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To cite this article: Danielle S. McNamara & Panayiota Kendeou (2022): The early automated writing evaluation (eAWE) framework, Assessment in Education: Principles, Policy & Practice, DOI: 10.1080/0969594X.2022.2037509

To link to this article: https://doi.org/10.1080/0969594X.2022.2037509

Published online: 04 Mar 2022.
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ABSTRACT
We propose a framework designed to guide the development of automated writing practice and formative evaluation and feedback for young children (K-5th grade) – the early Automated Writing Evaluation (early-AWE) Framework. e-AWE is grounded on the fundamental assumption that e-AWE is needed for young developing readers, but must incorporate advanced technologies inherent to AWE, speech recognition, and games. In line with interdisciplinary views on writing to support learners in the classroom, e-AWE must support a community of learners and interlace reading and writing instructional activities combined with feedback to use reading and writing strategies. The e-AWE Framework provides a guide for the development of tools that leverage and integrate cutting-edge technologies, some of which only recently have become widely available in educational settings. These tools can continue to provide usable and feasible means to offer high-quality automated writing practice and feedback to a diverse and large number of students.

Writing is a core skill to be developed by students across the lifetime, contributing to success across multiple academic domains and life in general. Like all complex skills, learning to write requires an enormous amount of practice, including multiple writing attempts and revisions based on timely feedback, generally from more experienced writers (usually teachers). However, many students do not begin the necessary process of engaging in compositional writing tasks (with feedback) until after primary school, resulting in a loss of up to seven foundational years in critical skills development. Consequently, students’ writing performance suffers. For example, writing performance by 4th grade students in the United States has remained low for the last few decades, with one in four students performing below basic proficiency level (The Nation Report Card, 2019). This means that these students fail to produce responses with accurate spelling and mechanics, sufficient supporting statements, and with any awareness of purpose and audience (The Nation Report Card, 2012). These persistent and troubling patterns highlight the need for targeted and integrated instruction and practice on core writing strategies as early as possible in the primary grades, while also ensuring student engagement and formative feedback (Graham, 2021; Graham & Alves, 2021).

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Meeting the complex needs of students who struggle with writing in the context of traditional classroom instruction is unfeasible. Teachers are not provided sufficient support, time, or training to, in turn, provide their students with the support, time, and training that they need to learn to write (Brindle et al., 2016; Harward et al., 2014; K. L. McMaster et al., 2017). This is a problem that persists throughout formal education, past primary school, to high school, and even beyond to college. Hence, many educators and researchers have turned to Automated Writing Evaluation (AWE) as a means to provide students with increased opportunities for writing practice and formative feedback. AWE leverages natural language processing (NLP) to provide pedagogically aligned feedback on multiple aspects of students’ writing (Allen et al., 2016; Crossley & McNamara, 2016; Shermis et al., 2016; Wilson & Roscoe, 2020). While AWE offers many potential benefits and advantages, there are few systems available for K-5 students. If we are to prevent writing failure in Grade 4, as reported consistently by NAEP assessments, then systematic instruction and practice needs to begin as early as Kindergarten. Hence, our first, overarching, supposition is that AWE programs are needed for K-5 students.

Our second supposition is that there are multiple technological barriers that must be overcome in order to facilitate students’ technology use at such early ages, particularly for writing practice. A traditional AWE system provides a writing prompt, which the students read and then compose a response, to which the system then provides written feedback, which is read by the student. At the very least, successful AWE at early ages, or early AWE (e-AWE), will require automated text-to-speech and automated speech recognition (ASR). More realistically, however, we call for more motivating, immersive interfaces and tasks that incorporate games, virtual reality, and augmented reality. In sum, more recent technological advances need to be leveraged and integrated in the service of effective writing assessment and instruction in the early grades.

Our third supposition is that e-AWE must engage a community of learners and writers. Perhaps, the most important aspect of writing is that its purpose is to communicate ideas to others. Writing is a means to provide consistent communication among a community of individuals and learners. Sociocultural researchers in particular advocate that writing is intrinsically embedded with the students’ cultural, community, and familial practices (Au, 2000; Purcell-Gates & Tierney, 2009). When students participate in a community of writers, they collaborate with other writers and learn to provide and receive feedback from their peers and teachers. In such a community, teachers create a supportive, engaging, collaborative environment that supports young writers (Graham, 2020). Thus, e-AWE must necessarily adapt to culturally bound practices and support the sense of community in classrooms, and even outside of the classroom, by creating a learner community.

Our fourth, fundamental, supposition is that approaches to AWE for K-5 students must consider and capitalize on the integral relations between reading and writing. Of course, there are strong correlations between students’ ability to read and write (Shanahan, 1987). Moreover, having students writing about what they read improves both their ability to understand text (i.e. reading ability) and their writing ability (Bereiter & Scardamalia, 1984; Graham & Herbert, 2011; S. Liu Graham et al., 2018). Reading and writing are symbiotic. Indeed, many or most primary school teachers instruct writing in the context of reading instruction and reading assignments (Graham, 2012a). Most
AWE, by contrast provide writing assessment and instruction separated from reading instruction. Teachers may be more likely to use AWE if it is integrated within other domains such as reading, and AWE is more likely to advance writing skills if it is interlaced with reading tasks. As such, a fundamental assumption that underlies e-AWE regards the need to interlace writing and reading, including early reading comprehension activities.

These four suppositions are realized in the Early-AWE (e-AWE) Framework, which is intended as a guide for the development of tools to provide feasible and effective automated writing practice and feedback to a broad range of young students. In the sections below, we first provide a brief description of AWE and some of the current tools available to provide automated scaffolding and feedback to young writers. We then provide an overview of research regarding the development of writing skills, with an emphasis on K-5. Next, we introduce the e-AWE Framework, and describe how its four fundamental suppositions translate into its core components and processes.

**Automated Writing Evaluation (AWE)**

Increasingly, the use of technology is integrated in explicit writing instruction. For example, most writing instruction requires that students learn to type and use a word processor, use the Internet to collect information, navigate computer- and web-based testing tools, and understand how different writing conventions apply to different media (S. Liu Graham et al., 2018). A central tenet to the use of technology in this context is Automated Essay Scoring (AES) and Automated Writing Evaluation (AWE).

The efficiency and reliability of automated writing assessment tools is well documented (Allen & Perret, 2016; Shermis, 2010, 2014; Shermis et al., 2016). Automated Essay Scoring (AES) systems typically provide summative essay scores by extracting the linguistic and semantic features of the essays using NLP computer programs. AES algorithms are based on machine learning models developed using a training set of essays rated by human raters according to a scoring rubric and then tested to ensure that the model generalizes to a separate subset or set of essays. The scores that are generated by the model are compared to the raters’ scores to confirm that they are well aligned, or reliable. Indeed, AES systems are generally quite reliable, reporting high correspondence and correlations with human raters (accuracy > ∼80%; r = .80 to 90; see Shermis et al., 2010; Warschauer & Ware, 2006; Yan et al., 2020).

The majority of AES systems (that provide scores or ratings) have been developed for prompt-based, timed persuasive essays that are independent of a source text and are used primarily for summative evaluation. For example, students might answer questions such as: Is competition better than cooperation? Or Do images and impressions have too much of an effect on people? AES systems generally provide summative scores for overall quality of the essays, and some provide scores on various aspects such as mechanics (grammar and spelling), organization, vocabulary, and style. For example, ETS's e-rater scores essays on six areas of analysis aligned with human scoring criteria: grammar, word usage, mechanics, style, inclusion of organizational segments (e.g. inclusion of a thesis statement or evidence), and vocabulary content (Attali & Burstein, 2006). The Intelligent Essay Assessor (T.K. Landauer et al., 2003) analyze the words in the essay using latent semantic analysis (LSA, T. K. Landauer et al., 2007) and n-gram analysis (i.e. sequences of
words such as word pairs or triplets). The algorithm computes the similarity of the words and word sequences between the incoming essay and the essays associated with each level of the scoring rubric. IntelliMetric (Rudner et al., 2006) matches the words in the essay to a vocabulary of over 500,000 unique words, identifies more than 500 linguistic and grammatical features that occur in the text, and analyzes this content through a word concept net, which examines similarities amongst words to determine their semantic meaning. These text characteristics are then associated with essays in each level of scoring rubric of the training corpus in order to discover which essay characteristics are most strongly diagnostic of each level.

AWE is similar to AES in terms of technological capacity, but also provides formative feedback on multiple aspects of writing quality based on pedagogical theories regarding feedback and writing development (Allen et al., 2016; Crossley & McNamara, 2016; Roscoe et al., 2015). Formative feedback generally translates scores to messages that describe the nature of students’ underlying knowledge and skills or actions that can be taken to enhance performance.

Formative assessment is key to students’ growth in writing. Graham et al. (2015) strongly recommended the inclusion of formative feedback in writing assessments based on their meta-analysis of studies with students in Grades 1–8. They reported effect sizes of 0.87, 0.58, 0.62, and 0.38, on the effects of formative feedback on writing provided by adults, peers, self, and automated feedback, respectively. AWE systems help students improve their writing quality (Franzke et al., 2005; Palermo & Thomson, 2018, 2019; Roscoe et al., 2018, 2014, 2013a; Roscoe & McNamara, 2013; Stevenson & Phakiti, 2014), their ability to effectively revise their writing (Knight et al., 2020; Roscoe et al., 2015, 2018; Wang et al., 2020; Wilson, 2017; Wilson et al., 2014), and their attitudes towards writing (Grimes & Warschauer, 2010; Roscoe et al., 2018; Wilson & Czik, 2016; Wilson & Roscoe, 2020).

Despite the potential benefits of formative feedback by AWE in contrast to summative feedback provided by AES systems, there is a paucity of empirically tested programs that provide automated formative writing evaluation to K-5 students (e.g. Wilson & Roscoe, 2020; Stevenson & Phakiti, 2014). Additionally, formative feedback on higher aspects of writing (e.g. organization, development of ideas, style) is far less common than feedback on surface qualities (e.g. number of words, spelling, grammar), which in turn is less effective on its own (e.g. Ballock et al., 2017; Graham & Santangelo, 2014).

The majority of AWE systems and tools have been developed for students who are in the secondary grades (>11 years old). These commercially available programs for adolescent writers include Criterion (Burstein et al., 2004; Educational Testing Service, 2008), WriteToLearn (Pearson Education, Inc, 2011; T.K. Landauer et al., 2003), Write and Improve (Cambridge English), NoRedLink (2012), and Feedback Studio (Turnitin, 2016 Notably, only few of these systems have been empirically assessed (for reviews of commercially available systems see Allen & Perret, 2016; Yan et al., 2020). In addition, the Writing Pal is currently available without cost (see adaptiveliteracy.com; Allen et al., 2014; Crossley et al., 2013; McCarthy et al., 2019; Roscoe & McNamara, 2013; Roscoe et al., 2015).

While there exist various options for adolescent and young adult writers, only a few systems target younger students. One example is Project Essay Grade (PEG; presently called MI-Write, Wilson, 2017; Wilson & Czik, 2016; Wilson et al., 2014, 2021). Students
are provided with video-based lessons regarding various aspects of writing such as word choice, sentence structure, planning, and organization, depending on strengths or weaknesses identified using the AWE algorithm. For example, if the AWE algorithm indicates that the student demonstrates strong word-level skills but grammatically incorrect sentences, the student would be directed toward lessons on sentence structure. In turn, students demonstrating proficiency at the sentence level might be directed toward lessons on improving writing organization.

PEG increases students’ revision attempts, and the quality of their essays across revisions, as well as attitudes toward writing (Wilson & Andrada, 2016; Wilson & Czik, 2016; Wilson et al., 2014; Wilson & Roscoe, 2019). Unfortunately, however, there is little evidence for the benefits of using PEG in terms of improving students’ writing skills as evidenced by transfer across essays without PEG support. For example, Wilson (2017) reported that students (grades 4–8) with and without disabilities who practiced writing with PEG improved their essays based on the feedback. However, students in schools without sufficient availability of computers did not improve and students did not improve on a subsequent essay, indicating that the benefits of feedback did not transfer across essays. Recently, Wilson and Roscoe (2019) compared the effectiveness of PEG to using Google Doc for a small sample of students in grade 6 ($n = 114$) who completed three writing assignments either within PEG (with feedback) or on a Google Doc form (comparable to Word). Similar to Wilson (2017), they found that PEG did not enhance writing quality from pretest to posttest, though students did have more positive attitudes toward writing. PEG nonetheless has excellent marketing and thus thousands of students are using the system.

The potential widespread use of an AWE such a PEG suggests a strong need for AWE. Teachers do not have sufficient time to provide students with feedback on their writing, but they also need to have greater assurances that the feedback provided by AWE is both valid and effective. While the impact of feedback on student revision quality demonstrates the potential for AWE to aid students in their writing, AWE is generally intended to impact students’ writing skills, not just the quality of a single writing sample. However, writing skills develop over time, with a great deal of practice, not within just a few sessions. Thus, more research is needed to examine the impact of AWEs over time, with more opportunities for students to write and revise. Such studies will inform on the effectiveness of AWE systems and point to ways that they can be improved to meet the needs of young, developing writers.

**Writing development**

Writing is an extremely complex process. Writers’ coordination of processes to produce comprehensible text is shaped by multiple levels of knowledge and discourse (e.g. J. Wilson et al., 2017). Writers must apply their knowledge of the domain, knowledge of language and writing (Bereiter & Scardamalia, 1987; Lin et al., 2007), and knowledge about the audience (i.e. readers) of the text (e.g. Kellogg, 2008; Magnifico, 2010; McNamara & Allen, 2017). Hence, it is not surprising that AWE (alone) has not heretofore led to substantial improvements in writing skill.
Writing calls for both producing and comprehending written language, planning, drafting, revising, reasoning, decision making, as well as a vast amount of knowledge, about language (i.e. vocabulary, grammar), the world, and the targeted topic. Planning entails the generation of ideas, gathering and organizing resources, and setting goals for both the writing task and desired outcomes. Drafting involves translating one’s ideas into coherent text (i.e. words, sentences, and paragraphs) that communicates main ideas and arguments to the reader. Revising entails (re)reading, proofreading, and editing of existing text to improve overall quality and to attain established goals. Even answering a question such as, *What did you do this summer?* Requires recalling the highlights of the summer, planning the response, considering the audience (i.e. the teacher), vocabulary to describe the events, reading and revising the response, and knowledge of how to organize such an essay, to name just a few cognitive processes (Abbott et al., 2010). Writing also requires consideration of the audience: the readers’ expectations, knowledge, and interests (e.g. Graham, 2018; Kellogg, 2008; Magnifico, 2012).

There have been a number of theoretical frameworks posited on writing. From one perspective, writing theorists have focused on overarching theories of writing, and from another perspective, theorists have focused on how writing skills develop across the lifespan. Early models of writing emphasized planning, translating (drafting), and reviewing (revising) as the three principal writing processes (Faigley & Witte, 1981; Flower & Hayes, 1981). Later versions of stage-theory models included the addition of various aspects of cognition such as working memory, motivation, and affect as playing important roles in writing (Hayes, 1996, 2006). By contrast, sociocultural theories of writing have emphasized the writer within their context, defined dynamically by the community, their mutual goals and norms (Bazerman, 2016; Kwok et al., 2016).

More recently, Graham (2018) has merged sociocultural theories of writing with cognitive theories in the *writer(s)-within-community (WWC)* model of writing. Accordingly, writing is shaped by the writer’s individual differences such as writing skills, memory, knowledge, and beliefs, as well as the writing community, including their purposes, history, and environment. The revised version of the WWC model places greater emphasis on the importance of communication between the writer and the reader, or audience. As such, the model puts a greater emphasis on the writer’s developing sense of audience as well as the importance of goals and culture in the communicative role of composition.

From the lifespan perspective, theories of writing development have put a greater emphasis on differentiating between the various skills. Theorists and educators have typically conceived of writing as hierarchically structured at the word, sentence, and discourse levels, and in turn developmentally structured such that writing proficiency grows correspondingly from words, sentences, paragraphs, to full texts. Researchers of early writing have focused primarily on the development of lower-level skills, with the assumption that these skills act as precursors to more complex writing processes (e.g. Berninger & Winn, 2006; Limpo & Alves, 2013). Many theorists also assume that cognitive processes such as attention and working memory play significant roles because developing writers who might struggle in one aspect of writing (e.g. vocabulary, spelling) must devote significant cognitive resources to lower-level processes, leaving fewer cognitive resources to devote to other aspects of writing (e.g. planning). Accordingly, basic
writing skills free up attention and memory to generate text and engage in self-regulatory processes such as goal setting, planning, organizing, and revising (Berninger & Winn, 2006; Ritchey et al., 2015).

According to the Simple View of Writing (e.g. Berninger et al., 2002; Juel, 1988), writing is the product of transcription (e.g. handwriting and spelling) and text generation (e.g. generating ideas and the words, sentences, and longer pieces of discourse to express those ideas). At the word level, orthographic and phonological skills, morphological awareness, and vocabulary knowledge influence students’ writing mechanics (i.e. spelling, handwriting), production, and choice of words (e.g. Abbott & Berninger, 1993; Dockrell et al., 2009). Thus, corresponding instructional interventions have typically focused on morphological awareness (Bowers et al., 2010), spelling and handwriting (Graham et al., 2000; Puranik & AlOtaiba, 2012), or vocabulary instruction (Loftus-Rattan & Coyne, 2013; McKeown & Beck, 2004).

At the sentence level, there is a focus on children’s ability to recognize or construct syntactically or grammatically correct sentences. Accordingly, many educators have focused instruction on grammar and syntax and feedback on students’ writing grammar as a means to improve writing. Another approach is to focus on sentence construction and combining (e.g. Datchuk & Kubina, 2013). While yielding some promissory notes, the bulk of evidence indicates that these approaches by themselves are insufficient (S. Liu Graham et al., 2018).

At the text and discourse level, instruction focuses on students’ abilities to produce texts that coherently express ideas, ranging from short responses comprising a few sentences to multiple-paragraph essays and reports. Instruction generally emphasizes processes corresponding to the writing phases, planning, drafting, and reviewing, as well as self-regulation and audience awareness. The Self-Regulated Strategy Development (SRSD) model (Graham & Harris, 2018; Harris et al., 2008) is arguably the writing model most relevant to the objective of helping young developing writing improve their writing skills at the discourse level. SRSD provides instruction on writing strategies that correspond to self-regulation, planning, drafting, and revising. For example, one mnemonic strategy specific to opinion writing is TREE: T- Topic sentence, Tell what you believe! R – Reasons, 3 or more, Why do I believe this? Will my readers believe this? E – Ending, Wrap it up right! E – Examine, do I have all my parts? The intervention includes six recursive stages of instruction: develop background knowledge, discuss it, model it, memorize it, support it, and independent performance. There is a wealth of evidence that SRSD effectively improves students’ writing skills, enhances attitudes toward writing, and increases motivation to write. Indeed, the effectiveness of SRSD has been examined in over 100 studies, with an average effect size of 1.17 for improving elementary grade students’ writing quality (Graham, 2012b).

The theoretical model undergirding SRSD assumes that writing strategies are key to writing quality. In this context, strategies are the tools that can help students generate content and carry out components of the writing process (S. Liu Graham et al., 2018). Mnemonics (e.g. TREE) help students to remember and enact the strategies while writing. Accordingly, the various aspects of writing are intertwined and interdependent, and thus instruction and practice in writing strategies, such as planning and organization can compensate for basic skills such as vocabulary knowledge. The model further assumes that strategies should be taught explicitly, beginning with information about the strategies, their purpose, rationale, and when to use them. Equally important to SRSD
is the assumption that it is crucial to develop a supportive community for teachers in which they can learn how to apply the strategies effectively and integrate the model into their own classroom environment.

Largely inspired by SRSD, The Writing Pal (Crossley et al., 2016; Roscoe & McNamara, 2013) is an Intelligent Tutoring System (ITS) for students in grades 7–14 that provides writing strategy instruction combined with writing practice using AWE. The Writing Pal is relatively unique in its focus on explicit strategy instruction along with varied opportunities for practice (i.e. game-based strategy practice and essay writing practice). Strategy instruction is delivered via lesson videos on the principal phases of the writing process: prewriting, drafting, and revising (Roscoe et al., 2014, 2015). The videos explain and demonstrate a variety of principles regarding writing and strategies to solve problems encountered during writing (see adaptiveliteracy.com). Students learn and reinforce their understanding of the strategies in the context of mini-games: identification games help students understand and remember strategies, and generative games help students apply those strategies (Proske et al., 2014; Roscoe et al., 2019; Roscoe & McNamara, 2013). Each game is designed to be brief and replayable so that students can engage in extended, deliberate practice (Roscoe et al., 2019, 2013a, 2013b).

Students practice writing essays in response to persuasive essay prompts provided by Writing Pal or on prompts entered by their teacher. After submitting their essay, they receive a summative score and formative feedback that provides individualized advice on how students can improve their future writing. One unique aspect of the Writing Pal is that the AWE Feedback messages align with the strategies taught in the lesson videos. Importantly, students can also revise their essays, giving them an opportunity to apply the advice from the feedback messages. The Writing Pal is effective, with reported increases in essay scores, strategy knowledge, and revising strategies (Allen et al., 2014; Crossley et al., 2013; Roscoe & McNamara, 2013; Roscoe et al., 2015).

The e-AWE framework

We propose the early Automated Writing Evaluation (e-AWE) Framework as a potential guide for the development of tools that leverage and integrate cutting-edge technologies that provide automated or semi-automated writing evaluation and instruction with scaffolding and feedback. Our overarching supposition is that there is a strong need for e-AWE. The need for e-AWE has been evidenced by low writing performance by students in primary grades, which tends to persist throughout students’ academic careers (Abbott et al., 2010), affecting potential success and livelihoods for those who struggle to write. Teachers are not provided with sufficient support, time, or training to provide students with sufficient opportunities to practice writing, with meaningful, dedicated feedback. e-AWE is needed for grades K-5 to remediate these problems. e-AWE offers students deliberate practice tasks that range across multiple genres and purposes. Teachers are provided with the ability to assign writing tasks, develop writing tasks, and view students’ performance. As such, they are afforded time to devote instruction toward students in particular need for individualized feedback. As shown in Figure 1, we further propose that e-AWE calls for integrating three necessary components:
e-AWE must incorporate advanced technologies.
e-AWE must support a community of learners.
e-AWE must interlace reading and writing instructional activities.

**Advanced technologies**

**Automated writing evaluation**

At the core, of course, e-AWE must incorporate advanced technologies in the area of AWE. Algorithms and methods to assess writing quality and various aspects of writing are continuously advancing. There are multiple approaches to assessing language within students’ writing. These can be divided into two categories. The first regards the features of language that are leveraged. The second regards the particular machine learning algorithm that is used to predict the target construct (if it is not captured using a single feature).

The features of language used to drive AWE algorithms can essentially be divided into three categories: a) the words, b) the words’ contexts, and c) the linguistic features of the words. The words as units can be used to inform surface features of the students’ writing as well as indicators of categories of constructs such as the incidence of academic words, emotion words, topic-relevant words, and so on. Essentially any ‘bag-of-words’ can be constructed and indexed depending on the context and pedagogical theory. The incidence of various words and word categories can be calculated to provide features of the text or parts of the text (e.g. paragraphs).
The words’ contexts provide information relative to the frequency that the words in the texts may appear in other similar contexts. Latent Semantic Analysis (T. K. Landauer et al., 2007) was one of the earliest computational methods for assessing word embeddings. The words’ contexts provide information regarding the semantic meaning of the writing by assessing overlap with other similar or targeted texts (e.g. poor or good writing; source texts; sample graded compositions). There have been significant advances in techniques for assessing word embeddings, including word2vec (Mikolov et al., 2013), GloVe (Pennington et al., 2014), and BERT (Devlin et al., 2019).

The linguistic features of words provide additional information about the nature of the writing. For example, the word bank is usually noun (but it can be a verb). As a noun, it has money, or you see it at the beach; it is a common word, it has many associations and meanings. Its noun-ness constrains which words and types of words it tends to accompany; its noun-ness constrains how we process it and how we use it differently from other words. Linguistic features can be calculated related to various constructs such as syntax, lexical properties, and semantics.

These various types of features of the writing are in turn processed using machine algorithms in order to predict the target construct (e.g. regression, decision trees, SVM, etc.; Balyan et al., 2017). Unsupervised learning algorithms such as principal component analysis, cluster analysis, or factor analysis methods can be leveraged for some purposes. In the context of AWE, machine learning is usually used to build supervised algorithms that predict scores based on a corpus of previously scored writing samples (Warschauer & Grimes, 2008).

AWE is a powerful method to provide writing assessments and guide feedback to students. However, the underlying pedagogical model drives what is done with the algorithms to provide feedback to the students or teachers (Roscoe et al., 2016; Wilson et al., 2021). Pedagogical models vary widely across AWE systems, which may in turn impact their effectiveness (Chen & Cheng, 2008; Roscoe et al., 2013c). An important aspect of an e-AWE will be the pedagogical assumptions motivating the features used in the algorithms and the types of feedback provided to both the students and the teachers.

**Speech technologies**

Given the potential power of AWE, why are there not more AWE programs currently available for K-5 students? One simple answer to that question regards the traditional approaches to providing AWE – namely having students read prompts, type responses, and read feedback provided by the system – restricts usability to those students who can read and type, which is unviable for many K-5 students. The incorporation of speech technology into e-AWE constitutes a key, if not basic ingredient. e-AWE must allow students the option to hear words they are struggling to read via Text-to-Speech (Mayer, 2009) and the ability to speak aloud responses they are struggling to type via Automated Speech Recognition (ASR; Hagen et al., 2007).

Text-to-speech is readily available in many technologies, with relatively good pronunciation accuracy depending on the particular speech engine. Indeed, Google Docs already supports text-to-speech, and some schools and teachers often encourage its use.
speech is necessary to support students who are still in the process of developing reading skills or students with reading disabilities (MacArthur, 1996). Optimally, this component of speech processing should allow students to select specific words or text to be read aloud to them, for example by a pedagogical agent (Mayer, 2009). Some of the text-to-speech software that are readily available include Watson Text to Speech (IBM), Polly (Amazon), Text to Speech (Microsoft Azure), Select and Speak (iSpeech), Vocalware, and TTSReader. The majority of these options are cloud-based and provide APIs for windows and mac.

ASR is necessary to relieve the burden of typing from the task of composition such that students can write at earlier ages. Currently, ASR technologies are sufficiently advanced such that they can be incorporated within AWE programs with relative ease and success. Students’ performance is undeniably limited by their ability to translate their ideas into language and then transcribe those words into written text (Berninger et al., 2009). Even students in the 3rd and 4th grades can struggle with generating longer strings of text on a keyboard because they still ‘hunt and peck’ for the letters and symbols that they need rather than typing fluently (Wijekumar et al., 2012). Consequently, students may produce fewer words and recall less when typing or hand writing a response relative to speaking (Bourdin & Fayol, 1994; cf Spilling et al., 2021).

Best practices suggest that students should be introduced to typing in first grade, and begin regular typing practice by second grade (Graham, 2012a; Jones, 1994). Indeed, when students are given opportunities to type early on, they produce texts of similar length and quality in both modalities, highlighting the potential for early typing practice (Spilling et al., 2021). If instruction in typing is also accompanied with instruction in how to use a word processor, then students would be able to type fluently relatively early in the primary grades. Nonetheless, ASR will remain a necessary component of e-AWE due to the importance of allowing students to focus on the primary task of composing. In turn, text-to-speech can provide students with the possibility to listen to the words and sentences that they have typed. As such, e-AWE would also allow the students (who are able to read) to edit the text generated via ASR. If the student checks the text and finds errors, this may increase frustration, which can be detrimental to learning. However, the verification stage may also increase the need for revision and the likelihood that the student will monitor and self-regulate the writing process. As such, fixing system errors may have some benefits if there are not so many that it tips the frustration balance to excess.

While ASR technologies have advanced remarkably in recent years, conventional speech recognition systems that are modeled on adult data tend to fail to perform satisfactorily on children’s speech input (Das et al., 1998). This is primarily due to significant differences between adults’ and children’s vocal characteristics as well as choice of vocabulary and sentence construction. Children have a smaller vocabulary, are more spontaneous and talk less grammatically than adults (Liao et al., 2015). Such differences make it difficult for those systems that were developed based on the adults’ speech patterns to accurately analyze children’s input. Nonetheless, speech technology offers great promise in the field of automated literacy and reading tutors for children (e.g. Hagen et al., 2003). For example, SoapBox (soapboxlabs.com) Lab’s was designed specifically to be used with mobile devices and without headsets for children.
ages 2–12, reporting high accuracy, generalization, and mobility (Fainberg et al., 2016). We expect that ASR will become relatively common, providing a viable means of affording students opportunities to generate responses – without necessarily tapping on a keyboard.

**Immersive technologies**

At the very least, e-AWE requires automated text-to-speech and ASR. However, we can do better. More recent technological advances need to be leveraged and integrated in the service of effective evaluation and instruction in the early grades. We can make writing more fun, engaging, and embodied with cutting-edge immersive technologies such as games, virtual reality, and augmented reality. Games are increasingly considered as a means to providing entertaining, goal-directed environments for assessing skills and competencies. Meta-analyses have reported that across a wide range of individuals (e.g. gender and age), games are more engaging than traditional learning and testing environments, and potentially lead to better, more sustained attention and positive affect (S. Barab et al., 2012; Barab et al., 2007; Garris et al., 2002; Steinkeuhler, 2006; Vogel et al., 2006; K. A. Wilson et al., 2009; cf. Adams et al., 2012). Being and feeling ‘tested’ can induce anxiety and change how students respond to the assessments (i.e. reactivity, Onwuegbuzie & Leech, 2007) and thus games potentially offer means of engaging students and reducing anxiety (Jackson & McNamara, 2013; Roscoe & McNamara, 2013).

Gaming environments differ widely, ranging from accruing points in a tutoring environment to full-fledged games with narration, embedded worlds, beginning-end states, rules, interactions, and reward systems (Gee, 2003; Rieber, 1996; Ritterfeld & Weber, 2006). Complex forms of participation can occur during game play with various affordances such as perception–action cycles, collaborative inquiry, opportunities for consequentiality, and exploration of situated identities (Barab et al., 2010; Dede & Barab, 2009; see Clark et al., 2009; Young et al., 2012, for reviews).

Games are not generally considered in the context of AWE because it was born out of a tradition of standardized assessment within AES. Hence, there are no AWE per se that we are aware of that incorporate games. The Writing Pal incorporates games as a means to provide instruction on writing strategies, but it does not currently use the games as a means of assessment per se. Nonetheless, there is increasing interest in the potential for stealth assessment in games (Fang et al., 2021; Shute & Ventura, 2013; Shute et al., 2016).

In stealth assessment, evaluation of students’ ability occurs during the activity rather than at summative or check-point assessments that interrupt the regular learning activity. In a well-designed game assessment scenario, students may be not aware that skills are being assessed during game-play. The experience of ‘play’ may have greater salience than the experience of ‘testing’. Importantly, this approach focuses on inferring learner skills based on online (i.e. during gameplay) and dynamic (i.e. actions and interactions over time) data, which aligns well with the need to assess the online and dynamic processes of writing, comprehending, and communicating with text. In sum, game environments afford the means to assess learners’ aptitudes and skills in authentic, engaging ways, which has strong potential to enhance external and internal validity. To the extent that these assessments are also ‘stealthy’ the experience of learners may emphasize exploration and enjoyment rather than measurement or evaluation – learners can simply play the game while educators or others gain insight into their literacy skills and competencies.
Notably, however, there is little evidence that games that are designed for assessment improve learning; nor is there sufficient evidence regarding educators’ use of stealth assessment and how such assessments can support instructional practice in the classroom (cf. Shute, 2011).

**Community of writers**

Writing is communication – namely, to others; it is a means to convey thoughts and ideas coherently such that they can be used or transformed by others. This nature of writing is often lost in the instructional process, and more so in the space of technologies that automate the evaluation process. To the extent possible, an e-AWE should infuse the sense that the student is writing to an audience, for a purpose, and within a community of writers. To a large extent, that depends on how an e-AWE is implemented by the teacher within the community; but, it also depends on the affordances offered by the system. e-AWE calls for the creation of a community of writers, where students collaborate as writers, have opportunities to give and receive feedback on their writings, and also publish their writings beyond the classroom.

**Writing for a purpose**

Across the developmental spectrum, students need practice and formative feedback in various types of writing including asking questions, paraphrasing, writing summaries, writing stories, answering questions, writing explanations, and finally, writing essays and short reports. Most writing assignments and assessments implement the writing (and reading) tasks divorced from real-world settings and scenarios – divorced of purpose (Olinghouse et al., 2012). Optimally, assignments or assessments should relate to tasks that the children routinely encounter. Authentic tasks challenge learners to apply learned information to topics and products that are contextually meaningful and realistic (Ashford-Rowe et al., 2014; Gulikers et al., 2004, 2008). Authentic tasks are more engaging and satisfying, taken more seriously by learners, and can contribute to formative assessment and skill development (Gulikers et al., 2008; James & Casidy, 2018; Sotiriadou et al., 2019). Finally, authentic tasks that incorporate writing for different purposes also help students expand their understanding of different genre, text structures, and audiences.

**Peer Feedback.** Formative feedback is fundamental for students’ learning (Llorens et al., 2014; Shute, 2008). In the context of writing, such feedback is often provided in a written form, and most often by the teacher. One purpose of e-AWE is to automate feedback, or automate scaffolds for the teacher to provide feedback. Another source of feedback is from students’ peers within the classroom.

Peer feedback serves dual purposes. From one perspective, students receive feedback regarding the coherence of their writing, and the extent to which it communicates effectively with the intended audience (Cohen & Riel, 1989). From another perspective, students have the opportunity to see examples of writing, critique writing from an objective standpoint, engage in collaborative learning, and in turn, apply their own
critiques to their own writing (Moore & MacArthur, 2012; Philippakos & MacArthur, 2016). Thus, opportunities to both receive and provide feedback have potential to help students develop strategies and language for written feedback (Graham et al., 2005).

It is well established (most often at higher grades) that peer feedback is beneficial (for a meta-analysis, see Graham et al., 2015). Peer feedback improves students’ writing quality as well as their understanding of the expectations, genres, and audiences of academic writing (K. J. Topping, 2009; Patchan et al., 2016; Philippakos & MacArthur, 2016; Schunn et al., 2016; K. Topping, 1998). Indeed, when adequate peer-review prompts and incentives for reviewing are included, peer feedback can be equally beneficial to feedback from teachers (Cho & MacArthur, 2010, 2011; Patchan et al., 2009).

One caveat to the use of peer feedback, particularly in early grades, is that peer feedback can often consist of short, generic positive feedback with too little information about how to improve if the peer is not provided sufficient training or structure (Simmons, 2003). Although there have been previous success using peer feedback with younger students (e.g. Philippakos & MacArthur, 2016), we expect that interface design, usability, and structure will play strong roles in the extent to which it will be useful with K-5 students. Nonetheless, peer feedback not only provides a means for additional sources of feedback, and experience reading others’ writing, it also encourages senses of community, collaboration, and cooperation, which are intrinsic to writing (Z. A. T. Philippakos & MacArthur, 2020). We not only write to an audience, many or most adult writers compose collaboratively – even single authored papers generally have reviewers or publishers who give generous feedback on writing. As such, peer feedback mimics real-world writing that young students will experience later in life.

**Teacher Interface.** e-AWE is unique in that it also provides formative feedback on multiple aspects of writing not only to the student but also to the teacher about a student’s writing or assessment (Allen et al., 2016; Crossley & McNamara, 2016; Roscoe et al., 2018, 2013a, 2016, 2015). Formative feedback generally translates scores to messages that describe the nature of students’ underlying knowledge and skills or actions that can be taken to enhance performance. Such feedback is often obtained by teachers using curriculum-based measures in writing (CBM-W). When CBM-W are used frequently (e.g. weekly), they allow teachers to monitor student progress and engage in data-based decision making (Butterfuss et al., 2021). Data-based decision making can directly inform instructional decisions about what kind of additional practice the student needs to improve their writing and on what areas those efforts should focus (Hopfenbeck, 2018). To that end, e-AWE must include a teacher interface that effectively reports data timely and in ways that allow teachers to engage in data-based decision making (Kerr et al., 2006). In this context, it would be important to identify the types of data that teachers need or want (e.g. data on the features of writing, the quality of students writing, strategies that the students can use, potential instructional techniques that the teachers might adopt, and the extent that teachers can modify or even control AWE feedback).

The design of teacher interfaces is complex (Roscoe et al., 2017), requiring myriad considerations to optimize use, usability, and feasibility. Developers often ignore usability from the point of view of the teacher; however, a critical consideration of an e-AWE regards how the teacher will use the system, integration with the teachers’ needs, while also expanding their capabilities and resources, without overloading them with excess,
unnecessary, or extraneous information (Heffernan & Heffernan, 2014). It is the same balancing act as with the learners’ interface, but even more complex because it is challenging to foresee all of the various circumstances and needs faced by teachers.

One critical consideration is to consider how the teachers operationally define writing in the context of their curriculum and instruction. In some cases, there may be a vast gap separating the theoretical underpinnings of an AWE and teachers’ assumptions concerning writing development, ability, and quality. Such schisms are likely to affect the extent to which teachers will incorporate or adopt an AWE. Assuming the AWE is aligned to a theoretical perspective (a grounding assumption of e-AWE), there are multiple considerations: (a) the extent that professional development can aide in improving alignment between the AWE and the instructor’s operational definitions of writing, (b) whether a different AWE may be better aligned with the instructor’s pedagogical objectives for writing, and (c) the extent that the AWE can be adaptive to the instructor’s operational definitions of writing and pedagogical objectives.

Most importantly, e-AWE should adopt user-centered, participatory design in the development of the teacher interface (Fishman et al., 2013). Design of such systems is also iterative, with a cyclical process of design, gathering feedback, and modifications in relatively short timescales (Stone et al., 2018). Involving teachers in the development and improvement of the e-AWE is crucial to the success of the system, and it can also be beneficial to their knowledge and skills about writing and the use of technologies in writing instruction. Thus, we encourage developers to consider not only what they are getting from their teacher-collaborators, but what they can give in return.

**Writing interlaced with reading**

While the e-AWE Framework focuses on writing, it assumes that writing performance is closely related to reading, and that interlacing the two within an e-AWE is crucial. Writing is a complex activity that entails multilevel, nonlinear, and iterative processes of comprehension, idea generation, organization, translation, and refinement (e.g. Flower & Hayes, 1981; Galbraith & Torrance, 2004; Hayes, 2012; McNamara & Allen, 2017; Olive, 2014; van den Bergh & Rijlaarsdam, 2006). Reading and writing are intrinsically interlaced during the developmental process, particularly during the developmental stages in grades K-5 (Graham & Herbert, 2011; Shanahan, 1987). Reading provides the bases on which children can build their writing skills, and writing improves reading comprehension. Skilled writing requires that writers not only possess a coherent representation of the ideas and the sources of those ideas (e.g. texts they have previously read), they must also consider how to express those ideas in ways that allow readers to comprehend the text.

Central to comprehension is the construction of a coherent mental representation of the text in the reader’s mind. In this representation, the reader successfully connects statements and ideas from the text within the text itself and with background knowledge. Comprehension is not a unitary process or skill, but rather a family of skills that develop concurrently (Cutting & Scarborough, 2006; Duke, 2005; van den Broek et al., 2005; Vellutino et al., 2007). This family of skills includes lower-level processes such as decoding, but more importantly, they include higher order processes such as inference generation and reasoning, which are key to reading comprehension (McNamara, 2020).
Indeed, providing students with instruction and practice to use comprehension strategies early in elementary school is essential (Duke & Pearson, 2002; NRP, 2000; National Early Literacy Panel, 2008; Pressley, 2000). To that end, there exist well-established classroom-based interventions, such as Reciprocal Teaching (RT; Palincsar & Brown, 1984), Concept-Oriented Reading Instruction (CORI; Guthrie et al., 2007, 1996; Wigfield et al., 2014), and Let’s Know! (LK), a multicomponent, supplemental curriculum for pre-K through grade 3 (Johnson et al., 2016; Pratt et al., 2014). However, instruction and training for the development of comprehension strategies requires substantial time and extended deliberate practice (C. E. Snow et al., 1998; Pearson et al., 2020). And, just as is the case for writing, teachers have limited time to instruct learners on higher-level reading strategies, offer practice opportunities, and provide individualized feedback (Goldman et al., 2016).

Given classroom constraints, intelligent tutoring systems (ITSs) are uniquely positioned to fulfill crucial roles in supporting teachers and students. ITSs with fully-automated adaptive responses provide the opportunity for individualized instruction and practice that would not otherwise be possible in the classroom (e.g. Kendeou et al., 2020; K. L. McMaster et al., 2019; McCarthy et al., 2020a; Meyer & Wijekumar, 2016; Wijekumar et al., 2017). One such program that leverages writing to improve comprehension for young developing readers (grades 3 to 5) is iSTART-Early – an ITS designed to provide explicit strategy instruction along with varied opportunities for game-based and text-based practice for children (McNamara, 2020). iSTART-Early is currently under development within the larger context of iSTART, which is geared toward adolescent, undergraduate, and adult literacy students (Jackson & McNamara, 2013; McCarthy et al., 2018, 2020b; McNamara, 2004, 2017; McNamara et al., 2006; E. L. Snow et al., 2016).

The comprehension strategies targeted by iSTART-Early are those often used by skilled readers, and include paraphrasing, inferencing (prediction, bridging, elaboration), explanation, and summarization (McNamara, 2004). These are strategies that are key to enhancing comprehension, but also require constructing written responses, which in turn underlie successful writing. Paraphrasing, restating the text in different words, helps less skilled readers to construct a textbook level understanding and recognize potential comprehension gaps (Best et al., 2005; McNamara, 2004; McNamara et al., 2006). The ability to word the same ideas in various ways is also fundamental to writing (Chen et al., 2013; Keck, 2006).

Paraphrasing helps readers to form a stronger textbook, but going beyond the sentence requires generating inferences to connect ideas within the text and beyond. Inferencing ability is one of the unique and significant predictors of reading comprehension (Barth et al., 2015; Best et al., 2006, 2005; Kendeou et al., 2008, 2020, 2009; J. V. Oakhill & Cain, 2012). Less skilled readers as young as 4th grade benefit from instruction on making inferences (Hansen & Pearson, 1983; McNamara, 2004; Oakhill, 1982, 1984; J. Oakhill & Yuill, 1988). Explanation also serves as a vehicle for students to move beyond the text and generate inferences that connect ideas in the text and background knowledge. Self-explanation, the process of explaining (orally or in writing) the meaning of written text to oneself (e.g. Chi et al., 1994), provides a means to externalize students’ strategy use which in turn improves self-explanation quality (McNamara, 2004, 2017). Explanation is also key to writing (Nielsen, 2012). Skilled writers explain and elaborate their ideas and
their evidence for their thesis and claims (Ferretti et al., 2000). Learning to write arguments is fundamental to writing skill (De La Paz et al., 2012; Philippakos & MacArthur, 2019).

Finally, summarization, helps to reduce the text to its core ideas. This process helps readers identify irrelevant information, integrate content with pre-existing knowledge and better remember text information, enhancing also conceptual understanding (Graham & Herbert, 2011; Wade-Stein & Kintsch, 2004), particularly for lower achieving students and those with learning disabilities (Gil et al., 2010). Summarization is also key to writing (Graham & Perin, 2007). Summarization provides students with models of good writing (i.e. the target text) as well as practice in condensing multiple ideas to core concepts (references; need to get them from Graham & Perin, 2007). Writing summaries is also a common target writing assignment that students will encounter throughout their academic career.

These strategies have demonstrated effectiveness in improving developing readers’ comprehension, particularly when taught in the context of understanding specific texts (McKeown et al., 2009). In iSTART, students compose their responses while reading the texts, and feedback regarding the quality of the response and pointers on how to improve comprehension are provided based on NLP algorithms that assess features of the language. Likewise, NLP algorithms are able to assess the quality of writing, and point students to strategies to improve their writing skills (Botarleanu et al., 2021; Jackson & McNamara, 2012; P. M. McCarthy et al., 2009; McNamara et al., 2018; Nicula et al., 2021; Roscoe et al., 2016, 2015).

**Conclusions and future directions**

We propose and describe a framework designed to guide the development of automated writing evaluation and feedback for young children (K-5th grade) – the early Automated Writing Evaluation (e-AWE) Framework. In summary, e-AWE is grounded on the fundamental assumptions that e-AWE is needed for young developing readers and must incorporate advanced technologies inherent to AWE. Specifically, the system must provide automated feedback that is immediate and formative in nature, using cutting-edge NLP and AWE technologies, and in line with interdisciplinary views on writing, e-AWE must support a community of learners. Additionally, we have proposed that an effective e-AWE tool for K-5 should:

1. Support input using text to speech, and automated speech recognition;
2. Integrate writing with reading tasks;
3. Enable students to undertake simple text-based writing tasks, such as paraphrasing, summarization, or annotation;
4. Be embeddable within meaningful social activities (e.g. publishing a blog or a newsletter);
5. Include games that motivate students to write and receive strategy training;
6. Include instructional activities combined with feedback to use reading and writing strategies;
7. Include a teacher interface that allows for progress monitoring and data-based decision making.
There are multiple technical challenges of accomplishing these goals, including those intrinsic to the development of automated evaluation regardless of the students’ age level. These parallel some of the same challenges encountered in the context of reading research, such as the need for performance benchmarks, which require example writings from diverse samples of students scored using reliable, valid, culturally responsive rubrics. AWE is generally based on linguistic and semantic features of text that are extracted using NLP. The choice of which features to use, including their reliability, validity, and alignment with theories of discourse and writing, essentially drives the success of the algorithm that performs the evaluation. These challenges are further complicated for the writing of young children. For example, young children often have difficulty producing written text, and thus speech-to-text tools may be needed to record the children’s verbal text. While these technical capabilities exist, they have not yet been implemented (at least not widely), and moreover, they have not been tested for feasibility and efficacy.

Yet, given the potential of e-AWE in addressing fundamental instructional and assessment needs in the primary grades, we expect that it has the potential to transform both the teaching and learning of writing. At the same time, e-AWE may also present new challenges and opportunities for advancing both research in AWE as well as the design of e-AWE systems. For example, developing skilled writing that transfers beyond the supports of an e-AWE in new contexts and assessments remains a pressing need for existing AWE systems and those that have yet to be developed. Use of e-AWE, however, can provide opportunities for identifying the boundaries of skill development and successful transfer by adapting to the developing writer’s needs and gradually releasing control, thus supporting independence.

There is an intricate relationship between reading and writing. Writing depends on the ability to read and reading comprehension is enhanced by engaging in writing tasks (S. Liu Graham et al., 2018). Yet, unique processes and skills underline the development of each. The development of reading skills requires learning how to comprehend ideas, whereas the development of writing skills requires learning how to communicate ideas. These skills do not emerge without systematic instruction early in the developmental process. This instruction needs to include practice, scaffolding, and formative feedback. Sufficiently varied and individualized writing and reading practice with feedback is beyond the capacity of teachers in our school systems. Although we have developed a host of educational technologies to support reading, writing presents unique challenges that have hindered the development of comparable systems. The need to better support early development and evaluation of writing skills in tandem with reading also stems from the indisputable importance of writing skills to academic and life success.

Within the context of e-AWE, and writing instruction generally, there are an abundance of questions that remain to be addressed in writing research. Generally, we assume that a successful AWE must be theoretically driven and grounded by a strong empirical foundation. Notably, however, theories of writing and operational definitions of the construct of writing vary across frameworks – that is the nature of science. Moreover, the ability to write and ‘good quality writing’ are defined in different ways in different curricula and by different teachers. Hence, the extent to which the operationalization of writing within an AWE aligns with teachers’ pedagogical assumptions is a critical consideration, both in assessing its utility and in enhancing its potential. Further, we assume that the timing and types of feedback...
matter (e.g. Butterfuss et al., Butterfuss et al.; Kulik & Kulik, 1988; Roscoe et al., 2013c; Kellogg et al., 2010) however, there is too little research on when students should receive feedback (e.g. immediately or after a delay; Weston, 2015) or the amount of feedback that students should receive (Roscoe et al., 2014). Likewise, we assume that students need to be engaged in the writing tasks, but there is too little to guide educators and researchers on which techniques are most effective in engaging students. Similarly, we assume that students need to spend a sufficient amount of time learning how to write and engaging in writing tasks (Graham et al., 2002; Many et al., 1996), but we do not fully understand how much time is needed, and how those needs depend on the task and students’ abilities (not to mention the constraints of the classroom). Along those lines, there is little to guide pedagogy on whether or how to personalize writing topics to students’ interests: on the one hand, they may have more to write if they write about their interests; on the other hand, they may learn more if they write on topics that they consider less interesting at the outset – students in K-5 are still uncovering their interests as they learn about new things. Within the e-AWE Framework, we envision that numerous empirical studies can be designed to answer these, as well as any number of other questions regarding writing instruction.

When teachers use e-AWE, students are provided with opportunities and time to read and write for various purposes and text genre, in an environment that supports reading and writing strategies via deliberate practice, automated feedback, gamification, ASR, and text-to-speech capabilities. By integrating automated reading and writing strategy instruction with these capabilities and supports, students will simultaneously learn how to both comprehend and communicate ideas, while receiving in-time and individualized scaffolding and formative feedback. We hypothesize that instruction with e-AWE will result in integrated and more effective reading and writing instruction, that in turn will improve student reading and writing performance. Furthermore, the interlace of writing and reading in e-AWE provides a unique opportunity to facilitate the interdependency of these fundamental processes and skills early in a student’s life, and potentially accelerate the development of both reading and writing. Indeed, theorists have recently called for the sciences of reading and writing to be more fully integrated (Graham, 2020). We contend that e-AWE answers that call and opens up new possibilities for advancement in both theory and practice.

Acknowledgments

This paper was partially supported by the Institute of Education Sciences, U.S. Department of Education, through Grants R305A190050, R305A180261, and R305A170163, and by the Office of Naval Research Grants N00014-20-1-2623 and N00014-17-1-2300 to Arizona State University.

Disclosure statement

No potential conflict of interest was reported by the author(s).

Funding

The author(s) reported there is no funding associated with the work featured in this article.
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