CHAPTER 6

Supporting Reading Comprehension in the Upper Elementary Grades

Kristen L. McMaster
Panayiota Kendeou

In this chapter, we discuss our attempts to bridge the science of literacy research and practice in ways intended to have a meaningful, sustainable, positive impact on students' reading comprehension. First, we discuss why we focus on reading comprehension, the importance of aligning theory to practice, and how we strive to do so within current educational service delivery models (i.e., multi-tiered systems of support [MTSS]). Then, we provide examples of our work at the upper elementary levels designed for implementation at Tiers 1 and 2, along with efforts to develop a personalized intelligent tutoring system that may be implemented across tiers using innovative technology tools. We end with implications for practice and directions for future research aimed at improving reading comprehension using the best scientific evidence available.

Why Reading Comprehension?

Supporting students' successful development of the skills needed to comprehend and learn from a wide array of complex and challenging texts is an educational imperative. Few would dispute that reading comprehension is essential for success in school and beyond—indeed, our information-driven society can only thrive if its citizens can engage with, understand, use, and respond to various texts. Success in doing so has become increasingly challenging at a time when people are inundated with information and *mis*information that can (and does) have dire consequences for key societal functions, including education, public health, government, and even democracy as we know it (Ecker et al., 2022; Kendeou & Johnson, 2024).

For many learners, successful reading comprehension does not simply arise from the development of fluent word recognition skills but requires intentionally designed teaching and learning opportunities. Thus, researchers and practitioners have exerted extensive efforts to understand the complex and multidimensional processes involved in reading comprehension (Kendeou et al., 2024), to develop and test theories that describe these processes (van den Broek & Kendeou, 2022), and to design instruction and interventions to support reading comprehension. Indeed, decades of research have been devoted to developing and evaluating ways to teach reading comprehension skills and strategies (e.g., Snow, 2002), including for readers who experience difficulties (see Filderman et al., 2022, for a recent meta-analysis).

While the importance of this work cannot be overstated, national assessment data suggest that even these efforts have not been sufficient. High proportions of students continue to perform below proficient levels of reading; in fact, for decades, a persistent one-third of elementary-level schoolchildren have not reached proficiency on the National Assessment of Educational Progress (U.S. Department of Education, 2022). Moreover, alarming gaps persist for historically marginalized students, including Black and Brown students and children living in poverty (Terry, 2021), multilingual learners (Choi et al., 2025), and students with disabilities (Choi et al., 2025; Gilmour et al., 2019). It is clear that continued, concerted effort is needed to close these gaps and to find ways to ensure that all students have opportunities to achieve success in reading.

Aligning Theory to Practice

We, along with other scholars, have argued that the seemingly intractable high rates of below-proficient levels of reading are likely due, in part, to gaps between theory, empirical research, and practice (McMaster & Kendeou, 2023); that is, the teaching of reading (including instruction, intervention, and assessment) does not always reflect what we know to be "evidence based," and even research-based practices do not always connect directly to theory. Yet a stronger alignment of theory to teaching practices should lead to more robust and sustained student outcomes—as theory can help specify and explain the processes involved in reading and why they might break down for some readers, as well as the conditions that need to be in place to support these processes to achieve successful reading.

In our work, we have attempted to bridge theory and teaching practices by drawing from a cognitive view of reading comprehension to design instruction and interventions that are directly aligned to processes central to successful reading comprehension. According to this perspective, successful comprehension requires the reader to construct a coherent representation of text in memory (Kintsch, 1988), thereby building a *situation model* (Kintsch & Van Dijk, 1978). Readers construct this situation model by forming a network of semantic (meaningful) relations between text elements and prior knowledge as they progress through a text. Readers make a variety of such connections during reading; in our work, we focus

specifically on *causal* connections, as these are central to comprehension (Oakhill & Cain, 2007).

Causal connections help link events or ideas within text, and between the text and prior knowledge (e.g., connecting a character's actions to their motivation to achieve a goal). Forming such connections often requires readers to make *inferences*—or to fill in gaps that are not explicitly stated in the text. Readers often seem to make inferences automatically, with little conscious thought, but at times they must make inferences *strategically* by actively searching and connecting parts of the text with each other or with background knowledge to fill in those gaps (Rapp & van den Broek, 2005; van den Broek et al., 2005). For example, consider the following two phrases from a popular children's book, *If You Give a Pig a Pancake*, by L. J. Numeroff (1998):

If you give a pig a pancake, she'll want some syrup to go with it.

Some readers automatically draw the inference needed to understand the connection between these two phrases (in fact, you might have done so and not realized that you made an inference). These readers most likely have knowledge of, or experience with, eating pancakes as a sweet breakfast treat, and understand that syrup is often poured on top. Other readers need to strategically search for the connection between the two phrases. Readers who are accustomed to eating pancakes as a savory dish with meat or vegetables might not automatically associate syrup with pancakes. These readers might need to actively search the text and/or their background knowledge for more information to meaningfully connect the two phrases. This example is intended to illustrate how creating a network of semantic relations involves a combination of automatic and strategic processes, and that the extent to which these processes are automatic or strategic depends to some degree on the reader's prior knowledge (Compton et al., 2014); of course, readers often encounter much longer and more complex texts that require them to engage in such processes to a much greater extent than in the example.

Two additional factors influence the reader's ability to create a semantic network: (1) the reader's general inference-making ability (Cain & Oakhill, 2006, 2012; Oakhill & Cain, 2007; van den Broek et al., 2009) and (2) the reader's standards of coherence. *Standards of coherence* refers to the extent to which the reader aspires to maintain coherence while reading (Todaro et al., 2010; van den Broek et al., 1995). An individual reader's standards of coherence influence the extent to which they implement strategies to maintain overall comprehension of a text (Oakhill & Cain, 2012). For example, some readers who did not understand the connection between pancakes and syrup might try to figure out the relation, while others might decide to continue to read without trying to understand the connection.

In summary, a cognitive view of reading comprehension suggests that readers must engage in actively building networks of semantic relations between text information and prior knowledge to form a coherent representation of the text, and that the construction of this network depends on both automatic and strategic

processes. Furthermore, some readers have more difficulty than others in constructing this network, and readers vary in their standards of coherence. Our work is motivated by this view, which leads to questions regarding whether and how readers can be taught to engage in these processes in ways that lead to improved reading comprehension.

Research has revealed that one factor that is central to such improvement is inference making. Inference making is a two-stage process that involves the *activation* and *integration* of information from text and from prior knowledge (Kintsch, 1988). Key findings from research provide guidance for developing reading instruction that promotes inference making, including that inference making (1) is a general skill that develops and transfers across media (Kendeou et al., 2009), (2) can be prompted with questioning (to prompt the necessary *activation* and *integration* of information) and facilitated with scaffolding and feedback (McMaster et al., 2012, 2014), and (3) can be facilitated by leveraging media affordances—that is, the supports that technology can offer such as audio and video, interactive features, and ways to automate and personalize various functions (Kendeou et al., 2020). We return to these key findings in our description of relevant work later in this chapter.

Multi-Tiered Systems of Support

In addition to aligning with theory, our work is situated within a framework known as MTSS. Many U.S. school districts have adopted an MTSS framework to meet students' diverse learning needs in an equitable, inclusive, and resource-efficient way. MTSS is intended to be an integrated framework for educational service delivery that draws on evidence-based practices to address all students' academic, behavioral, and social–emotional needs. This framework is prioritized in U.S. educational policy (Every Student Succeeds Act, 2015).

Although the implementation of MTSS varies, it typically comprises several common key components: (1) universal screening and progress monitoring, (2) increasingly intensive "tiers" of instruction and intervention, and (3) data-based decision making to identify students in need of more intensive instruction and to evaluate the effectiveness of that instruction (Burns et al., 2016). MTSS is driven by the assumption that the vast majority (approximately 80%) of students will benefit from core instruction (Tier 1) provided by the general education teacher. Some (around 15%) will require additional support, usually in the form of Tier 2 research-based, standard interventions delivered by a qualified interventionist to small groups of students. Creating such groups relies on reliable and valid assessment data that can be obtained in a timely manner. For example, in reading, assessment data might indicate several students in a class need more targeted support in learning to make inferences to comprehend text; these students might be grouped together to receive Tier 2 instruction. This approach reserves Tier 3, the most resource-intensive, individualized instruction, for a small number of students

(around 5%) who are most likely to benefit from specialized instruction tailored to their specific needs.

Inference-Making Instruction and Intervention

Our research teams have worked to develop reading comprehension instruction and interventions that align with cognitive theory and are designed to be implemented within MTSS frameworks. This work has focused primarily on supporting inferencing and the use of other core strategies to promote overall reading comprehension in upper elementary schoolchildren. In this section, we describe work that aligns with Tiers 1 and 2 of MTSS, as well as technology-based instruction that can be personalized to fit the needs of individual learners.

Tier 1 Instruction

In 2004, we, along with other researchers at the University of Minnesota, initiated a comprehensive program of research that aimed to (1) describe the reading processes and products of elementary- and secondary-level students and the extent to which these processes and products differed for readers with varying skill levels and (2) use insights gained from that research to develop instructional approaches that would support reading comprehension development. This work was conducted in the context of core instruction provided to all students within the general education classroom, thus aligning with Tier 1 in MTSS frameworks. Here we focus on the work conducted with upper elementary (fourth-grade) students.

To meet the first aim of this research, we administered behavioral measures of reading (using eye-tracking methodology) and think-aloud protocols to assess the reading *processes* that students engaged in, along with an extensive battery of reading- and cognitive-focused measures to assess the *products* of students' reading, as well as characteristics that might contribute to their reading outcomes (see Rapp et al., 2007). First, fourth graders were asked to read four grade-level texts (two narrative and two expository) that varied in difficulty level (easy vs. hard) based on the overall coherence of each text. Their eye movements were tracked while they read these texts on a screen. Eye-tracking data showed the points in the text where readers fixated their eye gaze, for how long, and both within and across sentences, as they proceeded through each text. These data enabled us to deduce the processes in which readers engaged as they read, such as whether they were drawing particular inferences (e.g., by looking back at key points in text needed to make connections) or experiencing difficulties (e.g., by slowing down) at different points in the text (Rayner et al., 2006). We noticed that readers identified as more highly skilled based on traditional reading assessments tended to proceed more quickly through the text than those identified as lower skilled, and showed patterns consistent with strategic reading (e.g., looking back at specific points needed to generate inferences vs. fixating on difficult words).

Whereas eye-tracking data gave us some insights into specific behaviors in which readers of different skill-levels engaged, such insights were indirect and required us to make assumptions about readers' specific processes. Thus, we complemented the eye-tracking data with think-aloud protocols. Think-aloud methods have a long history in cognitive research as a way to learn what individuals are thinking about as they read texts (Ericsson & Simon, 1984). During think-alouds, we asked readers to read new grade-level texts (two narrative, two expository, which again varied in difficulty level) line-by-line, pausing after each sentence to state what they were thinking. Responses were transcribed and coded to provide insight into the processes in which readers engaged as they read. For example, readers paraphrased or repeated text, called on background knowledge to fill in missing information in the text (i.e., explanatory inferences), predicted what might happen next in the text (i.e., predictive inferences), related what they were reading to their own lives (i.e., associations), and engaged in other types of processes.

Whereas results from think-alouds revealed that readers of all skill levels engaged in a variety of processes, one particularly interesting finding emerged. We hypothesized that those readers identified as lower skilled were a heterogeneous group (i.e., that they encountered difficulties for a variety of reasons), so we conducted a cluster analysis to see if we could detect subgroups of readers whose difficulties might be related to different patterns of processing during reading. Sure enough, this analysis revealed two specific subgroups—one that pervasively relied on paraphrasing and repeating text during the think-aloud activity (and thus we referred to them as "paraphrasers"), and one that engaged in a high proportion of elaborative inferences (in which they attempted to connect the text to their background knowledge; thus dubbed "elaborators"). Although paraphrasing and elaborative inferences are often useful processes that support comprehension (McNamara, 2004), it seemed that lower-skilled readers were using these processes to the exclusion of others that might also be helpful—and sometimes in inaccurate or ineffective ways (e.g., they might connect the text to background knowledge that was irrelevant to the content they were reading). Upon examination of these subgroups' performance on standardized cognitive and reading assessments, we found that paraphrasers and elaborators did not differ on listening or reading comprehension, oral reading fluency, decoding and word recognition, vocabulary, general intelligence, motivation, or working memory.

Our findings from eye-tracking and think-aloud methodologies led us to two important conclusions; first, that evidence from "online" or in-the-moment assessments of reading—obtained during the actual reading *process*—provided different information from "offline" assessments obtained after the fact (i.e., the *product* of reading, such as responses to multiple-choice questions answered after reading a passage); second, that such insight into readers' *processes* might be instructionally useful—that is, it might provide guidance as to what to focus on during reading instruction and how to support readers' engagement in processes that lead to successful comprehension.

This latter conclusion motivated the next stage of our research, which was to design instructional protocols to support readers' comprehension in the context of whole-class (Tier 1) instruction and determine whether students at different skill levels or profiles (paraphrasers and elaborators) would respond differently to different questioning approaches (see McMaster et al., 2012). In line with our cognitive view of reading comprehension, we designed questioning approaches to prompt students to make connections in text to support inference making. We compared three different questioning approaches to test (1) whether questions designed to promote inference making would lead to stronger comprehension than simply asking literal "who," "what," "where," and "when" ("Wh") questions about text and (2) whether questions designed to elucidate causal relations in text ("causal" questions) would lead to stronger comprehension than questions designed to prompt the reader to make any kind of connections ("general" questions). Furthermore, we examined whether students identified as paraphrasers versus elaborators (using think-alouds) would respond differently to the different questioning approaches.

To develop causal questions, we analyzed grade-level narrative texts according to their causal structure, identified places where an inference was needed to support the reader's construction of a coherent representation of the text, and inserted a specific "why" or "how" question to prompt a text-based inference. "Wh" questions were also specific to the text and inserted in the same places as the causal questions but were literal rather than inferential in nature. General questions consisted of prompts (again, in the same locations as the causal and "Wh" questions) for the reader to "Connect it!" during reading—in other words, to connect the current sentence to earlier parts of the text. This approach was designed to provide readers with a generic strategy that they could apply to any text that they read.

Participating fourth graders (n = 246) were identified as struggling, average, or good readers based on performance on a standardized, norm-referenced reading test and curriculum-based reading measures. Furthermore, struggling readers were identified as "paraphrasers" or "elaborators" using think-aloud protocols. Students were stratified by skill level and assigned randomly to instructional groups (causal, general, or "Wh" questioning). Classroom teachers delivered the instruction in a classwide peer tutoring format for 20–30 minutes, two to four times per week, for 9 weeks. Specifically, students worked in pairs to read the texts together, and when they came to the questions inserted in the text, they prompted each other to answer them.

On average, students in all three questioning conditions made significant pre- to posttest growth; however, there were no reliable differences among the three conditions on readers' recall of central events in stories they read at posttest, regardless of their skill level. However, further analyses revealed that subgroups of struggling readers responded differently to the different questioning approaches. Specifically, those identified as "elaborators" outperformed "paraphrasers" in the causal condition (d = 0.86), paraphrasers outperformed elaborators in the general condition (d = 1.46), and paraphrasers in the general condition outperformed paraphrasers in the causal condition (d = 1.52). These findings tentatively supported

our hypothesis that the two subgroups would respond differently to the different questioning approaches. Theoretically, the differential responses made sense: Elaborators likely benefited from prompts to connect information within the text rather than relying on background knowledge that might or might not be relevant. Paraphrasers may have benefited from prompts to make any kind of connection, rather than simply paraphrasing or repeating what they read.

Tier 2 Intervention

Intrigued by our initial finding that different instructional approaches might have varying effects for different types of struggling comprehenders, our research team further developed and tested the questioning approaches described earlier. We decided to focus specifically on students identified as experiencing comprehension difficulties and designed a more intensive intervention (to be delivered in small groups by a trained interventionist as a supplemental "Tier 2" intervention). We worked in partnership with classroom teachers to ensure that the intervention would be both feasible for classroom use and responsive to the needs of subgroups of struggling readers. Similar to McMaster and colleagues (2012), we developed narrative texts (fiction and biographical nonfiction) with questions inserted where inferences were needed for the reader to generate a coherent representation of the text.

Again, we developed specific causal ("why" and "how") questions, to be compared to the more generic prompt to "Connect it." With input from classroom teachers, we also developed versions in which questions would be asked "online," or during the reading process, versus "offline," or after reading the complete text. We did so to address the question of whether prompting inferencing *during* reading would actually change the reading process in a way that would positively impact the reading outcome, or whether such an approach would be too disruptive (in which case, asking questions *after* reading might be more effective).

After development of the intervention with extensive input and feedback from teacher partners, we identified 60 fourth graders performing at the bottom 25th percentile in reading comprehension (but not decoding), and further identified them as "elaborators" and "paraphrasers," once again using a think-aloud task (see McMaster et al., 2014, 2015). We assigned groups of three to five students randomly to Causal or General questioning conditions; all readers responded to questions asked *during* or *after* reading, in counterbalanced order. Highly trained tutors delivered intervention to the groups for 20–30 minutes, three times per week, for 18 sessions. Similar to McMaster and colleagues (2012), there were no reliable main effects of questioning approach on students' text recalls or oral reading fluency, although students made significant pre- to posttest growth in both conditions. An effect size of $d = 0.88$ for the proportion of gist story units recalled, though not statistically significant, favored the Causal questioning approach. Also, quantitative results suggested no meaningful difference between asking questions during versus after reading, though feedback from tutors indicated that asking them during reading was more feasible. Additionally, and in contrast to previous

findings, there were no differential effects for elaborators versus paraphrasers (McMaster et al., 2014).

Results of this study led us to conclude that (1) asking causal questions during reading emerged as having the most promise when triangulating theory, evidence, and practical considerations and (2) this conclusion held true for both paraphrasers and elaborators. We hypothesized that the two subgroups did not respond differently to the two different questioning approaches because they worked in small groups that included both types of readers (unlike in McMaster et al., 2012, in which they worked in pairs), which meant they were not only exposed to a variety of responses to the questions but also received specific feedback from the tutor that addressed their specific learning needs.

In fact, as we further refined the intervention, we developed scaffolding and feedback options that tutors could use in response to individual readers' answers to questions (e.g., feedback that directed them either to make text-based connections when they overrelied on irrelevant background knowledge or to make an inference instead of simply paraphrasing). In this way, the scaffolding and feedback served as the means of differentiating instruction. In a final study in which we assigned 59 students randomly to receive the final version of the intervention or to serve as a business-as-usual control, we observed a positive effect (d = 0.20) favoring the intervention on the Multiple-Choice Online Cloze Comprehension Assessment (MOCCA; Carlson et al., 2014), demonstrating the promise of this intervention to improving outcomes for readers with comprehension difficulties.

Personalized Learning Using Technology

Even though supplemental interventions can effectively support comprehension, many students would likely benefit from more personalized reading instruction than can be offered in large or small groups. Such instruction can be adapted to the specific strengths and needs of the student, offering opportunities for both targeted instruction and deliberate practice. However, teachers have limited time to provide one-to-one or small-group personalized instruction, offer practice opportunities, and provide personalized feedback (McCarthy & Yan, 2024).

Given these classroom and time constraints, educational technology and specifically intelligent tutoring systems (ITSs) are uniquely positioned to fill a role for developing reading comprehension strategies. ITSs with fully automated adaptive responses provide the opportunity for personalized instruction and practice that would not otherwise be possible in the classroom. Using natural language processing (NLP), ITSs can provide immediate, automated feedback on learners' use of reading strategies. Such ITSs can also supplement reading classroom instruction, offering more intensive opportunities for instruction and practice.

Recognizing the promise of ITSs, McNamara and colleagues (2006) designed and tested a series of theories based ITSs to support the development of reading comprehension strategies called iSTART (Interactive Strategy Training for Active Reading and Thinking). iSTART combined self-explanation, a means to externalize students' strategy use, with comprehension strategy instruction (McNamara,

2004). Specifically, students learn how to explain challenging texts with instruction on how to use effective strategies such as paraphrasing, making bridging inferences, and elaborating using prior knowledge. iSTART has a strong evidence base, showing efficacy to improve comprehension for middle school (McNamara et al., 2007), high school (O'Reilly et al., 2004), and college students (Magliano et al., 2005).

These effects, though, do not mean that using this exact system would be appropriate or effective for younger students. Therefore, together we recently developed iSTART–Early (Kendeou et al., 2022; Watanabe et al., 2024) to address the needs of students in upper elementary school, by building and expanding on the latest version of iSTART (McNamara, Arner, et al., 2023). In iSTART–Early, upper elementary school students learn five comprehension strategies drawing on the self-explanation reading strategy training model (McNamara, 2004), in addition to question asking and summarization through video lessons, guided demonstration, and game-based practice (Jackson & McNamara, 2013). These strategies were adapted specifically for upper elementary school and include *ask*, *reword*, *find*, *explain*, and *summarize*.

Ask focuses on comprehension monitoring and question asking, facilitating better regulation and comprehension (McCarthy et al., 2018). *Reword* focuses on paraphrasing, an important part of the comprehension process because it helps readers to build on and draw inferences (McNamara, Newton, et al., 2023). *Find* focuses on identifying important sentences in the text, an effective strategy to improve comprehension performance (Butterfuss et al., 2024). *Explain* enables students to generate inferences that connect ideas in the text (bridging) and with background knowledge (elaborations). Finally, *summarize* helps readers reduce the text to its core ideas and integrate it better with their background knowledge (McNamara et al., 2004).

Most importantly, three major technological advances were incorporated into iSTART–Early to make it developmentally appropriate for upper elementary school students (Balyan et al., 2022). The first advance is automated speech recognition technology, which enables easy interaction with the system, without the need for the students to type in responses. The second advance is the expansion of NLP algorithms, which enable more precision in the assessment of less structured or syntactically incorrect phrases typical for this age group. The third advance is text-to-speech, which enables the option to have the text read-aloud by a pedagogical agent. Incorporating these advances allows iSTART–Early to provide automated reading strategy training to a younger age group more effectively. With these core components and advanced features, iSTART–Early provides explicit instruction for comprehension strategies, with grade-level informational texts, so that students can build relevant background knowledge while learning reading strategies. Immediate feedback, gamification, and deliberate practice are designed to enhance student motivation and self-regulation. Based on our initial pilot studies and prior work, iSTART–Early is usable and feasible for school implementation, also showing initial promise to improve comprehension (Butterfuss et al., 2024; Kendeou et al., 2022; McNamara, Arner, et al., 2023; Watanabe et al., 2024). It is important to note that we view such technology as a promising and innovative way to

supplement the broader literacy curriculum, and that the expert role of the teacher in making critical instructional decisions to meet students' needs will likely remain paramount to their success.

Implications of This Work

The work described in this chapter has several important implications for bridging science and practices that focus on improving reading comprehension for students in upper elementary grades. First, our work underscores the importance of aligning practice with theory. We have built reading comprehension instructional approaches that draw from cognitive theories that help us understand reading processes and ways those processes might support (and sometimes detract from) successful comprehension. Our work builds on existing research that shows that promotion of inference making and the use of other core strategies can improve outcomes for readers with a range of skill levels, and that we can optimize the effects of such instructional approaches through timing, scaffolding and feedback, and a variety of technological advances.

Second, our work highlights the importance of asking questions regarding "for whom" and "under what conditions" instruction and interventions are most likely to be effective. Given that readers who experience comprehension difficulties are not a homogeneous group, but rather struggle in different ways for different reasons, it is important to gather information about their specific strengths and needs and align instruction to those strengths and needs. Effects of such instruction might vary depending on the instructional context (e.g., whether instruction is delivered to the whole class vs. a small group)—which is a highly relevant consideration in the context of MTSS, in which students have opportunities to receive instruction at varying tiers of intensity depending on their needs. Related to this point is a third important implication: that technology offers a promising way to personalize instruction, which might ultimately lead to greater efficiency and efficacy in the way that instruction is delivered across tiers.

Future Directions

Much of the work described in this chapter shows the *promise* of practices designed to promote successful comprehension for readers in upper elementary grades. Further work is needed to continue to develop instructional materials that are culturally appropriate and motivating for diverse learners, to establish the *efficacy* of these approaches for samples of students who are representative of diverse learners in our schools (including students of historically marginalized racial and ethnic backgrounds, multilingual learners, and those with disabilities), and ultimately to determine whether they are effective when implemented at scale.

Another critical direction for future research is the ongoing need for theory- and intervention-aligned assessment. One of the challenges we have encountered

in this work is the limited availability of assessments of reading comprehension processes that have evidence of strong psychometric properties (e.g., reliability and validity), are sensitive to students' growth in response to instruction, and can help identify relevant subgroups of readers in an efficient and instructionally useful way. Some existing measures have shown promise to do so (e.g., the MOCCA; Carlson et al., 2014); however, further research is needed to show how such assessments can be used seamlessly to inform instruction and intervention within MTSS.

Finally, ongoing development of educational technology is a critical direction for future research. A considerable amount of evidence suggests that technology such as games, interactive applications, and ITSs improves a variety of student-level outcomes, such as motivation, engagement, and learning (e.g., Jackson & McNamara, 2013). With the introduction of large language models via chatbot systems (e.g., ChatGPT), the automatic evaluation of reading strategies in systems such as iSTART–Early may be further improved, significantly influencing learner experience, as well as scalability of these personalized systems (Nicula et al., 2023). Advances in artificial intelligence (AI) offer opportunities to evaluate learner strengths and needs via stealth assessments (McNamara, Arner, et al., 2023) that in turn can be used to tailor feedback and adaptivity in the system (McCarthy & Yan, 2024). With generative AI, content can also be tailored to student needs and interests far more effectively and at scale. Given that AI systems are inherently susceptible to algorithmic bias, it is important to be cautious and continue to push for theory- and evidence-based application in education that is also responsible, ethical, and human-centered (Allen & Kendeou, 2024).

Conclusion

In this chapter, we have described how we designed instructional practices to promote reading comprehension in upper elementary students, including examples of our work using whole-classroom instruction, small-group intervention, and personalized learning. Our work underscores the importance of aligning theory with practice, as well as attending to questions regarding *for whom* and *under what conditions* such practices will be most effective. Ongoing research is needed to continue to address these questions, to align assessments with theory and instruction, and to leverage technology to create personalized learning systems that show initial promise to improve a variety of outcomes for diverse learners.

ACKNOWLEDGMENTS

The research reported here was supported in part by the Institute of Education Sciences, U.S. Department of Education, through Grant Nos. R305G040021, R324A110046, R305A190050, and R305A220107 to the University of Minnesota. The opinions expressed are those of the authors and do not represent views of the Institute or the U.S. Department of Education.

REFERENCES

Allen, L. K., & Kendeou, P. (2024). ED-AI Lit: An interdisciplinary framework for AI literacy in education. *Policy Insights from the Behavioral and Brain Sciences, 11*(1), 3–10.

Balyan, R. Arner, T., Li, T., Orcutt, E., Butterfuss, R., Kendeou, P., & McNamara, D. (2022). (2022). Integrating speech technology into the iSTART–Early Intelligent Tutoring System. In S. Crossley & E. Popescu (Eds.), *International conference on intelligent tutoring systems* (pp. 362–370). Springer International.

Burns, M. K., Jimerson, S. R., VanDerHeyden, A. M., & Deno, S. L. (2016). Toward a unified response-to-intervention model: Multi-tiered systems of support. In S. R. Jimerson, M. K. Burns, & A. M. VanDerHeyden (Eds.), *Handbook of response to intervention: The science and practice of multi-tiered systems of support* (2nd ed., pp. 719–732). Springer.

Butterfuss, R., McCarthy, K. S., Orcutt, E., Kendeou, P., & McNamara, D. S. (2024). Identification of main ideas in expository texts: Selection versus deletion. *Reading and Writing, 37*(3), 757–785.

Cain, K., & Oakhill, J. (2006). Profiles of children with specific reading comprehension difficulties. *British Journal of Educational Psychology, 76*, 683–696.

Cain, K., & Oakhill, J. (2012). Reading comprehension development from seven to fourteen years: Implications for assessment. In J. P. Sabatini, E. R. Albro, & T. O'Reilly (Eds.), *Measuring up: Advances in how we assess reading ability* (pp. 59–76). Rowan & Littlefield Education.

Carlson, S. E., Seipel, B., & McMaster, K. (2014). Development of a new reading comprehension assessment: Identifying comprehension differences among readers. *Learning and Individual Differences, 32*, 40–53.

Choi, S., Bak, M. Y. S., & McMaster, K. L. (2025). *Reading development of multilingual and English-monolingual students with and without disabilities in response to intervention: An exploratory study.* Manuscript under review.

Compton, D. L., Miller, A. C., Elleman, A. M., & Steacy, L. M. (2014). Have we forsaken reading theory in the name of "quick fix" interventions for children with reading disability? *Scientific Studies of Reading, 18*, 55–73.

Ecker, U., Lewandowsky, S., Cook, J., Schmid, P., Fazio, L., Brashier, N., . . . Amazeen, M. (2022). Drivers of misinformation belief and its resistance to correction. *Nature Reviews Psychology, 1*, 13–29.

Ericsson, K. A., & Simon, H. A. (1984). *Protocol analysis: Verbal reports as data*. MIT Press.

Every Student Succeeds Act, 20 U.S.C. § 6301 (2015). *www.congress.gov/bill/114th-congress/senate-bill/1177.*

Filderman, M. J., Austin, C. R., Boucher, A. N., O'Donnell, K., & Swanson, E. A. (2022). A meta-analysis of the effects of reading comprehension interventions on the reading comprehension outcomes of struggling readers in third through 12th grades. *Exceptional Children, 88*(2), 163–184.

Gilmour, A. F., Fuchs, D., & Wehby, J. H. (2019). Are students with disabilities accessing the curriculum?: A meta-analysis of the reading achievement gap between students with and without disabilities. *Exceptional Children, 85*(3), 329–346.

Jackson, J. G., & McNamara, D. S. (2013). Motivation and performance in a game-based intelligent tutoring system. *Journal of Educational Psychology, 105*, 1036–1049.

Kendeou, P., & Johnson, V. (2024). The nature of misinformation in education. *Current Opinion in Psychology, 55*, Article 101734.

Kendeou, P., McMaster, K., Butterfuss, R., Kim, J., Bresina, B., & Wagner, K. (2020). The Inferential Language Comprehension (*iLC*) framework. *Topics in Cognitive Science, 12*, 256–273.

Kendeou, P., McMaster, K., McNamara, D. S., & Wilke, B. C. (2024). Literacy. In P. A. Schutz & K. R. Muis (Eds.), *Handbook of educational psychology* (4th ed., pp. 553–575). Routledge.

Kendeou, P., Orcutt, E., Arner, T., Li, T., Balyan, R., Butterfuss, R., Watanabe, M., & McNamara, D. (2022). iSTART–Early: Interactive strategy training for early readers. In S. Crossley & E. Popescu (Eds.), *International conference on intelligent tutoring systems* (pp. 371–379). Springer International.

Kendeou, P., van den Broek, P., White, M. J., & Lynch, J. S. (2009). Predicting reading comprehension in early elementary school: The independent contributions of oral language and decoding skills. *Journal of Educational Psychology, 101*(4), 765–778.

Kintsch, W. (1988). The use of knowledge in discourse processing: A construction–integration model. *Psychological Review, 95*, 163–182.

Kintsch, W., & Van Dijk, T. A. (1978). Toward a model of text comprehension and production. *Psychological Review, 85*(5), 363–394.

Magliano, J. P., Todaro, S., Millis, K. K., Wiemer-Hastings, K., Kim, H. J., & McNamara, D. S. (2005). Changes in reading strategies as a function of reading training: A comparison of live and computerized training. *Journal of Educational Computing Research, 32*, 185–208.

McCarthy, K. S., Likens, A. D., Johnson, A. M., Guerrero, T. A., & McNamara, D. S. (2018). Metacognitive overload!: Positive and negative effects of metacognitive prompts in an intelligent tutoring system. *International Journal of Artificial Intelligence in Education, 28*, 420–438.

McCarthy, K. S., & Yan, E. F. (2024). Reading comprehension and constructive learning: Policy considerations in the age of artificial intelligence. *Policy Insights from the Behavioral and Brain Sciences, 11*(1), 19–26.

McMaster, K. L., Espin, C. A., & van den Broek, P. (2014). Making connections: Linking cognitive psychology and intervention research to improve comprehension of struggling readers. *Learning Disabilities Research and Practice, 29*(1), 17–24.

McMaster, K. L., & Kendeou, P. (2023). Refocusing reading comprehension: Aligning theory with assessment and intervention. *Learning and Individual Differences, 102*, Article 102256.

McMaster, K. L., van den Broek, P., Espin, C. A., Pinto, V., Janda, B., Lam, E., . . . van Boekel, M. (2015). Developing a reading comprehension intervention: Translating cognitive theory to educational practice. *Contemporary Educational Psychology, 40*, 28–40.

McMaster, K. L., van den Broek, P. A., Espin, C., White, M. J., Rapp, D. N., Kendeou, P., . . . Carlson, S. (2012). Making the right connections: Differential effects of reading intervention for subgroups of comprehenders. *Learning and Individual Differences, 22*(1), 100–111.

McNamara, D. S. (2004). SERT: Self-explanation reading training. *Discourse Processes, 38*, 1–30.

McNamara, D. S., Arner, T., Butterfuss, R., Fang, Y., Watanabe, M., Newton, N., . . . Roscoe, R. D. (2023). iSTART: Adaptive comprehension strategy training and stealth literacy assessment. *International Journal of Human–Computer Interaction, 39*(11), 2239–2252.

McNamara, D. S., Levinstein, I. B., & Boonthum, C. (2004). iSTART: Interactive strategy

training for active reading and thinking. *Behavior Research Methods, Instruments, and Computers, 36*(2), 222–233.

McNamara, D. S., Newton, N., Christhilf, K., McCarthy, K. S., Magliano, J. P., & Allen, L. K. (2023). Anchoring your bridge: The importance of paraphrasing to inference making in self-explanations. *Discourse Processes, 60*(4–5), 337–362.

McNamara, D. S., O'Reilly, T. P., Best, R. M., & Ozuru, Y. (2006). Improving adolescent students' reading comprehension with iSTART. *Journal of Educational Computing Research, 34*, 147–171.

McNamara, D. S., O'Reilly, T. P., Rowe, M., Boonthu, C., & Levinstein, I. B. (2007). iSTART: A web based tutor that teaches self-explanation and metacognitive reading strategies. In D. S. McNamara (Ed.), *Reading comprehension strategies: Theories, interventions, and technologies* (pp. 397–421). Psychology Press.

Nicula, B., Dascalu, M., Arner, T., Balyan, R., & McNamara, D. S. (2023). Automated assessment of comprehension strategies from self-explanations using LLMs. *Information, 14*(10), Article 567.

Numeroff, L. J. (1998). *If you give a pig a pancake*. HarperCollins.

Oakhill, J., & Cain, K. (2007). Issues of causality in children's reading comprehension. In D. S. McNamara (Ed.), *Reading comprehension strategies: Theories, interventions, and technologies* (pp. 47–71). Erlbaum.

Oakhill, J., & Cain, K. (2012). The precursors of reading ability in young readers: Evidence from a four-year longitudinal study. *Scientific Studies of Reading, 16*, 91–121.

O'Reilly, T. P., Sinclair, G. P., McNamara, D. S. (2004). iSTART: A web-based reading strategy intervention that improves students' science comprehension. In *Proceedings of the IADIS International Conference Cognition and Exploratory Learning in the Digital Age, Lisbon, Portugal* (pp. 173–180). IADIS Press.

Rapp, D., & van den Broek, P. (2005). Dynamic text comprehension: An integrative view of reading. *Current Directions in Psychological Science, 14*, 276–279.

Rapp, D. N., van den Broek, P., McMaster, K. L., Kendeou, P., & Espin, C. A. (2007). Higher-order comprehension processes in struggling readers: A perspective for research and intervention. *Scientific Studies of Reading, 11*(4), 289–312.

Rayner, K., Chace, K. H., Slattery, T. J., & Ashby, J. (2006). Eye movements as reflections of comprehension processes in reading. *Scientific Studies of Reading, 10*(3), 241–255.

Snow, C. E. (2002). *Reading for understanding: Toward an R&D program in reading comprehension*. RAND Corporation.

Terry, N. P. (2021). Delivering on the promise of the science of reading for all children. *Reading Teacher, 75*(1), 83–90.

Todaro, S., Millis, K., & Dandotkar, S. (2010). The impact of semantic and causal relatedness and reading skill on standards of coherence. *Discourse Processes, 47*, 421–446.

U.S. Department of Education. Institute of Education Sciences, National Center for Education Statistics. (2022). *National Assessment of Educational Progress 2022 Reading Assessment*. www.nationsreportcard.gov/highlights/reading/2022.

van den Broek, P., & Kendeou, P. (2022). Discourse comprehension: Inferences and mental representations. In M. Snowling, C. Hulme, & K. Nation (Eds.), *The science of reading: A handbook* (2nd ed., pp. 239–261). Wiley.

van den Broek, P., Rapp, D. N., & Kendeou, P. (2005). Integrating memory-based and constructionist processes in accounts of reading comprehension. *Discourse Processes, 39*, 299–316.

van den Broek, P., Risden, K., & Husebye-Hartman, E. (1995). The role of readers' standards of coherence in the generation of inferences during reading. In R. F. Lorch, Jr.

& E. J. O'Brien (Eds.), *Sources of coherence in text comprehension* (pp. 353–373). Erlbaum.

van den Broek, P., White, M. J., Kendeou, P., & Carlson, S. (2009). Reading between the lines: Developmental and individual differences in cognitive processes in reading comprehension. In R. K. Wagner, C. Schatschneider, & C. Phythian-Sence (Eds.), *Beyond decoding: The behavioral and biological foundations of reading comprehension*. (pp. 107–123). Guilford Press.

Watanabe, M., Arner, T., & McNamara, D. (2024). iSTART–Early and now I can read: Effective reading strategies for young readers. *Reading Teacher, 77*(4), 533–540.