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Computer-based Writing Instruction

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Acknowledgements: *The research reported here was supported by the Institute of Education Sciences, U.S. Department of Education, through Grants R305A180261 and R305A180144 to Arizona State University. The opinions expressed are those of the authors and do not represent views of the Institute or the U.S. Department of Education. We are also thankful to our many collaborators who have contributed to our research on writing, as well as the strong communities of researchers and practitioners who have contributed to the enormous growth in writing research over the past decade.*

Computer-based Writing Instruction

Writing is a cognitively complex process that requires task management, strategies, self-regulation, genre and background knowledge, and audience awareness (Flower & Hayes, 1980; Hayes, 2012; Zimmerman & Risemberg, 1992). This complexity, coupled with highly variable writing instruction in the United States (Brindle et al., 2016; Graham, 2019; Graham et al., 2014), may in part explain why writing achievement results are below expectations according to national assessment benchmarks (NAEP, 2011).

Amid calls to prioritize improvements in writing instruction and achievement (National Commission on Writing, 2003), the National Commission on Writing (2004, p. 31) lobbied for investments to support writing with technology, arguing that "technology holds out great promise as a means of expanding time for writing, for both students and teachers." Indeed, writing with computers was codified in the Common Core State Standards ([CCSS], 2010), which requires students across grades to use technology and the Internet to collaborate on writing tasks with peers and publish their work. Moreover, advancements in automated essay scoring have provided a further foundation of software development for improving writing achievement through computer-based instruction and assessment (Shermis & Hammer, 2013; Shermis & Wilson, in press). Recent systematic reviews and meta-analyses indicate that computer-based writing instruction (CBWI) may support gains in writing achievement (Li, 2023; Little et al., 2018; Nunes et al., 2022; Strobl et al., 2019; Williams & Beam, 2019; Zhai & Ma, 2023).

CBWI may entail any type of writing instruction involving computers (e.g., revising essays in shared, online documents), although often refers to instructional software such as automated writing evaluation (AWE) or intelligent tutoring systems (ITS; Allen et al., 2016; Banawan et al., 2023; Strobl et al., 2019). AWEs offer immediate, automated scores and formative feedback to

students and teachers over multiple drafts (e.g., Warschauer & Grimes, 2008). They may also allow teachers to assign writing prompts in different genres, game-based learning, peer reviews, and scaffolds (e.g., prewriting graphic organizers) to support the full writing process (e.g., Strobl et al., 2019). ITSs serve similar roles as AWEs, but may also deliver individualized instruction based on system-generated evaluations of students' writing performance (Allen et al., 2016; Roscoe & McNamara, 2013; Roscoe et al., 2014).

Allen and colleagues (2016) previously documented example computer-based tools used to support writing instruction, and multiple reviews have reported novel writing technologies, their affordances, and synthesized research findings on the effectiveness of computer-based systems on writing performance (Fu et al., 2020; Li, 2023; Little et al., 2018; Nunes et al., 2022; Strobl et al., 2019; Williams & Beam, 2019; Zhai & Ma, 2023). In this chapter, we discuss the affordances and limitations of computer-based writing instruction systems within the context of evidence-based practices (EBPs) and a writer(s)-within-community model of writing (Graham, 2018; McNamara & Kendeou, 2022). In doing so, we argue that to realize the potential of CBWI, researchers, and educators must (a) collaboratively integrate such technologies with effective instructional practices, while also (b) account for the strengths, needs, and development of writing communities in classrooms. We conclude with a discussion about future research directions, particularly concerning the use of generative artificial intelligence in writing instruction.

Supporting Deliberate Practice with CBWI

Multiple cognitive developmental frameworks have informed research in CBWI. However, one long-standing model prioritizes *deliberate practice* (Allen et al., 2016; McNamara & Kendeou, 2022)—the repeated effortful practice of a skill in which participants apply formative feedback and work through motivational barriers to achieve the explicit goal of improving performance

(Ericsson et al., 1993). For writing, Bereiter and Scardamalia (1987) proposed a developmental model in which maturing writers transition from writing to reproduce knowledge (i.e., knowledge-telling) to construct original knowledge (i.e., knowledge-transforming). Likewise, Zimmerman and Risemberg's (1997) social cognitive model emphasized the development of self-regulatory skills through feedback loops during writing experiences. To improve, writers must practice writing frequently with explicit goals and feedback over an extended period of time to master necessary self-regulatory skills (Kellogg, 2008) and transition to a more advanced knowledge-transforming and constructing modes of writing (Kellogg & Whiteford, 2009). Facilitating writing practice with formative teacher, peer, and computer feedback has been shown to be a highly effective writing instructional practice (Graham et al., 2015).

The effort required for teachers to assess writing, provide feedback, and facilitate ongoing practice with feedback is not feasible to employ consistently (Ahumada et al., 2013; Applebee & Langer, 2011; Harvard et al., 2014; Korth et al., 2016). Indeed, one of the most important resources that writing teachers need is *time* (National Commission on Writing, 2004). With some exceptions (e.g., Graham et al., 2021), surveys of writing teachers have revealed that teachers inconsistently devote enough time to facilitating writing practice and implementing evidence-based instructional practices (Brindle et al., 2016; Graham et al., 2014; Kiuhara et al., 2009). Moreover, many teachers report feeling unprepared to teach writing, which is negatively associated with teachers' implementation of evidence-based writing practices and their students' performance (Bañales et al., 2020; Coker et al., 2016; De Smedt et al., 2016; Gillespie et al., 2014; Graham et al., 2014; Hsiang et al., 2018).

The availability and affordances of AWE and ITS programs offer a potential solution for teachers to provide deliberate writing practice over multiple drafts (Kellogg et al., 2010) while

also optimizing teacher labor related to instruction and feedback (McNamara & Kendeou, 2022; Stevenson, 2016; Warschauer & Grimes, 2008). To meet these needs, computer-based programs for writing feedback and instruction leverage automated essay scoring (AES) systems. In general, AES systems work by using natural language processing (NLP) tools to quantify textual features, and then apply statistical models—including machine learning and artificial intelligence (AI) techniques—to identify textual features that are closely associated with human scores. These NLP features and statistical models are then used to generate scores for submitted essays that are similar to human ratings of essays with similar NLP characteristics (see Deane, 2013; Dikli, 2006; Shermis, 2020). AES scores have been shown to be highly reliable and correlated with human scores (e.g., Shermis, 2014; Shermis & Hammer, 2013; Wilson, 2018).

AWE programs also use automated feature detection and analysis to generate feedback to students and teachers (Grimes & Warschauer, 2010; Stevenson & Phakiti, 2014; Strobl et al., 2019), such as information about writing concepts and suggestions for revisions (Fu et al., 2022). AWE programs may also enable prewriting activities, communication between teachers and peers, pedagogical scaffolds, and interactive lessons (Strobl et al., 2019; Wilson et al., 2022). Likewise, ITSs such as the Writing Pal also provide both feedback and evaluation scores (Banawan et al., 2023; Roscoe & McNamara, 2013). Writing Pal, and ITSs in general, are more advanced than AWE systems because they also provide individualized instruction that adapts to students' performance (Allen et al., 2016). ITSs can be used to teach strategy instruction and goal setting while revising multiple drafts of essays, and also provides game-based instruction and practice (Butterfuss et al., 2022; Crossley et al., 2013; Roscoe et al., 2013, 2014; Roscoe & McNamara, 2013).

Driven by the aforementioned affordances and frameworks, literature reviews and meta-analyses have investigated the actual impact of AWE use (Fu et al., 2020; Li, 2023; Little et al., 2018; Nunes et al., 2022; Stevenson & Phakiti, 2014; Stevenson, 2016; Strobl et al., 2019; Williams & Beam, 2019; Zhai & Ma, 2023). Nunes et al. (2021) identified eight studies that analyzed quantitative measures of writing quality; half found no impact on writing quality when compared to feedback from teachers and/or peers (Ware, 2014; Wilson & Czik, 2016; Wilson & Roscoe, 2020). Moreover, participants in two studies (Frankze et al., 2005; Wade-Stein & Kintsch, 2004) improved their summary writing quality after receiving AWE feedback, but only in comparison to a control condition in which participants received no feedback. Fu et al. (2020) reached similar conclusions in their review (n = 48): feedback from AWE did not outperform feedback from teachers and peers, and that moderating factors (e.g., feedback type, learner characteristics, methodological factors) should be further examined. In sum, reviews suggest that feedback from AWE systems may support writing quality improvements, but differences between feedback from peers and teachers may be negligible.

Meta-analyses of AWE studies (Li, 2023; Little et al., 2018; Zhai & Ma, 2023) have also explored potential moderating factors. Li (2023) observed an overall positive effect of AWE on writing skill development when compared to instruction without AWE (g = 43, n = 25 studies). However, the effect sizes were moderated by several important factors. First, when comparing how participants interacted with computers and each other in studies (i.e., AWE vs. non-AWE, AWE vs. peer interaction, and AWE vs. teacher-interaction), only AWE compared to non-AWE produced a significantly positive effect. This outcome suggested that the benefits of AWE depend on the ways in which students interact with the system, their peers, and teachers. Moreover,

moderation analyses also highlighted the benefits of feedback that included informative tutoring, identification of misconceptions, and longer intervention durations (Li, 2023).

Wilson et al. (2023) provide robust evidence for AWE effects from a year-long randomized controlled trial of AWE implementation in middle school classroom settings (n = 2,547 students in n = 3 school districts). Students were assigned at the classroom level to either (a) an AWE condition in which teachers received ongoing coaching support on AWE implementation and minimum usage requirements or (b) a control condition in which teachers and students did not receive AWE access until after the conclusion of the study. Crucially, researchers found that AWE was not used consistently throughout the year, and when controlling for covariates such pretest performance and demographic variables, there was no significant difference between treatment and control conditions in writing quality or motivation (i.e., writing self-efficacy, beliefs about writing, and recursive process beliefs). Interestingly, when analyzing outcomes by district, a relationship between level of AWE use (i.e., fidelity) and outcomes emerged. Of the three districts, the district with the highest fidelity of AWE usage produced statistically significant positive effects on writing quality (g = 0.61); the district with lower fidelity produced negative effects or no effect. In sum, simply providing districts and teachers with AWE access does not necessarily influence writing outcomes, but consistent usage and authentic implementation are beneficial. These findings are consistent with conclusions from other reviews (Li et al., 2022) and analyses of large-scale naturalistic AWE implementations (Potter & Wilson, 2021).

To summarize, prior findings suggest that CBWI can facilitate deliberate practice (e.g., Kellogg et al., 2010), improve writing quality (e.g., Frankze et al., 2005; Palermo & Thomson, 2018), improve revising (e.g., Roscoe et al., 2018; Wang et al., 2020), improve beliefs about writing (e.g., Warschauer & Grimes, 2008; Wilson & Czik, 2016; Wilson & Roscoe, 2020), and

reduce teacher labor (e.g., Stevenson, 2016). However, recent reviews and meta-analyses (Fu et al., 2020; Li, 2023; Little et al., 2018; Nunes et al., 2022; Stevenson & Phakiti, 2014) and high-quality implementation studies (Cruz Cordero et al., 2023; Wilson et al., 2023) also reveal that the benefits of many systems by themselves are marginal.

We propose that the *implementation* of CBWI is crucially important for improving the teaching and learning of writing under the right conditions. Thus, in the following sections, we discuss two crucial factors in optimizing AWE effectiveness: (1) integration of AWE with *evidence-based writing instruction practices* and (2) emphasizing AWE implementation within a *community of writers* (Graham, 2018).

Enhancing CBWI with Evidence-Based Practices

Evidence-based practices (EBPs) in writing instruction have been identified via meta-analyses of writing intervention studies (e.g., Graham & Harris, 2017; Graham et al., 2018; Graham et al., 2015a; Graham et al., 2015b; Graham et al., in press; Koster et al., 2015). Perhaps the most effective forms of writing instruction involve strategy instruction and specifically *self-regulated strategy instruction* (SRSD; see Harris, 2021; Harris & Graham, 2016 for overviews). SRSD (Harris & Graham, 2019; Harris, 2021) involves a recursive set of stages in which students receive explicit instruction in strategies and self-regulatory behaviors (e.g., performance monitoring, positive self-talk). Students are taught background knowledge (e.g., genre features), discuss the strategy with peers and teachers, teacher modeling of the strategy, memorize the strategy, guided practice with feedback, and finally independent practice and performance.

Importantly, teachers can implement successful EPBs (e.g., SRSD) without the use of writing technologies, and CBWI technologies are themselves already an evidence-based resource (Graham et al., 2015a; Li, 2023; Little et al., 2018; Zhai & Ma, 2023). However, with exceptions

(e.g., McNamara & Roscoe, 2013; Palermo & Thomson, 2018; Wijekumar et al., 2022; Wilson et al., 2022), there is a relative paucity of research on *integrating* these two threads. Wilson and MacArthur (in press) argue that AWE affordances align to the principles of self-regulated learning (i.e., clarifying success metrics, practice opportunities, actionable feedback, collaboration, and ownership of learning; see Black & Wiliam, 2009), but more research is needed to empirically test this claim.

Several projects have begun to integrate writing technologies with strategy instruction. For example, the Writing Pal ITS offers self-directed, technology-supported strategy instruction—delivered by animated student and teacher characters—to support secondary students throughout the writing process (i.e., planning, drafting, revising) persuasive essays, including strategy lesson videos, practice games, and feedback reports (Roscoe & McNamara, 2013; Roscoe et al., 2014). In experimental studies (Roscoe et al., 2015; Roscoe et al., 2018), high school students have practiced writing persuasive essays using the complete Writing Pal (i.e., feedback, strategy lessons, and games) or only automated feedback. Students in both conditions revised, but strategy instruction was associated with more substantial revisions than feedback alone. Students who received strategy instruction and game-based practice may have been better positioned to attend to and revise based on AWE feedback. Integrating game-based strategy practice features in Writing Pal usage has also improved the writing performance and engagement of L1 and L2 high schoolers (Allen et al., 2014).

ITSs may also support integrating strategy instruction for both writing and reading. Weston-Sementelli et al. (2018) invited undergraduate students to write source-based essays using writing strategy training and practice from Writing-Pal along with reading comprehension strategy instruction from the *Interactive Strategy Training for Active Reading and Thinking* ITS (iSTART;

McNamara et al., 2004). Students received (a) training only in reading strategies via iSTART, (b) training in only writing strategies via Writing-Pal, (c) combined instruction using abridged procedures for both ITSs, or (d) a control group that did not receive either training. Students (regardless of prior ability) who learned with both ITS programs wrote higher quality source-based essays compared to students who received instruction using either or neither of the ITSs.

Wijekumar and colleagues (2022) have explored the ITS for Text Structure Strategy (ITSS). In a randomized controlled trial with 464 elementary school students, Wijekumar et al. (2022) found that integrating ITSS instruction with SRSD writing instruction was highly effective for teaching young students to plan and write source-based essays. The integrated intervention was implemented by teachers with practice-based professional development and ongoing coaching for ITS (6 weeks) and SRSD (12 weeks) and compared writing results to a business-as-usual (BAU). control. After ITSS instruction on how to read and take notes from sources (i.e., before writing instruction), students in the treatment condition improved their writing plan quality (ES = 0.77). Results also revealed significant difference in writing quality for students with lower levels of prior writing performance. Following SRSD writing instruction, very large effect sizes were revealed for planning (ES = 1.60) and writing quality (ES = 2.29). Results suggest that integrating ITSS for reading and SRSD for source-based writing within a comprehensive professional development framework can profoundly improve elementary-aged students' writing quality and processes.

SRSD implementation can be challenging for teachers even with researcher-provided professional development (McKeown et al., 2014). AWE and ITSs may reduce barriers for teachers to implement SRSD and strategy instruction. Palermo and Thomson (2018), for example, implemented a low intensity AWE+SRSD intervention without practice-based professional development. They conducted an experimental study with middle schoolers (n = 829) who

received teacher-led instruction over 16 lessons in one of three conditions. In one condition, students learned how to use AWE to practice writing and revising essays and completed AWE system lessons. A second condition integrated AWE practice with SRSD instruction. In addition to writing five essays, teachers were trained to deliver a set of SRSD lesson plans that included instruction in a strategy to plan and draft a persuasive essay. In a control BAU condition, students practiced writing and revising without AWE or SRSD. Crucially, students in the AWE+SRSD condition wrote posttest essays that were better quality, longer, and included more argumentative features than students in the other conditions. Students in the AWE-only condition wrote essays that were of significantly better quality than the BAU condition. AWE improved writing outcomes (*ES* = 0.65) but integrating AWE with SRSD (*ES* = 1.18) was more effective.

In sum, AWE affordances may be integrated within SRSD lessons (e.g., Palermo & Thomson, 2018) or as a supplement traditional SRSD instruction (e.g., Wijekumar et al., 2022). Components of SRSD (e.g., goal setting, performance monitoring, strategy instruction) can also be integrated with AWE affordances, such as producing formative assessment scores that inform feedback and classroom discussion (Wijekumar et al., in press), supporting students in setting and monitoring progress towards writing process and product goals (Wilson et al., 2022), or peer collaboration (Potter et al., 2020). Table 1 summarizes suggestions for aligning SRSD instruction with AWE. We hypothesize that CBWI may further enhance the implementation of already highly effective EPBs and vice versa. We encourage future research that continues to examine the integration of computer-supported writing with robust strategy instruction.

Enhancing CBWI Within a Community of Writers

CBWI must also consider the *contexts* in which technologies are implemented. Sociocultural frameworks define writing as a technology people use to communicate with one another, to build

relationships, develop identities, and participate in social situations (e.g., political discourse, Bazerman, 2016). Graham (2018) integrates sociocultural frameworks with cognitive models of writing (e.g., Hayes, 2012) via the revised Writers-Within-Community model (WWC).

In the WWC model, the teaching and learning of writing are shaped by classroom contextual factors (e.g., historical, political, and economic histories underlying curricula and beliefs), characteristics of community members (e.g., individual differences in literacy skills and motivation), writing goals (e.g., prompts), tools (e.g., AWE and ITS), and actions of community members. As with strategy instruction, developing a community of writers can occur without CBWI tools. For example, teachers can differentiate writing instruction based on students' prior knowledge or performance, facilitate peer review, and invite students to collaboratively write about meaningful topics for authentic audiences (e.g., writing political letters to local officials). Nonetheless, we contend that affordances offered by CBWI systems may further facilitate the development of a strong community of writers within school contexts.

McNamara and Kendeou (2022) posit that AWE development and research must draw on models such as the WWC to inform technology implementation within writing communities (i.e., classrooms) to develop writing with authentic audiences and purposes. For example, research studies that examine differences between computer-generated "versus" teacher feedback may lack ecological validity because teachers rarely implement AWE without providing their own feedback (Palermo & Wilson, 2020; Wilson & Czik, 2016). In this section, we expand upon McNamara and Kendeou (2022) to argue that another way to optimize CBWI is for (a) writing teachers to situate CBWI technology use within community-building and community-driven tasks, and (b) for technology developers to incorporate (more) features that enable or support writing communities (McNamara & Kendeou, 2022). Community member perceptions and goals are a starting place.

Teacher Perceptions and Implementation of Computer-based Writing Instruction

Teachers are typically leaders of their classrooms and writing communities, and thus their perceptions of AWE, EBPs, and necessary support systems are critical for integration. Teacher beliefs about AWE may impact their implementation (Li et al., 2015) and thus influence student writing achievement (Chen & Cheng, 2008; Wilson et al., 2023; Wilson et al., 2022). In general, teachers have reported favorable beliefs toward AWE, including social validity (e.g., Wilson & Czik, 2016; Wilson et al., 2021; Wilson & Roscoe, 2020). Despite favorable *attitudes*, studies have documented variance in how much teachers actually *use* AWE (Li et al., 2015; Potter & Wilson, 2021; Roscoe & McNamara, 2013; Wilson et al., 2022; 2023). For instance, Stevenson (2016) reviewed the ways that AWE has been integrated and used in classrooms. Stevenson (2016) concluded that teachers primarily used AWE to save time and promote student writing independence, but their practice generally did not include writing for an audience or learning how to write for multiple genres. Likewise, a descriptive study on a statewide implementation of AWE revealed that an embedded peer review function was rarely used (Potter & Wilson, 2021).

Analyses from focus groups and qualitative analyses of teacher data have illuminated several reasons for variance in teacher implementation. For example, elementary teachers have indicated that AWE-generated feedback was sometimes misaligned to their curricular goals or their own feedback, and thus they needed to manage student feedback uptake to prevent students from internalizing misaligned feedback (Wilson et al., 2021). Teachers have also discussed barriers to implementation due to school and district policies (e.g., limited time), and that it can be challenging for students with limited writing ability to apply feedback and work independently. In addition to influences from individual teacher beliefs and actions (e.g., Li et al., 2015; Wilson et al., 2023), teacher reports indicate that there may be systemic barriers to effective implementation

of computer-based writing systems (Wilson et al., 2021). Consequently, the WWC model can inform future research of CBWI by examining the ways in which systemic factors (e.g., curricula and teacher beliefs) and individual differences of students may impact the ways in which writing technologies are implemented and support authentic and collaborative writing tasks.

Student Perceptions and Implementation of Computer-based Writing Instruction

Writing is also shaped by the capacity of community members, such as students' literacy skills and knowledge, background experiences, and self-regulation (Graham, 2018). Therefore, it is necessary to consider individual differences (e.g., prior reading and writing ability) in students' perceptions and writing with respect to CBWI.

Perceptions and trust of AWE feedback may influence students' revising behavior and feedback uptake. AWE systems can sometimes overwhelm students with too much feedback, particularly for English language learners (Bai & Hu, 2017; Rannali, 2018; Ranalli et al., 2017). Additional factors that influence student revision behavior are low trust in AWE feedback (Ranalli, 2021; Zhang, 2020), the presentation and expectations of the system (Roscoe et al., 2017), gaps in writing knowledge or misunderstanding feedback (Wang et al., 2020), beliefs that achieving a high score means that no further work is needed (Moore & MacArthur, 2016), or discouragement after receiving low scores (Fu et al., 2022).

Individual differences may also influence whether certain modes of instruction are more optimal. For example, Roscoe et al. (2019) tested a version of Writing Pal in which students either practiced writing and revising essays with feedback, practiced with game-based features, or practiced with strategy instruction lessons. Students with stronger prior reading performance benefited more from traditional practice with feedback, but students with lower prior reading

performance benefited from game-based instruction. Consequently, technologies may need to include multiple forms of feedback and practice to serve a full range of students.

Implementation of CBWI must attend to the differences and needs of a community of writers. Supplementing computer-generated feedback with teacher feedback (e.g., Li, 2023), computer-generated instruction (e.g., Roscoe & McNamara, 2013), goal-setting support (Wilson et al., 2022), and teaching evaluation criteria may help students understand and apply feedback (MacArthur, 2016). Furthermore, developing systems with multiple modes of instructional delivery and practice may support students with varying proficiency levels (Roscoe et al., 2019).

Writing and Reading for an Audience in Computer-based Writing Instruction

Writing is a social, communicative (i.e., community-embedded) practice. Accordingly, using CBWI without human interaction (e.g., using the tool as a tutor or teacher) may be frustrating and limit learning (Chen & Cheng, 2008; Li, 2023). Indeed, expert writing teachers have suggested that computer-based writing tools should include mechanisms for teachers and students to communicate directly about their writing, and to also include model texts in which students can observe and model their own writing on (Li et al., 2022). Teachers also have expressed the need for integrating platforms with curricula requirements and assessments (Wilson et al., 2021).

One way that writing communities can engage with audiences is through affordances that encourage integrating reading and writing (McNamara & Kendeou, 2022). Integrating reading and writing instruction benefits performance in both domains (Graham et al., in press; Graham et al., 2018). Students apply reading skills when revising by rereading their own text to identify problems and monitor performance (MacArthur, 2016). Furthermore, integration of reading instruction via ITS and writing instruction via SRSD can be beneficial. Indeed, AWE technologies designed for

source-based writing also create opportunities for students to engage with rigorous texts and writing prompts that may support knowledge gains (Wang et al., 2020; Zhu et al., 2017).

CBWI systems may foster reading and writing communities through peer review and collaborative literacy activities. Peer review functions in AWE have been underused (Potter & Wilson, 2021; Wilson et al., 2021) despite their potential to foster collaborative writing experiences, which is both an EBP (e.g., Graham et al., 2015a) and a tenet of the WWC (Graham, 2018). Comparisons of peer review and automated feedback systems have concluded that integrating feedback from peers and AWE may be optimal because peers may be able to supplement shortcomings of AWE by providing feedback on complex ideas and content (Chen & Chang, 2008; Huang & Renandya, 2020; Shang, 2022; Zhang & Hyland, 2022).

Additional socioculturally informed CBWI research (Bazerman, 2016; Graham, 2018) is needed to support the integration of systems within authentic classroom writing experiences (McNamara & Kendeou, 2022). Such research may be used to develop and evaluate opportunities for peer feedback and collaboration in AWE systems (Stevenson, 2016), to integrate computer-generated feedback with that of teachers (e.g., Wilson & Czik, 2016), and to align CBWI to district and school-level curricula (e.g., Wilson et al., 2021). Table 2 presents suggestions for aligning CBWI affordances with Graham's (2018) WWC model.

Future Directions: Generative AI and Computer Based Writing Instruction

The advent of generative artificial intelligence tools (or "Gen-AI") such as ChatGPT (Generative Pre-trained Transformer 3, Brown et al., 2020) has the potential to transform writing instruction and assessment. Gen-AI is not new to developers of computer-based writing systems, but popular awareness and access (e.g., for educators and students) is a new phenomenon. One salient question is "What can a Gen-AI program such as Chat-GPT do?" with regards to writing instruction and

assessment. Current Gen-AI systems can easily complete most (if not all) writing assignments that are commonly used to assess writing skills. The writing is generally cohesive and comprehensible with excellent syntax and spelling. However, current systems do not (or cannot) check content accuracy because they are essentially stringing together common sequences of language regardless of veracity. The tools also generally lack human intuitions about language or register—they frequently use overly complex syntax or seem a bit too "intelligent" to be written by a fairly novice student lacking decades of education. However, with sufficient prompt engineering (and knowledge of writing and the world), an author can collaborate with ChatGPT to rapidly produce an adequate or even more than adequate composition (e.g., see McNamara, 2023).

Educators and researchers have expressed fears that Gen-AI will lead to increased plagiarism and render constructed response assignments unusable (Yeadon et al., 2023). However, ChatGPT may also offer some promise in *helping* writing instructors provide automated evaluation scores for their students (Wijekumar et al., in press) or *helping* student writers draft and reflect upon their own work. Gen-AI is a powerful tool and it is beyond the scope of our abilities and this chapter to prognosticate on how large-scale open-source language models will most influence CBWI. However, we can nonetheless consider potential threats and affordances that Gen-AI language models offer for writing instruction with computer-based systems.

Threats to Writing Instruction from Gen-AI

Gen-AI threatens fundamental pressures that undergird strategy instruction and SRSD: the need for students to develop self-regulation in writing. If students view themselves as "prompt engineers" instead of "writers," why bother to plan, draft, and revise when Gen-AI can do it for you? Writing becomes a process of nudging computer-generated output rather than expressing personally-generated ideas; two very different sets of cognitive processes. Future research should

investigate the potential threat of Gen-AI usage on students' problem-solving cognitive processes (Hayes, 2012) and critical reflection required to develop self-regulatory skills (Zimmerman & Risemberg, 1997). If students do not view Gen-AI produced work as their own, they may be more likely to adopt performance goal orientations (i.e., output or score-focused) instead of mastery goal orientations where students care about the writing process, their own voice and style, and developing their own skills and knowledge (e.g., Camacho et al., 2021).

Gen AI also threatens establishing a community of writers. If writers misuse generative AI (e.g., plagiarized content or not engaging in peer writing) or only engage with AI at the expense of their writing community members, they are not active members of a writing community. Additionally, while generative AI technologies such ChatGPT are highly coherent, they are often inaccurate (Cooper, 2023). Gen AI has the potential to provide misleading information to non-expert users (Deiana et al., 2023) and may also be used to widely spread false information (De Angelis et al., 2023). Consequently, steps must be taken to ensure the technology is used appropriately in classroom contexts.

Affordances of Gen AI in Writing Instruction

Encouragingly, there are opportunities for teachers and students to use the affordances of Gen-AI productively (Cooper, 2023; Su et al., 2023). For instance, Gen-AI tools may help students brainstorm and generate ideas more quickly (i.e., overcome writer's block and the problem of "getting started"), and may facilitate transcribing ideas to text. Results from developmental writing studies indicate that transcription challenges can constrain idea generation (Berninger et al., 2002). As such, perhaps Gen-AI can help students with processes related to generating ideas, initial drafts, correcting grammatical errors, and revising (Su et al., 2023) and thus support students in directing the writing process (i.e., self-regulating). New instructional approaches are needed to help students

develop control over the writing process (e.g., "I want to shift this paragraph to strengthen my argument."), while at the same time reducing students' emotional avoidance of writing. If Gen-AI removes the obstacles to producing text, perhaps we can support students in developing cognitive processes that support stages of the writing process (e.g., critically evaluating text and improving quality through revising).

A community of writers may harness affordances offered by Gen-AI. Gen-AI gives a point of contact with the community as something to talk about. For example, teachers can develop plans to model and provide collaborative practice to support students in learning genre features and background knowledge about a writing strategy (i.e., the first stage of SRSD) using prompts to generate and revise strong and weak examples of student essays. Gen-AI also offers students opportunities to learn about evaluation criteria and strategies for the revision process. For instance, Gen-AI prompts can be used to revise essays by prompting it to apply a particular writing strategy, improve computer-generated evaluation scores (e.g., word choice or sentence fluency), or integrate peer feedback. Revised essays provide a point of discussion for teachers and students to analyze how revising and monitoring progress towards writing goals can improve writing quality.

Conclusion

In conclusion, we have proposed here that the benefits of CBWI are more likely to be realized within instruction emphasizing principles of evidence-based writing practices that are incorporated within a community of writers. At the same time, educators have recently been thrust into a new world of CBWI – the world of generative AI. Clearly, the next-generation of CBWI technologies must harness the affordances of generative AI (Wilson & MacArthur, in press). As CBWI evolves in tandem with Gen-AI, it will be crucial that researchers and educators continue to incorporate evidence-based writing practices within a community of writers model.

References

Ahumada, S., Bañales, G., Graham, S., & Torres, M. L. (2022). Facilitators and barriers to writing instruction in Chile: teachers' preparation and knowledge about teaching writing. *Reading and Writing*, 1-33. https://doi.org/10.1007/s11145-022-10380-5

Allen, L. K. (in press). Expanding AWE to incorporate reading and writing evaluation. Submitted chapter to M. Shermis & J. Wilson (Eds.), *International Handbook of Automated Essay Evaluation* (2nd ed.). Routledge.

Allen, L. K., Crossley, S. A., Snow, E. L., & McNamara, D. S. (2014). L2 writing practice: Game enjoyment as a key to engagement. *Language Learning & Technology, 18*(2), 124-150. http://llt.msu.edu/issues/june2014/allenetal.pdf

Allen, L. K., Jacovina, M. E., & McNamara, D. S. (2016). Computer-based writing instruction. In C. A. MacArthur, S. Graham, & J. Fitzgerald (Eds.). *Handbook of writing research* (pp. 316–329). (2nd ed.). New York, NY: Guilford.

Applebee, A. N., & Langer, J. A. (2011). " EJ" Extra: A Snapshot of Writing Instruction in Middle Schools and High Schools. *The English Journal, 100*(6), 14-27.

Bahari, A., & Gholami, L. (2022). Challenges and affordances of reading and writing development in technology-assisted language learning. *Interactive Learning Environments*, 1-25. https://doi.org/10.1080/10494820.2022.2065308

Bai, L., & Hu, G. (2017). In the face of fallible AWE feedback: How do students respond?. *Educational Psychology, 37*(1), 67-81. https://doi.org/10.1080/01443410.2016.1223275

Bañales, G., Ahumada, S., Graham, S., Puente, A., Guajardo, M., & Muñoz, I. (2020). Teaching writing in grades 4–6 in urban schools in Chile: a national survey. *Reading and writing, 33*(10), 2661-2696. https://doi.org/10.1007/s11145-020-10055-z

Banawan, M., Butterfuss, R. Christhilf, K., Hsu, C. O'Loughlin, C., Taylor, K.S., Allen, L. K., Roscoe, R.D., & McNamara, D.S. (2023). The Future of Intelligent Tutoring Systems for Writing. In O. Kruse, C. Rapp, C. M. Anson, K. Benetos, E. Cotos, A. Devitt, A. Shibani (Eds), Switzerland: Springer International Publishing.

Black, P., & Wiliam, D. (2009). Developing the theory of formative assessment. *Educational Assessment, Evaluation and Accountability, 21*, 5–31. https://doi.org/10.1007/s11092-008-9068-5

Brindle, M., Graham, S., Harris, K. R., & Hebert, M. (2016). Third and fourth grade teacher's classroom practices in writing: A national survey. *Reading and Writing, 29*, 929-954. https://doi.org/10.1007/s11145-015-9604-x

Brown, T. B., Mann, B., Ryder, N., Subbiah, M., Kaplan, J., Dhariwal, P., Neelakantan, A., Shyam, P., Sastry, G., Askell, A., Agarwal, S., Herbert-Voss, A., Krueger, G., Henighan, T., Child, R., Ramesh, A., Ziegler, D. M., Wu, J., Winter, C., and Amodei, D. (2020). Language models are few-shot learners. *Advances in Neural Information Processing Systems, 33*, 1877–1901. https://proceedings.neurips. cc/paper/2020

Butterfuss, R., Roscoe, R. D., Allen, L. K., McCarthy, K. S., & McNamara, D. S. (2022). Strategy uptake in Writing Pal: Adaptive feedback and instruction. *Journal of Educational Computing Research, 60*(3), 696-721. https://doi.org/10.1177/0735633121104530

Camacho, A., Alves, R. A., & Boscolo, P. (2021). Writing motivation in school: A systematic review of empirical research in the early twenty-first century. *Educational Psychology Review, 33*, 213-247. https://doi.org/10.1007/s10648-020-09530-4

Coker, D. L., Farley-Ripple, E., Jackson, A. F., Wen, H., MacArthur, C. A., & Jennings, A. S. (2016). Writing instruction in first grade: An observational study. *Reading and Writing, 29*, 793-832. https://doi.org/10.1007/s11145-015-9596-6

Common Core State Standards: National Governors Association and Council of Chief School Officers (2010). Retrieved July 2023, from: http://www.corestandards.org/.

Cooper, G. (2023). Examining science education in chatgpt: An exploratory study of generative artificial intelligence. *Journal of Science Education and Technology, 32*(3), 444-452. https://doi.org/10.1007/s10956-023-10039-y

Crossley, S. A., Varner, L. K., Roscoe, R. D., & McNamara, D. S. (2013). Using automated indices of cohesion to evaluate an intelligent tutoring system and an automated writing evaluation system. In *Artificial Intelligence in Education: 16th International Conference*, AIED 2013, Memphis, TN, USA, July 9-13, 2013. Proceedings 16 (pp. 269-278). Springer Berlin Heidelberg.

Cruz Cordero, T., Wilson, J., Myers, M. C., Palermo, C., Eacker, H., Potter, A., & Coles, J. (2023). Writing motivation and ability profiles and transition during a technology-based writing intervention. *Frontiers in Psychology, 14*, 1196274. https://doi.org/10.3389/fpsyg.2023.1196274

Dahlkemper, M. N., Lahme, S. Z., & Klein, P. (2023). How do physics students evaluate artificial intelligence responses on comprehension questions? A study on the perceived scientific accuracy and linguistic quality of ChatGPT. *Physical Review Physics Education Research, 19*, 010142. https://doi.org/10.1103/PhysRevPhysEducRes.19.010142

De Angelis, L., Baglivo, F., Arzilli, G., Privitera, G. P., Ferragina, P., Tozzi, A. E., & Rizzo, C. (2023). ChatGPT and the rise of large language models: the new AI-driven infodemic threat in public health. *Frontiers in Public Health, 11*, 1166120.

De Smedt, F., Van Keer, H., & Merchie, E. (2016). Student, teacher and class-level correlates of Flemish late elementary school children's writing performance. *Reading and Writing*, 29, 833-868. https://doi.org/10.1007/s11145-015-9590-z

Deane, P. (2013). On the relation between automated essay scoring and modern views of the writing construct. *Assessing Writing, 18*, 7-24. https://doi.org/10.1016/j.asw.2012.10.002

Deiana, G., Dettori, M., Arghittu, A., Azara, A., Gabutti, G., & Castiglia, P. (2023). Artificial Intelligence and Public Health: Evaluating ChatGPT Responses to Vaccination Myths and Misconceptions. *Vaccines, 11*(7), 1217.

Dikli, S. (2006). An overview of automated scoring of essays. *The Journal of Technology, Learning and Assessment, 5*. https://ejournals.bc.edu/index.php/jtla/article/view/1640

Ericsson, K. A., Krampe, R. T., & Tesch-Römer, C. (1993). The role of deliberate practice in the acquisition of expert performance. *Psychological Review, 100*(3), 363–406. https://doi.org/10.1037/0033-295X.100.3.363

Flower, L., & Hayes, J. R. (1980). The cognition of discovery: Defining a rhetorical problem. *College composition and communication, 31*, 21-32.

Fu, Q. K., Zou, D., Xie, H., & Cheng, G. (2022). A review of AWE feedback: types, learning outcomes, and implications. *Computer Assisted Language Learning*, 1-43. https://doi.org/10.1080/09588221.2022.2033787

Gillespie, A., Graham, S., Kiuhara, S., & Hebert, M. (2014). High school teachers use of writing to support students' learning: A national survey. *Reading and Writing, 27*, 1043-1072. https://doi.org/10.1007/s11145-013-9494-8

Graham, S. (2018). A revised writer (s)-within-community model of writing. *Educational Psychologist, 53*(4), 258-279. https://doi.org/10.1080/00461520.2018.1481406

Graham, S. (2019). Changing how writing is taught. *Review of Research in Education, 43*, 277-303. https://doi.org/10.3102/0091732X18821125

Graham, S., Capizzi, A., Harris, K. R., Hebert, M., & Morphy, P. (2014). Teaching writing to middle school students: A national survey. *Reading and Writing, 27*, 1015-1042. https://doi.org/10.1007/s11145-013-9495-7

Graham, S., & Harris, K. R. (2017). Evidence-based writing practices: A meta-analysis of existing meta-analyses. In *Design principles for teaching effective writing* (pp. 13-37). Brill.

Graham, S., Harris, K. R., & Santangelo, T. (2015b). Evidence-based writing practices and the common core: Meta-analysis and meta-synthesis. *The Elementary School Journal, 115*(4), 498-522.

Graham, S., Hebert, M., & Harris, K. R. (2015a). Formative assessment and writing: A meta-analysis. *The Elementary School Journal, 115*(4), 523-547. https://doi.org/10.1086/681947

Graham, S., Liu, X., Bartlett, B., Ng, C., Harris, K. R., Aitken, A., Barkel, A., Kavanaugh, C., & Talukdar, J. (2018). Reading for writing: A meta-analysis of the impact of reading interventions on writing. *Review of Educational Research, 88*(2), 243-284. https://doi.org/10.3102/0034654317746927

Graham, S., Skar, G. B., & Falk, D. Y. (2021). Teaching writing in the primary grades in Norway: A national survey. *Reading and Writing, 34*, 529-563. https://doi.org/10.1007/s11145-020-10080-y

Graham, S., Kim, Y.G., Cao, Y., Lee, J., Tate, T., Collins, P., Cho, M., Moon, Y., Chung, H.Q., Olson, C.B. (in press). A meta analysis of writing treatments for students in grades 6 to 12. Accepted to *The Journal of Educational Psychology.*

Grimes, D., & Warschauer, M. (2010). Utility in a fallible tool: A multi-site case study of automated writing evaluation. *The Journal of Technology, Learning and Assessment, 8*(6). https://ejournals.bc.edu/index.php/jtla/article/view/1625

Harris, K. R. (2021). SRSD instructional research for students with or at-risk for LD across the content areas: History and reflections. *Learning Disabilities Research and Practice, 36*(3), 235-241. https://doi.org/10.1111/ldrp.12260

Harris, K. R., & Graham, S. (2016). Self-regulated strategy development in writing: Policy implications of an evidence-based practice. *Policy Insights from the Behavioral and Brain Sciences, 3*, 77-84. https://doi.org/10.1177/23727322156242

Harward, S., Peterson, N., Korth, B., Wimmer, J., Wilcox, B., Morrison, T. G., ... & Pierce, L. (2014). Writing instruction in elementary classrooms: Why teachers engage or do not engage students in writing. *Literacy Research and Instruction, 53*(3), 205-224. https://doi.org/10.1080/19388071.2014.896959

Hayes, J. R. (2012). Modeling and remodeling writing. *Written communication, 29*(3), 369-388. https://doi.org/10.1177/0741088312451260

Hsiang, T. P., Graham, S., & Yang, Y. M. (2020). Teachers' practices and beliefs about teaching writing: A comprehensive survey of grades 1 to 3 teachers. *Reading and Writing*, 33, 2511-2548. https://doi.org/10.1007/s11145-015-9597-5

Huang, S., & Renandya, W. A. (2020). Exploring the integration of automated feedback among lower-proficiency EFL learners. *Innovation in Language Learning and Teaching, 14*, 15-26. https://doi.org/10.1080/17501229.2018.1471083

Kellogg, R. T. (2008). Training writing skills: A cognitive developmental perspective. *Journal of writing research, 1*, 1-26. https://doi.org/10.17239/jowr-2008.01.01.1

Kellogg, R. T., & Whiteford, A. P. (2009). Training advanced writing skills: The case for deliberate practice. *Educational Psychologist, 44*(4), 250-266. https://doi.org/10.1080/00461520903213600

Kellogg, R. T., Whiteford, A. P., & Quinlan, T. (2010). Does automated feedback help students learn to write?. *Journal of Educational Computing Research, 42*(2), 173-196.

Kiuhara, S. A., Graham, S., & Hawken, L. S. (2009). Teaching writing to high school students: A national survey. *Journal of Educational Psychology, 101*, 136–160. https://doi.org/10.1037/a0013097

Korth, B. B., Wimmer, J. J., Wilcox, B., Morrison, T. G., Harward, S., Peterson, N., ... & Pierce, L. (2017). Practices and challenges of writing instruction in K-2 classrooms: A case study of five primary grade teachers. *Early Childhood Education Journal, 45*, 237-249. https://doi.org/10.1007/s10643-016-0774-1

Koster, M. P., Tribushinina, E., De Jong, P., & Van den Bergh, H. H. (2015). Teaching children to write: A meta-analysis of writing intervention research. *Journal of Writing Research, 7*(2), 299-324. https://doi.org/10.17239/jowr-2015.07.02.2

Li, R. (2023). Still a fallible tool? Revisiting effects of automated writing evaluation from activity theory perspective. *British Journal of Educational Technology, 54*(3), 773-789. https://doi.org/10.1111/bjet.13294

Li, T., Creer, S. D., Arner, T., Roscoe, R. D., Allen, L. K., & McNamara, D. S. (2022). Participatory Design of a Writing Analytics Tool: Teachers' Needs and Design Solutions. In A. F. Wise., R. Martinez-Maldonado, I. Hilliger (Eds.), *Proceedings of the 12th International Conference on Learning Analytics & Knowledge* (pp. 15-18). Online.

Little, C. W., Clark, J. C., Tani, N. E., & Connor, C. M. (2018). Improving writing skills through technology-based instruction: A meta-analysis. *Review of Education, 6*(2), 183-201. https://doi.org/10.1002/rev3.3114

MacArthur, C. (2016). Instruction in evaluation and revision. In C. MacArthur, S. Graham, & J. Fitzgerald (Eds.), *Handbook of writing research* (2nd ed., pp. 272-286). New York, NY: Guilford.

McKeown, D., FitzPatrick, E., & Sandmel, K. (2014). SRSD in practice: Creating a professional development experience for teachers to meet the writing needs of students with EBD. *Behavioral Disorders, 40*, 15-25. https://doi.org/10.17988/0198-7429-40.1.15

McNamara, D. S. (2023). AIED: From Cognitive Simulations to Learning Engineering, with Humans in the Middle. *International Journal of Artificial Intelligence in Education*, 1-13. https://doi.org/10.1007/s40593-023-00349-y

McNamara, D. S., & Kendeou, P. (2022). The early automated writing evaluation (eAWE) framework. *Assessment in Education: Principles, Policy & Practice, 29*(2), 150-182. https://doi.org/10.1080/0969594X.2022.2037509

McNamara, D. S., Levinstein, I. B., & Boonthum, C. (2004). iSTART: interactive strategy trainer for active reading and thinking. Behavior Research Methods, Instruments, & Computers, 36, 222–233. https://doi.org/10.3758/BF03195567

National Assessment of Education Progress [NAEP] (2011). The Nation's Report Card: Writing 2011. https://nces.ed.gov/pubsearch/pubsinfo.asp?pubid=2012470

National Commission on Writing. (2003). *The neglected "r": The need for a writing revolution*. New York: The College Entrance Examination Board.

National Commission on Writing. (2004). Writing: A ticket to work…or a ticket out. New York: The College Entrance Examination Board.

National Governors Association Center for Best Practices, Council of Chief State School Officers. (2010). *Common core state standards writing*. Washington D.C.: Author. http://corestandards.org/

Nunes, A., Cordeiro, C., Limpo, T., & Castro, S. L. (2022). Effectiveness of automated writing evaluation systems in school settings: A systematic review of studies from 2000 to 2020. *Journal of Computer Assisted Learning, 38*(2), 599-620. https://doi.org/10.1111/jcal.12635

Palermo, C., & Thomson, M. M. (2018). Teacher implementation of self-regulated strategy development with an automated writing evaluation system: Effects on the argumentative writing performance of middle school students. *Contemporary Educational Psychology, 54*, 255-270. https://doi.org/10.1016/j.cedpsych.2018.07.002

Potter, A., MacArthur, C., & Wilson, J. (2020, December). *Writing and revising with peer review and technology: Design research cycle 1 evaluation* [Paper presentation]. Annual conference of the Literacy Research Association, Houston, TX.

Potter, A., & Wilson, J. (2021). Statewide implementation of automated writing evaluation: analyzing usage and associations with state test performance in grades 4-11. *Educational Technology Research and Development, 69,* 1557-1578. https://doi.org/10.1007/s11423-021-10004-9

Ranalli, J. (2018). Automated written corrective feedback: How well can students make use of it?. *Computer Assisted Language Learning, 31*(7), 653-674. https://doi.org/10.1080/09588221.2018.1428994

Ranalli, J. (2021). L2 student engagement with automated feedback on writing: Potential for learning and issues of trust. *Journal of Second Language Writing, 52*, 100816. https://doi.org/10.1016/j.jslw.2021.100816

Ranalli, J., Link, S., & Chukharev-Hudilainen, E. (2017). Automated writing evaluation for formative assessment of second language writing: Investigating the accuracy and usefulness of feedback as part of argument-based validation. *Educational Psychology, 37*, 8-25. https://doi.org/10.1080/09588221.2018.1428994

Roscoe, R. D., Allen, L. K., Johnson, A. C., & McNamara, D. S. (2018, September). Automated writing instruction and feedback: Instructional mode, attitudes, and revising. In *Proceedings of the Human Factors and Ergonomics Society Annual Meeting* (Vol. 62, No. 1, pp. 2089-2093). Sage CA: Los Angeles, CA: SAGE Publications.

Roscoe, R. D., Allen, L. K., Weston, J. L., Crossley, S. A., & McNamara, D. S. (2014). The Writing Pal intelligent tutoring system: Usability testing and development. *Computers and Composition, 34,* 39-59. https://doi.org/10.1016/j.compcom.2014.09.002

Roscoe, R. D., & McNamara, D. S. (2013). Writing Pal: Feasibility of an intelligent writing strategy tutor in the high school classroom. *Journal of Educational Psychology, 105*(4), 1010–1025. https://doi.org/10.1037/a0032340

Roscoe, R. D., Snow, E. L., Allen, L. K., & McNamara, D. S. (2015). Automated detection of essay revising patterns: Application for intelligent feedback in a writing tutor. *Technology, Instruction, Cognition, and Learning, 10*, 59–79.

Roscoe, R. D., Snow, E. L., & McNamara, D. S. (2013). Feedback and revising in an intelligent tutoring system for writing strategies. In *Artificial Intelligence in Education: 16th International Conference*, AIED 2013, Memphis, TN, USA, July 9-13, 2013. Proceedings 16 (pp. 259-268). Springer Berlin Heidelberg.

Scardamalia, M., & Bereiter, C. (1987). Knowledge telling and knowledge transforming in written composition. *Advances in Applied Psycholinguistics, 2*, 142-175.

Shang, H. F. (2022). Exploring online peer feedback and automated corrective feedback on EFL writing performance. *Interactive Learning Environments, 30*, 4-16. https://doi.org/10.1080/10494820.2019.1629601

Shermis, M. D. (2014). State-of-the-art automated essay scoring: Competition, results, and future directions from a United States demonstration. *Assessing Writing, 20*, 53–76. https://doi.org/10.1016/j.asw.2013.04.001

Shermis, M. D. (2020). International Applications of Automated Scoring. In *Handbook of Automated Scoring* (pp. 113-132). Chapman and Hall/CRC.

Shermis, M. D., & Hamner, B. (2013). Contrasting state-of-the-art automated scoring of essays. In M. D. Shermis & J. Burstein (Eds.), *Handbook of automated essay evaluation: Current applications and new directions* (pp. 313–346). New York, NY: Routledge.

Shermis, M. D., & Wilson, J. (in press). Introduction to Automated Essay Evaluation. Submitted chapter to M. Shermis & J. Wilson (Eds.), *International Handbook of Automated Essay Evaluation* (2nd ed.). Routledge.

Stevenson, M., & Phakiti, A. (2014). The effects of computer-generated feedback on the quality of writing. *Assessing Writing, 19*, 51-65. https://doi.org/10.1016/j.asw.2013.11.007

Su, Y., Lin, Y., & Lai, C. (2023). Collaborating with ChatGPT in argumentative writing classrooms. *Assessing Writing, 57*, 100752. https://doi.org/10.1016/j.asw.2023.100752

Wang, E. L., Matsumura, L. C., Correnti, R., Litman, D., Zhang, H., Howe, E., Magoodab, A., & Quintana, R. (2020). eRevis (ing): Students' revision of text evidence use in an automated writing evaluation system. *Assessing Writing, 44*, 100449. https://doi.org/10.1016/j.asw.2020.100449

Ware, P. (2014). Feedback for adolescent writers in the english classroom. *Writing & Pedagogy, 6*(2), 223–249. https://doi.org/10.1558/wap.v6i2.223

Warschauer, M., & Grimes, D. (2008). Automated writing assessment in the classroom. *Pedagogies: An International Journal, 3*, 22-36. https://doi.org/10.1080/15544800701771580

Williams, C., & Beam, S. (2019). Technology and writing: Review of research. *Computers & education, 128*, 227-242. https://doi.org/10.1016/j.compedu.2018.09.024

Wilson, J. (2018). Universal screening with automated essay scoring: Evaluating classification accuracy in grades 3 and 4. *Journal of School Psychology, 68*, 19–37. https://doi.org/10.1016/j.jsp.2017.12.005

Wilson, J., & Czik, A. (2016). Automated essay evaluation software in English language arts classrooms: Effects on teacher feedback, student motivation, and writing quality. *Computers & Education, 100*, 94–109. https://doi.org/10.1016/j.compedu.2016.05.004

Wilson, J., & MacArthur, C.A. (2023). Exploring the role of automated writing evaluation as a formative assessment tool supporting self-regulated learning in writing. Submitted chapter to M. Shermis & J. Wilson (Eds.), *International Handbook of Automated Essay Evaluation* (2nd ed.). Routledge.

Wilson, J., Palermo, C., Myers, M., Cruz Cordero, T., Eacker, H., Coles, J., & Potter, A. (2023, April). Impact of MI Write automated writing evaluation on middle-grade writing outcomes. Paper presented at the *National Council on Measurement in Education* (NCME), Chicago, IL.

Wilson, J., Potter, A., Cordero, T. C., & Myers, M. C. (2022). Integrating goal-setting and automated feedback to improve writing outcomes: a pilot study. *Innovation in Language Learning and Teaching, 17*(3), 518-534. https://doi.org/10.1080/17501229.2022.2077348

Wilson, J., & Roscoe, R. D. (2020). Automated writing evaluation and feedback: Multiple metrics of efficacy. *Journal of Educational Computing Research, 58*, 87–125. https://doi.org/10.1177/0735633119 830764

Wijekumar, K. K., Harris, K. R., Graham, S., & Lei, P. (2022). A teacher technology tango shows strong results on 5th graders persuasive writing. *Educational technology research and development, 70*(4), 1415-1439. https://doi.org/10.1007/s11423-022-10117-9

Wijekumar, K. K., McKwoen, D., Lei, P., Hruska, N., & Pirnay-Dummer, P. (in press). We Write automated scoring. Submitted chapter to M. Shermis & J. Wilson (Eds.), *International Handbook of Automated Essay Evaluation* (2nd ed.). Routledge.

Yeadon, W., Inyang, O. O., Mizouri, A., Peach, A., & Testrow, C. P. (2023). The death of the short-form physics essay in the coming AI revolution. *Physics Education, 58*(3), 035027. https://doi.org/10.1088/1361-6552/acc5cf

Zhai, N., & Ma, X. (2023). The effectiveness of automated writing evaluation on writing quality: A meta-analysis. *Journal of Educational Computing Research, 61*(4), 875-900. https://doi.org/10.1177/07356331221127300

Zhang, Z. V., & Hyland, K. (2022). Fostering student engagement with feedback: An integrated approach. *Assessing Writing, 51*, 100586. https://doi.org/10.1016/j.asw.2021.100586

Zhu, M. X., Lee, H. S., Wang, T., Liu, O. L., Belur, V., & Pallant, A. (2017). Investigating the impact of automated feedback on students' scientific argumentation. *International Journal of Science Education, 39*(12), 1648–1668. https://doi.org/10.1080/09500693.2017.1347303

Zimmerman, B. J., & Risemberg, R. (1997). Becoming a self-regulated writer: A social cognitive perspective. *Contemporary educational psychology, 22*, 73-101.

Table 1
Affordances of Computer-Based Writing Instructional Practices Aligned to Stages of SRSD

SRSD Stages	Intended Outcome	Computer-Based Writing Instructional Practices to Achieve Intended Outcome
1. Develop and activate background knowledge	Students understand essential genre, topic, and strategy knowledge.	● Use ITS (e.g., Wijekumar et al., 2022) and strategy instruction videos (e.g., Roscoe et al., 2014; 2015) to provide explicit instruction in strategy use or teach evaluation criteria for revision (MacArthur, 2016). ● Integrate source texts to develop background or content knowledge (e.g., Allen, in press; Wang et al., 2020; Zhu et al., 2017). ● Provide exemplar essays for discussion (e.g., Li et al., 2022) to establish key features of strong and weak essays.
2. Discuss the strategy	Students understand the purpose of the strategy.	● Facilitate discussions (e.g., via Google Docs) with teachers and students to discuss a writing strategy and make plans for implementing the strategy.
3. Model the strategy	Students observe how to use the strategy.	● Embed videos modeling a strategy throughout the writing process (e.g., planning, drafting, revising). ● Provide opportunities to discuss modeling videos (e.g., strategy usage or self-talk) and exemplar writing samples.
4. Memorize the strategy	Students understand the writing strategy and commit it to memory.	● Embed quizzes and checks for understanding within systems. ● Provide scaffolded individualized lessons and game-based instruction and practice opportunities based on levels of student performance (e.g., W-Pal; Roscoe & McNamara, 2013; Roscoe et al., 2019).
5. Support the strategy	Students practice the strategy with feedback to develop mastery.	● Provide opportunities for students to plan, write, and revise drafts collaboratively using strategy think sheets, self-statements, and goal-setting templates (e.g., Palermo & Thomson, 2018; Wijekumar et al., 2022). ● Use automated scores to facilitate discussion and feedback (e.g., Wijekumar et al., in press). ● Integrate feedback from AWE, teachers, and peers by facilitating peer review and collaborative revising opportunities (e.g., Huang & Renandya, 2020; Shang, 2022; Zhang & Hyland, 2022). ● Support students in setting goals using AWE evaluation metrics (e.g., Wilson et al., 2022).
6. Independent practice	Students practice independently and demonstrate mastery.	● Integrate reading and writing by assigning source-based writing prompts (e.g., Allen, in press; Wang et al., 2020; Zhu et al., 2017). ● Support students in progress monitoring of product and process goals using AWE scores (e.g., Wilson et al., 2022). ● Integrate AWE-generated assessment data with teacher-created rubrics (e.g., Li et al., 2022) to provide summative assessments separate from AWE scores (e.g., Wilson et al., 2021).

Table 2
Computer-Based Writing System Affordances that Support the Tenets of Writers-Within-Communities Model

WWC Tenets	What does this mean in classroom contexts?	Computer-Based Writing Instructional Practices to Achieve Intended Outcome
1. Writing is shaped by the writing community and the resources of community members.	A writing community in a classroom must have a shared set of goals and norms, capitalize on available resources, and foster the commitment of students to improve their writing abilities.	● Teach evaluation criteria (MacArthur, 2016) using AWE and teacher-generated metrics (Li et al., 2022) to develop a shared understanding for common writing goals and practices. ● Support students in setting goals and monitoring progress towards goals using automated scoring and AWE/ITS scaffolds (e.g., Wilson et al., 2022). ● Use digital tools for students to publish writing using multimedia literacy techniques (e.g., PPT presentations or podcasts).
2. Writing is shaped by the capacities of the writing community and community members.	A writing community in a classroom should use affordances offered from writing technologies, as well as the capacities of each other, to improve their writing abilities.	● Use AWE and intelligent tutoring to provide writing practice with feedback to reduce teacher labor (e.g., Kellogg et al., 2010; Stevenson, 2016). ● Use ITS to deliver explicit strategy instruction and game-based instruction and practice to reduce teacher labor and support differentiation (e.g., Roscoe et al., 2014; 2015).
3. Writing is shaped by variability in writing communities and individual differences among community members.	A writing community in a classroom must use strengths of community members to support other community members in developing their writing abilities.	● Differentiate instruction using intelligent tutoring (e.g., Roscoe et al., 2014; 2015; Wijekumar et al., 2022). ● Use AWE scores to provide formative feedback to support differentiation and peer review and collaboration (e.g., Zhang & Hyland, 2022). ● Use ITS and other technologies (e.g., Google Forms) to administer surveys to learn about student beliefs and motivation about writing. ● Provide source-based writing prompts and feedback to support building background and content knowledge (e.g., McNamara & Kendeou, 2022)
4. Writing development is shaped by participating in writing communities and changes in capabilities of community members.	A writing community in a classroom must develop procedures for students to monitor their progress towards writing product and process goals, and also ensure that students with constraints on learning have the necessary tools to learn and grow.	● Support students in setting and monitoring progress towards writing product and process goals using automated scores and feedback so that students and teachers can track developmental progress (e.g., Wilson et al., 2022). ● Use AWE and ITS scaffolds to support students in implementing self-regulatory behaviors (e.g., Roscoe et al., 2014; Wijekumar et al., 2022).

Note. *WWC = Writers-within-community model (Graham, 2018)*