und Design der Studie, Literaturrecherche, Datenerhebung, Datenanalyse, Interpretation der Ergebnisse, Schreiben des Manuskripts, Überarbeitungen im Reviewprozess

Charlotte Dignath: Einwerbung von Forschungsfördermitteln, Konzeption und Design der Studie, Überprüfung und Feedback, Korrekturlesen und Endredaktion

Zusammenfassung. Jahrzehntelange Forschung zeigt wiederholend Zusammenhänge zwischen schulischer Leistung und familiären Kontexten, wie dem sozioökonomischen Status und Migration. Kinder mit solchen bildungsrelevanten Risiken, aber auch mit Lern- und Aufmerksamkeitsstörungen stehen vor besonderen Herausforderungen. Gleichzeitig betonen Studien die Bedeutung von selbstreguliertem Lernens (SRL) für den Bildungserfolg. Diese Studie untersucht den Einsatz von SRL-Strategien und metakognitivem Wissen bei Schüler*innen mit bildungsrelevanten Risiken. SRL von jungen Lernenden wurde dazu multimethodisch erfasst. Ergebnisse zeigen Zusammenhänge mit dem sozioökonomischen Hintergrund der Eltern und der SRL Strategienutzung gemessen mit dem Selbstbericht. Im Zusammenhang mit Migration zeigen die Analysen, dass Kinder mit Migrationshintergrund im SRL-Strategienutzung Selbstbericht besser abschneiden. Analysen in Bezug zu Lernschwierigkeiten zeigten ebenfalls Zusammenhänge mit geringerer SRL-Strategienutzung gemessen mit dem Elternbericht. Es konnten keine Zusammenhänge zwischen den verschiedenen Risikofaktoren und dem metakognitiven Wissen von Schüler*innen gefunden werden. Diese Ergebnisse bieten erste Einblicke in die Beziehung zwischen SRL und bildungsrelevanten Risiken und bieten eine Grundlage für zielgerichtete Interventionen zur Förderung von SRL. **Schlüsselwörter:** Selbstreguliertes Lernen, Bildungsrelevante Risiken, Lernschwierigkeiten, metakognitives Wissen

Abstract. Decades of research repeatedly highlight the relations between academic achievement and family contexts, such as socioeconomic status and migration. Children facing these educational risks, as well as those with learning and attention disorders, encounter several challenges. A broad body of research emphasizes the relevance of self-regulated learning (SRL) for educational success. This study investigates the use of SRL strategies and metacognitive knowledge among students with educational risks. SRL among young learners was assessed using a multimethod approach. Results indicate relations with parents' socioeconomic background and self-reported SRL strategy use. Regarding migration, results show, that children from immigrant backgrounds show higher SRL strategy use in self-reports. Analysis also indicated associations of learning difficulties with lower SRL measured with the parent rating. No relations were found between the various risk factors and students' metacognitive knowledge. These findings offer first insights into the relations between SRL and educational

risks, providing a basis for tailored interventions to enhance SRL. **Keywords:** Self-regulated learning, students at risk, metacognitive knowledge, learning difficulties

Introduction

Numerous studies have shown that self-regulated learning (SRL) is a strong predictor of academic performance and motivation to learn (Dent & Koenka, 2016) and is therefore considered an important basis for lifelong learning (Bjork et al., 2013). Accordingly, students, who plan their learning, set themselves goals, monitor and control their learning performance and use a variety of strategies, tend to show higher motivation and self-efficacy beliefs (Bai & Guo, 2021; Schunk & Ertmer, 2000). On the other hand, deficits in SRL predict diverse future problems in academic context and social life (Robson et al., 2020; A. Sawyer et al., 2015). School closures and distance learning during the Covid-19 pandemic once again emphasized the importance of SRL in education (F. Berger et al., 2021). However, for many students, SRL has presented a major challenge during the pandemic (F. Berger et al., 2021), and the dramatic learning deficits of the affected student cohorts are currently evident in national and international school performance studies (Betthäuser et al., 2023; OECD, 2023).

Not only during the pandemic, but over the last decades, the strong influence of various educational risk factors on students' academic performance has been repeatedly demonstrated (OECD, 2023). These can be family-related risk factors such as socio-economic status (SES) and migration background, but also individual risk factors, including learning and attention difficulties as well as learning disorders (LD) and attention-deficit/hyperactivity disorder (ADHD) (Arnold et al., 2020; Büttner & Hasselhorn, 2011). Many students with educationally relevant risks have difficulties with learning that may be partly caused by a deficient SRL. However, to date, the extent to which students' SRL is related to educational risk factors has not been sufficiently explored. Nevertheless, previous research suggests that differences in SRL related to risk factors may exists in young children and that the identification of risk factors associated with SRL may provide crucial insights for overcoming educational barriers and promoting educational success. This study aims to investigate the extent to which students at educational risk are impaired in their SRL competencies. To this end, the current study investigates whether the use of SRL strategies and students' metacognitive knowledge are associated with

RQ1: socio-economic risks (SES and parental education)

RQ2: migration-related risks (immigrant background and frequency German is spoken at home)

RQ3: developmental risks (learning and attention disorders and need for homework support).

The study thus provides insights into the interplay between risk factors and SRL in the context of young students' learning in schools, which are relevant for both further research and for practice.

Theoretical Background

SRL and Metacognitive Knowledge

Self-regulated learners plan their learning approach, set themselves goals, use multiple strategies to advance their learning process and reflect on what could be improved (Zimmerman, 2000). At the heart of SRL is a variety of strategies that learners use to regulate their own learning process. These strategies include various cognitive, metacognitive, resource-oriented, emotion-regulatory and motivational processes that are used to achieve learning goals and enhance learning outcomes (Pintrich, 2000). While cognitive strategies, such as elaboration and organization, are used to regulate information processing, metacognitive strategies are involved in evaluating and adapting the learning process, for example through planning (Boekaerts, 1996). In addition, SRL theories highlight the need for students to maintain or increase their motivation and to regulate emotions within the learning process, by using diverse strategies like positive self-talk or cognitive reappraisal (Boekaerts, 2007; Efklides, 2011). SRL has been shown to be a dynamic and cyclical process including different phases. In the forethought phase, learners set themselves goals, plan their strategy use and activate prior knowledge (Zimmerman, 2000). This is followed by the performance phase, where individuals employ the planned strategies, monitor their progress, and adjust their approach as needed. Finally, the self-reflection phase involves evaluating the own performance and reflecting on improvement for future learning scenarios. Within this process students constantly monitor their learning approach and evaluate it against their self-set goal or standard for their task performance (Pintrich, 2000).

The complex process of SRL can be seen as an overarching framework, including different concepts and abilities (Dinsmore et al., 2008; Roebers, 2017). Besides the diverse SRL strategies, one key component of SRL is metacognition, which includes metacognitive

regulation and metacognitive knowledge (Händel et al., 2013). The regulative aspect of metacognition, often integrated in the set of the various SRL strategies (Boekaerts, 1996), can be further distinguished and described as the interplay of monitoring and control of one's own cognitive and behavioral processes (Nelson & Narens, 1994). Metacognitive knowledge on the other hand describes the understanding of one's own learning strategies, tasks, and abilities (Schneider, 2008). In order for learners to know when and how to use which SRL strategy most effectively, they need this metacognitive knowledge, i.e. knowledge about SRL strategies and about the conditions under which SRL strategies are used (Weinstein et al., 2000). Metacognitive strategy knowledge refers to an individual's awareness of strategies that can be employed to enhance learning (declarative knowledge), their understanding about how a strategy can be applied effectively (procedural knowledge) and which strategy is the appropriate approach to solve the task (conditional knowledge) (Flavell, 1979; Händel et al., 2013). Together metacognitive knowledge and SRL strategy use enable students to shape their learning process autonomously and proactively (Pintrich, 2000; Zimmerman, 2000).

Research with young children often focus on self-regulation beyond the learning context, describing the ability to regulate emotions, behaviors, and cognition in diverse contexts (Moilanen, 2007; Wesarg-Menzel et al., 2023).Within this research field, studies often focus on behavioral self-regulation or executive functions, as a set of higher-order cognitive processes, like working memory, shifting and inhibition abilities (Roebers, 2017). SRL can be seen as a concept which tries to integrate metacognition, cognitive and behavioral self-regulation, aiming to bridge the different research traditions in the academic domain (Dinsmore et al., 2008). Despite the extensive research on SRL, the assessment of SRL, especially with young learners, such as primary school students, remains challenging. Especially in large samples, questionnaires remain the most common assessment method in SRL research because they are time efficient in administration, although their validity and reliability have been repeatedly questioned (Gascoine et al., 2017; Veenman, 2011; Veenman & van Cleef, 2019). More valid methods such as observations, interviews, and think-aloud protocols can produce a vast amount of verbal and nonverbal behavior data, which are resource-intensive and time-consuming in their preparation and analysis (Veenman & van Cleef, 2019). Furthermore, some of these approaches can only be applied in controlled laboratory environments, making them less suitable for practical use in school-based or digital research (Marulis et al., 2016; McClelland & Cameron, 2012). Based on these challenges, recent research calls for multi-method approaches to investigate SRL (Veenman & van Cleef, 2019; Winne, 2010).

SRL and Academic Achievement

Empirical evidence supports the positive association between SRL and academic achievement across different populations and educational settings (Dent & Koenka, 2016). In line with this, some research shows that self-regulatory abilities in a young age, involving regulation of emotion, attention, behavior, and cognition, is associated with school readiness and early academic outcomes (e.g. Howard et al., 2021). In school age, students who employ effective SRL strategies tend to outperform their peers in academic tasks (Dent & Koenka, 2016) and display superior problem-solving abilities (e.g. Hatala et al., 2023; Paquette et al., 2021; Tzohar-Rozen & Kramarski, 2017). Moreover, previous research highlights the enduring impact of SRL on individuals' educational attainment and the risk for school drop-out (Meyers et al., 2013). Besides the positive relationship between academic achievement, several studies emphasized the relation of SRL and motivational aspects, such as academic self-efficacy, task value and task interest (Callan et al., 2021; Lim & Yeo, 2021; Pintrich, 1999; Zimmerman & Schunk, 2011).

Contrary, children with lower levels of self-regulation in early childhood have been found to be at risk for lower performance in academic tasks (McClelland et al., 2006; McClelland et al., 2000) and future behavior problems (A. Sawyer et al., 2015).

Based on the diverse research showing that even young learners can apply SRL strategies (Bryce & Whitebread, 2012; Wesarg-Menzel et al., 2023), childhood is considered to be a critical period for the development of SRL. In addition, metacognitive knowledge and regulation, as components of SRL, emerge in the early school years and become more differentiated with increasing age (Veenman et al., 2006). Metacognitive knowledge of strategies develop with increasing age, as does the ability to regulate behavior (Wigfield et al., 2011). Children as young as seven are able to monitor and adjust their use of strategies (Schneider, 2008). Some studies indicate gender differences in SRL (Vandevelde et al., 2013), with girls tending to use more SRL strategies and more deep level SRL strategies (Heirweg et al., 2019)

Despite the recognized relevance and well-documented benefits of SRL, many learners struggle to use SRL strategies effectively (Bjork et al., 2013). Nevertheless, meta-analyses show the effect of training, even for young learners (Dignath et al., 2008). Moreover, it is shown that in particular children with various difficulties in schooling benefit from these trainings (Berkeley & Larsen, 2018; Dignath & Hasselhorn, 2023). While the benefits of SRL are

evident, the effective implementation of SRL in schools and the promotion of SRL pose challenges. Tailored training is needed to address individual differences in learners, such as cognitive abilities, motivational orientations, resources and socio-cultural backgrounds. Additionally, the integration of SRL principles into educational curricula requires collaboration between researchers and educators, and increased sensitivity to students who might face difficulties in SRL.

Risks for Academic Underachievement

National and international studies have repeatedly highlighted that students' school performance is strongly related to demographic variables like socio-economic status, parents' education and immigrant background (Mang et al., 2023; OECD, 2023; Reiss et al., 2019; Schwippert et al., 2020). It is assumed that these factors have an influence on the educational trajectory of children, due to, for example, availability of financial resources for education-related material or activities and cultural capital, as well as by decisions regarding education (Barone, 2006; Schwippert et al., 2020). Distance learning during the Covid-19 pandemic has further increased the influence of the different opportunities for parents to support their children and therefore the associated educational inequalities (Anger & Plünnecke, 2021; Betthäuser et al., 2023).

Considering the high prevalence of LD (Grigorenko et al., 2020; Hasselhorn, 2022) and ADHD (Schlack et al., 2007; Thomas et al., 2015) and the call for inclusive education (Convention on the Rights of Persons with Disabilities, 2007) students with learning and attention disorders are also increasingly at risk for educational underachievement and challenges in education.

Socio-economic Status as a Risk Factor

The recent international comparative PISA study (Programme for International Student Assessment) (OECD, 2023) highlights once again the relevance of the socio-economic status to various educational outcomes. A variety of indicators are used to measure SES, such as parental occupation, parental education, and family income (Sirin, 2005). In OECD countries, socio-economically disadvantaged students are significantly more likely to perform below the level of basic competency levels in mathematics and science, with a similar trend observed in reading literacy (OECD, 2023). A meta-analytic review suggests a medium to strong association between students’ SES and their academic achievement (Sirin, 2005). In addition to the relation between sociodemographic risk factors and actual academic performance

(Berkowitz et al., 2017; O'Connor et al., 2019), students from low SES backgrounds often face difficulties in the motivational aspect (Hornstra et al., 2013) and tend to have higher school dropout rates (Winding & Andersen, 2015).

It is repeatedly shown, that besides parents' SES, parents' education is associated with childrens' educational pathways and their academic achievement in Germany (Anger & Plünnecke, 2021). For example, children of academics are more likely to go on higher education than children whose parents did not study (Lergetporer et al., 2021). Large-scale international comparative studies have repeatedly shown significant differences in math's, science (Schwippert et al., 2020) and reading skills (Reiss et al., 2019) between, for example, students with at least one parent with a tertiary education compared to students of parents without a tertiary education.

Migration as a Risk Factor

Several studies have shown that immigrant students face significant disadvantages in the school context (Heath et al., 2008). Migration is a complex phenomenon and the group of learners defined having a migration background is often very heterogeneous and is not universally defined (Gogolin & Maaz, 2019; Heath et al., 2008). In order to take into account not only the migration experience of the students themselves, but also the indirect migration experience of the family which might influence educational trajectories, the currently widely accepted concept of migration is based on a generational approach (Gogolin & Maaz, 2019; Heath et al., 2008). Research typically considers at least one generation (parents' migration) or even more than one generation (grandparents' migration) to assess migration and in addition asks for further information, such as the time of migration and the countries of origin (Gogolin & Maaz, 2019).

Previous research suggests that students from immigrant background show lower academic performance in various areas (e.g. Heath et al., 2008; Kao & Thompson, 2003; OECD, 2023). Across different countries and outcome measures, a pattern has emerged showing that in western countries, certain minorities whose parents come from less developed non-European countries, are at risk of having a significantly lower level of educational attainment then their peers (Heath et al., 2008). For example, the international comparative PISA study has repeatedly shown that children from immigrant families have comparatively low reading skills in the national language across all OECD countries (OECD, 2023; Reiss et al., 2019). Moreover, some studies suggest that immigrant students are significantly more likely

to drop out of school (e.g. Kao & Thompson, 2003) or do not continue in higher education (e.g. Becker & Klein, 2021). Furthermore, there is empirical evidence that these negative educational trajectories already occur at a young age (e.g. Becker & Klein, 2021; Hahn & Schöps, 2019; Sprong & Skopek, 2022).

In addition, immigrant students are often at risk in several ways. In addition to their immigrant background, their families often have a low SES as well and they rarely speak the national language at home, which can lead to several challenges in educational systems (OECD, 2023). The PISA study suggests that students with an immigration background often speak a different language at home than the one used in schools, especially first-generation students born abroad (OECD, 2023). In many countries, the number of students speaking a different language at home has risen in recent years, posing a challenge for integration in the educational systems due to language barriers (OECD, 2023). In line with this, the PISA results for Germany suggest that children who speak German less frequently at home have significantly lower reading skills in German (OECD, 2023; Reiss et al., 2019). Along with these findings, there is a strong link between migration and language and its influence on educational trajectories (Gogolin & Maaz, 2019; Hahn & Schöps, 2019; Washbrook et al., 2012).

However, these finding are not conclusive and empirical studies show that the educational disadvantages and challenges do not apply equally to all immigrant groups (Washbrook et al., 2012).

Learning and Attention Disorder as a Risk Factor

Learning disorder (LD), whether unspecified as unexpected poor academic performance that cannot be explained by cognitive potential or by external factors, as well as specific learning disorders, like dyslexia and dyscalculia (Büttner & Hasselhorn, 2011; World Health Organization [WHO], 2021), both cause low academic achievement and various difficulties in school performance (WHO, 2021). Central to the definition of LD is that children or adolescents have deficits in essential learning processes (Kavale & Forness, 2000). There is a large body of research that demonstrates the disadvantages and challenges faced by students with LD in schools (Bender & Smith, 1990). Consistent with the core symptom of LD, students with LD, such as dyslexia and dyscalculia, show lower performance in various academic domains (e.g. Landerl et al., 2009; Walker & Nabuzoka, 2007). Moreover, studies indicate that students with LD have low academic self-efficacy beliefs (e.g. Bear et al., 2002; Hampton & Mason, 2003), more negative academic emotions, such as anxiety towards school related tasks (e.g. Sainio et al., 2019), and more negative behaviors, such as being disruptive or bullying (e.g. Walker &

Nabuzoka, 2007). In addition, meta-analysis shows the negative impact of various learning difficulties on school drop-out (Gubbels et al., 2019).

But not only students with learning disorders, but also students diagnosed with attention-deficit/hyperactivity disorder ADHD show difficulties in school and in academic performance (Arnold et al., 2020). ADHD is associated with the core symptoms of inattention, hyperactivity and impulsivity, or a combination of these (WHO, 2021). Students with ADHD often face barriers in their academic careers, putting them at a higher risk of academic underachievement (e.g. Ehm et al., 2014; McConaughy et al., 2011) and emotional and behavioral problems (Al-Yagon, 2016). Some studies have highlighted the relevance of inattention in particular and the moderation of classroom behavior and homework performance on the academic achievement of students with ADHD (Langberg et al., 2011; Massetti et al., 2008). In general, meta-analyses indicate a moderate to large discrepancy in academic achievement between students with ADHD and student without the diagnosis (Frazier et al., 2007). Longitudinal studies show that ADHD predicts academic performance in mathematics, reading and spelling, even when controlling for IQ (e.g. Iines R. et al., 2023; Massetti et al., 2008). As a recent systematic review shows, ADHD has long-term effects on academic outcomes (Arnold et al., 2020). In addition, ADHD often co-occurs with LD, putting the children at even greater risk of academic underachievement (Barnard-Brak et al., 2011).

However, there are inconsistencies in operationalization of LD and common definition for unspecific LD as a substantial IQ–achievement discrepancy are repeatedly criticized (Büttner & Hasselhorn, 2011; Kavale & Forness, 2000) and disregards a large number of children with various learning difficulties. Therefore, some authors point out that in addition to a formal diagnosis, students with symptoms but without diagnose should also be included and compared when investigating academic underachievement (e.g. Büttner & Hasselhorn, 2011; Loe & Feldman, 2007). As students with ADHD and LD face significantly more homework difficulties than their peers, this could be one first indicator for learning difficulties, which should be observed and targeted to support students not (yet) have been diagnosed with a clinical learning or attention deficit (Bryan et al., 2001; Langberg et al., 2010).

Previous Findings to SRL and Risk Factors

Students differ greatly in their use of SRL strategies (Barnard-Brak et al., 2010; Wigfield et al., 2011) and some face great difficulty regulating their learning (Winne, 2005). While previous research has already explored the different facets of SRL and highlighted the relevance

of SRL in the context of academic achievement (Dent & Koenka, 2016; Robson et al., 2020; Weinstein et al., 2011) and positive developmental outcomes (Robson et al., 2020), the factors that explain the variation in students' use of SRL strategies and their metacognitive knowledge, especially among young learners, remain relatively unexplored.

Based on the various findings described above supporting that family background, such as SES, parental education but also immigrant background and the frequency the national language is spoken at home has a strong influence on students' academic achievement, it can be assumed that these factors also influence students' SRL. A recent meta-review demonstrates that childrens' development of self-regulation (in learning) is related to various parental behaviors (Wesarg-Menzel et al., 2023). In addition, a systematic review highlights the relevance of parental behavior related to SRL in particular (Pino-Pasternak & Whitebread, 2010). Students' use of SRL strategies and also their development of metacognitive knowledge may therefore be related to resources such as the time and money parents have to invest in education, parental support for SRL and also their own educational experiences.

Socio-economic Risks and SRL

As well as on academic performance, it can be assumed that the SES also has an influence on the development of childrens' SRL. Families with a low SES often face diverse challenges, like poverty or higher stress (Blair & Raver, 2015). The burdens families with low SES experience can be related to less learning opportunities, fever educational material for children or less interactions that support education and cognitive development in these families (Ermisch, 2008). In addition, parents with a lower SES may not be able to draw sufficiently on their own experience in the educational system and pass on skills and knowledge to their children. They may therefore provide only a limited direct or indirect support for SRL, for example through modelling SRL, which in turn is an important aspect in the early promotion of SRL (Pino-Pasternak & Whitebread, 2010; Wesarg-Menzel et al., 2023).

In line, a meta-analysis indicates that the environment has a strong influence on childrens' development of self-regulation (Wesarg-Menzel et al., 2023). So far, there has predominantly been research on the relation between socio-economic status and behavioral regulation, especially in pre-school aged children. For example, it has been shown that children from low socio-economic families or families with a low household income show less behavioral regulation (e.g. Sektnan et al., 2010; Størksen et al., 2015). Poverty has been found to affect the quality of parents' caregiving practices, and therefore may also be related to pre-school aged childrens' reduced self-regulation (e.g. Blair & Raver, 2015; Li-Grining, 2012). In

addition, some studies indicate that preschoolers' behavioral regulation is also related to their parents' educational background, especially maternal education (Miech et al., 2001; Montroy et al., 2016).

While there is comprehensive research investigating the relationship between pre-school aged childrens' behavior regulation and socio-economic risk factors, there is a lack of research focusing on the possible impact on learners' SRL. The limited research to date suggest that students use fewer SRL strategies (Vandevelde et al., 2017) and show lower levels of metacognition (Pappas et al., 2003). However, intervention studies highlight that children from low SES households in particular benefit from training and that these not only improve the use of SRL strategies but also academic performance (Azevedo et al., 2023; Rosário et al., 2016).

Migration-related Risks and SRL

As described above, it is well documented that immigrant background, and the various specific challenges this pose, can impact students' educational trajectories. This also appears to be of interest with regard to the development and differences in students' SRL.

Related to immigration, potential cultural differences in the relevance of behavioral regulation in culture and society, but also students' underlying motivational beliefs influenced by their background, may have an impact on the development of SRL abilities of learners (Blom & Severiens, 2008; Wanless et al., 2011). Previous findings on differences in SRL based on students' immigrant background are inconclusive. The few existing studies show on the one hand that immigrant students tend to use fewer SRL strategies (Alivernini, Manganelli, et al., 2019; Vandevelde et al., 2017), while on the other hand if taking into account interaction effects between gender and immigrant background, some studies show that immigrant girls report using the most deep-level SRL strategies compared to their classmates (e.g. Blom & Severiens, 2008). Insight from studies focusing on pre-school aged children, show that there might be differences in behavior regulation in different countries (Wanless et al., 2011).

In the context of migration and language, for example being a dual language learners, who speaks primarily a minority language at home, is also considered to have an impact on children's' self-regulation (Hanno & Surrain, 2019). During learning, students use words and private speech to organize and evaluate thoughts and behavior, making language essential for cognitive development (Vygotsky, 1986). Previous research therefore suggests that the development of SRL, especially metacognition, is bi-directionally related to children's level of expressive language (e.g. Bohlmann et al., 2015). In the case of bilingual students it was found,

that if the used languages were balanced students use private speech in two languages (J. Sawyer, 2016). However, there is no empirical evidence showing the impact of bilingual private speech or language use on SRL so far. Nevertheless, it can be argued that students' proficiency in the language used in school can be seen as a key factor enabling students to take part in classroom learning and interactions.

While the few existing research focuses on the relationship between language and behavioral regulation in young childhood, there is a lack of research investigating the impact of language specifically on SRL strategy use and metacognitive knowledge. However, when considering a relation between language and SRL, context seems to be important. Coping with regulatory challenges at school might therefore also be more closely related to the language spoken at school (Hanno & Surrain, 2019) rather the general language abilities. So far, there has been limited research into the relation with young students' SRL.

Learning and Attention Difficulties as Risk and SRL

Experiencing difficulties in regulating cognitive processes, emotions and behavior is often a challenge for students with learning difficulties, in particular LD and ADHD (Mason & Reid, 2018). These barriers to learning are strongly associated with deficits in SRL. Studies have shown that students with LD have difficulties in self-monitoring (Crane et al., 2017), use less appropriate metacognitive and SRL strategies (Mason & Reid, 2018), and show deficits in working memory and executive function (Johnson et al., 2010). Some studies suggest that these difficulties with SRL in relation to LD already appear at an early age (e.g. Tzohar-Rozen et al., 2021). Children aged five to six years who are at risk for specific LD have been found to use less monitoring and control during task performance and to have difficulties with metacognitive regulation (Tzohar-Rozen et al., 2021) and show poorer metacognitive knowledge (Desoete et al., 2006). Even when students are not yet diagnosed with LD, but only indicate difficulties in learning, studies have found a negative association with SRL strategy use (Bergey et al., 2017). Difficulties while executing homework and the support needed from parents during learning at home can be one indicator for learning difficulties (Bryan et al., 2001; Langberg et al., 2010). For example, previous research on students' learning independence and need for parental help showed significant correlations with scores on the hyperactivity subscale of the German version of the Strengths and Difficulties Questionnaire (SDQ-Deu) (Blume et al., 2021; Woerner et al., 2002),which may be related to SRL, but is also a strong indicator for attention difficulties.

Besides LD, ADHD is also strongly associated with difficulties in executive functions and impulse control and results in reduced self-regulation (Barkley, 2014; Willcutt et al., 2005).

Students with ADHD show problems in applying SRL strategies and show low persistence in learning (Bakracevic Vukman et al., 2013). Moreover, students with ADHD also show lower self-efficacy beliefs for SRL in comparison to students without (Bakracevic Vukman et al., 2013; Major et al., 2013). Overall, students with LD or ADHD often face challenges with SRL-related activities such as inhibiting behavior, delaying gratification, maintaining persistence and focus during task performance, and organizing and directing actions towards goals (Reid et al., 2012). Although there is research evidence that at-risk students benefit from SRL interventions (Berkeley & Larsen, 2018; Burke et al., 2020; Reddy et al., 2018), there is a paucity of studies that examine and document differences in young students' SRL in the context of LD.

The Present Study

Overall, previous research provides initial indications that family-related risk factors such as SES and migration background, but also individual risk factors, including learning and attention difficulties have not only a direct influence on learning outcomes but also on SRL of young learners, and thus have an additional impact on the potential learning trajectories. However, apart from evidence for the association between the various risk factors and behavioral regulation, there is limited research on the relationship between these risks and students' underachievement and SRL in particular. Nevertheless, studies show that especially students with these risk factors benefit from SRL training (Azevedo et al., 2023; Rosário et al., 2016). SRL can therefore also be seen as an important ability that could also compensate for potential risk factors for educational underachievement. Identifying which group of learners need special support due to family or individual risk factors is therefore even more important, to develop and provide targeted interventions. Accordingly, the study aims to offer a first step towards closing this research gap and to investigate

RQ1. To what extent do primary school students differ in SRL strategy use and metacognitive knowledge due to family background (parent's profession and occupation and parental education)? Hypothesizing that:

H1: Students from families with a lower SES, combining parent's profession and occupation and parental education as indicators, show lower SRL strategy use and lower metacognitive knowledge.

RQ2. To what extent do primary school students differ in their use of SRL strategies and metacognitive knowledge due to their immigration background (migration of parents and German language spoken at language)? The following hypothesis was formulated:

H2: Students with a higher migration-related risk, combining migration of parents and frequency German language is spoken at language as indicators, show lower strategy use and lower metacognitive knowledge.

RQ3. The extent to which primary school students differ in SRL strategy use and metacognitive knowledge due to learning difficulties (learning and attention disorders and need for homework support) was investigated. The following hypothesis was tested:

H3: Students with higher learning difficulties, combining learning and attention disorders and the need for homework support as indicators, show lower SRL strategy use and lower metacognitive knowledge.

Participants and Procedure

A total of 141 students from 2nd to 5th grade (age *M*= 9.9 years (SD = 1.25, *Min* = 7.3, *Max* = 13.3 (*N*=133); 53% female (*N*=137)) and their parents participated in the study. Participants were recruited throughout Germany via social media, newspapers and in addition via schools in the federal states of North Rhine-Westphalia and Hesse with informed parental consent was obtained for their own and their children's participation in the study. Families received a toy and book voucher for their participation. The data was collected completely online due to school closures and social distancing requirements during Covid-19 pandemic. Children participated in the study with their personal computers at home, with guidance provided by trained test administrators via telephone. The study was approved by an ethics committee prior to being conducted.

Instruments

In response to the substantial criticism regarding the validity of SRL assessment, particularly in the context of young students, we adopted a multi-method approach to comprehensively assess SRL and its components.

Self-regulated Learning Measures

SRL self-report. The students completed a self-report questionnaire (adapted from Blasiman et al., 2017) in which they indicated how often they use a set of ten different SRL strategies from the areas of metacognition, motivation, emotion-regulation and resource strategies. Short examples of two fictional characters who use a certain SRL strategy while learning were presented for each item as an introduction. Following these short scenarios, students were asked to rate how often they use each strategy by themselves on a 4-point-likert scale from 1= never to 4 = always (e.g. ‘Pauli and Toni make a plan before doing their

homework: they think about which tasks they have to do and when, how much time they need to complete them and which task they start with. How often do you make a plan for your homework?'). The internal consistency of the scale was moderate, McDonald's Omega Total (ωt) = 0.75.

SRL parent rating. Parents were asked to rate their children's use of SRL strategies during homework and learning at home (e.g. 'My child makes a schedule to help organize his or her study time') on a 5-point-likert scale questionnaire (1= never to 5= always). For this purpose the Self-Regulation Strategy Inventory: Parent Rating Scale (SRSI-PRS) (Chen et al., 2015) was adapted to the context of primary school students. Items related to learning for math were rephrased to the context of learning at home. To align with the structure of the other instruments utilized in this study, we incorporated three items from a questionnaire for assessing emotion regulation in children and adolescents (J. F. Greuel et al., 2018). These emotion regulation items were adjusted by including the context of 'while learning.' Additionally, three items that relate to SRL during the self-reflection phase of learning (Otto, 2007) were included to assess the whole SRL process as described earlier (Zimmerman, 2000). In total, the questionnaire consisted of 29 items. The questionnaire showed good reliability, McDonald's Omega Total (ωt) = .9.

Metacognitive knowledge. In addition, the NEPS declarative metacognition test for 3rd grade was used to assess students' strategy knowledge (Lockl, 2017). Students were presented with a series of ten scenarios in which a child faces realistic challenges in different school and out of school contexts (See Lockl (2017) for an example item). For each scenario, the students had to rate the usefulness of three approaches to deal with the situation, which differed in their quality on a three-point Likert scale. The possible approaches presented included the use of cognitive, metacognitive and resource-orientated strategies. To enhance understanding, each scenario and the three possible strategic approaches, were supplemented with illustrations. The scenario test is scored using paired comparisons based on expert judgment of the relative usefulness of the approaches presented. The scenario tests showed good reliability, McDonald's Omega Total (ωt) = .87.

Education-related Risks

Socio-economic status. To measure the parental socio-economic status, parent's profession and occupation were assessed. These variables were first coded according to ISCO 08 and afterwards transformed using the standard International Socio-Economic Index of

Occupational Status (ISEI) scale (Ganzeboom et al., 1992). The ISEI score serves as a measure that reflects an individual's position within an occupational hierarchy, while indirectly reflecting their educational attainment and income level (Connelly et al., 2016). The ISEI scale encompasses a broad range of occupations, spanning from agricultural laborers, such as farmers, to professionals like lawyers and scientists, and provides scores within the range of ten to 90 (Ganzeboom et al., 1992).

In addition to the ISEI, the highest level of parental education was assessed to provide more specific information on educational background. Educational background was then divided into parents with a tertiary education and parents without a tertiary education.

Based on these indicators, a combined score with scores ranging from 0 to 2 has been created from for further analysis (similar to Favre et al., 2023; Kassis et al., 2022). To do this, the ISEI was first divided into quintiles and children in the lowest quintile were coded as having a low family ISEI, while children in the middle three quintiles were coded as having a medium family ISEI and children in the highest quintile were coded as having a high family ISEI. Students with parents having a low ISEI and whose parents have no tertiary education were assigned a 2 in the combined SES score, which indicates a high SES risk factor. Students whose parents have tertiary education and also a high or medium ISEI score were coded to a 0 in the combined SES score, representing a low SES risk factor. The other children were assigned a 1 in the created SES score, indicating a SES medium risk factor.

Migration and language. To investigate migration- and language related disparities in young students' SRL, parents were asked whether the mother and the father were born in Germany. Based on this information, the participating children were divided into two groups (with and without any immigrant background), regardless of the child's place of birth. Children with at least one parent not born in Germany were assigned to the group with an immigrant background.

Another indicator of migration- and language-related risks was the frequency with which the test language (German) was spoken at home, as an indicator for bilingualism. Parents were asked how often German was spoken at home (1 = always to 4 = never). The participants were then divided into two groups, children who always or almost always speak German at home and children who sometimes or never speak German at home.

Based on previous discussion about the operationalization of migration status (Kemper et al., 2021) and since previous research has demonstrated that the impact of immigration on students educational trajectories is complex and that the parents' immigrant status is not

necessarily the influential factor, and in order to include overlaps in immigration status and the frequency with which German is spoken at home in the sample in the analyses, a new variable was created on the basis of these two variables which combines them into a joint score, ranging from 0 to 2. Students who have a migration background as described above and who also never or rarely speak German at home were coded with a 2 for a high migration and language related risk factor in this area. Students for whom only one of the two variables applied (either immigrant or never speaking German at home) were assigned a 1 in the new combine migration variable, indicating a medium risk factor. Students who often or always speak German at home and whose parents are not migrants were assigned a 0, representing a low risk in this area.

Learning and attentions disorder/ learning difficulties. Some parents indicated that their children had been diagnosed with a LD or ADHD. As not all children were formally tested for learning disorders, parents were additionally asked with three items how much support their child needs for homework (1 = never to 5 = always) (e.g. “How often does your child need help while completing their homework?” or “How often does your child need help with checking homework?”) (1 = never to 5 = always) as an indicator for difficulties in the context of learning. The questionnaire was adapted based on questions from studies on the COVID-19 pandemic and the involvement of parents in their childrens’ learning process during that time (Blume et al., 2021; Schmidt et al., 2021). The questionnaire showed good reliability, with McDonald's Omega Total (ωt) = .87.

As with the other two risk areas, a variable was created that combines the two variables and thus reflects overlaps and particular learning difficulties, ranging from 0 to 2. To this end needed homework support was recoded based on quantiles, and children were coded into low (lowest quantile), medium (middle three quantiles), and high (highest quantile) need for homework support. Based on that, students who showed both a diagnosed learning or attentions disorder and a high need for support with their homework were coded as 2 for a high learning difficulty risk factor, while children without a diagnosis and with low or moderate need for homework support were assigned a 0, indicating a low learning difficulty risk factor. The remaining students were coded with 1, as a medium learning difficulty risk factor. Although previous studies have often used several indicators (mostly IQ, performance and diagnoses) to form categories related to learning difficulties and disorders (Fischbach et al., 2013), the

approach of including a subjective assessment of difficulties with homework and forming a score based on these indicators is new.

Analyses

All statistical analyses were created in *R*, version 4.2.2. As a result of technical challenges during data collection, the data exhibited missing values that occurred completely at random. To address missing values in the SRL variables, multiple imputations were performed using multiple imputation by chained equations (MICE) algorithm with the *mice* package in R (van Buuren & Groothuis-Oudshoorn, 2011) generating 30 datasets with 10 iterations each to ensure stable estimates. Missing values in the variables for the education-related risk factors were not imputed. Imputing dichotomous variables, like Germany as country of birth, could have lead to distortions, affecting the authenticity of the data. Since these predictor variables were potentially not subject to random missingness, but rather a result of intentional non-response, we decided imputation would not be inappropriate for them. The cases with missing values in these variables were not included in the analyses of the corresponding risk factor, which leads to different numbers of cases in the following analyses. Cases, which included missings for all items of a variable, were not included in imputation process. To ensure the robustness of the results, we conducted sensitivity analyses comparing the results from the analysis and descriptive statistics of the scales from the imputed datasets with those from the complete cases, inspecting convergence diagnostics, and evaluating potential variations across imputations. In addition, the data was tested for outliers. Realistic outliers in the childrens' or parents' data were not excluded. Realistic outliers were defined as values exceeding two standard deviations from the mean without indicating systematic response patterns (e.g., consistently selecting the same response) or implausible data entries (e.g., an age of 100), representing natural variance, particularly in SRL measures."

Based on previous studies weak relations resp. small effects were assumed for the SES (Miech et al., 2001; Montroy et al., 2016; Sektnan et al., 2010), migration and parents education (Alivernini, Cavicchiolo, et al., 2019; Blom & Severiens, 2008), learning difficulties (Bergey et al., 2017) on self-regulation (in learning) and metacognitive knowledge. The most appropriate way of analysis would have been conclusive multiple regression models or moderation analysis including analysis of interaction effects.

However, post hoc power analyses showed that the sample was too small for multiple regression models that include all different indicators for risk for underachievement as

predictors. As a result, the combined risk scores were defined as described above and an approach was chosen in which several analyses were carried out for the three risk areas. This approach has implications and limitations which will be addressed in the discussion, but is intended to provide initial insights despite the small sample size. To take into account the potential of false discoveries among the results of the several tested models Benjamini-Hochberg procedure (Benjamini et al., 2009) as false discovery rate (FDR) approach was used to adjust the p-values in all analysis.

Results

Descriptive statistics for the different variables divided across the groups based on the single indicators for risks are presented in BII - Table 1 and also grouped based on the created combined risk scores in BII - Table 2. The parents came from a total of 22 different nations (including Germany), of which 13 were non-European.

BII - Table 1: *Descriptive statistics for SRL measures and demographics grouped by risk factors.*

	Parental Education		**Immigration Background**		**German Language at Home**		**Diagnosed Learning or Attention Disorder**	
	Tertiary education	**No tertiary education**	**No**	**Yes**	**Always / Nearly always**	**Sometimes / Never**	**No**	**Yes**
	***N*=90**	***N*=44**	**N=107**	**N=28**	***N*=122**	***N*=15**	***N*=82**	***N*=8**
N (%)								
Gender								
female	43 (47.8%)	26 (59.1%)	51 (47.7%)	18 (64.3%)	59 (48.4%)	11 (73.3%)	46 (56.1%)	3 (37.5%)
male	47 (52.2%)	18 (40.9%)	56 (52.3%)	10 (35.7%)	63 (51.6%)	4 (26.7%)	36 (43.9%)	5 (62.5%)
Age	9.82 (1.27)	10.0 (1.13)	9.97 (1.29)	9.74 (1.11)	9.94 (1.27)	9.76 (1.02)	10.1 (1.75)	10.1 (1.75)
M (SD)								
SRL Parent rating	2.64 (0.55)	2.72 (0.57)	2.61 (0.54)	2.92 (0.53)	2.63 (0.55)	2.90 (0.53)	2.72 (0.55)	2.38 (0.47)
SRL Self report	2.54 (0.43)	2.41 (0.41)	2.45 (0.41)	2.72 (0.45)	2.46 (0.42)	2.77 (0.42)	2.47 (0.40)	2.10 (0.16)
Metacognitive Knowledge	0.68 (0.20)	0.65 (0.22)	0.69 (0.20)	0.58 (0.21)	0.68 (0.21)	0.56 (0.17)	0.70 (0.19)	0.65 (0.15)
Needed Homework support	2.87 (1.03)	2.76 (0.96)	2.79 (1.00)	3.00 (0.99)	2.81 (1.01)	3.16 (0.91)	2.49 (0.92)	3.79 (0.78)
SES (ISEI 08)	60.6 (13.2)	47.8 (8.76)	55.6 (12.8)	60.7 (15.8)	56.7 (13.3)	55.2 (17.0)	54.4 (13.7)	62.6 (9.68)

Note. Table display N and percentage (%) in round brackets, retrospectively Means = *M*, and standard deviation = *SD* in round brackets

BII - Table 2: *Descriptive statistics for SRL measures and demographics grouped by risk Indices*

	Combined SES Score			**Combined Migration-related Risk Score**			**Combined Learning difficulties Score**		
	0	**1**	**2**	**0**	**1**	**2**	**0**	**1**	**2**
	N=70	***N=33***	***N=21***	***N=106***	***N=14***	***N=14***	***N=78***	***N=13***	***N=3***
Age	9.69 (1.31)	9.95 (1.19)	10.4 (1.03)	9.97 (1.29)	9.68 (1.20)	9.81 (1.04)	10.1 (1.16)	10.2 (1.31)	9.11 (2.46)
SRL strategy use – Parent rating	2.66 (0.56)	2.62 (0.50)	2.59 (0.58)	2.61 (0.54)	2.90 (0.54)	2.94 (0.53)	2.75 (0.55)	2.53 (0.46)	1.93 (0.16)
SRL strategy use – Selfreport	2.53 (0.44)	2.46 (0.40)	2.34 (0.39)	2.45 (0.41)	2.59 (0.51)	2.83 (0.36)	2.47 (0.40)	2.52 (0.45)	2.30 (.)
Metacognitive Knowledge	0.68 (0.20)	0.64 (0.19)	0.68 (0.22)	0.69 (0.20)	0.62 (0.25)	0.55 (0.17)	0.70 (0.19)	0.69 (0.17)	0.50 (.)

Note. Table display N and percentage (%) in round brackets, retrospectively Means = *M*, and standard deviation = *SD* in round brackets

Relationship Between Students' SRL and Risk Factors

BII Appendix - Table 1 reports the correlations among all assessed variables. Positive significant correlations were found between all three of the SRL-related measures: SRL strategy use rated by the parents, self-reported SRL strategy use and metacognitive knowledge (r = .19 - .35; p < .05). In addition, there were significant correlations between the different assessments for each risk factor. For example, we found a significant correlation between parental education and SES (r = -.45; p < .01), indicating that parents without a tertiary degree tend to have a lower SES. The correlation between the different indicator from one risk area support the approach to create combined scores for further analysis to investigate the combined influences of these. However, no significant correlations were found between the different risk factors (e.g. migration and SES).

Moreover, correlation analyses indicated significant relations between some of the risk factors and SRL strategy use and metacognitive knowledge, which were further analysed by means of regression.

Differences in Young Students' Use of SRL Strategies

The aim of the current study was to investigate how young students' SRL strategy use is related to three categories of risk factors for educational underachievement RQ1. socio-economic risks (SES and parental education); RQ2. migration-related risks (immigrant background and language); RQ3. developmental risks (learning and attention disorder and need for homework support). Despite the broad body of research showing that socio-economic variables, migration, frequency the national language is spoken at home and learning and attention difficulties have an impact on learning outcomes and academic achievement, the potential influence on young students' SRL, as a crucial basis for lifelong learning, has so far only been investigated to a limited extent. Consistent with previous research that has strengthened the age-related nature of SRL (Wesarg-Menzel et al., 2023) and previous findings indicating gender differences in SRL (Heirweg et al., 2019; Vandevelde et al., 2013) age and gender were added as covariates to all regression models. In order to capture potential non-linear relationships and group-specific differences that might not be evident in a linear approach the predictors were modeled as factors (low, medium or high risk factor) in the following regression analysis.

Differences in Students' SRL Related to Social-economic Status

To investigate the potential relationship of the SES and students' SRL strategy use and metacognitive knowledge, linear regression analyses were conducted for each SRL outcome variable. In these analyses, the combined SES score based on the ISEI and parental education, as described above, was used as a predictor. Age and gender were included as covariates.
The results revealed a small significant negative relationship between SES and SRL strategy use measured with the self-report. Compared to the reference group of students with a low SES risk factor, students in the high SES risk factor group showed significantly less use of SRL strategies (B = -0.26, 95% CI [-0.49, -0.03], $t(96)$ = -2.21, *adj. B-H* p = .05), while there was no significant effect found in the group of students with a medium SES risk factor compared to the reference group. However, SES did not show an effect on the parents' rating of students SRL strategy use or students metacognitive knowledge ($p > .05$) when age and gender were included as a covariates. BII Appendix - Table 2 provides an overview of the results.

Differences in Students' SRL Related to Migration and Language

Based on parents' immigrant background and the frequency German is spoken at home as reported by the parents as indicators for migration-related risks for students underachievement, a combined score variable was created as described above. Regression analysis were used to investigate the potential impact of this migration score on SRL strategy use and metacognitive knowledge. For SRL strategy use measured with students' self-report, linear regression analysis with age and gender as covariates indicated a statistically significant positive association with the combined migration-related risk score as factor variable. Contrary to our hypothesis, children with a higher migration-related risk score, scored significantly higher than the reference group of children with a lower migration risk score (B = 0.41, 95% CI [0.14, 0.68], t(105) = 2.98, adj. B-H p = .01). There was no significant effect found for the medium migration related risk factor. However, the regression analysis with students' metacognitive knowledge showed an opposite tendency but did not reveal a significant effect of the migration related risk (B = -0.13, 95% CI [-0.26, -3.25e-03], $t(105)$ = -2.03, *adj. B-H* p =.10) (see BII Appendix - Table 3 for detailed results).

Differences in Students' SRL Related to Learning Difficulties

To explore whether learning difficulties are associated with young learners' SRL, we investigated the relationship between the combined learning difficulties score as factor variable

and SRL strategy use and metacognitive knowledge assessed with the different measurements. There was no significant association found for learning difficulties with students' self-reported SRL strategy use ($p > .05$). Nevertheless, the regression analysis revealed a statistically significant negative association with SRL strategy use measured with the parent rating. Compared to the reference group of children with a low learning difficulty risk factor, parents of children with a high learning difficulty risk factor rated their childrens' SRL strategy use significant lower ($B = -0.74$, 95% CI[-1.37, -0.12], $t(80) = -2.36$, *adj. B-H* $p = .05$). There was no effect found related to the medium learning difficulty risk factor. However, we found no statistical significant association between students' metacognitive knowledge and learning difficulties ($p > .05$) (See BII Appendix - Table 4 for detailed results).

Discussion

There are several educational risk factors that can present barriers to students' learning and to their academic achievement. Whereas most research investigating these risk factors mainly tested in how far students' learning outcomes (such as their academic achievement) are related to being at risk, we need more understanding of the relationship between such risk factors and students' learning *behavior* (such as their SRL). The present study aimed to shed light on the relationship between young students' SRL and various risk factors for educational underachievement. Our multi-method approach enabled us to consider various facets of SRL.

The first research question addressed differences in students' SRL based on SES, with parents' occupation and parental education as indicators. The analyses showed a significant relationship between students' SRL measured with the self-report and their families' SES. Students with a lower combined SES score rated their SRL strategy use lower in the self-report, while there was no relationship between SES and students' SRL strategy use rated by parents or metacognitive knowledge. These findings therefore only partially confirm our hypothesis and agree limited with the with previous research on the relationship between SES, maternal education and SRL (e.g. Vandevelde et al., 2017) or pre-schoolers behavior regulation (e.g. Sektnan et al., 2010). The absence of a significant relationship between SES, and two of the three SRL measurements suggests that other factors, not captured in this study, may play a more prominent role in influencing young learners' SRL. This raises the question of how relevant common measures, such as SES are to students' SRL, and whether more specific measures might be more appropriate. For example, besides typical measures like income and SES, families' background seems to be linked to their educational expenses as well as to parenting

styles (Anger & Plünnecke, 2021). These in turn could also have an influence on the development of learners' SRL. Previous research investigating parental behavior related to the self-regulation of young children, and in particular to behavior-regulation and SRL in primary school children (e.g. Pino-Pasternak & Whitebread, 2010), provides first insights into the potential to explore this relations specifically in the context of SRL as well.

Related to the second research question regarding differences based on migration related risks, contrary to our hypothesis, students with a higher migration-related risk, with immigration background and the frequency German is spoken at home, showed higher scores in the self-reported SRL strategy use. These results are in line with previous research demonstrating both lower and higher SRL in students with an immigration background compared to their peers (e.g. Blom & Severiens, 2008; Neubauer et al., 2014; Vandevelde et al., 2017). The differences found in SRL strategy use and metacognitive knowledge in this study and previous research related to immigration, may be traced back to the value of behavioral regulation in societies, culture specific parenting practices, childrens' general role in society or immigrant students' underlying motivational beliefs (Wanless, McClellan (Blom & Severiens, 2008)d, Acock, et al., 2011), which have to be investigated further.

Another potential reason for the inconsistent findings in this study could relate to SRL measurement. Overall, SRL research in recent years has increasingly criticized validity of both self-reports and adult rating (McCoy, 2019; Veenman, 2011), and the question arises as to what extend these methods are dependent on culture and language and if these instrument possibly measure different cultural-dependent concepts. In addition, previous research suggests that learners tend to overestimate their SRL in self-reports (e.g. Boekaerts & Corno, 2005; Cromley & Azevedo, 2007). Even if several studies highlight the academic disadvantages of students with immigrant background, some studies suggest that these students are often optimistic but incoherent when they assess their own performance, self-efficacy and self-expectations (Hornstra et al., 2013). However, the contrary findings can also be due to ambitious educational goals and a special optimism of immigrant families (Heath & Brinbaum, 2007), that may have a positive effect on SRL of learners with an immigration background. Moreover, the contradictory findings indicate that the mere operationalization of immigration background based on the parents' origin is no longer a sufficient measure. Transmigration is becoming increasingly common and the origins are diverse, involving different cultural influences that could also have an impact on the relevance and the support of SRL within families. Studies

investigating differences in academic achievement have indicated that the challenges that education poses to learners differ between immigrant groups and that not all groups are equally affected (Brinbaum & Heath, 2014).

Related to the third research question, differences in students' SRL were investigated based on developmental risks, with learning and attention disorders and needed homework support as indicators. The analyses showed that students with higher learning difficulties had significant lower SRL in the parent rating. These findings are in line with previous research showing a negative association of learning and attention disorders with SRL strategy use (e.g. Mason & Reid, 2018), but only confirm our hypothesis with one of the SRL measures. However this finding also support previous finding with studies assessing students SRL deficits related to other indicators for learning difficulties besides clinical diagnoses (e.g. Bergey et al., 2017) and take into account the critique on current LD definitions (Büttner & Hasselhorn, 2011).

The regression analyses using factor variables for the risk factors revealed that particularly children with high risk scores in the three areas (SES, migration and language, learning difficulties), who are affected by both indicators, showed significant associations with SRL. In contrast, children with medium risk scores, affected by only one of the indicators, did not show significant effects, highlighting the need for further investigation of these groups in future studies.

Limitation and Future Directions

The findings of this study should be interpreted within the context of several limitations. Firstly, the sample size was relatively small, which may limit the generalizability of the discussed relationships between risk factors for academic underachievement and young students SRL. Based on the sample size and the assumption that the effects tend to be relatively small, a multitude of models were analyzed which could have led to alpha inflation.

Secondly, this study recruited families online, leading to a convenience sample and the possibility of selection bias. Additionally, the investigated groups varied in size, with only a few children exhibiting the specific risk factors, especially being diagnosed with LD or ADHD. The small sample size of participants, particularly those with a diagnosis of LD/ADHD, may have limited the power to detect notable effects of learning disorders on SRL. These factors should be considered when interpreting the implications of this research, highlighting the need for larger, more diverse samples in future investigations. In addition, the various series of risks for educational underachievement were assessed using established but very simplified

measures. Therefore, future studies with a larger sample size should examine, for example, more precise socio-economic and cultural background variables, values and educational styles in addition to the simplified measure used in this study.

Additionally, the cross-sectional design of this study limits the ability to draw causal inferences, especially the development of SRL related to risk factors. Moreover, the study was conducted during the pandemic, which may have influenced students' SRL and thus limits the generalizability of the findings. Further research on inter-individual differences in students' SRL is needed, given that the various benefits of this important skill have been established throughout years of research.

Since SES and parental education had limited explanatory value, research would be of interest that is more closely orientated to childrens' environments and examines the connections between learners' SRL and, for example, parenting style, given autonomy and agency, hobbies or parents' time resources as underlying mechanisms influencing academic achievement and also SRL. This study did not assess these indicators or the socio-cultural status as assessed, for example, in international school performance studies (Lewalter et al., 2023). These background variables would be of particular interest for future research.

In order to continue researching the above-mentioned differences in relation to students' immigration background, special attention should be paid to the assessment of SRL. In addition to a precise examination of cultural dependency in SRL measurements, such as questionnaires, methods that assess students' actual SRL strategy use during task processing in a cultural and language independent way should be developed, validated and included in future research investigating inter-individual differences in SRL. Moreover, to make the actual underlying mechanism related to immigration background visible, future research should investigate the relevance of SRL in culture, students' motivational beliefs related to diverse cultures or also parents perceived value of SRL in that context. Additionally, exploring the interplay between language, SRL, and metacognitive knowledge — including the language used in students' private speech — could provide valuable insights into inter-individual differences.

In particular, SRL strategy use and metacognitive knowledge has been insufficiently investigated in children with learning disorders and ADHD. Our study gives first insights of SRL deficits of students with learning and attention disorders and student who need more support during homework. However, there is a lack of meta-analyses addressing the specific deficits of learners with learning and attention disorder in for example SRL strategy use, self-

efficacy and utility beliefs regarding SRL and metacognitive knowledge. Especially in the context of students with learning difficulties, empirical research on SRL with task-related assessment methods such as observations, think aloud or trace data would be useful to avoid bias. Moreover, the multifaceted relationship between required homework support, learning difficulties, and students' SRL should be further investigated, along with additional indicators of learning difficulties and their impact on SRL.

Furthermore, based on previous research on the relationship between risk factors, SRL strategy use and metacognitive knowledge, it could be of interest whether there are certain SRL aspects in which children at risk show deficits. Research on the different strategy areas (metacognition, cognition, motivation- and emotion-regulation) could be informative. A limitation of this study is that we did not assess the adaptive use or quality of SRL strategy use. While these aspects are crucial for a comprehensive understanding of SRL, research in this area remains limited, highlighting the need for further studies to explore these aspects and potential differences in students in greater depth.

Based on these results, specific trainings could be developed for students with learning difficulties. In particular, it is necessary to recognize young learners in order to equalize possible differences in educational opportunities based on risk factors for underachievement and to empower students’ at risk to become self-regulated learners as early as possible.

Conclusion

The findings of this study underline the complexity of the diverse influences on students’ SRL and call for further investigation to uncover additional contributing factors that may explain differences in young learners’ SRL strategy use. With the multi-method approach to assess the complex construct of SRL from different perspectives, this study shows that various risk factors for educational underachievement are related to the SRL. It was found that students at risk show SRL deficits in some areas whereas some risk factors for academic underachievement are not related to young students SRL or, in the case of immigrant background, are even related to a greater SRL strategy use. In the context of the widely researched links between SRL and academic achievement, SRL can also be seen as a protective factor that could reduce existing disadvantages through early promotion of SRL among students at risk. Therefore, the study once again reinforces the need to promote SRL in the classroom.

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BII Appendix

BII Appendix - Table 1: *Means, standard deviations, and correlations with confidence intervals*

Variable	*M*	*SD*	1	2	3	4	5	6	7	8	9
1. SRL parent rating	2.67	0.55									
2. SRL self-report	2.50	0.43	.35** [.18, .50]								
3. Metacognitive knowledge	0.67	0.20	.23* [.05, .40]	.19* [.00, .35]							
4. ISEI 08	56.56	13.34	.01 [-.17, .19]	.05 [-.14, .24]	.10 [-.09, .29]						
5. Parents Education *(0 = tertiary education)*			.07 [-.10, .24]	-.15 [-.33, .03]	-.05 [-.24, .13]	-.45** [-.58, -.29]					
6. Immigration Background *(0 = no immigrant background)*			.23** [.06, .38]	.25** [.07, .41]	-.21* [-.38, -.03]	.14 [-.04, .31]	-.10 [-.27, .07]				
7. German Language at Home *(0 = always/ nearly always)*			.15 [-.01, .31]	.23* [.05, .39]	-.19* [-.36, -.01]	-.03 [-.20, .15]	-.01 [-.18, .16]	.66** [.56, .75]			
8. Diagnosed Learning Difficulty			-.18	-.21	-.06	.17	-.04	-.12	-.10		

(0 = no diagnose)			[-.37, .03]	[-.42, .02]	[-.28, .18]	[-.05, .37]	[-.25, .16]	[-.32, .09]	[-.30, .11]			
9. Needed Homework support	2.85	1.00	-.49** [-.61, -.36]	-.13 [-.30, .06]	-.24** [-.41, -.06]	.13 [-.05, .30]	-.05 [-.22, .12]	.09 [-.08, .25]	.11 [-.06, .27]	.38** [.19, .54]		
10. Gender *(0 = female)*			-.21* [-.36, -.04]	-.02 [-.20, .17]	-.11 [-.28, .08]	.19* [.01, .35]	-.11 [-.27, .06]	-.13 [-.30, .03]	-.16 [-.32, .01]	.11 [-.10, .31]	.21* [.05, .37]	
11. Age	9.92	1.25	.13 [-.04, .29]	.23* [.04, .40]	.30** [.12, .46]	-.16 [-.33, .02]	.09 [-.08, .26]	-.07 [-.24, .10]	-.04 [-.21, .13]	.01 [-.20, .22]	-.19* [-.35, -.02]	.12 [-.05, .28]

Note. *M* and *SD* are used to represent mean and standard deviation, respectively. Values in square brackets indicate the 95% confidence interval for each correlation. The confidence interval is a plausible range of population correlations that could have caused the sample correlation (Cumming, 2014). * indicates $p < .05$. ** indicates $p < .01$.

BII Appendix - Table 2: *Separate linear Regression Analysis with the combined SES Score as Factor Variable as Predictor and different SRL measures as outcome*

	SRL parent rating					***SRL self-rating***					***Metacognitive knowledge***				
Outcome variable	***B***	***Std. Error***	***t-value***	***adj. B-H p***		***B***	***Std. Error***	***t-value***	***adj. B-H p***		***B***	***Std. Error***	***t-value***	***adj. B-H p***	
Intercept	1.99	0.401	5.01	.00		1.78	0.334	5.27	.00		0.22	0.157	1.41	.27	
SES (medium risk factor)	-0.07	0.116	-0.59	.55		-0.10	0.097	-1.07	.36		-0.04	0.046	-0.93	.41	
SES (high risk factor)	-0.19	0.141	-1.33	.23		-0.26	0.118	-2.21	.05*		-0.05	0.056	-0.82	.41	
Age	0.08	0.041	2.03	.07		0.08	0.034	2.46	.04*		0.05	0.016	3.19	.01**	
Gender (0 = female)	-0.23	0.101	-2.24	.07		-0.05	0.084	-0.65	.52		-0.07	0.040	-1.85	.17	
				Adj. R^2	.04					***Adj. R^2***	.05				***Adj. R^2*** .09

Note. SRL = self-regulation of learning. *p < .05. **p < .01. ***p < .001.

BII Appendix - Table 3: *Separate linear Regression Analysis with the combined Migration Score as Factor Variable as Predictor and different SRL measures as outcome*

	SRL parent rating					***SRL self-rating***					***Metacognitive knowledge***				
Outcome variable	***B***	***Std. Error***	***t-value***	***adj. B-H p***		***B***	***Std. Error***	***t-value***	***adj. B-H p***		***B***	***Std. Error***	***t-value***	***adj. B-H p***	
Intercept	2.00	0.376	5.33	.00		1.62	0.316	5.13	.00		0.23	0.150	1.51	.16	
Migration (medium risk factor)	0.28	0.152	1.84	.07		0.16	0.131	1.20	.29		-0.06	0.062	-0.89	.38	
Migration (high risk factor)	0.30	0.164	1.84	.07		0.41	0.138	2.98	.01**		-0.13	0.065	-2.03	.10	
Age	0.07	0.038	1.95	.07		0.08	0.032	2.68	.01**		0.05	0.015	3.35	.005**	
Gender (0 = female)	-0.22	0.095	-2.32	.05*		-0.02	0.079	-0.19	.85		-0.07	0.038	-1.89	.10	
					Adj. R^2 .08					***Adj. R^2*** .1					***Adj. R^2*** .12

Note. SRL = self-regulation of learning. *p < .05. **p < .01. ***p < .001.

BII Appendix - Table 4: *Separate linear Regression Analysis with the Combined Learning Difficulties Score as Factor Variable as Predictor and different SRL measures as outcome*

	SRL parent rating				***SRL self-rating***				***Metacogintive Knowledge***			
Outcome variable	***B***	***Std. Error***	***t-value***	***adj. B-H p***	***B***	***Std. Error***	***t-value***	***adj. B-H p***	***B***	***Std. Error***	***t-value***	***adj. B-H p***
Intercept	2.09	0.477	4.37	.00	1.75	0.440	3.97	.00	0.21	0.195	1.05	.61
Learning Difficulties (medium risk factor)	-027	0.173	-1.55	.17	0.003	0.164	0.02	.98	0.05	0.072	0.70	.61
Learning Difficulties (high risk factor)	-0.74	0.316	-2.36	.05*	0.04	0.434	0.10	.98	-0.07	0.192	-0.39	.70
Age	0.07	0.047	1.51	.17	0.07	0.042	1.62	.27	0.05	0.019	2.65	.05*
Gender (0 = female)	-0.0	0.116	-0.78	.43	0.01	0.100	0.14	.98	-0.03	0.044	-0.77	.61
				Adj. R^2 .09				**Adj. R^2** -0.01				**Adj. R^2** .07

Note. SRL = self-regulation of learning. *p < .05. **p < .01. ***p < .001.

6.3 Weiterführende Analysen (Beitrag III): Take a deep Breath or scream it all out: Emotion Regulation Strategies of Young Learners.

van Berk, B. & Dignath, C. (2025): Take a deep Breath or scream it all out: Emotion Regulation Strategies of Young Learners. [Manuskript unter Begutachtung bei *Learning and Instruction*]

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Beiträge der Autorinnen zu der Publikation:

Bernadette van Berk: Konzeption und Design der Studie, Literaturrecherche, Datenerhebung, Datenanalyse, Interpretation der Ergebnisse, Schreiben des Manuskripts, Überarbeitungen im Reviewprozess

Charlotte Dignath: Einwerbung von Forschungsfördermitteln, Konzeption und Design der Studie, Überprüfung und Feedback, Korrekturlesen und Endredaktion

Abstract

Background. Emotion regulation (ER) is a critical component of effective self-regulated learning (SRL), which has been increasingly researched in the last decades. However, there is still insufficient empirical research on emotions and emotion regulation in early years of schooling.

Aims. This study aims to identify ER strategies of young learners, assess different ER measures, and investigate variables that explain variation in ER.

Sample. 82 primary school students aged from 7 to 12 years (*M*=10.16 (*SD*=1.24); 51% female) and their parents participated in the study.

Method. To gain deep insights into young students' ER in achievement situations, a multi-method approach was applied. In a semi-structured interview, students were asked to report their approach when facing negative emotions, low motivation or low concentration during learning. In addition, students' think-aloud during a problem-solving task, their ER self-report and their parents' rating about ER was assessed.

Results. Results highlight the different nature of the various ER assessment methods that measure different aspects of ER. Moreover, findings suggest that elementary school students use a range of ER strategies depending on the contexts. Furthermore, students' expectancy and value beliefs regarding ER strategy use were associated with ER strategy use measured with the interview and reported in self-ratings.

Conclusion. This study offers valuable insights into how young learners regulate their negative emotions during learning, highlighting the importance of understanding factors influencing ER in young learners and why some students may not engage in ER strategies during learning. By emphasizing the need for multi-method approaches and intentional use of specific ER assessment methods beyond traditional questionnaires, the study advances the field, offering a more nuanced understanding of young learners' ER processes within the SRL context.

Introduction

A rapidly developing body of research has empirically demonstrated the importance of emotions, particularly achievement emotions, in academic performance and suggests a bidirectional link between emotions and learning performance (Camacho-Morles et al., 2021; Pekrun & Linnenbrink-Garcia, 2014).

The idea of the 'always-happy student' seems to address many educational challenges and suggests that maintaining constant positive emotional states would automatically enhance performance. However, this impression is misleading, as students unavoidably encounter negative emotions in their learning pathways (Pekrun & Linnenbrink-Garcia, 2014). Therefore, the aim of the educational system and society should rather be, to foster children and adolescent become individuals who are able to regulate emotions actively and effectively in order to control their learning process. In particular, negative emotions seem to be negatively related to academic performance (Camacho-Morles et al., 2021), hence it seems relevant to consider the regulation of these emotions in the context of learning.

Emotion regulation (ER) describes monitoring, controlling, and adjusting emotions, enabling adaptation to situations and goal achievement (Gross & Thompson, 2007). Beyond the impact of emotions on learning, research has also demonstrated that ER positively affects academic performance (Wong et al., 2023).

In contrast to the emergence and impact of emotions, especially achievement emotions, the factors that may explain differences in learners ER are poorly understood. In particular, there is a paucity of research examining the ER in elementary school students (Gullone & Taffe, 2012) and attempting to explain why some children do not use ER strategies in learning. Moreover, emotion regulation assessment primarily relies on self-reports, with limited research utilizing multi-method approaches (Ng et al., 2022; Zeman et al., 2007).

Drawing on the Integrated Model of Emotion Regulation in Achievement Situations (ERAS) (Harley et al., 2019) and on research on self-regulated learning (SRL), this study aims to provide in-depth insights into young learners' use of different ER strategies to regulate negative emotions during learning, which could be obtained through multi-method assessment. In addition, the study aims to explore expectancy and value beliefs regarding ER strategies as possible factors influencing young students' ER from an expectancy-value theory perspective (Wigfield & Eccles, 2000).

Theoretical Background

Achievement Emotions

Over the last decades, research has theoretically elaborated and empirically demonstrated the important impact of emotions on learning processes, academic achievement and educational trajectories (Camacho-Morles et al., 2021; Pekrun & Linnenbrink-Garcia, 2014). Although learning is often described as a highly cognitive process, it is fundamentally intertwined with emotions, which both influence and are influenced by academic performance and achievement outcomes (Lichtenfeld et al., 2023; Pekrun & Linnenbrink-Garcia, 2014). In order to emphasize the impact of emotions and the need to regulate negative emotions in particular, the definition of emotions, especially achievement emotions and their influence on learning will be briefly discussed.

Emotions can be defined as positive or negative affective states, caused by specific events (Gross, 2015). In relation to variations in the individuals' experience, behavior, and peripheral physiology, emotions develop over time depending on the situational context, the individuals' attention, their subjective appraiseal and response (Gross, 2015; Scherer & Moors, 2019).

Achievement emotions are defined as emotions which are specifically related to achievement situations (Pekrun, 2006) and emerge as response to evaluations of activities based on competence standards or (perceived) success or failure in academic performance (Pekrun, Marsh, Elliot, et al., 2023). While earlier research focused primarily on *outcome emotions*, which are related to the (perceived) outcomes of achievement activities, such as anxiety related to an upcoming test, more recent research also takes into account *activity emotions*, like enjoyment and boredom, related to the ongoing achievement activity itself (Pekrun et al., 2009; Pekrun, Marsh, Elliot, et al., 2023). Achievement emotions can be distinguished based on their valence (positive vs. negative), arousal (activating vs. deactivating), object focus (activity- vs. outcome-related) and time frame (retrospective, actual or prospective) (Pekrun, Marsh, Elliot, et al., 2023). Based on these dimensions, different groups of emotions can be classified (Pekrun, 2006; Pekrun, Marsh, Elliot, et al., 2023). Valence describes the pleasantness of emotions, while arousal refers to the physiological activation associated with the emotion, object focus denotes the target to which the emotional experience pertains and time frame the temporal dimension to which the emotion refer to (Pekrun, Marsh, Elliot, et al., 2023).

An example for an activating, pleasant (positive) achievement emotion is enjoyment, while an inactivating, unpleasant (negative) achievement emotion represents boredom (Lichtenfeld et al., 2023). Both, enjoyment and boredom are categorized as activity emotions relating to an ongoing achievement activity as object focus. In contrast anxiety is seen as an unpleasant, but activating achievement emotion related to the outcome of an achievement situation (Lichtenfeld et al., 2023). However, these grouped achievement emotions, like general emotions as well, cannot always be clearly distinguished from one another and are rather considered as broad categories that represent a range of gradually differentiated emotions (Barrett, 2017; Pekrun, Marsh, Elliot, et al., 2023).Previous empirical studies have already repeatedly demonstrated a clear relationship between emotions and academic achievement. A recent meta-analysis has strengthened the relevance of achievement emotions in the context of learning by showing a moderate positive correlation between enjoyment ($\rho = .27$) and achievement and a negative association between negative achievement emotions, such as anger ($\rho = -.35$) or boredom ($\rho = -.25$) and academic performance (Camacho-Morles et al., 2021). Longitudinal studies indicate that there are age-related changes in achievement emotions, with pleasant achievement emotions such as enjoyment decreasing, while boredom increases or remains stable with increasing grade level across elementary and early secondary school (Lichtenfeld et al., 2023; Vierhaus et al., 2016). In addition, empirical evidence suggests that achievement emotions differ by gender, with females reporting more negative achievement emotions, such as boredom and anxiety, than males (Lohbeck et al., 2016; Pekrun et al., 2011; Pekrun, Marsh, Suessenbach, et al., 2023). However, in addition to momentary achievement emotions, affective states that occur prior to the actual learning process (e.g., frustration at having to do homework when one really wants to play), trait-like achievement emotions (e.g., math anxiety), or emotions not related to learning (e.g., sadness over a fight with a friend), also influence students' learning experience. Negative emotions, such as anger or anxiety, affect learning performance by distracting learners, limiting their cognitive capacity to process information and reduce motivation, focus, and attention (Zeidner, 2007).

The theoretical background on achievement emotions and previous empirical findings highlight the relevance of regulating achievement emotions that interfere with learning, especially negative achievement emotions. Based on this assumption, and empirical studies showing that ER has an impact on the learning process and academic success (Wong et al., 2023), the current study focuses on the identification of ER strategy use in young learners rather

than evaluating their effectiveness in altering emotional experiences or the impact of emotions. Focusing on ER therefore has the potential to provide valuable insights into a key process that significantly influences learning and performance.

Emotion within Self-Regulated Learning

Self-regulated learning (SRL) refers to the process by which individuals actively regulate their cognition, behavior and motivational-affective processes to achieve goals in achievement situations (Zimmerman, 2000). Most SRL models describe SRL as a process comprising several interrelated phases (Pintrich, 2000; Winne & Hadwin, 2013; Zimmerman, 2000). To regulate their learning approach, learners use a variety of cognitive, motivational, metacognitive and resource-orientated strategies (Pintrich, 2000). When necessary, students adapt their behavior or cognition to achieve their goals and optimize their outcomes (Winne & Hadwin, 2013). ER in achievement situations can be embedded in the overall context of SRL and existing SRL models, as ER also involves students' regulation of a specific area (Emotion) towards an academic goal (e.g. keep on doing homework).

Some SRL theories (Ben-Eliyahu, 2019; Boekaerts, 2007; Efklides, 2011) and empirical studies (Ben-Eliyahu & Linnenbrink-Garcia, 2013; Zheng et al., 2023) already incorporate the relevance of emotions in the SRL processes and the need to recognize and regulate emotions during learning. According to this, emotions are not only a product of learning processes, but also both an inherent component that influences the learning process and outcomes, and a distinct target within the SRL process (Ben-Eliyahu, 2019; Efklides, 2011). As an influential factor, emotions have an impact on motivation, effort, metacognitive behavior, and learners' interaction with a task (Boekaerts, 2007; Efklides, 2011).

In addition to influencing learners' academic achievement, emotions themselves are a target in the SRL process. Targeting emotions within the SRL process involves *metaemotion*, defined as regulation of emotional experience with cognitive, emotion-regulative, behavioral, and even somatic and motivational strategies and processes, on the one hand, as well as the awareness and knowledge of emotions on the other hand (Ben-Eliyahu, 2019). Embedded in the SRL process, during the forethought phase of the SRL cycle, learners set goals to attain or maintain pleasant emotions such as pride and joy, or prevent negative emotions such as anxiety. The following performance phase includes learners' awareness of their emotions, and their

active adaptation with different regulation strategies, and finally during the self-reflection phase of the SRL process the emotion-regulatory process is evaluated.

The various areas of SRL and SRL strategies cannot always be clearly assigned to just one particular aspect of SRL, but rather partly interact or influence each other. Even though emotions and motivation are distinct concepts that also involve specific regulatory strategies, there exist strong links between these two concepts in particular (Pekrun, 2006, 2021; Villar et al., 2024). For example, emotions can influence students' interest and motivation for learning (Pekrun, 2006) and motivational self-regulation has an impact on emotions experienced by learners (Villar et al., 2024). In particular, negative emotions can impair motivation and concentration for learning (Wong et al., 2023).

When considering emotions as a target within the SRL process, different ER strategies can be used to maintain or induce pleasant emotions before, during, or after learning.

Emotion Regulation in Achievement Situations

The Integrated Model of Emotion Regulation in Achievement Situations (ERAS) (Harley et al., 2019) combines two prominent theoretical frameworks in the field of achievement emotions and ER to describe the emotion-generating process and the adaptive regulation of emotions in academic achievement situations. By comprehensively representing ER across academic contexts, the ERAS model offers a strong theoretical foundation for the current study and the potential to expand the theoretical model to include factors potentially influencing ER.

Within the model the emotion generative process and the related ER is described in four phasesn: 1. situation, 2. attention, 3. appraisal, and 4. response.

First, the *achievement situations* may differ in terms of how evaluative they are and the setting in which they occur (individual vs. social).

The emotional response related to the specific situation can influence the second phase, students' *attention*. Students' attention is shaped by two core features of the emotion generative process: object focus and time frame. Learners' can therefore either focus on the achievement actifity itself or on the outcome (object focus) and direct their attention to prospective, concurrent,or retrospective activity or outcome (time frame). Students' attentional focus in achievement situations strongly influences the emergence of emotions.

Following the attention phase, the Control-Value Theory of Achievement Emotions (CVT; Pekrun, 2006) is incorporated as theory and a third phase, the *appraisal* phase, in the

ERAS model. It describes two distinct subjective appraisals that impact the occurrence of emotions in achievement situations. Within the CVT model, *control* is defined as the learners' appraisal of their ability to influence the learning outcome or performance through self-directed action. *Value*describes the appraisal of the usefulness or importance of the outcome or achievement activity itself.

As fourth phase the ERAS model describes the emotional *response* including the above described different achievement emotions. The three different phases situation, attention and appraisal within the emotion generative process shape the emotional response, while this response also impact the three phases before.

Related to these four phases of the emotion generative process, situation, attention, appraisal and response, the ERAS model proposes the use of different ER strategies.

As a theoretical foundation, the ERAS model embedded different ER processes as defined by Gross (1998, 2015), each of which serves different functions in addressing and regulating emotional experiences during the development of emotions in achievement situations. ER is generally defined as the monitoring, control or modification of internal and external factors to alter emotional arousal in order to adapt to situations and achieve goals (Gross & Thompson, 2007).

Gross (1998, 2015) categorized ER processes into five different areas within the emotion generative process. In this way, the model describes the potential to alter an emotional trajectory by intervening at different points in the generative process and enables a more nuanced view of the ER strategy use investigated in this study. *Situation selection* involves choosing or avoiding situations to manage emotions, such as selecting the best time for homework to increase enjoyment. *Situation modification* involves adapting the current situation to lessen emotional impact, like using SRL strategies while studying to reduce anxiety. Not all situations allow for selection or modification, especially for young learners in classrooms or exams. *Attentional deployment* is used to focus on specific aspects of a situation to manage emotions. *Cognitive change* involves reinterpreting situations to control emotions, like using reappraisal or normalizing making mistakes. *Response modulation* addresses the physiological and behavioral effects of emotions through techniques like relaxation or deep breathing. These strategies help regulate the intensity, quality, or duration of emotions to achieve goals. While in the situation phase of the ERAS model, situation selection and situation modification

represent core ER strategies, attention deployment is proposed as an effective strategy in the attention phase of the emotion generative process. In the phase of appraisal, cognitive change is described as a key ER strategy and lastly in the phase of emotional response, strategies from the area of response modulation come into play.

Not all ER strategies are useful for both regulating emotions and achieving goals. Some may regulate emotions but ignore achievement goals. Therefore, ER strategies can be categorized into maladaptive strategies, like avoidance, and adaptive, problem-oriented ones. In line, empirical research shows that some strategies are more effective, with cognitive change being superior and emotional suppression among the least effective (John & Gross, 2004). Research with elementary students suggests that ER strategies have different short- and long-term effects, with cognitive change regulating current emotions but not necessarily leading to long-term well-being (Somerville & Whitebread, 2019).

In the context of emotional socialization within the school environment, ER progresses from being co-regulated to increasingly self-regulated (Valiente et al., 2020). Moreover, the use of adaptive ER strategies increases with age during elementary school and the use of maladaptive ER strategies decreases (Vierhaus et al., 2016). However, the age-related development is not conclusive, indicating a linear development for some ER-strategies and non-linear patterns for others (Santos et al., 2021). The use of adaptive ER strategies increases with age, although some studies show a temporary decline in adolescence (Zimmermann & Iwanski, 2014).Some studies suggest that males and females differ in their ER, with females using more social support seeking ER strategies, while males tend to use more suppression (Gullone et al., 2010; Vierhaus et al., 2016; Zimmermann & Iwanski, 2014). However, some studies indicate no age and gender interaction related to ER (Santos et al., 2021; Zimmermann & Iwanski, 2014).

In addition to age and gender, previous research has focused on neurobiological and environmental factors influencing ER and its development, especially highlighting the relevance of the family environment and the role of parents in the development of ER (Morris et al., 2007; Sabatier et al., 2017).

Research using qualitative approaches has shown that students from elementary school to university apply a variety of strategies (Somerville & Whitebread, 2019; Webster & Hadwin, 2015; Yang & Zhao, 2024). Some studies have shown that strategies from the area of cognitive change, for example, are used less frequently by both elementary and older students than for

example situation modification (Somerville & Whitebread, 2019; Webster & Hadwin, 2015). However, ER is argued to be adaptive based on a complex interplay between personal factors (e.g., age, gender, personality, and acculturation), situational contexts (e.g. type and intensity of emotion, and social context), and the diverse chosen strategies (Doré et al., 2016).

Despite the increasing research on ER, the assessment of ER is still mainly based on questionnaires, especially in middle childhood, and often measures general ER ability, considering ER to be a relatively stable trait, which tends to be relative consistent across situations (Ng et al., 2022; Zeman et al., 2007). However, the validity of self-report questionnaires in particular for assessing the use of regulatory strategies has been increasingly criticized, and there is a lack of studies to date that also use and compare other methods for assessing ER (Ng et al., 2022; Waters & Thompson, 2014; Zeman et al., 2007). While some studies indicate a weak relation between self-reports and ER rating of adults, there is currently limited evidence regarding the relation of ER subscales in common observational methods and other assessment methods (Ng et al., 2022).

In addition, while research on ER in achievement contexts increasingly examines early childhood (Sarfaty & Ben-Eliyahu, 2023), studies focusing on middle childhood remain limited, and previous research often concentrate on adolescents, university students, or non-academic contexts such as pre-school environments (Gullone & Taffe, 2012).

While the ERAS model (Harley et al., 2019) and previous research described above provide a theoretical and empirical basis for explaining the development of achievement emotions and the ER within this process, there is a lack of research on potential explanatory factors that influence the use of ER strategies.

Expectancy-value theory (EVT) (Wigfield & Eccles, 2000), which is used in many contexts to investigate the impact of underlying beliefs on individuals' motivation for achievement-related choices and performance (Eccles & Wigfield, 2020), could also provide an insightful theoretical basis to explore influences on students' choice to use ER strategies. Within this theory, the concept of *expectancy beliefs* describes learners' beliefs in how well they will perform a specific task (Wigfield & Eccles, 2000). *Value beliefs* describe individuals' convictions regarding the importance and usefulness of performing a task or showing a certain behavior (Wigfield & Eccles, 2000).

While the above described CVT (Pekrun, 2006), which is integrated in the ERAS model (Harley et al., 2019), focuses on the explanation of the development of emotions, the EVT (Wigfield & Eccles, 2000) aims to explain motivation for a certain behavior and therefore can be applied to investigate students' motivation to apply ER strategies during learning. Nevertheless, both theories, EVT and CVT, share some structural similarities regarding theoretical concepts of self-beliefs and generalized outcome expectancies in their theoretical models and ground on the same theoretical history (Marsh et al., 2019).

Based on EVT theory (Wigfield & Eccles, 2000), it can be argued that specific expectancy beliefs in how well oneself can perform ER strategies and value beliefs regarding the value to apply ER strategies during learning potentially have an impact on students' motivation and choice to actually use these ER strategies when facing emotions in achievement situations. Even though a few studies have already explored young students' perceptions of the effectiveness of ER strategies (Waters & Thompson, 2014), research examining the associations between young learners' expectancy and value beliefs about ER strategies and their use of these strategies appears to be limited.

The ERAS model (Harley et al., 2019), with its description of the emotion-generative process in different achievement situations and the different ER strategies within this process, together with EVT (Wigfield & Eccles, 2000), provide an innovative basis for studying ER strategy use in young learners and exploring beliefs as potentially influencing factors on ER strategy use.

Current Study

The current study aims to investigate differences in young students' ER strategy use. In line with the described ERAS model (Harley et al., 2019), this study focuses on ER in individual, low-evaluative settings, namely executing school homework and a playful problem-solving task. To obtain a comprehensive picture of the different facets of ER in elementary school students, ER was assessed in a multi-method way with a standardized, scenario-based interview with open answers, think-aloud during task performance, a self-rating by the students on their ER strategy use and a parent rating on perceived ER strategy use of their children. All ER strategy use measures aimed to capture the ER strategy areas situation selection, situation modification, attention deployment, cognitive change and response modulation according to the ERAS model (Harley et al., 2019). The study aims to address the following research questions:

1. What ER strategies do young learners use in relation to the different measurements and across the three interview scenarios and two task conditions in the problem-solving task with think-aloud?

   H1a: Based on previous research (Somerville & Whitebread, 2019; Webster & Hadwin, 2015), it is hypothesized that all ER measures show only a low frequency of use of cognitive change strategies, while indicating higher frequency of usage of response modulation strategies.

   H1b: Differences in ER strategy use are expected across interview scenarios and between the two task conditions of the problem-solving think-aloud task. More challenging tasks may evoke greater use of ER strategies, while students may mention increased response modulation in the interview scenario on negative emotions during learning and more situation selection and modification strategies in the interview scenario on low concentration.

2. How do the different ER measurements (interview, think-aloud, self-rating, and parent rating) relate to each other?

   H2: Interview and think-aloud ER measures are expected to show weak correlations as both capture process-oriented strategies, while ER self- and parent ratings may exhibit no significant correlation with process orientated ER measures (Ng et al., 2022)

3. How do students differ in their ER based on gender and age?

   H3: Based on previous research (Vierhaus et al., 2016), it is assumed that the use of ER strategies measured by the different methods increases with age and that girls report using more ER strategies.

4. Do students' expectancy and value beliefs related to ER strategies predict ER strategy use across ER measures?

   H4: More and stronger expectancy and value beliefs regarding ER strategies are hypothesized to be associated with a greater use of ER strategies.

Procedure

Ethics committee approval was obtained before the study. Participants were recruited through schools, and all provided voluntary informed consent. To this end, school secretaries were contacted by telephone and initially sent information material if they were interested. If the teachers showed interest, detailed information and consent forms were sent to the school

for teachers, parents (also in easy language) and students. During the recruitment process, it was made clear that families would not be disadvantaged if they did not participate in the study, that data could be deleted at any time and that they could withdraw their consent. Data was collected online via a digital learning platform using the families' devices. Parents and children completed questionnaires (self-reports and parent rating) on the platform. Parents then scheduled the second session, which included the interview and the think-aloud problem-solving task, recorded by telephone. This session lasted 50 minutes to one hour, including a break. The interviews and the think-aloud tasks were conducted by trained test administrators who had received prior training and were continuously supervised as a team throughout the data collection phase.

Sample

A total of 82 elementary school students and their parents participated in the study. Descriptive information was missing in some cases. Based on the available information, 51% of the participating children were female, 49% male and no participant gender-divers (referring to the self-assigned gender of the child asked in the parent questionnaire with female, male and gender-diverse; *N*=78), The participating students attended grade 2 to 5, and the mean age was *M*=10.16 (*SD*=1.24; *N*=74). A detailed distribution of participants by age and grade level can be found in BIII Appendix - Table 9.

Instruments

Emotion Regulation

Interview-Scenarios and Instructions. Based on Zimmerman und Martinez-Pons (1986) Self-Regulated Learning Interview Schedule (SRLIS), a semi-structured interview was developed for elementary school students to assess students' ER in a more situation-related manner, but still from the students' perspective. Students were asked about their approach to three learning-related scenarios, illustrated with pictures, covering 1. low motivation, 2. low concentration, and 3. unpleasant emotions during learning. In scenario 3, emotions were directly addressed, while scenarios 1 and 2 presented situations that did not explicitly suggest negative emotions but could be associated with them. These scenarios were used to illustrate various contexts in which learners require ER and the theoretical relation of motivation and emotion regulative processes (Harley et al., 2019; Pekrun, 2006). In the current study,

specifically only ER strategy use mentioned in the interview was investigated, despite children also mentioning for example motivation regulation strategies, particularly in scenarios 1 and 2.

Following the structure of the SRLIS, each scenario started with a general question about the first steps in the given scenario (*Imagine you're angry, anxious or sad when you're studying because you didn't manage to do something at school. For example, you didn't manage to complete an assignment. Do you know this feeling?*), followed by more detailed questions *(What will help you deal better with this situation?).* To gain a deeper understanding of young students' approaches, interviewers paraphrased the child's previous statements when asking follow-up questions *(Okay, you've just told me_____ can you tell me again: What do you do to calm or comfort yourself and get on with your studies?)* (see BIII Appendix - Table 1). In addition, the interview started with a warm-up scenario to illustrate the level of detail expected.

Think-aloud - Task and Instruction. To assess students' specific ER strategy use during realistic task performance, a digital version of the Train Track Task (TTT) (Bryce & Whitebread, 2012) was utilized as a problem-solving task that includes think-aloud protocols to assess SRL in young children. Students had to reconstruct two shapes, one simple and one age-appropriate, more complex shape, with a given set of tracks in a digital environment. The task started by showing students a plan with a shape they had to rebuild, followed by a video that introduced the different buttons in the digital environment and their functions (rotate the tracks, zoom in and out, open the plan, technical support video, and skip to next task). Students could reopen the plan showing the shape they needed to rebuild at any time while working on the task.

To assess students' ER strategy use, participants were instructed to engage in a think-aloud procedure, in which they were asked to verbalize their thoughts, feelings, and actions while performing the task. The test administrators could not see what the participants were doing while working on the task and were explicitly instructed to provide technical assistance only. When the participantsa became quiet, standardized prompts were used to encourage children to continue thinking aloud. No time constraints were placed on the students.

Coding of ER Strategy Use Frequency in Interview and Think-aloud Data. The audio recordings of the interview and the think-aloud were transcribed, and then ER strategy use was coded by two trained research assistants according to the ERAS model (Harley et al., 2019) and existing coding schemes from previous research on ER strategies (Somerville & Whitebread,

2019; Webster & Hadwin, 2015) (see BIII Appendix - Table 2). In the original first coding the SRL process according to Zimmerman (2000) was taken into account, by coding ER strategies within the forethought, performance and reflection phase. Based on previous research with think-aloud, the five strategy areas according to the ER strategy areas included in the ERAS model (Harley et al., 2019) and various detailed strategies were assigned to the different phases of the SRL process, with some strategies also occuring in more than one phase. During the coding process, strategies were inductively added, while some predefined strategies were not identified in the interview and think-aloud data at all, as shown with 'not coded' in the coding system (BIII Appendix - Table 2). In addition, maladaptive ER strategies related to the categories blame and anger or avoidance were coded (BIII Appendix - Table 2).

At the beginning of the coding process, extensive trial coding was conducted and discrepancies in the coding between the two coders were discussed after each interview respectively think-aloud protocol to establish a shared understanding of the detailed ER strategies and areas. While in the interview, repetitions of ER strategies were only coded if they related to a distinctly modified achievement situation or a different emotion, the digital TTT measures ER strategy use in a process-related manner, where the same strategy can be used several times in a row. Therefore repetitions of ER strategy use were coded in the think-aloud data.

In preparation for the following analyses, the strategies from the different areas were combined into frequency scores for each participant. First, the use of ER strategies across the various phases of the SRL process was merged into a single measure for each strategy area (see BIII Table 1), and the SRL phases themselves were no longer analyzed separately. Additionally, total sum scores were calculated for each participant, representing the overall use of all adaptive ER strategies as well as a separate score for the maladaptive strategies. For the interview coding, Cohen's Kappa for interrater reliability was calculated and found to be κ=.83, indicating substantial agreement between the raters. Cohen's Kappa for the think-aloud data was κ=.88, also suggesting substantial inter-rater agreement.

BIII - Table 1: *ER Strategy Areas Coded in Interview and Think-Aloud*

ER Strategy Area	**Description**	**Example**
Situation Selection	Situation selection involves choosing to approach or avoid particular people, places, or objects in order to modify the emotional impact of a situation and regulate emotions (Gross, 1998).	[…] Sometimes I just do my homework in another room so that I do not have any toys or my equipment. And then I try to do my homework there quickly.
Situation Modification	Active efforts to directly modify external aspects of a situation with the aim of changing its emotional impact. (Gross, 1998; Webster & Hadwin, 2015)	Then I put everything that could distract me or is very interesting away from my desk. Take my mobile phone and tablet out of my room so that I don't even see it and feel like playing on it […].
Attention deployment	Directing attention towards or away from specific elements of a situation to influence emotional responses. (Webster & Hadwin, 2015)	Then I realise that it took me this long and then I go through what I did wrong, where I made mistakes, what I did wrong and then I correct them. And yes, then I simply feel much better. Then I feel better again.
Cognitive Change	Altering how a situation is appraised or interpreted to influence emotional responses. (Webster & Hadwin, 2015)	I think about others in my class or something, I'm sure they've also had difficulties or something. And then I think well, I'm not the only one, so it's not so bad.
Response Modulation	Modifying emotional reactions through methods like relaxation techniques, suppression or distraction typically after initial emotional responses have occurred (Gross, 1998; Webster & Hadwin, 2015).	Sometimes I just lie down and have a rest. And then it's just gone.

Note. Coded ER strategy areas were based on ERAS model (Harley et al., 2019), empirical and theoretical work from Gross (1998) and Webster und Hadwin (2015)

ER Self-rating. To assess the general use of ER strategies during achievement situations from the students' perspective, a self-rating questionnaire was administered. The self-ratings can be interpreted as a trait-based measure. The questionnaire consisted of five items related to the five areas of ER. Each item was introduced by a short scenario about two fictional characters using an ER strategy during school homework (e.g., *Sometimes Pauli and Toni are angry, anxious or sad when they are learning. Then they say to themselves: "The problem isn't that bad."*). Then the students were asked how often they use this strategy for themselves (*How often do you tell yourself that the problem isn't so bad when you're angry, anxious or sad;* Example from the ER strategy area cognitive change) on a scale from 1= never to 4= always. The questions (see BIII Appendix - Table 3) were adapted from an extensive SRL self-rating questionnaire for third and fourth graders by Otto (2007). The internal consistency of the scale was moderate (McDonald's Omega Total (ωt) = 0.61). For further analyses, mean scores representing students' frequency of ER strategy use were calculated and utilized.

ER Parent rating. In order to capture parents' perceptions of their children's ER strategy use, as a general but more objective measure, seven of the 23 items of the Self-Regulation Strategy Inventory: Parent Rating Scale (SRSI-PRS) (Chen et al., 2015), which was originally designed to assess SRL in 6th and 7th graders, were adapted to the context of elementary school students. These seven items on the SRSI-PRS were related to regulatory strategies within the emotion-generative process in achievement situations, such as situation selection (e.g., *My child tries to study in a place that has no distractions (e.g. noise, people talking*)) and attention deployment (e.g., *My child tells himself or herself to keep studying hard even when he or she gets confused.*). In the original questionnaire, the seven adapted items were categorized in three different factors 1. parents' perceptions of performance control (item 10, 12, see BIII Appendix - Table 4), 2. parents' perceptions of their children's maladaptive or ineffective regulatory behaviors (item 15, 17, 20 see BIII Appendix - Table 4) and 3. parents' perceptions of their children's use of environmental structuring strategies (item 21, 22 see BIII Appendix - Table 4). However, these factors do not represent the target area of regulation nor one of the typical strategy areas (Boekaerts et al., 2000; Pintrich, 2000). Therefore, the items with the focus on

ER strategies (adaptive and maladaptive) were chosen independent of the original factor structure.

To assess students' ER strategy use more directly, three additional items from a questionnaire assessing general ER in children and adolescents (FEEL-KJ) (J. Greuel et al., 2018) were adapted to the context of learning by adding the term 'during learning' to the items (see BIII Appendix - Table 4 and 5). Parents rated their children's use of regulatory strategies from 1 = never to 5 = always. The overall developed questionnaire including ten items showed good reliability, McDonald's Omega Total (ωt) = .84. Mean scores of parents perceived students' frequency of ER strategy use were computed and applied in subsequent analyses.

Expectancy and Value Regarding ER Strategy Use

To examine potential relationships between students' expectancy and value beliefs and their use of ER strategies, consistent with expectancy-value theory (Wigfield & Eccles, 2000), various assessment methods were employed.

***Self-rating questionnaires*.** Students completed two self-rating questionnaires to assess their expectancy and value beliefs about ER strategies alongside the questionnaire measuring the frequency of ER strategy use. At the time of the study design, no questionnaires on expectancy and value in relation to ER strategies for primary school students existed. Therefore, the following items were developed based on existing self-report questionnaires on frequency of SRL strategy use (Otto, 2007) and studies that have investigated expectancy beliefs (self-efficacy) regarding SRL (Usher & Pajares, 2008; Zimmerman & Kitsantas, 2007) and value beliefs (usefulness) regarding SRL strategies (Blasiman et al., 2017; Karabenick et al., 2021) in older learners.

To assess students' value beliefs related to the ER strategies, the scenario describing a certain ER strategy remained the same as in the questionnaire on the frequency of ER strategy use (e.g., for the ER strategy area cognitive change: *Sometimes Pauli and Toni are angry. anxious or sad when they are learning. Then they say to themselves: "The problem isn't that bad."*), while the following question asked how helpful the student finds the certain strategy (e.g., *How helpful do you find it to tell yourself that the problem is not so bad when you are angry, anxious or sad?*). Participants rated its perceived value of the ER strategies on a 4-point Likert scale (1 = not helpful at all to 4 = very helpful) (see BIII Appendix - Table 6 for all Items).

In addition, students rated their perceived ability (expectancy) to apply the strategy on a 4-point Likert scale (1 = not true at all to 4 = very true). Instead of a question, a statement was displayed, asking students if this applied to them (e.g. *When I am angry, anxious or sad while learning, I can tell myself that the problem is not that bad.*) (see BIII Appendix - Table 7 for all items). Internal consistency of the scales was acceptable, with ωt=.75 for value beliefs and ωt=.71 for expectancy beliefs.

Interview. Students' statements about their ER strategies were coded for expectancy and value beliefs, distinguishing between positive and negative beliefs. In preparation for the analysis, frequency scores for each participant were calculated, representing how many different positive and negative expectancy and value beliefs students have stated in the interview data. Cohen's Kappa for inter-rater reliability was κ=.68 (see BIII Appendix - Table 8).

Think-aloud. Concurrent with coding expectancy and value beliefs about ER strategy use in the interview data, the same four codes were applied to the think-aloud protocols. However, no statements related to students' expectancy and value beliefs about ER strategy use during TTT task performance were identified.

Analysis

All statistical analyses were conducted using R version 4.4.1. Due to technical issues in the digital learning platform, some data had missing values, which were determined to be completely random. Missing values in the questionnaire data were handled using the mice package for multiple imputations, but missing data in demographics (age and gender) and behavioral/interactional process data (interview and think-aloud) were not imputed. Cases with more than 60% of the relevant ER items missing (2 cases) were excluded from imputation. Sensitivity analyses were conducted to ensure the robustness of our findings. Realistic outliers in the child or parent data were retained after screening. As some variables are not normally distributed (ER identified in think-aloud, ER in self-rating and all belief variables), non-parametric methods were used in the corresponding analyses relating to these variables.

To address research question 1, descriptive statistics summarized the frequencies and types of ER strategies reported and one-way repeated measures ANOVA, respectively Mann-Whitney-U-Test, were used to assess differences in ER across the three interview scenarios and two task conditions. Research question 2 was addressed through correlation analysis (spearman's rank correlation) to explore relationships between different ER measures. To

address the third research question, regression analysis was used to evaluate the impact of age and gender on ER strategy use. For research question 4, multiple regression analyses evaluated whether expectancy and value beliefs about ER strategies predicted ER strategy use across different measures. Note that the number of participants varied across analyses due to incomplete data for some participants. All regression analyses regarding research questions 4 were controlled for student gender and age to ensure observed relationships were not artefacts of these variables. To account for the risk of alpha inflation due to multiple comparisons, the Benjamini-Hochberg correction was applied. This method controls the false discovery rate (FDR), making it particularly suitable for situations involving multiple tests, as it strikes a balance between limiting Type I errors and maintaining statistical power.

Results

BIII - Table 2 displays the descriptive statistics, including means and standard deviation for all variables. Further details on the distribution of age and grade levels of participant are displayed in BIII Appendix - Table 9.

BIII - Table 2: *Descriptive Statistics*

	N	Mean	SD	Median	Min	Max
Age	74	10.16	1.24	10.29	7.67	13.33
ER interview	82	8.33	3.53	8.00	1.00	18.00
ER think-aloud	79	3.38	3.02	2.00	0.00	12.00
ER self-rating *(from 1= never to 4= always)*	81	2.54	0.49	2.60	1.60	4.00
ER parent rating *(from 1 = never to 5 = always)*	81	2.97	0.56	2.90	1.70	4.20
Value ER self-rating *(from 1 = not helpful at all to 4 = very helpful)*	81	3.03	0.57	3.00	1.60	4.00
Expectancy ER self-rating *(from 1 = not true at all to 4 = very true)*	81	2.86	0.52	2.80	1.80	4.00
Expectancy ER positive interview	82	0.40	0.68	0.00	0.00	3.00
Expectancy ER negative interview	82	0.22	0.57	0.00	0.00	3.00
Value ER positive interview	82	1.20	1.22	1.00	0.00	5.00

Value ER negative interview	82	0.05	0.22	0.00	0.00	1.00

Note. For the questionnaires (ER self-rating, ER parent rating, Value ER self-rating, Expectancy ER self-rating), mean values of the scales are presented. For ER strategies recorded through the interview and think-aloud tasks, as well as expectancy and value beliefs identified in the interview, mean values of the frequencies with which strategies were reported are shown.

Young Students' ER Strategy Use

In the following, the frequency of the different ER strategy areas mentioned by students is examined and compared across different contexts.

During the interviews, the children described a range of ER strategies used in different contexts (see BIII - Table 2). Across all three scenarios (low motivation, low concentration, and unpleasant emotions), attention deployment (27.96%) and response modulation (26.94%) were the most frequently reported strategies. Cognitive change (8.93%) and situation selection (14.20%) were less common. In the low concentration scenario, attention deployment (35.46%) and situation modification (30.68%) were most frequent, with less situation selection (16.33%) and response modulation (12.75%). In contrast, for low motivation, attention deployment (40.51%) was also common, but situation modification (10.26%) was mentioned less frequently, and situation selection (22.05%) was reported more often. In this scenario, the most maladaptive strategies were reported. For unpleasant emotions, attention deployment (9.70%) was rarely used, and response modulation (50.63%) was the predominant strategy. Cognitive change strategies were least used overall, particularly in the low concentration scenario (4.78%).

One-way repeated measures ANOVA analysis across all cases revealed significant differences in students' reported use of situation selection, situation modification, attention deployment and response modulation ER strategy use in the different interview scenarios ($p < .05$), while this was not the case for cognitive change strategies. Moreover, one-way repeated measures ANOVA analysis revealed significant differences in the total ER strategies reported and the maladaptive strategies across the different scenarios (see Table 3).

BIII - Table 3: *ER Strategies assigned to ER areas reported by students in the Interview*

	Interview – Total		Interview - Low Concentration		Interview – Low Motivation		Interview - Emotions		$F(2, 243)$	p	$\eta 2$
	Total sum	Relative (%)	Total sum	Relative (%)	Total sum	Relative (%)	Total sum	Relative (%)			
Situation selection	97	14.20	41	16.33	43	22.05	13	5.49	10.70	< .001 ***	0.08
Situation modification	150	21.96	77	30.68	20	10.26	53	22.36	16.12	< .001 ***	0.12
Attention deployment	191	27.96	89	35.46	79	40.51	23	9.70	26.07	< .001 ***	0.18
Cognitive change	61	8.93	12	4.78	21	10.77	28	11.81	2.64	.074	0.02
Response modulation	184	26.94	32	12.75	32	16.41	120	50.63	39.15	< .001 ***	0.24
All ER strategies	683		251		195		237		4.32	.01 **	0.03
Maladaptive ER strategies	39		6		21		12		4.28	.01 **	0.03

Similar to the interview, students' think-aloud protocols showed that attention deployment (66.32%) was the most frequently used ER strategy during task performance. Situation modification (26.84%) was also used, but response modulation (5.79%) and situation selection (0%) were rarely mentioned, and cognitive change (1.05%) was seldomly used (see BIII - Table 3).

Descriptive analysis revealed differences between the easy and difficult tasks: students used more ER strategies overall in the difficult task, with a notable increase in maladaptive strategies like self-blame. For the easy task, situation modification (54.17%) and attention deployment (37.50%) were predominant, whereas for the difficult task, attention deployment (70.48%) was the most frequent, with few instances of response modulation (6.63%) and no situation selection.

To examine whether the identified ER strategies in think-aloud data differed between the two tasks, Mann-Whitney-U-Test tests were conducted due to non-normal distribution of the

think-aloud data. The analysis revealed significant differences between the two tasks for all ER strategy areas besides cognitive change (see BIII - Table 4).

BIII - Table 4: *ER Strategy use of students assigned to ER areas identified in the Think aloud*

	Think-aloud Total		Think-aloud Task 1 (easy)		Think-aloud Task 2 (more difficult)		*W*	*p*
	Total sum	Relative (%)	Total sum	Relative (%)	Total sum	Relative (%)		
Situation selection	0	0.00	0	0.00	0	0.00		
Situation modification	51	26.84	13	54.17	38	22.89	2751	.02*
Attention deployment	126	66.32	9	37.50	117	70.48	1870.5	<.001 ***
Cognitive change	2	1.05	2	8.33	0	0.00	3280	.16
Response modulation	11	5.79	0	0.00	11	6.63	2880	<.01 **
All ER strategies	190		24		166		1828	<.001 ***
Maladaptive ER strategies	78		16		62		2522.5	<.01 **

Even though each ER strategy area was represented by only one item in the self-rating questionnaire, the descriptive analysis of the strategy areas shows a tendency in the frequency of young learners' use of ER strategies from the different areas. While response modulation seems to be used frequently (*M*=3.20), cognitive change was reported to be used the least frequently (*M*=2.00) (see Table 5).

A similar pattern appears in the descriptive statistics of students' parent-rated ER strategy use. While parents rated their children's use of cognitive change ER strategies the least frequently (*M*=2.17), situation selection (*M*=3.40) and response modulation (*M*=3.30) were rated to be used the most frequently (see BIII - Table 5).

BIII - Table 5: *ER Strategy use measured with the students self-rating and parent rating questionnaire*

	Self-rating			Parent rating		
	N	Mean	SD	N	Mean	SD
Situation selection	81	2.88	1.04	81	3.40	0.97
Situation modification	81	2.46	1.05	81	3.08	0.77
Attention deployment	81	2.16	0.89	81	2.67	0.88
Cognitive change	81	2.00	0.84	81	2.17	0.89
Response modulation	81	3.20	0.78	81	3.30	0.93

Note. M and *SD* are used to represent mean and standard deviation, respectively.

Overall, students' reported strategies reflect the adaptive use of a diverse repertoire of strategies to regulate their emotions, illustrating the complex and multifaceted nature of ER in achievement situations.

Relation of Different ER Measures

Due to the non-normal distribution of two of the ER measures (think-aloud and self-rating) and all belief variables, Spearman's rank correlation was applied for analysis (see BIII - Table 6 for detailed results). The correlation analysis revealed that none of the ER measures were significantly related to each other ($p > .05$). The correlation coefficients between ER identified in the think-aloud task and all other measures were near zero, indicating a weak linear relationship between self-ratings, parent ratings, interviews, and think-aloud ER measures. These results highlight the different nature of the situation specific assessment of ER strategy use during task performance.

Moreover, expectancy and value beliefs regarding ER strategies measured with the self-rating were significantly and positively related to each other and to self-reported ER strategy use. In addition, students' ER strategy use reported in the interview is significantly related to value beliefs regarding ER measured with the interview and the value beliefs assessed with the self-rating. Moreover, the correlations between ER strategy use in the think-aloud task and expectancy and value beliefs measured through self-reports and interviews were near zero and not statistically significant.

Additionally, the high correlation between the value beliefs in the self-rating and ER strategy use self-rating (r = .72***) suggests potential multicollinearity, which required further examination in the following analysis.

BIII - Table 6: *Means, standard deviations, and Spearman's rank correlation coefficient*

Variable	*M*	*SD*	1	2	3	4	5	6	7	8	9	10	11
1. ER Interview	8.33	3.53											
2. ER Think-aloud	2.38	3.02	-.04										
3. ER Parent rating	2.97	0.56	.14	.01									
4. ER Self-rating	2.54	0.49	.17	-.06	.09								

5. Value ER Self-rating	3.03	0.57	.23*	.01	.1	.72**							
6. Expectancy ER Self-rating	2.86	0.52	.13	.03	.16	.58**	.52**						
7. Expectancy ER positive Interview	0.40	0.68	.41**	-.11	0	-.15	-.06	-.04					
8. Expectancy ER negative Interview	0.22	0.57	.23*	-.03	.02	.04	-.05	-.06	.13				
9. Value ER positive Interview	1.20	1.22	.42**	.05	.03	-.07	-.11	-.09	.16	.16			
10. Value ER negative Interview	0.05	0.22	-.09	.09	.03	.06	-.02	-.08	-.15	.05	-.12		
11. Age	0.49	0.50	.35**	.07	-.02	.23*	.12	-.07	.05	.08	.09	.07	
12. Gender *(0=female)*	10.16	1.24	-.25*	.06	-.14	.2	.17	.1	-.32**	.03	0	.12	.07

Note. *M* and *SD* are used to represent mean and standard deviation, respectively. * indicates $p < .05$. ** indicates $p < .01$.

Differences in Young Students' ER Based on Age and Gender

Separate regression models were performed for each ER measure as outcome variable to investigate the relation of ER strategy use with students' age and gender. In these regression models, age and gender were entered as Step 1 variables, without including further independent variables at this stage, allowing to first assess their influence before considering the expectancy and value beliefs in subsequent steps.

Regression analysis revealed a significant relationship with age (B = 1.10, $t(71) = 3.66$, $p < .001$) and ER measured with the interview, while this was only found on a descriptive level for the ER strategy use in the self-rating questionnaires (B = 0.09, $t(71) = 1.95$, $p = 0.05$). Results indicated that older learners reported using significantly more ER strategies than younger students did (see BIII - Table 10 in the supplemental materials). No significant relationship was found with age and ER identified in the think-aloud nor when measured with the parent rating.

In addition, the regression analysis revealed a significant association between gender (B = -1.82, $t(71) = -2.47$, $p = 0.016$) and the ER measured with the interview, indicating that boys reported to use less ER strategies in the interview. However, there was no such relation found

in the regression analysis with think-aloud, self-rating or parent rating as outcome variables (see BIII - Table 7 for detailed results).

BIII - Table 7: *Separate linear Regression Analysis with Age and Gender as Predictor and different ER Measures as Outcome*

	Age					*Gender*					
Outcome variable	*B*	*Std. Error*	*t-value*	*p*	*p-adjusted*	*B*	*Std. Error*	*t-value*	*p*	*p-adjusted*	*Adjusted R²*
ER in interview	1.1	0.3	3.660	.0001***	.001**	-1.821	0.736	-2.475	.02*	.02*	.18
ER in think aloud	0.047	0.097	0.490	.63	.96	-0.010	0.24	-0.043	.97	.97	-.03
ER self-rating	0.086	0.044	1.945	.05	.08	0.155	0.109	1.424	.16	.16	.06
ER parent rating	-0.024	0.053	-0.445	.66	.66	-0.140	0.13	-1.08	.29	.43	-.01

Note. ER = Emotion regulation. *$p < .05$. **$p < .01$. *** $p < .001$. *P-adjusted* indicated adjusted p-values with Benjamini-Hochberg correction.

Differences in Students' ER Based on Expectancy and Value Beliefs

An a priori power analysis was conducted using R-package *semP*ower (Jobst et al., 2023) to determine the minimum sample size required to test a structural equation model (SEM). Unlike a full SEM, the model to calculate the degrees of freedom did not include latent variables, factor analysis, or residual correlations, but rather focused solely on the regression paths, to calculate the minimum sample size to test the hypothesis with a SEM. Results indicated the required sample size to achieve 80% power for detecting a medium effect, at a significance criterion of $\alpha = .05$, was N = 212. Thus, the achieved sample size of N = 82 was not adequate to test the study hypothesis.

Due to the relatively small sample size, four separate multiple regression analyses were conducted to examine the relationship between students' expectancy and value beliefs regarding ER strategy use with ER strategy use as measured by the different instruments. To ensure comparability and reduce potential bias arising from different scaling assumptions in the measurements of expectancy and value beliefs, all regression analyses were conducted with standardized predictor variables, except for age and gender.

In the first model with the interview as the outcome, the regression analysis indicated that the combined expectancy and value beliefs about ER that students reported in the interview and in self-rating questionnaire, as well as age and gender explained a statistically significant and substantial proportion of the variance ($R2 = 0.52$, $F(8, 65) = 8.66$, $p < .001$, adj. $R^2 = 0.46$). Within the model, the relationship between value beliefs related to ER strategy use as measured by the self-rating questionnaire was statistically significant and positive ($\beta = 0.95$, $t(65) = 2.60$, $p = .01$), as were the positive value beliefs about ER reported in the interview ($\beta = 1.27$, $t(65) = 3.88$, $p < .001$). In addition, the association between ER strategies reported by students in the interview and the positive expectancy beliefs about ER as reported in the interview ($\beta = 0.94$, $t(65) = 2.81$, $p = 0.006$) appeared significant and positive in the regression analysis (see BIII - Table 8). A post-hoc power analysis was conducted to assess the power of the regression model with 8 predictors, using R-package *pwr* (Champely, 2020) and an effect size (f^2) derived from the model's R^2 value of 0.45. The analysis indicated a power 99% at a significance level of 0.05 and a sample size of 74.

BIII - Table 8: *Results of Linear Regression Model using ER reported in the Interview as the Criterion*

	β	*SE*	*t*	*p*	*p-adjusted*	95% CI		Fit
						LL	*UL*	
(Intercept)	0.84	2.55	0.33	.74	.84	-4.25	5.94	
Value ER self-rating	0.95	0.36	2.60	.01*	.02*	0.22	1.67	
Control ER self-rating	0.15	0.36	0.41	.68	.84	-0.56	0.86	

Control positive interview	ER	0.94	0.33	2.81	.01**	.02*	0.27	1.60
Control negative interview	ER	0.36	0.32	1.13	.26	.40	-0.28	0.99
Value positive interview	ER	1.27	0.33	3.88	< .001***	.002**	0.61	1.92
Value negative interview	ER	0.01	0.30	0.03	.98	.98	-0.58	0.60
Age		0.81	0.25	3.24	.002**	.009**	0.31	1.31
Gender *(0= female)*		-1.63	0.66	-2.48	.02*	.03*	-2.95	-0.32
								R^2 = 0.45
								*p < .001***

Note. β represents standardized regression weights. *LL* and *UL* indicate the lower and upper limits of a confidence interval, * indicates $p < .05$. ** indicates $p < .01$.*** indicates $p < .001$. *P-adjusted* indicated adjusted p-values with Benjamini-Hochberg correction.

In the second model, expectancy beliefs and value beliefs, controlled for gender and age, did not significantly explain the variance in ER identified in the think-aloud ($R^2 = 0.06$, $F(8,63) = 0.48$, $p = .87$, adj. $R^2 = -0.06$), with all predictors showing no significant effects ($p > .05$) (see BIII - Table 9). To assess the statistical power of the conducted regression analysis, a post-hoc power calculation with R-package *pwr* (Champely, 2020) was carried out using the f^2 effect size derived from the model's R^2 value of -0.06. The power was found to be 24%, assuming a significance level of 0.05 and a sample size of 72.

BIII - Table 9: *Results of Linear Regression Model using ER identified in the Think aloud as the Criterion*

	β	*SE*	*t*	*p*	*p-adjusted*	95% CI		Fit
						LL	*UL*	

(Intercept)		1.13	3.12	0.36	.49	.86	-5.10	7.37
Value ER self-rating		0.16	0.45	0.37	.71	.86	-0.73	1.06
Control ER self-rating		0.13	0.44	0.30	.76	.86	-0.74	1.01
Control positive interview	ER	-0.59	0.41	-1.44	.15	.86	-1.40	0.23
Control negative interview	ER	0.05	0.39	0.14	.89	.89	-0.73	0.83
Value positive interview	ER	0.23	0.40	0.57	.57	.86	-0.57	1.02
Value negative interview	ER	0.36	0.41	0.88	.38	.86	-0.46	1.18
Age		0.15	0.31	0.49	.62	.86	-0.46	0.76
Gender *(0= female)*		-0.55	0.80	-0.69	.49	.86	-2.16	1.05
								R^2 = -0.06 p = .87

Note. β represents standardized regression weights. *LL* and *UL* indicate the lower and upper limits of a confidence interval, * indicates $p < .05$. ** indicates $p < .01$. *P-adjusted* indicated adjusted p-values with Benjamini-Hochberg correction.

The third regression model analysis revealed that value beliefs about ER in the self-rating (β = 0.26, $t(65) = 5.89$, $p < .001$) and expectancy beliefs about the use of the ER strategies measured with the self-rating (β = 0.15, $t(65) = 3.40$, $p = 0.001$) were significant predictors of ER strategy use reported on the self-rating, explaining a substantial portion of the variance ($R^2 = 0.63$, $F(8, 65) = 14.12$, $p < .001$, adj. $R^2 = 0.59$), while controlling for age and gender. However, the expectancy and value beliefs measured in the interview did not show a significant relationship in this regression model (see BIII - Table 10). A post-hoc power analysis using R-

package *pwr* (Champely, 2020), based on the effect size f^2 derived from the model's R^2 of 0.59, revealed that the power of the regression model was 100%. This calculation was done using a sample size of 74 and a significance threshold of 0.05.

BIII - Table 10: *Results of Linear Regression Model using ER reported in Self-rating as the Criterion*

		β	*SE*	*t*	*p*	*p-adjusted*	95% CI		Fit
							LL	*UL*	
(Intercept)		1.89	0.31	6.20	< .001***	< .001***	1.28	2.50	
Value ER self-rating		0.26	0.04	5.89	< .001***	< .001***	0.17	0.34	
Control ER self-rating		0.15	0.04	3.40	.001**	.003**	0.06	0.23	
Control positive interview	ER	-0.01	0.04	-0.24	.81	.82	-0.09	0.07	
Control negative interview	ER	0.01	0.04	0.22	.82	.82	-0.07	0.08	
Value positive interview	ER	0.03	0.04	0.74	.46	.69	-0.05	0.11	
Value negative interview	ER	0.04	0.04	1.24	.22	.40	-0.03	0.11	
Age		0.06	0.03	2.03	.05*	.10	0.00	0.12	

Gender *(0= female)*	0.02	0.08	0.23	.82	.82	-0.14	0.18
							R^2 = 0.59
							p < .001***

Note. β represents standardized regression weights. *LL* and *UL* indicate the lower and upper limits of a confidence interval, * indicates $p < .05$. ** indicates $p < .01$. *P-adjusted* indicated adjusted p-values with Benjamini-Hochberg correction.

In the fourth model, with ER parent ratings as the outcome, none of the expectancy and value beliefs measured by self-rating or the interview explained any statistically significant amount of the variance ($R^2 = 0.07$, $F(8, 65) = 0.61$, $p = .766$, adj. $R^2 = -0.04$), with all predictors showing no significant relationships (see BIII Appendix - Table 11). To evaluate the adequacy of the sample size, a post-hoc power using R-package *pwr (Champely, 2020)* analysis was conducted based on the f^2 effect size derived from an R^2 of 0.07. The analysis indicated a power of 29% at a significance level of 0.05 with a sample size of 74.

BIII - Table 11: *Results of Linear Regression Model using ER reported in Parent rating as the Criterion*

	β	*SE*	*t*	*p*	*p-adjusted*	95% CI		Fit
						LL	*UL*	
(Intercept)	0.77	1.01	0.76	.45	< .01**	-1.25	2.78	
Value ER self-rating	0.01	0.14	0.07	.95	.95	-0.28	0.30	
Control ER self-rating	0.20	0.14	1.43	.16	.68	-0.08	0.48	
Control ER positive interview	0.04	0.13	0.30	.77	.90	-0.22	0.30	
Control ER negative interview	0.06	0.12	0.50	.62	.90	-0.19	0.31	
Value ER positive interview	0.03	0.13	0.26	.80	.90	-0.22	0.29	

Value ER negative interview	0.06	0.12	0.51	.61	.90	-0.17	0.29
Age	-0.05	0.10	-0.53	.60	.90	-0.25	0.14
Gender *(0= female)*	-0.32	0.26	-1.22	.23	.68	-0.84	0.20
							R^2 = 0.07
							p = .76

Note. β represents standardized regression weights. *LL* and *UL* indicate the lower and upper limits of a confidence interval, * indicates $p < .05$. ** indicates $p < .01$. *P-adjusted* indicated adjusted p-values with Benjamini-Hochberg correction.

Discussion

Since the important role of emotions for learning is undisputed and emotions can get in the way of learning, ER is a central competence for learners and has an impact on academic achievement. Previous research on students' ER has yielded important findings, yet several limitations persist. Middle childhood, as a critical phase for the development of SRL skills, remains underexplored. Additionally, previous studies have largely relied on self-reported measures, providing a limited view of how ER strategies are applied in different contexts. In addition, there is a lack of understanding regarding why some children do not apply ER strategies. This study addressed these gaps by examining ER in middle childhood, integrating diverse assessment methods, and exploring factors linked to ER strategy use. The findings provide valuable insights for both research and educational practice.

RQ1: Young Students' ER Strategy Use

Expanding previous research, a differentiated analysis of students reported use of ER strategy areas within different ER measures revealed interesting patterns, showing that young students use the variety of ER strategies and are able to adapt their use of ER strategies to different contexts and tasks.

While situation selection was reported to be a frequently used ER strategy in self-ratings, interviews, and parent ratings, no such statements appeared in the think-aloud protocols

during task performance. This shows the limited flexibility of young learners during achievement situations like task performance in the current study, as parents and adults often restrict their agency in these situations. The current study has shown that young students often used situation modification strategies when starting with a new task or experiencing low concentration. During challenging tasks or low motivation for homework, attention deployment strategies were most common. Parents reported that response modulation strategies were most frequently used by their children and were also frequently mentioned by students in the interview scenarios related to unpleasant emotions. Consistent with previous research (Somerville & Whitebread, 2019) and our hypothesis, cognitive change ER strategies were the least frequently used across all ER measures, despite previous research reinforcing the effectiveness of such appraisal strategies (John & Gross, 2004) . This suggests a potential need for specific training in this strategy area for young learners, which should be considered when developing interventions.

The findings, showing differences in students' strategy use depending on context and task, are consistent with the emotion-generative process described in the ERAS model and Gross' process model (Gross, 2015; Harley et al., 2019). Results demonstrate the adaptive use of ER strategies from different ER areas, depending on whether it is appropriate to prevent unpleasant emotions at the beginning of the process (situation selection, situation modification) or to directly regulate experienced unpleasant emotions (response modulation) that may negatively affect the achievement situation.

RQ2: Relation of Different ER Measures

ER assessment is very diverse, including a large number of questionnaires and only a few studies have so far assessed ER using multiple methods (Adrian et al., 2011; Ng et al., 2022). In this multi-method study, no relationship was found between the four different ER assessment methods (interview, think-aloud, self-rating and parent rating), contrary to our hypothesis expecting relations between interview and think –aloud data. These findings indicate the multifaceted nature of ER (Zeman et al., 2007). A critical consideration when interpreting the present findings concerns the granularity and temporal framework of the various assessment methods employed. Each method captures distinct aspects of ER over differing timeframes. Self-reports typically reflect generalized, retrospective perceptions of strategy use, often filtered through memory and subjective evaluation. In contrast, interviews and think-aloud

protocols capture immediate responses to specific scenarios, offering more context-specific but potentially less comprehensive insights.

The lack of relations between the instruments strengthens the assumption that the assessment methods actually capture different aspects of students ER. Even though parent ratings and self-ratings both assess ER as a stable trait or general ability, not all ER strategies, such as cognitive change but also self-calming, are easily identified by parents from the outside. For self-ratings and interviews, children need a high level of awareness to be able to monitor and evaluate their emotions and their use of ER strategies (Zeman et al., 2007), which may also explain the differences in the measures. Think-aloud protocols provide a novel approach to measuring ER, taking into account the processes-oriented nature and situational dependency of ER. However, like observations, think-aloud during task performance measures ER in a very situation-specific way.

Given these differences, direct correlations between measures may not be assumed, as they do not necessarily represent equivalent constructs. While think-aloud tasks may capture spontaneous strategy application under task-specific stressors, self-reports provide insight into habitual patterns that may only partially align with task-based ER strategies. This divergence is not a limitation but rather a reflection of the complexity inherent in understanding ER across different contexts and timescales. The current findings are in line with previous research showing only weak to no relation between observation and other-ratings (Somerville & Whitebread, 2019).

To advance research in this field, a multimodal approach to ER assessment is recommended (Noroozi et al., 2020), where the complementarity of methods is recognized. Interviews and think-aloud procedures are particularly suited for examining situational dynamics and identifying immediate regulatory responses, whereas self-reports remain essential for understanding long-term patterns and individual tendencies. Future studies could benefit from explicitly framing research objectives around these distinct dimensions of ER to clarify the unique contributions of each method and maximize their interpretative value. In addition, triangulating data by combining multiple methods within a closely connected context, such as using eye-tracking and think-aloud protocols during a specific task, followed by a retrospective interview and questionnaire immediately afterward, seems valuable for capturing the nuanced differences between these approaches more precisely.

RQ3: Differences in Young Students' ER Based on Age and Gender

Regarding the third research question, age did not show a significant relationship with ER identified in think-aloud, rated by parents or measured with self-rating, but was significantly associated with ER reported in the interviews. The increase in adaptive strategies reported in other studies (Vierhaus et al., 2016) and hypnotized in this study could therefore only be partially detected. Gender differences were also only found for ER measured in the interview, but are consistent with previous research suggesting that females use more ER strategies (Vierhaus et al., 2016).

These findings underscore the necessity to consider age and gender when examining the development and application of ER strategies. Future research should focus on refining measurement tools to better detect age-related differences and explore how contextual factors, including classroom dynamics, influence the use of ER strategies across genders. Such investigations are crucial for developing targeted interventions that support ER development in children and adolescents, irrespective of gender.

RQ 4: Differences in Students' ER Based on Control Expectancy and Value Beliefs

The results of this study introduce a novel perspective on understanding differences in young students' ER. It suggests that students' expectancy and value beliefs regarding ER strategies influence their overall ER strategy use, as reported by students themselves in self-reports and interviews. However, these beliefs did not seem to affect the specific ER strategies identified through think-aloud protocols or those measured through parent ratings. Our hypotheses were thus only partially proven. This discrepancy ones again emphasizes the importance of considering the broader context of ER assessment. It raises the critical question of what exactly is being measured by different ER methods, particularly the widely used self-report measures. These findings suggest that the beliefs explored in this study may shape students' general perceptions of their ER abilities or their overall approach to regulating emotions, rather than their use of specific strategies in real-time situations. However, this finding highlights the importance of addressing these beliefs in future research and interventions, as fostering positive expectancy and value beliefs could play a crucial role in supporting children's development of effective ER strategies.

All in all, the challenges of ER assessment, like the a processes-oriented analysis and vast differences in the individual experience in emotion and ER, which have been discussed by

authors years ago (Zeman et al., 2007), are not yet fully resolved and have fundamental implications for research on students' ER strategy use, its effects on specific learning processes, and influencing factors on learners ER development.

Limitation and Future Implication

Several limitations of this study should be noted. A primary limitation of this study is the small sample size, which may limit the generalizability of the presented findings and reduce the statistical power to detect smaller effects. In particular, the regression models for analyzing expectancy and value beliefs on ER measured with the think-aloud (power = .05) and parent rating (power = 29) showed weak power. Moreover, this study includes a slightly uneven distribution of participants across grade levels, with fewer students from the second grade. This imbalance may influence the generalizability of the findings and should be considered when interpreting the results. Longitudinal studies would be valuable to further investigate the influence of age and gender, as well as potential interactions between these factors, on emotion regulation in achievement contexts. Another potential limitation regarding variance lies in the age and ER variables (in particular self-reported ER strategy use), as the sample may not offer sufficient diversity in these areas to allow for broad generalizations

In addition, no emotions were induced during the think-aloud tasks, leading to a realistic but considerable variability in whether or not the children experienced emotions that required regulation or not. As a result, the need for ER may have varied considerably across participants. Incorporating emotion induction procedures into tasks in future research, for example by making tasks very difficult or even unsolvable, might standardize participants' emotional experiences and thus provide a clearer picture of how young students regulate emotions.

While this study did not employ a systematic triangulation of methods across diverse settings, it contributes to the under-researched field of using multiple measures to assess ER strategies in young learners. Future research would benefit from designs that systematically link different assessment methods to specific contextual settings in order to gain deeper insights into the setting-dependence of ER measures.

In addition, observational methods, which have shown promising results in previous research (Somerville & Whitebread, 2019), were not included in this study. Including this measure would perhaps explain and strengthen the difference between task-based, specific ER measures and assessments of more general, stable ER skills, such as questionnaires. In addition,

this study is limited by the absence of data to assess test-retest reliability or to examine convergent and discriminant validity, which could have provided a more comprehensive evaluation of the measurement quality in particular of the ER self-rating and the self-rating of expectancy and value beliefs related to ER strategy use.

Moreover, the study did not include emotions as a fundamental component and the onset for ER, which is a critical aspect of understanding how learners manage their emotions in different contexts (Zeman et al., 2007). Future studies should explicitly include emotions, to better understand the full process of emotion regulation in the generative process of achievement emotions. However, within-person designs are of particular importance here, as emotions can fluctuate intra-individually and the correlations between emotions and ER on a between-person design can probably hardly reflect this (Pekrun, Marsh, Suessenbach, et al., 2023).

Since there is not much research on students' beliefs about ER strategies, self-rating questionnaires and coding of these beliefs in interviews represent a novel approach and need to be further evaluated in future research. Finally, more multi-method research with larger sample sizes is needed to thoroughly investigate the potential of different ER assessments and especially the factors that influence young learners' ER.

Conclusion

This study underscores the context-specific and flexible nature of students' ER in educational settings, which needs be considered when developing interventions or supporting children in their ER during learning. Moreover, the findings highlight the critical role of ER assessment, particularly in real-life task performance, to validly and realistically capture the nuanced ways in which students regulate their emotions in different situations. Measures beyond self-ratings have the potential to provide insights into the processes-oriented nature of ER, and thus can provide information not only about whether, but also when, which, and why ER is important in task performance and achievement situations.

Finally, the results reinforce the need to target beliefs about the usefulness of ER and students' beliefs about their ability to apply ER strategies and regulate their emotions in the classroom and ER instruction to ensure that ER strategies are effectively communicated to young students.

Appendix

BIII Appendix - Table 1: *Interview Sceanrios and Questions*

Low motivation
Now imagine you don't feel like doing your homework at all. Do you ever get that feeling?
And why do you sometimes not feel like doing your homework?
Okay, and what do you do when you don't feel like doing your homework [because, as you just said, for example__]?
Why do you do it this way? [For example, why do you do __?]
Do you have any [other] tricks or something that helps you to do your homework anyway?
Difficulties concentrating
Imagine you can't properly concentrate on your homework and are constantly thinking about something else. You do actually want to do your homework, but you are distracted.
Why is it that you sometimes can't concentrate on your homework?
What do you do so that you can concentrate on your homework?
Many times students have problems completing a homework assignment because there are other more interesting things they would rather do. Do you have any particular method for moti- vating yourself to complete your homework under these cir- cumstances?
And if you would (still) prefer to do something else [for example__]? What do you do so that you can concentrate, i.e. so that nothing distracts you while doing your homework?
Do you have any [other] tricks or tips, anything that helps you to concentrate?
[Okay, you've just told me __ can you tell me again:] What do you do to make sure you really finish all your homework?
Emotion regulation
Imagine you are angry, anxious or sad while learning because you did not succeed in something at school. For example, you didn't manage to complete an assignment. Are you familiar with this?
Why do you feel like this sometimes?[a]
What helps you to better deal with the situation?

Okay, you've just told me __ can you tell me again: What do you do to calm yourself down or comfort you and to continue learning?
Do you have any [other] tricks or anything that helps you in a situation like this?

Note. *Adapted from* Zimmerman & Martinez-Pons, 1988[a] If the child said no, we presented an illustrative situation (for example: you wrote a test and got a bad grade).

BIII Appendix - Table 2: *Emotion Regulation Strategies*

Code	Detailed Description	Example (Interview)	Example (Think aloud)
Forethought phase			
Attentional deployment			
Self-orientated thoughts / actions	Thinking about the consequences of completing or not completing the task or reward for completing the task.	I always remember that I usually get told off if I don't do them.	Not coded
Situation selection			
Select a place	Adjusting one's surroundings to support emotional regulation, for example, by selecting a more suitable study environment.	Not coded	Not coded
Maladaptive ER strategies – blame and anger			
Screaming, shouting or getting angry	Attempt to regulate emotions through shouting, screaming, or becoming angry.	Not coded	Not coded
Performance phase			
Situation selection			

Code	Detailed Description	Example (Interview)	Example (Think aloud)
Select a place	Adjusting one's surroundings to support emotional regulation, for example, by selecting a more suitable study environment.	[…] Sometimes I just do my homework in another room so that I do not have any toys or my equipment. And then I try to do my homework there quickly.	Not coded
Task selection	Selecting or avoiding a task.	Maybe I switch to other homework when it's no longer fun.	Not coded
Time selection / postponement	Choosing when to engage in a task or deciding to delay it.	[…] If I don't have the subject the next day, then I postpone it to the next day.	Not coded
Situation modification			
Increasing skills / training	Improving competence or learning to reduce a challenging emotion.	I'll also try to be better next time and maybe learn a bit more.	I rotate this thing all the time, that's why I want to watch it now. Let me watch the video again.
Physical situation modification	Taking proactive steps to adjust the environment, like playing music to influence emotional experiences.	Then I put everything that could distract me or is very interesting away from my desk. Take my mobile phone and tablet out of my room so that I don't even see it and feel like playing on it […].	I am lining up all the parts at the bottom of the screen so that I have a better overview.

Code	Detailed Description	Example (Interview)	Example (Think aloud)
Social modification	The child seeks social support to adapt the emotionally challenging situation.	But my mum often says that I should do it now or my dad, because then I'm done with it. And then I ask again if I can at least get help. And that actually works. And then I slowly but surely get it right.	Where is dad?
Attentional deployment			
Focusing on task / making an effort	Focus on the task instead of the negative emotion or speed up the completion of the task to eliminate the associated feeling	I calmly try again to focus on the task and try again to do it correctly.	I'm thinking about it. I'm trying to make an effort right now. I'm trying to concentrate right now.
Trying to correct the mistakes	Making efforts to correct errors or improve one's performance in order to regulate emotions.	Then I realize that it took me this long and then I go through what I did wrong, where I made mistakes, what I did wrong and then I correct them. And yes, then I simply feel much better. Then I feel better again.	I just switched sides.
Self-orientated thoughts / actions	Thinking about the consequences of completing or	[…] If I don't do my homework, then firstly I'll get into trouble at school and then I still wouldn't be able to do	Not coded

Code	Detailed Description	Example (Interview)	Example (Think aloud)
	not completing the task or reward for completing the task.	this assignment. And yes, think that time flies if you do your homework.	
Cognitive change			
Cognitive change (of the situation)	Change in thinking or perception in relation to the task, e.g. by thinking positively about the value or importance of the task.	I always think to myself, there's not that much homework, I can manage it. And then it works better and faster.	Ups, well, [...]. Okay, it doesn't fit, but that's not so bad.
Trying to see the positive side of events	Emphasizing the relevance of the task, the joy of learning or the positive consequences of a task.	I'll think to myself, yes, maybe I'll get a better grade on my certificate because I've done more or something, maybe I'll be complimented or something for having done a lot.	Not coded
Normalization / relativisation of errors	Acknowledging that others also face difficulties and that making mistakes is a shared experience.	I think about others in my class or something, I'm sure they've also had difficulties or something. And then I think well, I'm not the only one, so it's not so bad.	Not coded
Response modulation			

Code	Detailed Description	Example (Interview)	Example (Think aloud)
Trying to calm down / adjusting the emotional response	Attempt to directly alter an emotion, e.g. by taking a deep breath or trying to relax or calm down.	Sometimes I just lie down and have a rest. And then it's just gone.	But I'll manage.
Trying to feel better by doing something	Distract oneself from the negative emotional reactions through an activity	Sometimes with toys or things that actually distract me. Then I do it briefly, set myself a time and then do my homework again after that time.	Not coded
Trying to feel better by spending time with others (family, adults or friends)	Seeking to improve one's emotional state by spending time with others, such as family members, adults, or friends, to gain support, distraction, or comfort.	Yes, if you still do it that day, you can first play with friends, get some fresh air and then you can do it afterwards.	Not coded
Trying to improve the issues by talking to someone	Seeking to address emotions or resolve issues through conversation with someone.	Or I'll talk about it.	Hm. That is difficult, mom.

Maladaptive ER strategies - blame and anger

Code	Detailed Description	Example (Interview)	Example (Think aloud)
Screaming, shouting or getting angry	Attempt to regulate emotions through shouting, screaming, or becoming angry.	Yes, then I behave really silly, and I get agitated.	Not coded
Blaming oneself for causing the negative event	Holding oneself responsible for the emotional experience.	Because then I'm just annoyed because I can't fulfil the tasks. And then I think woah why can't I do it? It's just such a simple task and why can the others do it but I can't?	That was stupid of me. Oh [child's name] what a doofus you are today?
Blaming someone else for the negative event	Attributing responsibility for the negative emotional experience to someone else.	Not coded	I feel like it won't work for me. And it does for everyone else. And it feels so strange somehow. I can't move it. It's because of my computer.
Keeping to oneself / isolating oneself	Withdrawing from others or choosing solitude.	Then I would just stop crying. Just not be angry. Just be quiet.	Not coded
Maladaptive ER strategies- avoidance			
Not talking about the issues	Avoiding conversation about the issues or emotional experience.	So it's either this repression again, that I say I'll deal with it later […].	Not coded

Code	Detailed Description	Example (Interview)	Example (Think aloud)
Not doing anything because the issues cannot be resolved	Avoiding action due to the belief that the issues cannot be resolved.	Then, yes, then I don't know either. I'll just do my homework anyway, because I have to.	Not coded
Self-reflection phase			
Response modulation			
Trying to feel better by spending time with others (family, adults or friends)	Seeking to improve one's emotional state by spending time with others, such as family members, adults, or friends, to gain support, distraction, or comfort.	Not coded	Mom come here.
Doing something to distract oneself (like watching TV or playing games)	Distract oneself from the negative emotional reactions through an activity	Then I check the assignments again to make sure I understand them. And then I relax after I've finished my homework.	Not coded
Cognitive Change			
Trying to see the positive side of events e.g. the relevance of the task, enjoyment of learning	Emphasizing the relevance of the task, the joy of learning or the positive consequences of a task.	Not coded	Not coded

Code	Detailed Description	Example (Interview)	Example (Think aloud)
Situation Modification			
Increasing skills / training	Improving competence or learning to reduce a challenging emotion.	Not coded	Not coded
Maladaptive ER strategies – blame and anger			
Blaming oneself for causing the negative event	Holding oneself responsible for the emotional experience.	Not coded	Not coded
Keeping to oneself / isolating oneself	Withdrawing from others or choosing solitude.	Not coded	Not coded
Maladaptive ER strategies– avoidance			
Not talking about the issues	Avoiding conversation about the issues or emotional experience.	Not coded	Not coded

Note. Codes and code description are based on Somerville & Whitebread, 2019; Webster & Hadwin, 2015 and Gross, 1998

BIII Appendix - Table 3: *ER Strategy use Self-rating Scale*

Item	Assigned ER strategy area
Pauli and Toni encourage themselves when doing difficult homework. For example, they tell themselves "I can do it!". How often do you encourage yourself like this when doing homework?	Attention deployment
Sometimes Pauli and Toni are angry. anxious or sad when they are learning. Then they say to themselves: "The problem isn't that bad." How often do you tell yourself that the problem isn't so bad when you're angry. anxious or sad?	Cognitive change
Pauli and Toni think of a reward for completing their homework. They reward themselves when they have finished the task (e.g. eating a biscuit or going to play football). How often are you thinking of a reward for yourself?	Situation modification
When Pauli and Toni don't know what to do, they ask their parents, teachers or other children for help. How often do you ask someone for help when you get stuck with your learning?	Response modulation
Pauli and Toni look for a place to study where they are less distracted. How often do you look for a place to study where you are less distracted?	Situation selection

Note. Adapted from Otto, 2007

BIII Appendix - Table 4: *ER Strategy use Parent rating*

Item Nr. In orginal questionnaire	Item	Assigned ER strategy area
10	My child tells himself or herself to keep studying hard even when he or she gets confused.	Attention deployment
12	My child studies hard for school even when there are more fun things to do at home.	Attention deployment
15	My child tries to forget about the topics that he or she has trouble learning.	Situation modification
17	My child gives up or quits when he or she does not understand something.	Attention deployment
20	My child tries to study in a place that has no distractions (e.g.. noise, people talking).	Situation selection
21	My child tries to study in a quiet place.	Situation selection
22	My child makes sure no one disturbs him or her during study time.	Situation modification

Note. Adapted from Chen et al., 2014

BIII Appendix - Table 5: *Additional Items Emotion Regulation in Parent rating*

Item	Assigned ER strategy area
My child tells herself/himself that the problem is not so bad if she/he is unhappy (sad. angry. anxious) while learning.	Cognitive change
My child goes to someone who can help her/him when she/he is unhappy (sad. angry. scared) while learning.	Response modulation
My child thinks about how to solve the problem when she/he is unhappy (sad. angry. anxious) while learning.	Response modulation

Note. Adapted from Greuel et al., 2018

BIII Appendix - Table 6: *Value beliefs of ER startegies self-rating scale*

Item	Assigned ER strategy area
Pauli and Toni encourage themselves when doing difficult homework. For example, they tell themselves "I can do it!". How helpful do you find it to encourage yourself with your homework?	Attention deployment
Sometimes Pauli and Toni are angry. anxious or sad when they are learning. Then they say to themselves: "The problem isn't that bad." How helpful do you find it to tell yourself that the problem is not so bad when you are angry, anxious or sad?	Cognitive change
Pauli and Toni think of a reward for completing their homework. They reward themselves when they have finished the task (e.g. eating a biscuit or going to play football). How helpful do you find it to think of a reward for yourself?	Situation modification
When Pauli and Toni don't know what to do, they ask their parents, teachers or other children for help. How helpful do you find it to ask someone for help when you are stuck with learning?	Response modulation
Pauli and Toni look for a place to study where they are less distracted. How helpful do you find it to find a place to study where you are less distracted?	Situation selection

BIII Appendix - Table 7: *Expectancy beliefs of ER strategies self-rating scale*

Item	Assigned ER strategy area
I can encourage myself when I am facing difficult tasks.	Attention deployment
When I am angry, anxious or sad while learning, I can tell myself that, the problem is not that bad.	Cognitive change
I manage to reward myself when I am learning and only take the reward when I have finished my work.	Situation modification
If I do not know what to do, I do not find it difficult to ask my parents, teachers or other children for help.	Response modulation
I can organize my desk in such a way that I am not distracted too much while studying.	Situation selection

BIII Appendix - Table 8: *Control and Value Beliefs regarding ER Strategies*

Code	Example (Interview)	Example (TTT)
Perceived control (positive)	Then I take a piece of paper and tear it into very small pieces and then I feel better.	Not coded
Perceived control (negative)	Then, yes, then I don't know either. I'll just do my homework anyway, because I have to.	Not coded
Perceived value (positive)	You just have to ask someone for help to explain it to you and then you can, if you are able to do it, it's fun. Then you can do it. Then it works better.	Not coded
Perceived value (negative)	But then the assignment won't be any good because you do it too quickly just to get back to another assignment.	Not coded

BIII Appendix - Table 9: *Detailed Age and Grade Level Distribution*

Grade Level	N
2	11
3	21
4	17
5	28
Missing information	5
Age	
7 to 8	6
8 to 9	7
9 to 10	21
10 to 11	15
11 to 12	24
> 12	1
Missing information	8

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7 Diskussion

Ein Ziel der Dissertation war die Entwicklung und Erprobung innovativer Methoden zur Erfassung von SRL bei jungen Lernenden. Hierzu wurden eine digitale Problemlöse-Aufgabe, anhand derer sich Laut-Denken-Protokolle und Log-Daten kombinieren ließen (Beitrag I), und ein Interview entwickelt und umgesetzt (Beitrag III). In allen drei Beiträgen wurden diese Methoden zusammen mit bereits erprobten Instrumenten wie Selbstbeurteilungsfragebögen, Elternbeurteilungsfragebögen und Szenario-Tests multimethodisch eingesetzt. Dabei wurde untersucht, inwieweit die verschiedenen Erfassungsmethoden die Nutzung von SRL-Strategien in verschiedenen Kontexten erfassen und ob die vielseitigen Instrumente miteinander in Zusammenhang stehen.

Ein weiteres Ziel war die Untersuchung von potenziellen Einflussfaktoren auf die SRL-Kompetenzen junger Lernender. Dazu wurde der Zusammenhang verschiedener kontextueller, kognitiver und motivationaler Faktoren mit der Nutzung von SRL-Strategien und dem metakognitiven Wissen untersucht.

7.1 Theoretische Integration der Befunde

Im Folgenden sollen die empirischen Befunde der vorliegenden Dissertation in die bestehende SRL-Theorie integriert werden und so die bisherigen theoretischen Annahmen vertiefen. Die Diskussion der Beiträge orientiert sich dabei an den vorab formulierten Forschungsfragen, auf welche das Promotionsprojekt aufbaute.

1. Wie kann SRL bei jungen Lernenden erfasst werden? (Beitrag I, II und III)
2. Welche Faktoren beeinflussen die SRL-Strategienutzung und das metakognitive Wissen von jungen Lernenden und erklären diese Unterschiede in der SRL-Strategienutzung und dem metakognitiven Wissen? (Beitrag I und III)

7.1.2 Erfassung von SRL

Die Erfassung von SRL bleibt ein zentrales Thema der aktuellen Forschung. Die unterschiedlichen methodische Ansätze, von Fragebögen über Interviews bis hin zur Erfassung mit Log-Daten, liefern teils divergierende Ergebnisse (Dörrenbächer-Ulrich et al., 2021; Veenman & van Cleef, 2019) und weisen jeweils spezifische Stärken und Limitationen auf (Rovers et al., 2019). Besonders diskutiert werden die Spannungsfelder zwischen SRL als

Ereignis innerhalb des Lernprozesses bzw. als situativer Strategieeinsatz (*event*) oder stabile Fähigkeit (*aptitude*) (Bannert et al., 2014; Winne & Perry, 2000), zwischen mikro- und makroanalytischen Zugängen (Greene & Azevedo, 2009) sowie zwischen Online- und Offline-Methoden (Veenman & van Cleef, 2019). Herausforderungen in der Erfassung von SRL zeigen sich besonders bei jungen Lernenden, da insbesondere in diesem Alter retrospektive Selbstberichte anfälliger für Verzerrungen sein können oder durch sprachliche Fähigkeiten beeinträchtigt werden können (Azevedo, 2009; Perry & VandeKamp, 2000; Whitebread et al., 2009). Vor diesem Hintergrund sollen die empirischen Befunde der drei Beiträge dieser Dissertation in die bestehende Diskussion eingeordnet werden.

Anknüpfend an die Forderung nach multimethodischer Erfassung von SRL (Azevedo & Gašević, 2019; Järvelä & Bannert, 2021), wurden in allen drei Beiträgen vielfältige Methoden zur Erfassung von SRL angewandt, wodurch wichtige Erkenntnisse zu Zusammenhängen und Differenzen zwischen den Methoden generiert werden konnten. In Beitrag I kamen Laut-Denken-Protokolle und Log-Daten zum Einsatz, in Beitrag II wurden ein Selbstbeurteilungsfragebogen, ein Fragebogen zur Beurteilung durch Eltern und ein Szenario-Test eingesetzt und in Beitrag III wurden sowohl Selbstbeurteilungsfragebögen, Beurteilungen durch Eltern, als auch ein Interview und Laut-Denken-Protokolle angewandt. In der Erfassung von metakognitiven Verhaltensweisen beim Bearbeitender digitalen TTT in Beitrag I zeigten sich Zusammenhänge zwischen den Laut-Denken-Daten und den Log-Daten. In Bezug auf die meisten der untersuchten metakognitiven Verhaltensweisen wie beispielswiese dem Ändern der Strategie ($r = 0.44$, $p < 0.01$), dem Prüfen des Planes ($r = 0.62$, $p < 0.01$) und dem *Monitoring* des Verständnisses und von Fehlern ($r = 0.62$, $p < 0.01$) zeigten sich signifikante Zusammenhänge zwischen den beiden Datenquellen. Bei einigen Strategien, wie dem Suchen nach Unterstützung, konnten jedoch keine Zusammenhänge in den beiden Erfassungsmethoden gefunden werden, was durch die besonderen Schwierigkeiten der Operationalisierung dieser metakognitiven Verhaltensweisen in Log-Daten erklärt werden könnte. In Beitrag II zeigten sich zwischen allen dreien Erfassungsmethoden (SRL- Selbstbeurteilungsfragebogen, SRL-Beurteilung durch Eltern und Szenario-Test zur Erfassung des metakognitiven Wissens) schwach positive Zusammenhänge ($r = .19$ - $.35$; $p < .05$). In den weiterführenden Analysen in Beitrag III zeigten sich wiederum keine signifikanten Zusammenhänge zwischen den

verschiedenen Erfassungsmethoden zur ER junger Lernender (Interview, Laut-Denken-Protokolle, Selbstbeurteilungsfragebogen und Beurteilung durch Eltern).

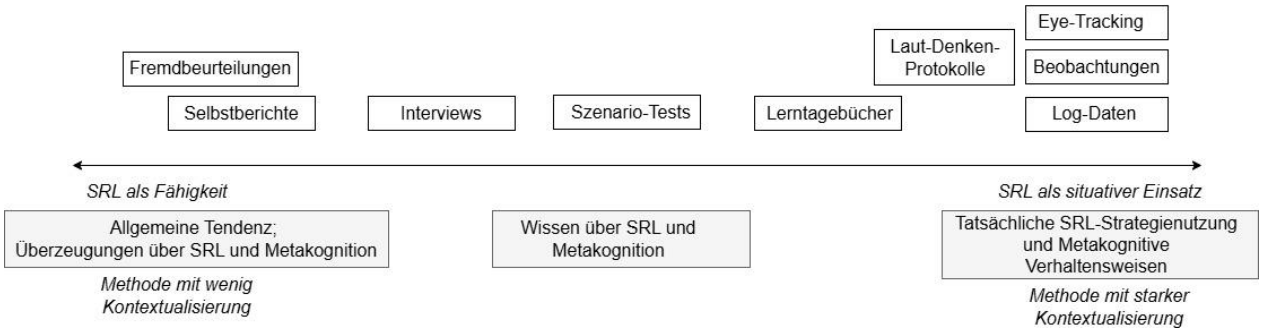
Innerhalb der aufgabenbezogenen Erfassungsmethoden, welche einer Online-Erfassung von SRL zuzuordnen sind (Beitrag I) und auch innerhalb der angewandten Offline-Methoden zur Einschätzung eines globalen Maßes der SRL-Fähigkeit (Beitrag II) zeigten sich dementsprechend Zusammenhänge. Zwischen den Online- und Offline-Methoden zur Erfassung eines spezifischen Teilbereiches von SRL, der ER, zeigten sich hingegen keine Zusammenhänge (Beitrag III). Diese Ergebnisse decken sich mit den bisherigen Befunden aus empirischen Studien, die SRL multimethodisch erfasst haben (Dörrenbächer-Ulrich et al., 2021; Veenman & van Cleef, 2019). Auch hier wurden keine bzw. nur schwache Zusammenhänge zwischen den jeweiligen Methoden gefunden (Bannert & Mengelkamp, 2008; Cromley & Azevedo, 2007; Dörrenbächer-Ulrich et al., 2021), während innerhalb von Offline bzw. Online-Methoden Korrelationen gezeigt werden konnten (Dörrenbächer-Ulrich et al., 2021; Veenman & van Cleef, 2019). Anknüpfend an die bisherigen empirischen Befunde untermauern die Ergebnisse der drei Beiträge die entscheidende Rolle methodischer Unterschiede bei der Erfassung von SRL und liefern weitere Belege für die divergenten Erfassungsweisen von Online- und Offline-Methoden. Die Befunde der Beiträge unterstreichen die unterschiedlichen Grundannahmen über SRL, die der Erfassung mit Offline- bzw. Online-Methoden zugrunde liegen. Während die in den Beiträgen der Dissertation angewandten Selbstbeurteilungen, Elternbeurteilungen, Szenario-Tests und auch Interviews SRL eher als eine stabile Fähigkeit beurteilen, geben Methoden wie Log-Daten und Laut-Denken-Protokolle den situativen SRL-Strategieeinsatz wieder. Auch wenn Interviews und Szenario-Tests bereits mehr Kontextualisierung bieten als klassische Fragebögen, erfragen diese einen retrospektiven bzw. prospektiven, allgemeine Nutzung von SRL-Strategien. Die Log-Daten und Laut-Denken-Protokolle während der digitalen TTT erfassen hingegen die momentane, gegenwärtige Nutzung von SRL-Strategien bei der Bearbeitung einer spezifischen Aufgabe. Zudem erfassen die Methoden SRL auf verschiedenen Ebenen bzw. in einer unterschiedlichen Genauigkeit. Während in den angewandten Offline-Methoden SRL auf der Ebene von Phasen oder SRL-Komponenten erfasst wird (Makro-Level), liefern Online-Methoden, wie die eingesetzte Erfassung mit Log-Daten und Laut-Denken-Protokollen eine hohe Genauigkeit auf einem Mikro-Level. Die Befunde in Beitrag III weisen zudem auf die Herausforderungen in der

Erfassung von spezifischen SRL-Bereichen hin, die von außen nicht gut zu beobachten sind, wie die ER junger Lernender. Dies könnte darüber hinaus die geringen Zusammenhänge zwischen Elternbeurteilungen und anderen Erfassungsmethoden erklären (McCoy, 2019).

Die multimethodische Erfassung von SRL im Rahmen der Dissertation gibt zudem Hinweise auf die Kontextabhängigkeit der SRL-Strategienutzung junger Lernender (Beitrag I und III). In Beitrag I zeigten sich Unterschiede in der Häufigkeit und der Abfolge von metakognitiven Verhaltensweisen in den Log-Daten, je nachdem ob die Teilnehmenden eine einfache oder eine schwierigere Aufgabe bearbeiteten. Ebenso konnte Beitrag III aufzeigen, dass Lernende im Grundschulalter, je nach dargestellter Lernsituation in den Interviewszenarien (geringe Motivation, geringe Konzentration oder negative Emotionen während des Lernens) und je nach Schwierigkeit der digitalen Problemlöse-Aufgabe die Nutzung von Strategien aus unterschiedliche ER-Strategiebereiche berichteten. Diese Befunde bestärken den Mehrwert von aufgaben- bzw. kontextspezifischen Erfassungsmethoden, welche die situationsabhängige und prozesshafte Natur von SRL abbilden können. Bietrag III hat gezeigt, dass auch die Erfassung mit Interviews hier Aufschluss über die detaillierte und kontextspezifische SRL-Strategienutzung von Lernenden geben kann.

Auf Grundlage der Befunde der drei Beiträge, welche Zusammenhänge und Unterschiede in den SRL-Erfassungsmethoden aufzeigen und Einblicke in die Strategienutzung auf einem Mikro-Level liefern, stellt sich dennoch die Frage, welche Aspekte von SRL die verschiedenen Methoden tatsächlich erfassen. Trotz der zahlreichen Überblicksartikel zu SRL-Erfassungsmethoden (z.B. Koivuniemia et al., 2021; Panadero et al., 2016) gibt es bisher keine übersichtliche Einordnung der verschiedenen Erfassungsmethoden. Auf Grundlage der bestehenden Diskussion zur SRL-Erfassung und der Erkenntnisse aus den empirischen Beiträgen dieser Dissertation wurde in Abbildung 1 eine systematische Anordnung der verschiedenen SRL-Erfassungsmethoden vorgenommen.

Abbildung 1: *Übersicht SRL Erfassungsmethoden*



Anmerkung: basierend auf der aktuellen Diskussion und Übersichtsarbeiten zu SRL-Erfassungsmethoden (Panadero et al., 2016; Rovers et al., 2019)

Die verschiedenen Erfassungsmethoden lassen sich dabei auf einer Skala von der Erfassung von SRL als stabile Fähigkeit (*aptitude*) bis hin zu SRL als Ereignis im Lernprozess (*event*) anordnen (Winne & Perry, 2000). Darüber hinaus wird mit der Übersicht ein Vorschlag gemacht, welche Aspekte von SRL die verschiedenen Methoden erfassen (Überzeugungen, Wissen, tatsächliche SRL-Strategienutzung). Im Kontext der üblichen Erfassung von SRL als stabile Fähigkeit mittels Fragebögen soll zur Diskussion gestellt werden, ob Selbstberichte und Fremdbeurteilungen angesichts häufiger Verzerrungen durch soziale Erwünschtheit und Subjektivität (Rovers et al., 2019) nicht eher individuelle Überzeugungen über SRL und Metakognition abbilden. Es wird argumentiert, dass Selbstberichte und Fremdbeurteilungen neben einer allgemeinen Tendenz zur Nutzung von SRL-Strategien auch latent widerspiegeln, welches Verhalten Individuen im Lernprozess als wünschenswert und nützlich einschätzen. Die Zusammenhänge zwischen Selbstbeurteilungsfragebögen zur ER-Strategienutzung und Überzeugungen hinsichtlich Selbstwirksamkeit und Nützlichkeit hinsichtlich dieser, zeigte sich beispieslweise auch in Beitrag III. Interviews, in welchen vorab keine SRL-Strategien vorgegeben oder benannt werden, könnten unterdessen sowohl eine allgemeine Tendenz in der SRL-Strategienutzung, als auch individuelle Überzeugungen und Wissen über Strategien darstellen. Lernende sind in Interviews nur in der Lage, diejenigen Strategien wiederzugeben, die sie benennen und beschreiben können. Es kann angenommen werden, dass sie dabei vor allem jene Strategien angeben, von denen sie überzeugt sind, dass sie als wünschenswert und nützlich erachtet werden. Auch diese Annahme könnte mit den Ergebnissen aus Beitrag III gestützt werden. Durch Szenario-Tests und den Vergleich von verschiedenen vorgegebenen

Strategien als mögliche Reaktionen, wird hingegen versucht direkt das metakognitive Wissen zu erfassen. Lernende müssen hier beurteilen, welche Strategie in der dargestellten Situation geeignet ist (konditionales Wissen). Das deklarative Wissen, die Definition und Beschreibung von SRL-Strategien, und auch das prozedurale Wissen, die Anwendung der Strategien (Händel et al., 2013), wird hier jedoch nur latent erfasst. Lerntagebücher sind durch die meist direkte Einbettung in den alltäglichen Lernkontext näher an der Erfassung der tatsächlichen, kontextspezifischen SR-Strategienutzung (Panadero et al., 2016). Doch auch hier greifen Lernende auf eine prospektive Beurteilung zum Beispiel vor den Hausaufgaben und eine retrospektive Beurteilung ihrer Strategienutzung nach den Hausaufgaben zurück, wodurch die tatsächliche Nutzung von SRL-Strategien, während den Hausaufgaben, nicht verlässlich erfasst wird. Laut-Denken-Protokolle werden zwar während der Bearbeitung einer konkreten Aufgabe erfasst, dennoch kann auch hier argumentiert werden, dass die damit erfasste SRL-Strategienutzung durch den Bericht des Lernenden verfälscht ist. Auch wenn es Belege für eine geringe Reaktivität dieser Methode gibt (Fox et al., 2011), bleibt unklar, ob Lernende ihre Strategienutzung ungefiltert berichten. Zudem benötigen Lernende zumindest deklaratives Wissen und metakognitive Fähigkeiten, um möglicherweise automatisierte Handlungen so benennen zu können, dass sie nachfolgend als SRL-Strategien von Forschenden identifiziert werden können. Beitrag I zeigte entsprechend, dass sich die Häufigkeit der von den Lernenden benannten metakognitiven Strategien in den Laut-Denken-Protokollen teilweise von der Häufigkeit der tatsächlich während der Bearbeitung umgesetzten Strategien unterscheidet, die anhand der Log-Daten erfasst wurden. Bei der Erfassung mit Hilfe von Log-Daten wird hingegen gezielt der situative Einsatz von SRL-Strategien fokussiert und somit der tatsächliche, kontextabhänge SRL-Prozess erfasst. Mit Log-Daten können zwar nicht alle SRL-Komponenten und Strategiebereiche gleichermaßen erfasst werden, wie sich ebenfalls in Beitrag I zeigte, dennoch können bei einer eindeutigen, validen Operationalisierung von SRL-Strategien Aussagen über die tatsächliche Strategienutzung von Lernenden gemacht werden. Ähnlich kann bei der Erfassung von SRL mit Hilfe von Beobachtungen und innovativen Methoden wie Eye-Tracking argumentiert werden. Auch diese Methoden erfassen das Lernverhalten und SRL-Strategienutzung unmittelbar während der Bearbeitung einer Aufgabe.

Die vorgeschlagene Übersicht stellt einen ersten Schritt dar, verschiedene SRL-Erfassungsmethoden in einem übersichtlichen Zusammenhang zu präsentieren und bietet eine Grundlage für weitere vertiefende Forschung.

7.1.3 Zusammenhänge und Einflussfaktoren auf SRL

Während einige Lernende schon früh verschiedene SRL-Strategien problemlos anwenden, ihren Lernprozess gut planen, beobachten und mit einem vielfältigen Repertoire an SRL-Strategien modulieren, zeigen andere Lernende große Schwierigkeiten in der SRL (Wigfield et al., 2011; Winne, 2005). Bisher wurden die potenziellen Faktoren, welche sich auf die SRL-Kompetenzen auswirken, nur wenig untersucht. Hier setzen Beitrag II und Beitrag III an.

In Beitrag II konnte sowohl ein Zusammenhang zwischen der SRL-Strategienutzung erfasst mit Selbstbeurteilungsfragebögen und Elternbeurteilungen und kombinierten SÖS-Indikatoren, als auch mit migrationsbezogenen Variablen gefunden werden. Dabei berichteten Kinder, deren Eltern nicht in Deutschland geboren sind und die zu Hause seltener Deutsch sprechen, mehr SRL-Strategien zu nutzen. Dieser Befund widerspricht der Annahme, dass Kinder mit einem erhöhten migrationsbedingten Bildungsrisiko geringere SRL-Kompetenzen aufweisen, welche auf den Befunden zu negativen Zusammenhängen mit der schulischen Leistung (Heath et al., 2008; OECD, 2023) basiert. Die Befunde aus Beitrag II decken sich insgesamt mit bisherigen Forschungsergebnissen, die auf einen negativen Zusammenhang zwischen SRL und einem niedrigen SÖS (Vandevelde et al., 2017) und gemischten Befunden hinsichtlich Migrationshintergrund (Alivernini et al., 2019; Blom & Severiens, 2008) hinweisen. Die gemischten Befunde zur Migration könnten auf besondere Stärken in der SRL von Kindern mit Migrationshintergrund oder auf die methodischen Herausforderungen in der Erfassung von SRL zurückzuführen sein. Ausgehend von Schwierigkeiten in der Erfassung von SRL, könnte eine mögliche Erklärung für die zum Teil höhere Beurteilung der eigenen SRL-Strategienutzung bei Lernenden mit Migrationshintergrund auch eine Schwierigkeit mit der Selbsteinschätzung durch diese Kinder liegen. Die tendenzielle Überschätzung der eigenen Leistung durch Lernende mit Migrationshintergrund wird auch als *Immigrant Optimism Paradox* bezeichnet (Kao & Tienda, 1998) und beschreibt die Tendenz von Lernenden mit Migrationshintergrund dazu, ihren Bildungsweg und ihre Fähigkeiten trotz möglicher Barrieren positiver einzuschätzen (Cebolla-Boado et al., 2021; Kao & Tienda, 1998). Auf Grundlage

dessen kann argumentiert werden, dass Verzerrungen durch eine systematische Fehleinschätzung der eigenen Fähigkeiten, bei dieser Gruppe von Lernenden eventuell stärker ausgeprägt sind. Insgesamt zeigten sich in Beitrag II keine Zusammenhänge mit den kontextuellen und demografischen Faktoren und dem metakognitiven Wissen.

Zudem wurde in Beitrag II ein negativer Zusammenhang zwischen breitgefassten Lernschwierigkeiten und SRL-Beurteilungen durch Eltern aufgezeigt. Auch diese Befunde decken sich mit den bereits in anderen Studien gezeigten negativen Zusammenhängen zwischen SRL und Lernschwierigkeiten (Bergey et al., 2017). Im Bezug auf Kinder mit Aufmerksamekitsstörungen, kann dieser Zusammenhang beispielsweise mit grundlegenden Defiziten in der Selbstregulation begründet werden, welche sich wiederum auf die spezifischen SRL-Kompetenzen auswirken (Barkley, 2014; Reddy et al., 2018). Zudem kann davon ausgegangen werden, dass hier bedeutende Interaktionen zwischen allgemeinen Lernschwierigkeiten bzw. diagnostizierten Lernstörungen, und motivationalen Faktoren bestehen, welche die SRL-Kompetenzen von Lernenden beeinflussen. So zeigten bisherige Studien bereits, dass Kinder mit Lernstörungen eine geringere allgemeine Selbstwirksamkeit zeigen (Bear et al., 2002; Hampton & Mason, 2003). Kinder mit allgemeinen Lernschwierigkeiten und diagnostizierten Lern- und Aufmerksamkeitsstörungen könnten demnach auch eine geringe Selbstwirksamkeit im Hinblick auf ihre SRL-Kompetenzen haben, die wiederum die SRL-Strategienutzung negativ beeinflussen könnte. Zusammenhänge mit metakognitivem Wissen, auf welche bisherige Studien hinweisen (Desoete et al., 2006; Pappas et al., 2003), konnten in Beitrag II der Dissertation jedoch nicht repliziert werden, wobei diese Studien andere Methoden zur Erfassung von metakogntiven Wissen eingesetzt wurden. Die Befunde aus Beitrag II könnten darauf hindeuten, dass Kinder mit Lernschwierigkeiten durchaus einschätzen können, welche Strategie in einer bestimmten Situation angemessen wäre, die eigentliche Herausforderung jedoch in der Umsetzung dieser Strategien liegt.

Hinzukommend wurde in Beitrag II und III der Zusammenhang von SRL mit Alter und Geschlecht der Lernenden untersucht. In korrelativen Analysen zeigte sich in Beitrag II ein positiver Zusammenhang zwischen Alter und der SRL-Strategienutzung in Selbstbeurteilungsfragebögen und dem metakognitiven Wissen erfasst mit den Szenario-Tests. In Beitrag III zeigte sich ein ähnlicher Zusammenhang bei der Erfassung von ER mit dem nach Zimmerman und Martinez-Pons (1986) adaptierten Interview, wobei ältere Lernende und

Mädchen mehr ER-Strategienutzung im Interview berichteten. Ein Zusammenhang mit dem Geschlecht der Lernenden wurde in Beitrag I nur bei den Elternbeurteilungen gefunden, wobei Eltern für Jungen weniger SRL-Strategienutzung berichten. Die Befunde stimmen weitestgehend mit den bisherigen empirischen Befunden überein, nach denen Mädchen tendenzielle eine höhere SRL-Strategienutzung zeigen (Heirweg et al., 2019; Leutwyler, 2009) und in Bezug auf den Zusammenhang mit Alter gemischte Belege gefunden wurden (Bardach et al., 2023; Meijs et al., 2009). Die Zusammenhänge mit dem Alter werden zum Teil durch eine fortschreitende biologische und sozial geprägte Entwiclung der Exekutiven Funktionen, wie der Aufmerksamkeit, dem Arbeitsgedächtnis und der inhibitorische Kontrolle begrüdnet werden, welche eine Grundlage für die Witerentwicklung von SRL-Kompetenzen darstellt (Blair & Raver, 2015; Perry et al., 2018). Die gemischten Befunde im Zusammenhang mit Alter weisen jedoch auf die besondere Bedeutung von Erfahrungen hin (Pintrich & Zusho, 2002). Unterschiede in den SRL-Kompetenzen könnten dementsprechen in der Übung und Förderung von SRL zurückführen sein. Die uneindeutigen Befunde zu Geschlechterunterschieden werden unter anderem mit Unterschieden in der Selbstwirksamkeitsüberzeugung sowie mit möglichen Erfassungsverzerrungen diskutiert, die mit dem Geschlecht in Zusammenhang stehen könnten (Vandevelde et al., 2013).

In Beitrag III wurde der Einfluss von motivationalen Faktoren auf die ER der Lernenden, als ein spezifischer Teilbereich von SRL, untersucht. Dabei zeigte sich, dass Erwartungsüberzeugungen hinsichtlich der eigenen Selbstwirksamkeit ER-Strategien anwenden zu können, im Zusammenhang mit der ER-Strategienutzung im Selbstbeurteilungsfragebogen und im Interview positiv zusammenhängen. Ebenso zeigten sich positive Zusammenhänge zwischen den Wertüberzeugungen hinsichtlich ER, den Überzeugungen, dass ER-Strategien nützlich sind, mit dem SRL-Strategienutzung gemessen mit dem Selbstbeurteilungsfragebogen und dem Interview. Die Erwartungs-Wert-Theorie bietet eine fundierte theoretische Grundlage, die den Zusammenhang von motivationalen Faktoren und (Lern-)verhalten erklärt (Wigfield & Eccles, 2000). Bisherige Forschung in anderen Bereichen, konnte hier bereits die Relevanz von motivationalen Faktoren aufzeigen (Rosenzweig et al., 2022). Bisher liegen allerdings nur wenige empirische Befunde zu dem Einfluss von spezifischen motivationalen Faktoren hinsichtlich SRL und der SRL-Strategienutzung vor. Erste Studien mit Lernenden der Sekundastufe geben jedoch Hinweise

darauf, dass sowohl die Selbstwirksamkeitsüberzeugungen hinsichtlich der Nutzung von SRL-Strategien (z.B. Joo et al., 2000), als auch die Nützlichkeitsüberzeugungen in Bezug auf SRL-Strategien (z.B. Karabenick et al., 2021) in einem Zusammenhang mit der SRL-Strategienutzung durch die Lernenden stehen.

Tabelle 2 gibt einen Überblick über die in den beiden Beiträgen untersuchten Zusammenhänge.

Tabelle 2: *Untersuchte Zusammenhänge zwischen SRL-Kompetenzen und kontextuellen, kognitiven und motivationalen Einflussfaktoren*

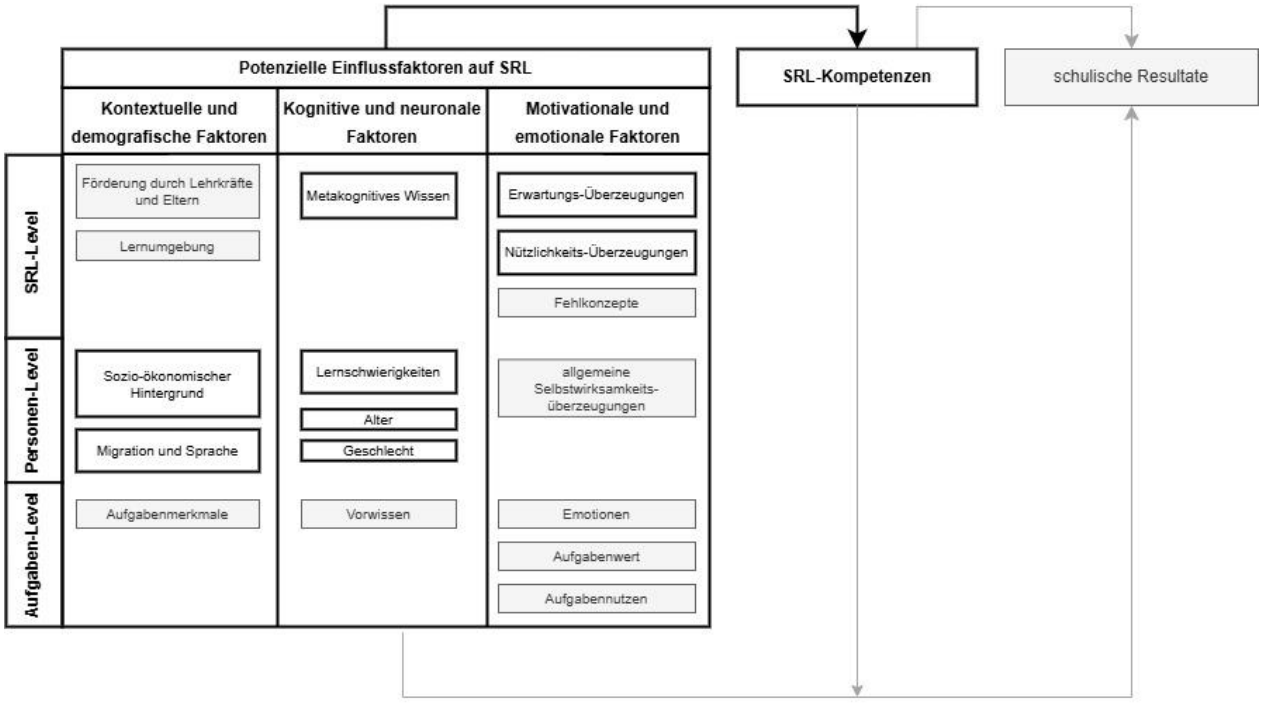
	Beitrag II			Beitrag III			
Prädiktorvariablen	**SRL-Selbstbeurteilungsfragebogen**	**SRL-Fremdbeurteilung**	**Szenario-Test metakognitives Wissen**	**ER-Selbstbeurteilungsfragebogen**	**ER-Fremdbeurteilung**	**ER-Interview**	**Laut-Denken-Protokolle (ER)**
Kontextuelle und demografische Faktoren							
SÖS	x						
Migration	x						
Kognitive und biologische Faktoren							
Lernschwierigkeiten		x					
Alter	x		x			x	
Geschlecht		x				x	
Motivationale Faktoren							
Erwartungs-überzeugungen hinsichtlich SRL-Strategien (Selbstwirksamkeit)				x		x	
Wert-Überzeugungen hinsichtlich SRL-Strategien (Nützlichkeit)				x		x	

Anmerkung. Ein x zeigt einen signifikanten Zusammenhang an. Nicht untersuchte Zusammenhänge sind grau markiert. Leere Zellen zeigen an, dass kein Zusammenhang gefunden wurde.

Bisher fehlt es an Übersichten, welche zentrale Einflussfaktoren und deren Auswirkungen systematisch abbilden. Ein solche übersichtliche Einordnung der potenziellen Einflussfaktoren, ist allerdings entscheidend für ein umfassendes Verständnis von SRL und die gezielte Weiterentwicklung theoretischer sowie empirischer Arbeiten zur Erklärung interindividueller Unterschiede in der SRL und zur Entwicklung von SRL-Trainings. Im Folgenden wird daher eine systematisierte Übersicht vorgestellt, die einen klaren und zugänglichen Überblick über die verschiedenen Einflussfaktoren liefert.

Die in Abbildung 2 dargestellte Übersicht integriert die in theoretischen Ansätzen formulierten sowie in empirischen Studien untersuchten Einflussfaktoren (siehe Kapitel 2.3). Basierend auf theoretischen Überlegungen wurden die Einflussfaktoren in drei übergeordnete Bereiche (1. Kontextuelle und demografische Einflussfaktoren; 2. kognitive und neuronale Einflussfaktoren; 3. Motivationale und emotionale Einflussfaktoren) unterteilt, die wiederum in drei Level (1. SRL-Level, 2. Personen-Level und 3. Aufgaben-Level) differenziert sind.

Abbildung 2: *Potenzielle Einflussfaktoren auf SRL-Prozess und resultierende Ergebnisse*



Anmerkung. Basierend auf theoretischen Annahmen von Zimmerman (2000); Winne und Hadwin (1998); Pintrich (2000); Weinstein et al. (2011); Wolters (2003); Miele und Scholer (2018); Harley et al. (2019) und bisherigen empirischen Befunden (siehe Kapitel 2)

Kontextuelle und demografische Einflussfaktoren. Die kontextuellen und demografischen Faktoren beschreiben vor allem Variablen, die den Lern- und Entwicklungskontext der Lernenden betreffen. Auf dem SRL-Level können hier beispielsweise die Förderung durch Lehrkräfte und Eltern, sowie die Lernumgebung eingeordnet werden. Dem Personen-Level werden hier beispielsweise Einflussfaktoren wie SÖS und Migration zugeordnet, die auch in den Beiträgen dieser Dissertation untersucht wurden. Das Aufgaben-Level beschreibt hier kontextuelle Einflussfaktoren wie Aufgabenmerkmale. Bei den so zusammengefassten kontextuellen und demografischen Einflussfaktoren besteht weiterer Forschungsbedarf, insbesondere hinsichtlich relevanter Einflussgrößen auf dem Personen-Level, die über klassische demografische Variablen hinausgehen. Kulturelle Aspekte, etwa kutlurelle geprägte Überzeugungen zu Lernen und Bildung, sowie spezifische Lebensumstände von Kindern und Jugendlichen, wie beispielsweise familiäre Strukturen und der Zugang zu spezifischen Bildungsressourcen, könnten zukünftig weitere, vertiefende Einblicke liefern, als allgemeine Konstrukte wie der SÖS oder der allgemeine Migrationshintergrund.

Kognitive und neuronale Einflussfaktoren. Die kognitiven und neuronalen Faktoren umfassen Faktoren, welche in einem engen Zusammenhang mit der kognitiven Entwicklung der Lernenden stehen, die sowohl durch die biologischen, neuronalen Reifungsprozesse als auch soziale Einflussfaktoren geprägt sind. Auf dem SRL-Level ist hier beispielsweise das metakognitive Wissen einzuordnen, welches nicht nur eine wichtige SRL-Kompetenz darstellt, sondern auch eine Voraussetzung für die SRL-Strategienutzung. Auf dem Personen-Level sind beispielsweise die in den Beiträgen untersuchten Lernschwierigkeiten, insbesondere Lern- und Aufmerksamkeitsstörungen, das Alter und Geschlecht zu verorten. Hinzukommend ist beispielhaft das aufgabenspezifische Vorwissen auf dem Aufgaben-Level zu nennen. Auch im Bereich der kognitiven und neuronalen Einflussfaktoren lassen sich weitere relevante Einflussgrößen ergänzen, etwa das Arbeitsgedächtnis, räumliches Denkvermögen oder sprachliche Fähigkeiten, die für SRL eine zentrale Rolle spielen könnten, in dieser Arbeit aber nicht ausführlich diskutiert wurden.

Motivationale und emotionale Einflussfaktoren. Als eine dritte Gruppe an Einflussfaktoren wurden motivationale und emotionale Faktoren zusammengefasst. Die motivationalen Überzeugungen können sich auf dem SRL-Level direkt auf die Anwendung von SRL-Strategien oder den eigenen SRL-Prozess beziehen oder auf dem Personen-Level

Überzeugungen zu den eigenen allgemeinen Fähigkeiten umfassen. Auf dem Aufgaben-Level finden sich aufgabenspezifische motivationale Überzeugungen von Lernenden oder auch die leistungsbezogenen Emotionen. Auch hier ließen sich weitere Einflussfaktoren ergänzen, die bisher nur wenig Beachtung gefunden haben. Erste Forschungsansätze gibt es zum Beispiel im Hinblick auf die Erforschung der Zusammenhänge von impliziten Theorien über das Lernen, und SRL-Kompetenzen (z.B. Hertel & Karlen, 2021).

In der Übersicht in Abbildung 2 sind in grau diejenigen spezifischen Einflussfaktoren und Zusammenhänge dargestellt, welche in SRL-Theorien formuliert wurden oder deren Einfluss bereits in vorangegangener Forschung untersucht wurde, die aber nicht in den Beiträgen der Dissertation erforscht wurden. Die Ergänzung durch diese Faktoren und Zusammenhänge soll dazu dienen, Beispiele für mögliche Einflussfaktoren zu geben und die theoretischen und empirischen angenommenen Zusammenhänge übersichtlich darzustellen. In weiß sind die Faktoren dargestellt, deren Zusammenhang mit SRL in den drei vorgestellten Beiträgen untersucht wurde und bei welchen ein Zusammenhang mit mindestens einer der Erfassungsmethoden von SRL gezeigt wurde.

Die vorgestellte Übersicht und Einordnung der Einflussfaktoren auf SRL dient als Ausgangspunkt für die systematisierte Untersuchung der zugrundeliegenden Mechanismen und bietet eine Grundlage für die Weiterentwicklung theoretischer Modelle sowie empirischer Forschungsansätze in zukünftigen Forschungsarbeiten zu SRL. Auch wenn die vorgestellte Übersicht nicht sämtliche bisher identifizierten Einflussfaktoren abbildet, ermöglicht sie eine strukturierte Einordnung zentraler Einflussfaktoren und trägt somit zur Präzisierung bestehender Modelle und zur Identifikation offener Forschungsfragen bei.

7.2 Stärken und Limitationen

Die vorgestellten Studien im Rahmen der Dissertation leisten einen wichtigen Beitrag zur aktuellen SRL-Forschung, insbesondere durch ihre multimethodische Erfassung von SRL und dem Fokus auf eine bislang wenig untersuchte Zielgruppe, der jungen Lernenden im Grundschulalter. Während sich ein Großteil der SRL-Forschung auf ältere Lernende der Sekundarstufe oder Studierende konzentriert, liefert diese Dissertation neue Erkenntnisse zur situationsabhängigen Nutzung verschiedener SRL-Strategien bei Lernenden im Grundschulalter. In der SRL-Forschung, insbesondere mit jungen Lernenden, dominieren

zudem retrospektive oder wenig differenzierte Erhebungsmethoden (Koivuniemia et al., 2021; Panadero et al., 2016; Winne & Perry, 2000), wohingegen in der vorliegenden Dissertation innovative Verfahren, wie Laut-Denken-Protokolle, Interviews und Log-Daten einsetzt wurden, die tiefgehende Erkenntnisse ermöglichen. Die Aufbereitung und Analyse von Interviews und Laut-Denken-Protokollen ist zwar ressourcen- und zeitintensiv, zeigte sich in den verschiedenen Beiträgen aber als geeignet und gewinnbringend, um detaillierte Erkenntnisse über die SRL-Strategienutzug und SRL-Prozesse von jungen Lernenden zu erlangen. Die Dissertation zeigt daher auf, dass diese Methoden eine detaillierte Analyse der SRL-Strategienutzung im Verlauf des Lernprozesses sowie in Abhängigkeit von verschiedenen Lernszenarien ermöglichen. Zudem liefert die tiefergehende Analyse von Interview-Daten in Beitrag III wertvolle Einblicke in schwer zu beobachtende SRL-Prozesse und die zugrundeliegenden Faktoren für die Nutzung oder das Ausbleiben von SRL-Strategien, wie motivationale Überzeugungen. Die Kombination verschiedener Methoden in den Beiträgen der Dissertation trug nicht nur zur Gewinnung weiterer methodischer Erkenntnisse über die Erfassung von SRL bei, sondern verdeutlichte auch, dass sich einige Methoden in ihrem Erkenntnisgewinn sinnvoll ergänzen (z. B. in Beitrag I Log-Daten und Laut-Denken-Protokolle). Mit der digitalen TTT liefert die vorliegende Dissertation darüber hinaus eine innovative Erfassungsmethode, welche effizient in der Erhebung und Analyse von Log-Daten ist, sich aufgrund der geringen Abhängigkeit von sprachlichen Fähigkeiten bereits bei jungen Kindern einsetzen lässt und eine weitere Triangulation von Datenquellen ermöglicht (z.B. Eye-Tracking, Beobachtungen, retrospektive Interviews und physiologische Methoden).

Zudem liefert die Arbeit erste Erkenntnisse zu der Erklärung individueller Unterschiede in der SRL, anstatt etablierte Zusammenhänge mit Lernerfolg zu reproduzieren. Auf Grundlage der dargestellten Zusammenhänge mit kontextuellen und demografischen, kognitiven und neuronalen und motivationalen und emotionalen Faktoren ergeben sich weitere theoretische Annahmen, die in zukünftigen empirischen Studien weiter exploriert werden sollten. Dabei wurden neben klassischen Indikatoren wie dem Geburtsland oder diagnostizierte Lern- und Aufmerksamkeitsstörungen auch weitere Indikatoren, wie beispielsweise die zu Hause gesprochene Sprache und Schwierigkeiten bei den Hausaufgaben verwendet, um Risiken für Bildungsmisserfolg und potenzielle Einflüsse auf SRL umfassender abzubilden. Mit der Erforschung von Erwartungs- und Wertüberzeugungen hinsichtlich SRL-Strategien untersucht

die Dissertation zudem bisher unzureichend erforschte motivationale Zusammenhänge, die aber auf Grundlage der Erwartungs-Wert-Theorie (Wigfield & Eccles, 2000) fundiert begründet sind.

Mit den empirischen Beiträgen und dem Versuch, diese in bestehende Theorie zu integrieren und eine Übersicht zu geben, trägt die Dissertation zur Weiterentwicklung theoretischer Modelle bei. Die vorgestellte systematische Einordnung der SRL-Erfassungsmethoden und die erarbeitete Übersicht der SRL-Einflussfaktoren, liefern dabei integrative Überblicks-Modelle, die eine Grundlage für weitere empirische Arbeiten bieten.

Limitationen in der Operationalisierung und Erfassung. In allen Beiträgen wurde die systematische Triangulation der unterschiedlichen SRL-Erfassungsmethoden bislang nicht umfassend umgesetzt. SRL wurde zwar multimethodisch erfasst, eine multi-modale Erfassung, welche die verschiedenen Methoden im gleichen Kontext bzw. zeitgleich einsetzt (Järvelä & Bannert, 2021; Noroozi et al., 2020), hätte darüber hinaus das Potenzial gehabt tiefergehende Erkenntnisse über die Differenzen der verschiedenen Erfassungsmethoden zu liefern. Die Log-Daten und Laut-Denken-Protokolle wurden zwar zeitgleich erfasst, in den Beiträgen der Dissertation bisher jedoch aufgrund der methodischen Herausforderungen nicht in eine zeitliche Übereinstimmung gebracht. Zudem war eine systematische Triangulation der eingesetzten Messinstrumente nur schwer umzusetzen, da die Methoden sich zum Teil in ihrem Kontext, ihrer Operationalisierung und Granularität unterschieden.

In der SRL-Theorie wird davon ausgegangen, dass die SRL von Lernenden abhängig von dem spezifischen Kontext ist (Greene et al., 2015). Die Nutzung von SRL-Strategien wird daher häufig im Zusammenhang mit spezifischen Lernkontexten wie Rechnen, Schreiben oder Lesen untersucht. Diese Vorgehensweise führt jedoch dazu, dass empirische Befunde auf einen einzelnen Kontext beschränkt bleiben und eine Generalisierbarkeit erschwert wird. Im Rahmen der vorliegenden Dissertation wurde SRL daher kontextunabhängig erfasst, wobei der Fokus auf dem Lernen zu Hause sowie der Anwendung von SRL-Strategien während einer spielerischen Problemlöse-Aufgabe lag. Dies führte jedoch dazu, dass SRL nicht immer in der angenommenen Kontextabhängigkeit abgebildet wurde. Ein stärkerer Bezug zu einem spezifischen Lerninhalt über alle Erfassungsmethoden hinweg hätte eine systematische Triangulation ermöglicht und die Untersuchung von Zusammenhängen mit spezifischen Leistungsmaßen unterstützt.

In der vorliegenden Dissertation lag der Fokus zudem insbesondere auf der Häufigkeit der Nutzung von SRL-Strategien. Die daraus gewonnenen Erkenntnisse sind jedoch in ihrer Aussagekraft begrenzt, da nicht untersucht wurde, inwieweit eine häufige Nutzung von SRL-Strategien tatsächlich mit einem effizienten und anforderungsspezifischen Einsatz dieser Strategien korreliert. Daher können keine Rückschlüsse auf die Qualität der SRL-Strategienutzung gezogen werden.

Die Operationalisierung zentraler Einflussfaktoren stellte eine weitere Herausforderung und Limitation in der vorliegenden Dissertation dar. Insbesondere in Beitrag II fehlt es neben den klassischen Indikatoren von SÖS, Migration und diagnostizierten Lernstörungen (Büttner & Hasselhorn, 2011; Gogolin & Maaz, 2019; Sirin, 2005) als Risiko für Bildungsmisserfolg an weiteren, differenzierten Indikatoren für die Risikofaktoren, die SRL potenziell beeinflussen könnten. Zusätzliche familiäre und individuelle Indikatoren für die formulierten Risikofaktoren, wie beispielsweise zur Verfügung stehende Zeit der Eltern mit den Kindern oder bildungsrelevante, kulturbedingte Überzeugungen von Eltern könnten hier aufschlussreich sein. Auch die bisherige Forschung zu Zusammenhängen zwischen SRL und Elternverhalten könnte eine Grundlage für weitere mögliche Indikatoren bieten (Dermitzaki & Kallia, 2021; Pino-Pasternak & Whitebread, 2010; Wesarg-Menzel et al., 2023). In Beitrag II wurde ein Ansatz zur Operationalisierung von Lernschwierigkeiten entwickelt, der über klinische Diagnosen hinausgeht, um auch Kinder mit besonderen Herausforderungen beim Lernen einzubeziehen, die bislang nicht klinisch erfasst wurden. Dennoch weist auch diese Operationalisierung Einschränkungen zum Beispiel durch die einseitige, subjektive Einschätzung der Lernschwierigkeiten durch Eltern auf. Auch hier wären zusätzliche Indikatoren hilfreich, um die heterogene Gruppe von Kindern mit Lernschwierigkeiten besser zu erfassen (Büttner & Hasselhorn, 2011).

Methodische Limitationen. Methodisch sind verschiedene Einschränkungen zu beachten. Vor allem stellt die kleine Stichprobe in allen Beiträgen eine Einschränkung dar, da sie die Generalisierbarkeit der Befunde limitiert. Die geringe Stichprobengröße begrenzt die statistische Power der Analysen und erschwert somit differenzierte Schlussfolgerungen.

Zudem sind die verwendeten statistischen Verfahren teils begrenzt, sodass zukünftige Forschung innovative analytische Ansätze und multivariate Analysemethode mit einer geeigneten Stichprobengröße in Betracht ziehen sollte. Die Vielzahl an getesteten Modellen

birgt zudem das Risiko einer Alphafehler-Inflation. Mit Hilfe der Benjamini-Hochberg-Korrektur (Benjamini et al., 2009) wurden hier Maßnahmen ergriffen, um das Fehlerniveau zu kontrollieren.

Limitationen Studiendesign. Zudem liegt eine wesentliche Limitation der Beiträge in dem querschnittlichen Studiendesigns. Daraus ergibt sich die fehlende Möglichkeit, kausale Zusammenhänge zwischen den kontextuellen, kognitiven und motivationalen Einflussfaktoren und SRL-Kompetenzen junger Lernender zu bestimmen, da lediglich eine einmalige Erhebung ohne Berücksichtigung zeitlicher Dynamiken erfolgte. Darüber hinaus können intraindividuelle Entwicklungsverläufe von SRL-Strategienutzung und metakognitivem Wissen nicht abgebildet werden, was die Identifikation von Veränderungsprozessen und deren Einflussfaktoren einschränkt.

Ein weiterer methodischer Einflussfaktor ist die COVID-19-Pandemie, die sowohl die Datenerhebung als auch das Lernverhalten der Teilnehmenden potenziell beeinflusst hat. Dies sollte bei der Interpretation der Ergebnisse berücksichtigt werden, weist aber gleichzeitig die besondere Herausforderung von Lernenden während dem Lernen mit hohen SRL-Anforderungen hin.

7.3 Implikationen

Die vorliegende Dissertation liefert wichtige Erkenntnisse für die Erforschung von SRL bei jungen Lernenden und zeigt zugleich offene Fragen und zukünftige Forschungsbedarfe auf. Auch für die pädagogische Praxis lassen sich daraus bedeutsame Implikationen ableiten. Im Folgenden werden zentrale Implikationen für die Forschung sowie Ansatzpunkte für die (schulische) Praxis diskutiert.

7.3.1 Implikationen für die Forschung

Auf Grundlage der empirischen Befunde aus den einzelnen Beiträgen und der Diskussion und theoretischen Einbettung dieser ergeben sich vielfältige Implikationen für die zukünftige SRL-Forschung. Zunächst unterstreichen die Befunde dieser Arbeit die Notwendigkeit einer multi-modalen Erfassung von SRL, in welcher Methoden zukünftig nicht nur multimethodisch kombiniert, sondern darüber hinaus systematisch trianguliert werden (Järvelä & Bannert, 2021; Noroozi et al., 2020). Diese Triangulation von verschiedenen Datenquellen zur SRL-Erfassung könnte ein umfassenderes Bild der zugrundeliegenden Prozesse und eine stärkere

Differenzierung der Erfassungsmethoden ermöglichen. Dabei sollten die verschiedenen Methoden zeitgleich (z.B. simultanes Laut-Denken, Log-Daten Erfassung, Eye-tracking, Beobachtung) oder direkt aufeinanderfolgend (z.B. im Anschluss ein retrospektives Interview und einen Fragebogen) konzipiert sein und sich auf den gleichen, spezifischen Lernkontext beziehen (z.B. beim Lesen eines Textes oder beim Lösen mathematischer Aufgaben).

Im Anschluss an die aktuellen Herausforderungen in der Erfassung von SRL (Roll & Winne, 2015; Rovers et al., 2019) bedarf es zudem mehr Validierungsstudien, um besser zu verstehen, was mit den verschiedenen Messinstrumenten tatsächlich erfasst wird und wie und wozu unterschiedliche Erhebungsmethoden zur Weiterentwicklung der SRL-Forschung beitragen können. Dazu sollten verschiedene Online- und Offline-Methoden oder auch eine Kombination aus qualitativen und quantitativen Methoden eingesetzt werden. In der Dissertation wurde basierend auf den Ergebnissen der Einzelbeiträge und der Überblicksartikel zu SRL-Erfassungsmethoden eine systematische Anordnung der Erfassungsmethoden entwickelt, die es nun weiter empirisch zu untersuchen gilt.

Der Fokus dieser Forschungsarbeit lag auf der Erfassung der Häufigkeit der SRL-Strategienutzung Lernender, wobei deutlich geworden ist, dass Erkenntnisse zur Qualität der Strategienutzung fehlen. Zukünftige Forschung sollte daher verstärkt darauf abzielen, nicht nur die Quantität, sondern auch die Qualität der Strategienutzung zu untersuchen, um differenziertere Aussagen über die Effektivität von SRL-Strategien treffen zu können. Es gibt bereits erste Hinweise dafür, dass vor allem der Einsatz von qualitativ hochwertigen SRL-Strategien für Lernende von Vorteil ist und zu besseren Leistungen führt (Leopold & Leutner, 2015). Allerding ist für die Erfassung der Qualität der Strategienutzung eine starke Kontextualisierung der Erfassungsmethoden notwendig, die es ermöglicht Aussagen darüber zu treffen, welche Strategien für eine spezifische Aufgabe am geeignetsten und effektivsten sind und die Erreichung der aufgabenspezifischen Ziele unterstützt (Leopold & Leutner, 2015).

Ein weiteres Potenzial der zukünftigen SRL-Forschung liegt in der weiteren Exploration der Prädiktoren und interindividuellen Unterschiede von SRL, die bereits in dieser Dissertation untersucht wurden und zusammenfassend in einer Übersicht dargestellt wurden. Überzeugungen Lernender über SRL, einschließlich potenzieller Fehlkonzepte, könnten erklären, warum einige Lernende kaum oder keine SRL-Strategien einsetzen. Die vorliegende Arbeit hat hierzu erste empirische Befunde aufgezeigt. Theoretische Modelle wie

beispielsweise die Erwartungs-Wert-Theorie (Wigfield & Eccles, 2000) bieten bereits eine fundierte theoretische Grundlage, auf welcher aufbauend zukünftige Studien den Einfluss von spezifischen Überzeugungen Lernender auf ihre SRL-Strategienutzung weiter untersuchen sollten. Ein besonderer Fokus sollte auf der Untersuchung veränderbarer Einflussfaktoren gelegt werden, die in SRL-Trainings gezielt adressiert und gefördert werden können.

Hinzukommend fehlt es bisher an systematischen Übersichten und Metaanalysen zu den bislang untersuchten Einflussfaktoren auf SRL, sodass ein umfassender Überblick über konsistente Befunde und potenzielle Forschungslücken fehlt. Dies erschwert die Ableitung theoretischer Implikationen sowie die Entwicklung gezielter Fördermaßnahmen, da unklar bleibt, welche Faktoren in verschiedenen Lernkontexten besonders relevant sind und welche moderierenden Variablen eine Rolle spielen.

Zur weiteren Erforschung von Faktoren, welche SRL beeinflussen, braucht es neben Querschnittstudien, wie den Beiträgen im Rahmen der Dissertation, vor allem längsschnittliche Studien, welche ermöglichen kausale Schlussfolgerungen zu ziehen und den Einfluss von verschiedenen Prädiktoren auf die Entwicklung von SRL-Kompetenzen zu untersuchen.

Zuletzt bietet die in der Dissertation entwickelte Problemlöse-Aufgabe weiteres Potenzial für die zukünftige SRL-Forschung. Mit digitalen Aufgaben können Log-Daten aufgezeichnet werden, welche eine innovative und effiziente Erfassung von SRL ermöglichen. Zudem bietet die digitale TTT eine wenig intrusive Erfassungsmethode, bei welcher Lernende kaum in ihrem Lernprozess beeinflusst oder gestört werden. Noch steht die aktuelle SRL-Forschung vor der Herausforderung, geeignete Indikatoren und Operationalisierungen zu entwickeln (Roll & Winne, 2015), mit Hilfe welcher sich SRL zuverlässig in Log-Daten identifizieren lässt. Die vorliegende Arbeit hat hierzu einen Beitrag geleistet. Ein vielversprechender Ansatz wäre es, bereits entwickelte Operationalisierungen, wie die aus Beitrag I, auf andere Aufgaben und Zielgruppen zu übertragen, um so Indikatoren zu validieren und eine umfassende Erfassung mit Hilfe von Log-Daten zu ermöglichen. Darüber hinaus ermöglichen digitale Aufgaben, wie die entwickelte digitale TTT, in Zukunft eine innovative Erforschung der direkten, aufgabenbezogenen Förderung von SRL durch beispielsweise die Integration von unmittelbarem Feedback während der Bearbeitung.

Ein weiteres Forschungspotenzial liegt in der Nutzung neuer Technologien, wie künstlicher Intelligenz (KI), die dabei helfen könnte Daten aus innovativen

Erfassungsmethoden wie Log-Daten oder Eye-Tracking effizient zu verarbeiten und zu analysieren. Auf der Grundlage menschengenerierter Operationalisierungen von SRL könnten durch den Einsatz von KI oder maschinellen Lernansätzen Muster in den Daten identifiziert, Vergleiche angestellt und möglicherweise neue Indikatoren für SRL entwickelt werden.

7.3.2 Implikationen für die Praxis

Die Ergebnisse dieser Arbeit unterstreichen die Bedeutung einer gezielten, schulischen Förderung von SRL im Grundschulalter. Ein zentraler praktischer Nutzen der vorliegenden Arbeit liegt in der Identifikation von Gruppen mit besonderem Förderbedarf, um gezielte Unterstützungsmaßnahmen entwickeln zu können. Beitrag II der Dissertation hat gezeigt, dass SÖS-bezogene Faktoren und Lernschwierigkeiten mit einer geringeren Nutzung von SRL-Strategien im Zusammenhang stehen. Auch wenn alle Lernenden von einer verstärkten Förderung von SRL profitieren können, haben bisherige Studien gezeigt, dass insbesondere Lernende mit besonderem Förderbedarf von SRL-Training profitieren (Azevedo et al., 2023; Berkeley & Larsen, 2018; Boer et al., 2018; Dignath et al., 2008; Theobald, 2021). Lehrkräfte können durch die Identifikation individueller Herausforderungen bei SRL von Lernenden in ihren Klassen gezielte Fördermaßnahmen anbieten. In Anschluss an die noch zu klärenden Ursachen für die höhere Einschätzung der SRL-Strategienutzung bei Kindern mit höherem migrationsbezogenem Risiko in Beitrag II, ist zudem die Förderung der metakognitiven Selbsteinschätzung sowie die Unterstützung des systematischen Monitorings des eigenen Strategieeinsatzes der Lernenden durch Lehrkräfte erforderlich. Nur auf diese Weise können Lernende ihre eigenen Bedarfe im Lernprozess erkennen und geeignete Kontrollstrategien anwenden.

Auch über die Identifikation von Risikolagen hinaus liefert diese Dissertation wichtige Erkenntnisse. Die entwickelten und in Relation zueinander gesetzten Messmethoden liefern wichtige Hinweise und Werkzeuge für die Erfassung von SRL selbst. Eine angemessene Diagnostik von SRL-Fertigkeiten bei Kindern ist dabei elementar, um Handlungsbedarf in der Förderung von SRL zu erkennen. Dabei bestehen verschiedene Ansatzmöglichkeiten für eine gezielte Förderung.

Beispielsweise konnte in Beitrag III gezeigt werden, dass die Überzeugungen von Lernenden über SRL einen relevanten Einfluss auf die SRL-Strategienutzung haben. Dementsprechend sollten Lehrkräfte nicht nur Wissen über Strategien vermitteln, sondern auch

das Vertrauen der Kinder in ihrer eigenen Fähigkeit stärken, ihr Lernen durch SRL-Strategien selbst steuern und verbessern zu können. Zudem sollten Lehrkräfte die Nützlichkeit der vielfältigen SRL-Strategien für das Lernen verdeutlichen. Die Bildungspraxis sollten daher explizit darauf abzielen, positive Überzeugungen über SRL aufzubauen und mögliche Fehlkonzepte von Lernenden hinsichtlich SRL zu adressieren.

Zuletzt bieten digitale Lernumgebungen und Aufgaben, wie die in Beitrag I vorgestellte und evaluierte digitale TTT, das Potenzial SRL gezielt zu unterstützen, indem sie Lernenden individualisierte Rückmeldungen zur Strategienutzung geben könnten und damit Reflexionsprozesse über das eigene Vorgehen anregen könnten. Durch die zusätzliche Entwicklung eines automatisierten adaptiven Feedbacks und einer interaktiven, adaptiven Aufgabengestaltung könnte die digitale TTT und ähnliche Aufgaben in der Schulpraxis dazu beitragen, dass Lernende ihre Fortschritte besser einschätzen und ihre Strategien gezielt anpassen können. Besonders hilfreich wären dafür digitale Tools, die metakognitive Prozesse wie Planung, Überwachung und Reflexion abbilden und damit die Eigenverantwortung im Lernprozess stärken. Digitale Aufgaben, die gezielt zur Strategieanwendung und -reflexion anregen, können daher in der schulischen Praxis zukünftig eine wichtige Rolle spielen und Lehrkräfte in der Förderung von SRL unterstützen. Damit solche Ansätze wirksam sind, bedarf es jedoch einer gezielten Einbindung in den Unterricht sowie einer unterstützenden Begleitung durch Lehrkräfte, die den sinnvollen Einsatz digitaler Lernumgebungen fördern und die Reflexion über die genutzten Strategien anleiten.

7.4 Fazit

SRL stellt einen wichtigen Prädiktor für die schulische Leistung dar (Dent & Koenka, 2016) und spielt eine zentrale Rolle für das lebenslange Lernen (OECD, 2018; Usher & Schunk, 2018). Trotz umfangreicher Forschung stellt die präzise Erfassung von SRL, insbesondere bei jungen Lernenden, eine erhebliche methodische Herausforderung dar (Perry & VandeKamp, 2000; Whitebread et al., 2009). Zudem ist bislang wenig darüber bekannt, welche Faktoren interindividuelle Unterschiede in den SRL-Kompetenzen von Lernenden beeinflussen (Boekaerts, 1996; Dong et al., 2024). Die vorliegende Dissertation adressiert diese aktuellen Herausforderungen und Forschungslücken in der SRL-Forschung. Beitrag I trägt dazu bei, indem eine innovative Erfassungsmethode, die digitale TTT, vorgestellt und untersucht wurde,

inwieweit mit Hilfe von Log-Daten metakognitive Verhaltensweisen von jungen Lernenden erfasst werden können. In Beitrag II liefert wichtige Erkenntnisse zu Einflussfaktoren auf SRL indem untersucht wurde, inwieweit kontextuelle Einflussfaktoren, wie SÖS und Migration, sowie kognitive Einflussfaktoren, wie Lernschwierigkeiten, die Nutzung von SRL-Strategien und das metakognitive Wissen junger Lernender beeinflussen. Beitrag III ergänzt diese Erkenntnisse, indem basierend auf Theorien zu Emotionsregulation (Harley et al., 2019) und der Erwartungs-Wert-Theorie (Wigfield & Eccles, 2000) untersucht wurde, ob motivationale Überzeugungen die ER-Strategienutzung Lernender, als einen spezifischen Bereich von SRL, beeinflussen. Die im Rahmen der Dissertation entwickelte und in Beitrag I vorgestellte und erprobte digitale TTT, als innovative Erfassungsmethode, hat das Potenzial auch zukünftig in der SRL-Forschung eingesetzt und weiterentwickelt zu werden. Zudem bieten die Erkenntnisse aus der in allen Beiträgen umgesetzten multimethodischen Erfassung von SRL eine wichtige Grundlage für die Differenzierung und den gezielten Einsatz von SRL-Erfassungsmethoden für die zukünftige Forschung. Dabei zeigen sie die Bedeutung von einer Kombination aus unterschiedlichen Datenquellen auf und betonen, wie wichtig klare Operationalisierungen von SRL sind. Die in Beitrag II und III untersuchten Einflussfaktoren geben erste Hinweise darauf, warum einige Lernende weniger SRL-Strategien nutzen und welche Gruppen gezielt gefördert werden sollten. Die Ergebnisse bieten wertvolle Erkenntnisse für die weitere Erforschung potenzieller Einflussfaktoren auf SRL-Kompetenzen, die Entwicklung gezielter Interventionen und die Förderung in der schulischen Praxis. Die in dieser Dissertation entwickelten systematischen Übersichten zu SRL-Erfassungsmethoden und Einflussfaktoren, die auf bestehenden theoretischen Annahmen und empirischen Befunden basieren, bilden eine theoretische Grundlage für zukünftige Forschung und leisten einen wichtigen Beitrag zur Weiterentwicklung der SRL-Forschung. Die vorliegende Dissertation leistet somit nicht nur einen wichtigen Beitrag zum Verständnis der SRL-Prozesse von jungen Lernenden, sondern zeigt auch Perspektiven auf, wie SRL in zukünftigen Bildungspraktiken effektiv gefördert werden kann – ein entscheidender Schritt, um Lernende besser auf Zeiten der technischen Transformation, globale Herausforderungen und eine sich stetig verändernde Bildungslandschaft vorzubereiten.

8 Literaturverzeichnis 2

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9.4 Eidesstattliche Erklärung

Hiermit versichere ich **schriftlich** und **eidesstattlich** gemäß § 11 Abs. 2 PromO v. 08.02.2011/08.05.2013:

1. Die von mir vorgelegte Dissertation ist selbstständig verfasst und alle in Anspruch genommenen Quellen und Hilfen sind in der Dissertation vermerkt worden.

2. Die von mir eingereichte Dissertation ist weder in der gegenwärtigen noch in einer anderen Fassung an der Technischen Universität Dortmund oder an einer anderen Hochschule im Zusammenhang mit einer staatlichen oder akademischen Prüfung vorgelegt worden.

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3. Weiterhin erkläre ich **schriftlich** und **eidesstattlich**, dass mir der „Ratgeber zur Verhinderung von Plagiaten“ und die „Regeln guter wissenschaftlicher Praxis der Technischen Universität Dortmund“ bekannt und von mir in der vorgelegten Dissertation befolgt worden sind (der Text ist auf der Homepage der TU Dortmund hinterlegt).

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