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Katerina Sergi
Mississippi State University and Delta State University, katser71.14@gmail.com

Anastasia Elder
Mississippi State University, aelder@colled.msstate.edu

Tianlan Wei
Mississippi State University, ewei@colled.msstate.edu

Kristin H. Javorsky
Mississippi State University, kj911@msstate.edu

Jianzhong Xu
Mississippi State University, jx18@colled.msstate.edu

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Katerina Sergi, Mississippi State University and Delta State University
Anastasia D. Elder, Mississippi State University
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Kristin Javorsky, Mississippi State University
Jianzhong Xu, Mississippi State University

Abstract

The purpose of this study was to investigate metacognitive self-regulated learning (SRL) differences in computer- and paper-based reading assignments across elementary students. Students in two after-school programs in a southeastern U.S. public school district were recruited. The final sample consisted of 48 students in Grades 2–5 who participated in two counterbalanced conditions involving a computer- and a paper-based reading assignment. The study employed a 2 x 4 (condition-by-grade) mixed-model analysis of variance (ANOVA) and follow-up tests to examine metacognitive SRL differences between conditions and grades. The results indicate that elementary students used various metacognitive SRL skills across both conditions. The mixed-model ANOVA results show a significant interaction in control processes in paper-based reading for students in fifth grade, a significant main effect of condition in evaluation practices in computer-based reading for all grades, and a significant main effect of condition in conditional knowledge in the paper reading assignment for all grades. The results suggest that students can benefit from focused instruction to apply metacognitive SRL skills between the two reading formats.

Keywords: ***self-regulated learning, metacognition, online reading, reading strategies, elementary grades***

Metacognitive self-regulated learning (SRL) involves higher order thought processes that can increase learning and motivation (Panadero, 2017; Schraw & Moshman, 1995). Metacognitive SRL processes consist of awareness and regulation of learning experiences including reading (Brown, 1977; Brown & DeLoache, 1977; Flavell, 1979). Reading is a foundational skill for achieving competence and success through the echelons of school life (Common Core State Standards Initiative, 2019; U.S. Department of Education, National Center for Education Statistics, 2018). When reading occurs in different platforms—digital or print—it evokes different facets of cognition, metacognition, and motivation (Azevedo & Hadwin, 2005; Deekens et al., 2018; Halamish & Elbaz, 2020; Koutsouraki, 2020; Wigfield & Guthrie, 1997; Zou & Ou, 2020). Metacognitive SRL processes develop as students advance grades, and this is evident in both computer- and paper-based reading performance (Muis et al., 2006; Paans et al., 2019). Secondary and tertiary students can detect gaps in their own learning, use strategies to overcome these gaps, and become effective learners (Gresch et al., 2017; Gutierrez de Blume, 2022; Kunz et al., 1992; Pintrich & de Groot, 1990; van de Pol et al., 2019). There is limited evidence, however, about whether elementary students as young as second grade use metacognitive SRL processes during computer-based reading and, if so, whether these students exhibit differences in metacognitive SRL processes between computer and paper. Filling these research gaps may strengthen metacognitive SRL and motivational practices and inform teachers' instructional efforts regarding computer-based reading contexts, helping students succeed academically. In this context, our research questions were as follows: Are there differences in metacognitive SRL processes between computer-based and paper-based reading tasks in second-, third-, fourth-, and fifth-grade students? Do any grade-associated patterns of metacognitive SRL processes differ between the two conditions? It was hypothesized that older elementary students would exhibit more metacognitive strategy use overall than younger students, but it was unknown whether the specific SRL strategies that students chose to implement would differ between the two conditions.

Review of Research on Metacognition and SRL

In this section, we first present definitions and extant literature on metacognition and SRL, then we discuss the existing research on metacognitive SRL first in relation to traditional print, or paper-based reading and then to computer-based reading. Finally, we conclude our review with a contrast of how metacognitive SRL develops in students across grade levels under the two reading formats: computer and paper.

Metacognitive SRL and Paper-Based Reading

Metacognition implies awareness, management, and regulation of cognitive processes (Brown et al., 1981; Flavell, 1979; Squire et al., 1998). According to Flavell (1979, 1992), the purpose of using metacognitive strategies is not to attain specific goals but to assess how goals are reached. Metacognition consists of knowledge and regulation of higher order thinking processes. Metacognitive knowledge entails the dimensions of *declarative knowledge* conceptualized as the ability to recall facts and events, which requires conscious effort and explicit memory (Boekaerts, 1995, 1997); *conditional knowledge* expressed as knowledge of when and why to learn (Flavell, 1979; Schraw, 2006); and *procedural knowledge* conceptualized as knowledge of applying certain procedures and learning strategies to achieve learning goals (Winne, 1995, 2011). Metacognitive knowledge is a product of memory monitoring of actions or strategies; it involves regulation of past cognitive processes for producing successful output (Koriat, 2012). Metacognitive experiences are associated with task completion and are the product of direct cognitive enterprises (Flavell, 1979). Also, metacognitive experiences entail motivational aspects that promote persistence with a task (Efklides, 2006). Reading is a foundational skill that requires developing or developed metacognitive processes (Gough & Tunmer, 1986; Pressley, 2002). Conscious and controlled use of SRL strategies can assist students in extracting meaning during reading (Duffy, 1993; Pressley & Afflerbach, 1995). SRL and metacognitive processes involve planning, monitoring, control, and evaluation (Corno, 1994; Schunk, 2008). *Planning* is the development of desired actions that lead to specific objectives (Bandura, 1991). *Monitoring* is the diagnosis of learning needs (Hadwin et al., 2007; Pintrich, 1999; Zimmerman, 1990); it affects control processes to remedy gaps in learning (Nelson et al., 1994; Nelson & Narens, 1990). *Control* refers to identifying appropriate learning strategies in task completion using cognitive and memory functions (Koriat, 2002). Lastly, *evaluation* involves the mechanism by which a learner assesses whether the desired goals have been met (Manlove et al., 2007; Zimmerman, 1989). All these actions converge as metacognitive processes that regulate behavior, increase motivation, and may lead to positive academic outcomes.

Students may also use SRL strategies to compensate for weaknesses or to overcome difficulties in paper-based reading. Students may initially use surface-level strategies such as underlining, connecting words with text clues, or annotating to extract meaning and later segue into deeper level strategies of rewording, asking questions, and representing with tables or diagrams to facilitate the more demanding stages of comprehension (Dunlosky et al., 2013; Moir et al., 2020; Schwartz, 2016). Use of metacognitive SRL processes can aid reading comprehension and contribute to academic success (Graesser et al., 2001; Kendeou & van den Broek, 2007).

Metacognitive SRL and Computer-Based Reading

While considerable research has been done on metacognitive reading strategies during traditional paper-based reading tasks, less is known about how metacognitive SRL practices are expressed in alternative reading formats, even as computer-based instruction has been increasingly common in preK–12 educational settings (Organisation for Economic Co-operation and Development, 2015). Students involved in computer-based learning experiences show increased academic performance in science, writing, mathematics, and English (Naseri & Motallebzadeh, 2016; Roussel, 2011; Zheng et al., 2016). However, computer-mediated learning may require extra pedagogical support of learning management systems (e.g., prompts, feedback) to facilitate metacognitive SRL awareness in students (Karaoglan Yilmaz & Yilmaz, 2019; Moning & Roelle, 2021). In a number of studies, college students have demonstrated planning, monitoring, control, and evaluation during online courses that recorded computer log trace data (Lin et al., 2017; Nesbit & Hadwin, 2006; Pratt & Martin, 2017). Also, middle and high school students have shown increased motivation in computer-mediated learning environments, documented as task interest and persistence as well as self-efficacy (Malmberg et al., 2014; Stevenson et al., 2017; Van Laer & Elen, 2019). Therefore, examining metacognitive SRL processes in elementary students may shed additional light onto adaptation of such strategy usages across new and emerging reading media.

Development of Metacognitive SRL in Computer- Versus Paper-Based Reading

Metacognitive SRL skills and reading comprehension ability develop as students advance grades. Preschool students who are 3 to 5 years old can exhibit metacognitive and self-regulatory abilities during problem-solving play tasks (Whitebread et al., 2009). Further, students in preK to Grade 6 can produce metacognitive reflections and select correct strategies to successfully complete reading and writing assignments (Hennessey, 1999; Steiner et al., 2020). Self-efficacy for SRL strategies (e.g., self-monitoring) may be minimal in language arts among fourth- to seventh-grade students but evident in eighth- to tenth-grade students (Pajares & Valiante, 2002).

Recent studies have documented differences in screen versus print reading. U.S. middle school students in Grades 5–8 have been shown to exhibit the control strategies of highlighting and annotating more in paper than in computer reading due to greater familiarity with the former medium (Goodwin et al., 2020). Likewise, Norwegian 10-year-old students have demonstrated higher paper-based reading performance than computer-based reading performance as an effect of better reading skill and more purposeful reading strategies (Støle et al., 2020). However, in a study involving sixth-grade Turkish students, no statistically significant differences were recorded between electronic PDF and printed e-books in reading motivation and comprehension abilities (Liman Kaban & Karadeniz, 2021). This lack of differences suggests that these students may not have adapted their reading skills and learning strategies to these two reading formats and have failed to adapt SRL skills across mediums. Collectively, research has found that metacognitive SRL processes are domain specific and sensitive to the age of students. In this context, the purpose of the present study was to examine differences in metacognitive SRL processes between computer-based and paper-based reading tasks in students across elementary grades. The findings could have important implications for how to improve learning and teaching practices across elementary grades.

Methods

Recruitment

We recruited elementary students from two after-school programs in one southeastern U.S. public school district. The first program was fee based and served preK to Grade 5 students who received recreational and enrichment activities. The second program was grant funded and served Grade 5 students who received academic tutoring. Data collection was conducted during after-school hours to avoid interference with regular morning instruction. The after-school programs operated for approximately 2 hours daily. We contacted 156 parents, and 69 agreed to let their child participate (44% return rate). Written consent was provided from parents and written assent from students. In spring 2020, all school operations stopped because of the COVID-19 pandemic, and data collection ended. The final sample included 48 students with full data.

Sample

G*Power (Faul et al., 2009) analysis was calculated to compute the required sample size. A-priori power analysis for the within-subjects effect indicated that, in order to detect a medium-sized effect that corresponds to partial eta squared = .06 (Cohen's f = .25) with 84% power in a repeated measures analysis of variance (ANOVA; four grades by two conditions, α = .05, nonsphericity correction = 1), we would need 36 participants. A power of 84% represents an accepted minimum level according to theorists (Cohen, 2013; Lakens, 2013).

The 48 students were from 32 classrooms (second grade: 7 classrooms; third grade: 12 classrooms; fourth grade: 7 classrooms; fifth grade: 6 classrooms). Participants' ages ranged from 7 to 11 years (M = 9.04, SD = 1.18; 63% boys, 37% girls); 27% were African American, 6% Asian, and 67% White. Among participants, 21% received free lunch, 4% received reduced-priced lunch, and 75% paid for their lunch (see Table 1).

Table 1

Demographic Profile of All Participating Students in Grades 2–5 (N = 48)

Demographic Profile	2nd grade Count (%)	3rd grade Count (%)	4th grade Count (%)	5th grade Count (%)	Total Count
Age					
7 years	4 (50%)				4
8 years	4 (50%)	10 (77%)			14
9 years		3 (23%)	9 (56%)		12
10 years			7 (44%)	5 (46%)	12
11 years				6 (54%)	6
Sex					
Boys	6 (75%)	8 (62%)	11 (69%)	5 (46%)	30
Girls	2 (25%)	5 (38%)	5 (31%)	6 (54%)	18
Race					
African American	2 (25%)	3 (23%)	3 (19%)	5 (46%)	13
Asian American	0 (0%)	0 (0%)	2 (12%)	1 (9%)	3
European American	6 (75%)	10 (77%)	11 (69%)	5 (45%)	32
Free or reduced- priced lunch					
Free	1 (22%)	3 (21%)	1 (6%)	5 (42%)	10
Reduced-price	0 (0%)	1 (7%)	1 (6%)	0 (0%)	2
Paid	7 (78%)	9 (72%)	14 (88%)	6 (58%)	36

Students' self-reported average computer use at school was almost 3 days a week (*M* = 2.79, *SD* = 1.76) for about 46 minutes a week (*M* = 46.16, *SD* = 14.19). Paper and pen use was approximately 5 days a week (*M* = 4.56, *SD* = 0.98) for more than 100 minutes a day (*M* = 109, *SD* = 104.24).

Procedures

Each student attended two sessions for evaluating metacognitive skills under two conditions: Condition 1 involved a reading task using a computer, and Condition 2 involved a reading task using paper and pencil. Each student served as their own control. The benefit of this approach was that participant variance was minimized, increasing the likelihood of detecting a real difference in SRL skills among conditions (Abrami et al., 2013). Furthermore, the order of conditions was counterbalanced and separated by approximately 7 to 15 days to reduce practice or carryover effects that might pose a threat to internal validity (Field, 2013).

In the computer condition, the principal researcher asked students to log in to their personal account on i-Ready, an online assessment and instruction program aligned with Common Core State Standards and used daily in the local school system across the K–7 grade levels (Curriculum Associates, 2019). Students then accessed an instructional reading assignment determined by their teacher. In the paper-based reading, students read printed versions of i-Ready passages and completed reading worksheets recommended by the state department of education (Mississippi Department of Education [MDE], 2016) and the local school district for exemplar units and lessons (MDE, 2019). We followed a pacing guide for reading standards suggested by the school district to ensure i-Ready paper reading assignments were equivalent for the school term and grade level. For both conditions, blank sheets of paper for side notes (annotations) were available to students while completing tasks, and usage was documented, although specific content of such annotations was not further analyzed. Reading passages ranged from magazine articles, scientific ideas, and literary texts to myths, folktales, vocabulary games, and elements of plays. Recognizing that differences in metacognitive SRL processes may stem from individual differences in background knowledge or interest in passages used in the study, potential threats to internal validity were mitigated by randomizing the allocation of conditions per student and grade and by counterbalancing the conditions.

During each session, we conducted structured interviews with participants after completing the reading tasks. Participants rated items using a three-choice rating scale (i.e., never, sometimes, always). On average, structured interviews lasted 19 minutes for the computer condition (*M* = 18:56 min, *SD* = 4:23 min) and 20 minutes for the paper condition (*M* = 20:00 min, *SD* = 5.25 min). To meet the operating hours of the after-school programs, two students were interviewed under one randomly assigned condition per day.

Measures and Survey Instruments

The Junior Metacognitive Awareness Instrument (Jr. MAI; Sperling et al., 2002) designed for students in Grades 3 through 8 was used as the basis for interviews. Jr. MAI was an adaptation of the original MAI, developed by Schraw and Dennison (1994), that consisted of two subscales: (a) *regulation of cognition*, defined as the cognitive processes that facilitate control, and (b) *knowledge of cognition*, defined as the cognitive processes that facilitate reflection. The original MAI has high internal consistency ($\alpha = .93$ and .88 for knowledge of cognition and regulation of cognition subscales, respectively; Schraw & Dennison, 1994). Jr. MAI has a reported internal consistency of $\alpha = .76$ for students in early elementary grades (3-5; Sperling et al., 2002). In the present study, Internal consistency for *the regulation of cognition* scale was acceptable to good ($\alpha = .66$ and .72 for the computer and paper conditions, respectively). The *knowledge of cognition* subscale had acceptable internal consistency ($\alpha = .68$ and .57 for the computer and paper conditions, respectively). While the coefficients for this subscale are lower than in previous studies, the reading content per condition and grade also varied in this study, which was not the case in previous studies. The calculated coefficients represent different reading topics that students encountered during the study, as this research was situated in the authentic context of the after-school program.

Each subscale was adapted to reflect engagement with computer-based and paper-based tasks. Items were read to the students and sometimes rephrased for clarity. The *regulation of cognition* subscale included the following dimensions: *planning* (three items), *monitoring* (two items), *control-learning strategies* (three items), and *evaluation* (four items). The *knowledge of cognition* subscale included the following dimensions: *declarative knowledge* (four items), *conditional knowledge* (two items), and *procedural knowledge* (two items). Three motivation dimensions were *technical skills* (two items) conceptualized as awareness of navigating and completing reading tasks (Brown & DeLoache, 1977); *self-efficacy* (three items) conceptualized as belief in one's ability to successfully realize their goals, which contributes to self-confidence (Bandura, 1977, 1989); and *reading motivation* (three items) expressed as engagement and preferences about reading (Wigfield, 1997; Wigfield & Guthrie, 1997). Each item was scored as 0 = never, 1 = sometimes, and 2 = always to indicate students' metacognitive SRL use. A total score for each dimension was calculated, and the mean was used in statistical analyses. (Note: All items associated with a construct can be found in the supplemental file available online.)

Data Analysis

Statistical analysis was conducted using SPSS 26.0. Significance was determined at an alpha level of .05. To examine the effects of condition and grade, data were analyzed using a 2 x 4 (condition-by-grade) mixed-model analysis of variance (ANOVA) with follow-up tests as warranted. Independent variables were the condition (computer-based vs. paper-based) and grade (2, 3, 4, and 5). The mixed-model ANOVA was run separately for each dependent variable. Dependent variables were the total scores of metacognitive SRL processes as rated during the interview: (1) *regulation of cognition* constructs (i.e., planning, monitoring, control, and evaluation), (2) *knowledge of cognition* constructs (i.e., declarative knowledge, conditional knowledge, and procedural knowledge), and (3) motivation constructs (i.e., technical skills, self-efficacy, and reading motivation). To examine differences between conditions for each grade in the presence of significant condition-by-grade interaction, we performed simple effects analysis using paired-sample *t*-tests with Bonferroni-adjusted alpha ($.05 \div 4 = .0125$). Additionally, the effect of grade was examined using within-condition one-way ANOVA and, upon significant main effect of grade, post hoc Bonferroni tests. Effect sizes were reported as partial eta squared (η_p^2). Table 2 shows the analyses conducted and the corresponding research question.

Table 2

Statistical Analyses Conducted for Metacognitive Self-Regulated Learning (SRL) Constructs

Statistical analysis		Research question
Mixed model ANOVA Two conditions (computer and paper) by four grades (2nd, 3rd, 4th, 5th)	Main effect of condition (computer based vs. paper-and-pencil)	Are there differences in metacognitive SRL processes between the two conditions regardless of grade level?
	Main effect of grade	Are there differences in metacognitive SRL processes across different grade levels regardless of condition?
	Interaction effect between condition and grade	Do the grade-associated patterns of metacognitive SRL processes differ between the two conditions?
Paired samples t-test (upon significant interaction in the mixed-model ANOVA)		Are there differences in metacognitive SRL processes between the two conditions at each grade level?
Within-condition one-way ANOVA		Does grade have an overall effect on SRL processes for each condition?
Bonferroni tests (upon significant main effect of grade in the one-way ANOVA)		Are there differences in metacognitive SRL processes between grades for each condition?

Results

Assumptions

Given that ANOVA is one of the general linear model methods, we began our analysis by testing a set of general linear model–related assumptions including univariate normality and homogeneity of variances. The sphericity assumption for repeated measures design was not relevant because there were only two measurement occasions. The z scores of skewness and kurtosis of each continuous variable indicated that data were normally distributed. Normality testing revealed appropriate levels of significant skewness and/or kurtosis (z-values within ±1.96), a normal distribution of scores (Shapiro-Wilk test $p < .001$), and homogeneity of variances across conditions and grades was assumed for all variables because Levene's tests returned nonsignificant results ($p > .05$). Below we present the statistical analyses per construct.

Regulation of Cognition Constructs

The *regulation of cognition* subscale included the dimensions of planning, monitoring, control, and evaluation.

Planning

Planning did not differ between the computer and paper conditions, and there were no differences between grades. These were indicated by nonsignificant main effects of condition, $F(1, 43) = .92$, $p = .34$, $\eta_p^2 = .02$, and grade, $F(3, 43) = 1.29$, $p = .29$, $\eta_p^2 = .08$, and a nonsignificant interaction, $F(3, 43) = 1.11$, $p = .35$, $\eta_p^2 = .07$ (see Figure 1A).

Monitoring

Monitoring did not differ between conditions or grades, as indicated by nonsignificant main effects of condition, $F(1, 44) = .23$, $p = .63$, $\eta_p^2 = .005$, and grade, $F(3, 44) = 0.44$, $p = .73$, $\eta_p^2 = .03$, and a nonsignificant interaction, $F(3, 44) = 0.04$, $p= .99$, $\eta_p^2 = .003$ (see Figure 1B).

Control

The grade-associated responses of control differed between conditions, leading to higher control in the paper than the computer condition at fifth grade. Control demonstrated a significant condition-by-grade interaction in mixed-model ANOVA, $F(3, 44) = 4.14$, $p = .011$, $\eta_p^2 = .22$ (see Figure 1C). The main effect of condition was not significant, $F(3, 44) = 2.06$, $p = .16$, $\eta_p^2 = .05$, but the main effect of grade was significant, $F(3, 44) = 2.93$, $p= .04$, $\eta_p^2 = .17$. Paired sample t-tests indicated that control was higher in the paper than the computer reading task for fifth-grade students only $t(10) = –2.96$, $p = .014$; there were no significant differences for other grades. In follow-up one-way ANOVA, the effect of grade was nonsignificant for the computer reading task, $F(3, 44) = 1.20$, $p = .32$, $\eta_p^2 = .08$. The effect of grade, however, was significant for the paper reading task, $F(3, 44) = 4.99$, $p = .005$, $\eta_p^2 = .25$. Students in fifth grade demonstrated higher control during the paper task than students in third and fourth grades ($p = .018$ and $p = .005$, respectively); there were no differences between other grades.

Evaluation

Students across grades had higher scores for evaluation during the computer than the paper condition, as demonstrated by a significant main effect of condition, $F(1, 44) = 5.54$, $p = .02$, $\eta_p^2 = .11$, and a nonsignificant interaction, $F(3, 44) = 1.29$, $p = .29$, ηp2 = .08 (see Figure 1D). The main effect of grade was not significant $F(3, 44) = 0.32$, $p = .81$, $\eta_p^2 = .02$.

Knowledge of Cognition Constructs

The *knowledge of cognition* subscale represented the dimensions of declarative knowledge, conditional knowledge, and procedural knowledge.

Declarative Knowledge

The mixed-model ANOVA showed that declarative knowledge did not differ between conditions or grades. There were nonsignificant main effects of condition, F(1, 44) = 1.01, p = .32, η_p^2 = .02, and grade, $F(3, 44) = 0.81$, $p = .49$, $\eta_p^2 = .05$, and a nonsignificant interaction, $F(3, 44) = 0.89$, $p = .45$, $\eta_p^2 = .06$ (see Figure 1E).

Conditional Knowledge

Conditional knowledge was higher in the paper than the computer condition. This was demonstrated by a significant main effect of condition, $F(1, 44) = 5.23$, $p = .03$, $\eta_p^2 = .11$. There were not differences between grades as the main effect of grade was not significant, $F(3, 44) = 0.35$, $p = .79$, $\eta_p^2 = .02$, and there was a nonsignificant interaction, $F(3, 44) = 1.91$, $p = .14$, $\eta_p^2 = .12$ (see Figure 1F).

Procedural Knowledge

Procedural knowledge did not differ between conditions or between grades. The mixed-model ANOVA yielded nonsignificant main effects of condition, $F(1, 43) = 1.16$, $p = .29$, ηp2 = .03, and grade, $F(3, 43) = 0.32$, $p = .81$, $\eta_p^2 = .02$, and a nonsignificant interaction, $F(3, 43) = 0.28$, $p = .84$, $\eta_p^2 = .02$ (see Figure 1G).

Motivation Constructs

The motivation subscale included the dimensions of technical skills, self-efficacy, and reading motivation.

Technical Skills

Technical skills did not differ between conditions or between grades. There were nonsignificant main effects of condition, $F(1, 44) = 1.28$, $p = .26$, $\eta_p^2 = .03$, and grade, $F(3, 44) = 2.31$, $p = .09$, $\eta_p^2 = .14$, and a nonsignificant interaction, $F(3, 44) = 0.36$, $p = .78$, $\eta_p^2 = .02$ (see Figure 1H).

Self-Efficacy

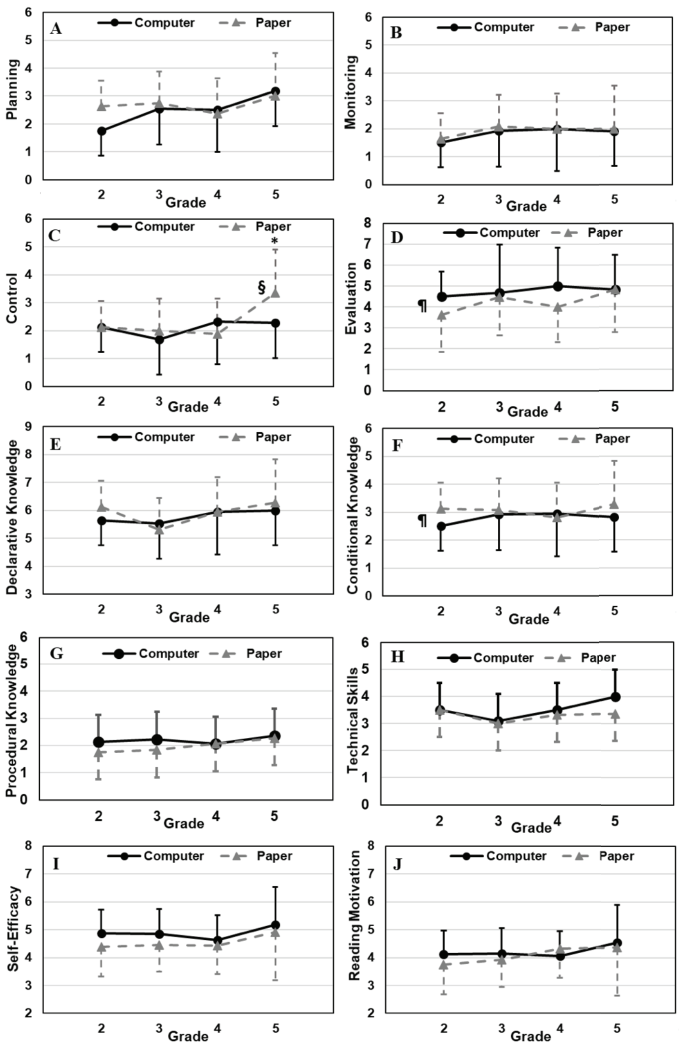
Self-efficacy did not differ between conditions or between grades as indicated by nonsignificant main effects of condition, $F(1, 44) = 3.61$, $p = .06$, $\eta_p^2 = .08$, and grade, $F(3, 44) = 1.20$, $p = .32$, $\eta_p^2 = .08$, and a nonsignificant interaction, $F(3, 44) = 0.33$, $p = .80$, $\eta_p^2 = .02$ (see Figure 1I).

Reading Motivation

Reading motivation did not differ between the computer and paper conditions, and there were no differences between grades. These were indicated by nonsignificant main effects of condition, $F(1, 44) = .88$, $p = .35$, $\eta_p^2 = .02$, and grade, $F(3, 44) = .29$, $p = .83$, $\eta_p^2 = .02$, and a nonsignificant interaction, $F(3, 44) = 1.02$, $p = .39$, $\eta_p^2 = .07$ (see Figure 1J).

Figure 1

Regulation of Cognition, Knowledge of Cognition, Technical Skills, Self-Efficacy, and Reading Motivation Dimensions During the Computer and Paper Conditions in Elementary Students in Grades 2, 3, 4, and 5.



* significantly higher in the paper than in the computer condition in paired-samples t-test (p = .01) following significant interaction in mixed-model ANOVA.

§ fifth grade significantly higher (p ≤ .04) than third and fourth grades for the paper reading condition in Bonferroni tests following one-way ANOVA.

Note. The inserted symbols in some charts indicate ¶ p < .05 for main effect of condition in mixed-model ANOVA. Lines represent means, and error bars represent standard deviations for each condition and grade.

Discussion

In this study, we investigated how metacognitive SRL processes may differ between computer-based and paper-based reading tasks in elementary students. The main findings were that from second to fifth grade, students were more aware of their conditional knowledge in paper-based reading, yet they practiced evaluation more during computer-based reading. Fifth-grade students also reported using control processes to a greater extent during paper-based reading than when reading on the computer.

When examining metacognitive SRL skills between computer and paper conditions, the results indicate that these skills were present in both contexts, but significant differences occured in two regulatory and one knowledge of cognition dimensions. Students across grades had higher levels of *evaluation* processes during computer-based reading tasks than paper-based ones. This is a novel finding among elementary students, extending prior research in students of middle and higher education levels, where evaluation has been shown to be significantly associated with outcome expectations in computer-based science and history assignments (Deekens et al., 2018). Similarly, for kindergarten students, computer feedback has been shown to result in higher levels of achievement in literacy skills than no feedback (Muis et al., 2015). One possible reason for the current findings is that elementary students may exert greater evaluation processes during computer than paper reading assignments because in computer assignments students directly elicit personal judgments of present performance (Schunk, 1996). As has been argued, students rely on feedback and performance outcomes to evaluate their comprehension during computer-based reading (Cavalcanti et al., 2021). This is critical for judgments of learning as students revise responses for optimal reading and comprehension (Koriat, 2012; Lipko et al., 2009).

The elementary students in this study showed significantly higher levels of *conditional knowledge* during paper-based reading tasks than during computer-based reading tasks. These results agree with previous studies showing that students in fifth grade apply multiple sources to guide their SRL choices in literacy instruction (Connor et al., 2015; Hattan & Dinsmore, 2019) and that task orientation of preschoolers and kindergarteners affects SRL (Lepola et al., 2020; Nielsen, 2017). Furthermore, past research in typologies of reading applications among undergraduate students demonstrated that reading a text serves the purposes of self-assessment, obtaining information, and enjoyment (Lorch et al., 1993). Taken together, the present and past findings suggest that elementary students can recognize which strategies are relevant across reading tasks, but this is apparently more evident in paper than computer reading, as other research on students in Grades 3–7 has shown (Garner, 1990; Goodwin et al., 2020; Hennessey, 1999; Taouki et al, 2022).

In this study, there was also a difference in *control* processes between the two reading conditions, but this was dependent on grade as shown by a significant condition-by-grade interaction. Follow-up analysis indicated that this was true only for fifth-grade students who demonstrated higher control in paper- than computer-based reading. Fifth-grade students also had higher control than younger students during the paper reading condition, but this difference disappeared under the computer condition. These findings are unlike past research showing that guided computer-based reading and writing instruction produces significantly higher levels of control learning strategies than traditional instruction in fourth, sixth, and eighth graders (Ponce et al., 2013).

This disparity from previous research cannot be easily explained. One possible explanation is that fifth-grade students in our study may have demonstrated high levels of control strategies because they may have received targeted instruction in school related to such strategy use. Alternatively, higher levels of control in paper- than computer-based reading among fifth graders may suggest that awareness of control strategies is a metacognitive SRL process that students do not adapt equally across reading contexts; this lack of adaptation has been documented in earlier research (Delgado et al., 2018; Delgado & Salmerón, 2021). Control strategies may be more developed in fifth graders than in younger students because fifth graders may exert more automatic than conscious control processes to reading comprehension (Connor et al., 2015). This enables students to become autonomous learners (Martin, 2004; Vorstius et al., 2013). Since the present data were cross-sectional, inferences on development cannot be directly made. It is possible, however, that students in upper elementary grades have stronger literacy skills than younger students, resulting in automatic controlled processes, as others have demonstrated (Abrami et al., 2013; Earle et al., 2020; Paris & Flukes, 2005). Furthermore, elementary teachers may model metacognitive SRL skills at a greater extent in paper- than computer-based reading assignments, as past empirical work has shown (van de Oudeweetering & Voogt, 2018). Metacognitive SRL teaching practices may not be fully integrated in digital reading curricula, potentially explaining the differences between reading conditions.

There were no differences in *planning, monitoring, declarative* and *procedural knowledge* between computer- and paper-based reading. The lack of differences between computer and paper may be attributed to inherent characteristics of each medium that elicit similar cognitive decisions. For example, similar visual aids in both computer and paper reading may disable opportunties to apply new or spontaneous planning processes. Also, visual cues may create overexposure to information where critical details for comprehension are missed, as studies on digital and print reading in 10th grade and college students have shown (Mangen et al., 2013, 2019). Furthermore, adaptation of strategy use to reading concepts and procedures occurs naturally when a level of consistency between reading interfaces is present (Goodwin et al., 2020; Harvey & Anderson, 1996; Javorsky & Trainin, 2014). Reading requires mental representations and connections to prior knowledge to achieve comprehension (Kendeou et al., 2003; Kendeou & van den Broek, 2007). In our study, computer and paper reading shared some common features, such as informational boxes and hints, but the participating students did not seem to make the necessary mental connections for reading representations and processes. Hence, consistency in design and intentional instruction can possibly aid the adaptation of metacognitive SRL knowledge and skills in elementary students.

We did not record any differences in t*echnical skills, self-efficacy levels,* and *reading motivation* between conditions. This agrees with past research on fourth-grade students whose lower literacy skills in ePIRLS (the computer-based version of PIRLS, the Progress in International Reading Literacy Study assessment) have been attributed to unequal access and low socioeconomic status (Combrinck & Mtsatse, 2019). Even though we cannot directly infer an association between social factors and reading comprehension, our results suggest that low levels of reading skill may negatively impact motivation; this may yield nonsignificant differences between computer- and paper-based reading comprehension. Socioeconomic status could possibly mediate the relationship between students' reading comprehension and exposure to reading opportunities—print or digital—but this could be an area for future investigation.

Apart from control processes that were higher in fifth grade than younger students, there were no other grade-associated differences in metacognitive SRL processes. A possible explanation for the nonsignificant differences between grades is that students overall are still less familiar with applying metacognitive SRL processes for computer-based reading assignments, as other researchers have shown (Goodwin et al., 2020; Støle et al., 2020). Even so, in this study, students across grades and even very young students demonstrated these processes to some extent. These results extend prior research showing positive metacognitive and motivation effects on learning outcomes of computer-based tasks in secondary and tertiary students (Abrami et al., 2013; Chen et al., 2019). Past research suggests that metacognitive skills, which are nearly developed in fifth-grade students, are still emerging in third-grade students (Pratt & Martin, 2017; Roebers, 2014). While findings on the development of metacognition may stem from measurement methods that make it difficult to truly detect the metacognitive maturity of very young students (Azevedo, 2015; Greene, 2015), the results of this study indicate that as early as second grade, students are capable of metacognitive thinking and flexible strategy use for computer-based reading.

Implications

The present study has implications for the application of SRL and metacognition in computer-mediated educational settings. From a theoretical standpoint, the study provides evidence that students in elementary grades use SRL processes and metacognitive strategies to a certain degree while completing computer- and paper-based reading assignments. Our data show that students control, evaluate, and know when to use a learning strategy for both reading modalities: computer and paper. The multidimensional aspect of metacognition comprises interconnected thought processes and regulatory skills (Hennessey, 1999; Koriat, 2012; Nelson & Narens, 1994). Students still have to learn how to set goals, monitor, and become aware of their reading capacities and procedures to improve performance and increase motivation (Brown et al., 1981; Flavell, 1979; Ortlieb et al., 2014; Pintrich & de Groot, 1990). From a practical standpoint, our results suggest that metacognitive SRL strategies are present and can help young students read and complete reading tasks effectively. To reinforce the application of metacognitive SRL processes in computer-based environments, teachers can instruct students to look for definitions and context clues, read the entire text, ask themselves questions, read aloud, organize responses, and use feedback to revise. Also, schematic representations such as diagrams and tables can potentially contribute to forming cognitive connections and applying SRL strategies. Students could reduce cognitive deficiencies by cultivating cognitive schemas (e.g., memory, attention) that facilitate connections with different reading genres. Furthermore, modeling and scaffolded instruction could aid the process of acquiring SRL skills, especially in low-stakes and nongraded reading assignments, and motivate readers.

Limitations

This study had several limitations. The sample size did not allow for an equal distribution of students among grades and gender because of the COVID-19 interruption. Sample size may have limited the power of some analyses. Another limitation was the variance of the text genres; reading assignments ranged from narrative and nonfiction texts to poetry and vocabulary. We also recognize that the scale used was not validated in the context of computer- and paper-based reading assignments. Despite these limitations, the study had several strengths. The within-participants aspect of the design and the counterbalancing of conditions increased confidence of detecting true differences between reading conditions. An additional strength was that the data provided direct comparisons of typical computer- and paper-based reading assignments in elementary students to guide future instructional and research practices. Overall, the results extend the literature on metacognitive SRL skills in authentic computer and paper reading environments.

Future Research

Researchers should continue to investigate computer- versus paper-based reading tasks from the viewpoint of instruction, measurement, and development. More research is needed to examine how teachers instruct students to apply metacognitive SRL skills during computer and paper reading assignments. How teachers monitor students' reading comprehension that results from thought processes requires empirical evaluation. It is also worthwhile to pursue research on the academic outcomes of students who successfully adapt metacognitive skills across computer and paper contexts. Furthermore, replication of the current study that includes analysis of the presently adjusted Jr. MAI and MAI scales through statistical techniques such as exploratory and confirmatory factor analysis would further inform composite and subscale validity evidence when used in the context of computer and paper reading tasks. Finally, longitudinal examinations will yield greater insight into the development of computer-based metacognitive SRL skills in elementary students.

Conclusion

In summary, students reported conditional knowledge to a greater extent during paper-based reading tasks than during computer-based reading tasks, but they used evaluation processes more during computer-based reading than during paper-based reading. Control was higher in paper-based reading than during computer-based reading only for fifth-grade students, who also had higher control than younger students during paper-based reading. There were no grade- or condition-associated differences in other metacognitive SRL skills. These results indicate a need for teachers to intentionally instruct metacognitive SRL processes to their students and for students to learn to apply metacognitive SRL skills between the two reading modes: computer and print.

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About the Authors

Katerina Sergi is an educational psychologist with a research focus on metacognitive development, self-regulated learning, and motivation. She is interested in the use of computer technologies in elementary school literacy and STEM education.

Anastasia D. Elder is a professor in the Department of Counseling, Educational Psychology, and Foundations, Mississippi State University. She serves as the associate dean and the provost scholars mentor in the Shackouls Honors College. Her research has emphasized investigating and assessing developing cognition and the design of educational environments and tools that foster understanding and critical thinking.

Tianlan Wei is an associate professor of educational psychology in the Department of Counseling, Educational Psychology, and Foundations, Mississippi State University. Her research activities are situated in three subcategories: gender and ethnic differences in learning and performance, academic emotions and motivation, and quantitative methodology and psychometrics.

Kristin Javorsky is an associate professor in the Department of Curriculum, Instruction and Special Education, Mississippi State University. Her research interests center on contemporary factors that influence early literacy acquisition, both in and beyond the classroom.

Jianzhong Xu is a professor in the Department of Counseling, Educational Psychology, and Foundations, Mississippi State University. His research focuses on teaching and learning in the school, home, and online settings, in home–school relationships and in partnerships with families from diverse cultural backgrounds. His work appears in journals such as *American Educational Research Journal, Computers & Education, Educational Research Review, Contemporary Educational Psychology, and Internet* and *Higher Education.*

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Supplement File: Survey Instrument

Item **When I complete a reading assignment on computer …… /** **When I complete a reading assignment on pen and paper……..**	**Never (0)**	**Sometimes (1)**	**Always (2)**
Reading Motivation			
1. I find reading interesting			
2. I look forward to reading			
3. I find reading enjoyable			
Technical Skills			
4. I know my way to the computer program / worksheet.			
5. I know where to start and finish.			
Self-Efficacy			
6. I can understand the content of the reading assignment.			
7. I am confident with my reading skills.			
8. **(skip prompt)** I can complete the reading assignment using computers / worksheets.			
Declarative Knowledge			
9. I know when I understand something.			
10. I know what the teacher expects me to learn.			
11. I learn more when I am interested in the topic.			
12. I am good at remembering information.			
Conditional Knowledge			
13. I can make myself learn when I need to.			
14. I learn best when I already know something about the topic.			
Procedural Knowledge			
15. I try to use ways of completing the assignment that have worked for me before.			
16. I know the best ways to complete the assignment.			
Planning			
17. I think of several ways to answer a question and then choose the best one.			
18. I think about what I need to learn before I start working.			
19. I make side notes before answering a question.			
Monitoring			
20. I ask myself how well I am doing while I complete an assignment.			
21. I check my answers before moving to the next question.			

Control Strategies			
22. I draw pictures or diagrams to help me understand while learning.			
23. I really pay attention to important information/signals.			
24. I read questions aloud.			
Evaluation			
25. I stop and go back over new information that is not clear.			
26. I stop and reread when I get confused.			
27. When I am done with my assignment, I ask myself if I learned what I wanted to learn.			
28. I know how well I did once I finish.			