Instruction

Using Explicit and Systematic Instruction to Support Working Memory

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Charlotte is a third grader at Evergreen Elementary who has working-memory difficulties that interfere with her learning beyond those challenges associated with her reading disability. These difficulties, although present every day, are almost unnoticeable as a persistent learning need that requires additional teacher support. Yet, Charlotte's difficulty processing multiple pieces of information at the same time impedes her ability to effectively engage, attend, and make important connections required for advancing her learning. Ms. Oratio, the special education teacher at Evergreen, has been noticing that Charlotte has difficulty following multistep directions, even when she appears to pay attention and understand the task. For example, by the time Charlotte gets to the second step of a mathematics word problem, she has forgotten what to do next. Although Charlotte seems to be trying her best, Ms. Oratio frequently *needs to redirect Charlotte to get "back on track" during independent seatwork because she has a tendency to be off task while others are fully engaged. Ms. Oratio has also noticed that Charlotte needs extra time and greater support than her peers to make connections with what she has previously learned; without it, important relationships among concepts don't seem to "stick" and Charlotte gets easily confused. Because Charlotte is unable to effectively self-regulate all that her brain simultaneously processes, her working-memory difficulties pose a particular threat to her academic success.*

Many teachers, like Ms. Oratio, observe students struggling in a variety of ways with a range of tasks every day in school. Although learning is considered an obvious part of schooling, the processes that enable it are covert and not accessible to teachers for observation, re-direction, or immediate correction. One important aspect of learning often taken for granted is the expectation that learners successfully engage in complex thinking about multiple pieces of information simultaneously, such as when following multistep directions, problem solving, or self-managing other implicit demands across a lesson or instructional goal (e.g., keeping track of relevant information that accumulates over extended periods of time). However, this seemingly basic ability is complicated, involving well-coordinated cognitive processing among at least three executive functions: inhibitory control, working-memory updating, and mental shifting (Miyake et al., 2000).

Working-memory capacity is typically characterized as the range of information that individuals can process at the same time to perform complex tasks (see Miyake & Shah, 1999, for an overview). The greater one's capacity, the more robustly attention can be controlled to effectively manipulate information and avoid processing interference (Engle, 2002). This mental multitasking is accomplished by concurrent processing that emerges from coordinated and timely control of one's attention to information accessed from highly activated long-term memories or temporarily maintained short-term memories (Barrouillet, Bernardin, & Camos, 2004). In this way, working memory functions like a mental "spotlight" that selectively shines on relevant information from one moment to another to actively keep relevant material in mind as needed for processing (Rohrer, Pashler, & Etchegaray, 1998). Ineffective functioning of this working-memory spotlight increases the risk that distracting information will disrupt thinking by allowing nonrelevant information to be processed, which can overload limited capacities (Engle, 2002) or obstruct efficient spotlight shifting in ways that cause forgetting (Barrouillet et al., 2004).

Students with poor working memory are less successful at completing complex tasks, exhibit greater distractibility and forgetfulness, and need teacher redirection or reteaching more often than their peers (Alloway, Gathercole, Kirkwood, & Elliott, 2009). Thus, poor working memory can contribute to learning difficulties through the burden it places by surreptitiously fragmenting task engagement. Students who forget what they are doing or become easily distracted when performing complex tasks are likely to experience undetected but repeated disruptions that result in disjointed learning and confusion. Classroom observations of children with poor working memory have revealed clear difficulties in keeping up and effectively using what they know during lessons (Gathercole, Lamont, & Alloway, 2006).

Students with learning disabilities may particularly struggle with classroom activities that require mental construction and integration of, or modifications to, information in real time because the challenges associated with the disability can place additional constraints on their working memory capacity, making them more vulnerable to mental overload or forgetting. Decades of research have shown that children with various learning disabilities experience working-memory difficulties (deJong, 1998; Siegel & Ryan, 1989; Swanson & Jerman, 2006), and recent findings indicate that successful intervention outcomes may partially depend on working-memory capacity (Swanson, Lussier, & Orosco, 2015). For example, Swanson et al. (2015) found an effect of working-memory capacity among children with math difficulties, in that greater growth in postintervention problem-solving accuracy was associated with higher capacity. Moreover, the researchers also reported differential intervention strategy effectiveness that was associated with working-memory capacity. It is important to note that the intervention approach used by Swanson and colleagues employed elements of explicit and systematic instructional design, which we address in our recommendations.

Because concurrent processing facilitates the self-management of information flow, working memory functions best when the design and delivery of academic information effectively controls students' attention to prevent mental overload and promote efficient remembering (Artino, 2008). Because the self-regulation of thinking and doing is not visible, methods that help to make the learning process more observable may be particularly beneficial for optimizing working-memory functioning.

Explicit and systematic instruction is an evidence-based practice for increasing students' reading and math acquisition through unambiguous and careful sequencing of skill-building activities (Gersten et al., 2008, 2009). Studies on explicit and systematic instruction have reported strong effects on student outcomes. In reading, for example, past and recent research has shown that students with reading difficulties draw significant benefits from instruction that is systematically designed and explicitly delivered (Gersten et al., 2008). Mathematics intervention studies echo this beneficial effect. For example, Gersten et al. (2009) synthesized 41 mathematics intervention studies and reported a large effect for interventions that employed a systematic and explicit instructional approach on the outcomes of students who face difficulties in mathematics.

Although research has yet to pinpoint the specific mechanisms of explicit and systematic interventions that improve student achievement (e.g., Doabler et al., 2015), it is reasonable to assume that the effectiveness of such interventions is due at least in part to the indirect enhancement of working memory. Explicit and systematic instruction is a plain and orderly instructional approach that makes learning more accessible at crucial junctures *during* classroom activities rather than *after* lessons are complete. Consequently, the strategies of explicit and systematic instruction are highly relevant for improving students' working memory. Explicit and systematic instruction

- uses simple, brief, and concise language to reduce language demands;
- activates prior knowledge to enhance long-term memory accessibility;
- scaffolds instructional support to facilitate associations that students may miss when processing is overloaded;
- provides frequent review and practice to solidify effortless long-term memory accessibility;
- allows sufficient time to rehearse and process new information to minimize processing efficiency demands;
- includes visual aids to reduce verbal processing demands and make concepts more plain; and
- provides specific feedback to catch misconceptions that may later intrude on processing (Dehn, 2008).

We believe that when such strategies are well integrated, they are ideal for facilitating working memory.

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Facilitating Working Memory

Initial learning across different academic areas is effortful and attention demanding for all learners (Ackerman, 2005). As skills become more deliberately practiced, learners come to rely more on direct retrieval of integrated long-term memorized procedures and less on attention-demanding working-memory processing. Therefore, the management of working-memory load is essential to supporting active processing during the initial stages of skill building, when the material is novel and lacks previously established long-term procedural memories. Working-memory support remains important during the intermediate stage of learning when the task is sufficiently complex and inherently requires concurrent processing for task performance (e.g., during reading comprehension, writing, or complex mathematics). A student's level of skill development and criterion level of performance—not the amount of time spent receiving instruction—determine the learning stage and needs for working-memory support. Struggling learners may require greater and longer working-memory support than either students with stronger initial skill levels or those with stronger working-memory capacity for self-managing their learning. With greater initial support, greater efficiency with learning is to be expected.

Supporting Working Memory During Instruction

Although there are many definitions of explicit and systematic instruction, there are four defining features that teachers can implement to optimize working-memory support during reading and math instruction. Each feature aligns with recommendations for managing working-memory load during instruction and has benefits for optimizing working memory.

One feature is to **strategically select and sequence examples of new skills**. Instructional sequences build skills gradually by introducing skills first in isolation and then integrating them with other skills to enable students to practice and to build generalization. Ensuring that students have the necessary prerequisite skills will allow students to focus attention on the essential objective of the lesson. When too much information is presented at once, or when processing demands are too great (e.g., similar skills are taught together), working-memory functioning can become overwhelmed. The result of this cognitive overload is student confusion or forgetting. Therefore, to implement this instructional strategy, present information in a logical sequence in which less difficult skills are introduced and taught before more difficult and complex skills. Small amounts of information should be presented with adequate practice opportunities to ensure retention. For example, when identifying the sequence of teaching new skills and strategies, consider (a) teaching easier skills before harder skills, (b) teaching high-frequency skills before skills that are less frequently used, and (c) separating skills or content that are similar during initial instruction of a new skill (e.g., separating the letters *b, d, p*, and *q* in a letter naming task; Archer & Hughes, 2011; Carnine, Silbert, Kame'enui, Tarver, & Jungjohann, 2006; Doabler & Fien, 2013).

A second feature is to **provide clear explanations and models**. Teacher explanations are used to introduce, demonstrate, and describe a task or activity using clear and consistent language. This allows students to see and hear the steps that are involved with a task, which sometimes can seem unclear to them. Unclear language can distract and overwhelm students' thinking by creating confusions that intrude on working-memory processing. Therefore, to implement this feature, use clear and unambiguous language to explain what students will do and model an example of how to complete the task. Whenever possible, "think aloud" to show students the steps that you are taking to complete the task, and demonstrate all the steps that you expect students to complete. This helps to make plain the mental steps needed for engagement, which alleviates the need for students to figure it out on their own (thereby creating additional working-memory demands). Use familiar vocabulary and simple sentences that omit unnecessary information. When introducing new strategies, skills, and content, activate prior knowledge by connecting to past ideas and content and identifying connections to students' lives.

A third feature is to **carefully guide practice opportunities**. *Guided practice* refers to providing scaffolded support as students practice a new skill, and systematically withdrawing that support as students become more proficient. Supporting students during initial stages of learning a new skill gives them opportunities to be successful and confident in using the skill (Archer & Hughes, 2011; Carnine et al., 2006; Doabler & Fien, 2013). During guided practice, use the same wording as used in the explanation and modeling of the task to provide consistency. This allows students to focus attention on the new skill instead of figuring out the prompt. The use of visual memory aids— such as number lines, cubes, lists of steps, graphic organizers, and sentence starters—reduces working-memory processing demands because the information that must be worked with is tangible and not required to be kept in mind. As students demonstrate success, gradually increase task difficulty as you decrease the level of guidance (Archer & Hughes, 2011; Carnine et al., 2006; Doabler & Fien, 2013). Plan for frequent repetition and distributed practice of skills over days and weeks to allow for sufficient practice and rehearsal of information. As students are successful with the initial instruction, encourage active application and advanced manipulation of content.

A fourth feature is to **monitor student responses and provide immediate feedback**. Monitoring responses includes checking for engagement and accuracy throughout an activity to let students know whether their responses are accurate or not. Monitoring student responses closely and providing timely feedback immediately after a mistake allows teachers to catch early confusion and misconceptions. Providing timely feedback helps students deliberately encode only relevant and accurate information as long-term memories for later use. To implement this feature, carefully watch and listen to students' responses, focus on the target skill, and include modeling of the target skill or concept using clear and consistent language. Whenever possible, reinforce success by pointing out correct responses.

Although each of these identified features of explicit and systematic instruction may benefit working memory (see Figure 1), they are most beneficial when implemented together. For some content, each of these features may occur in one lesson (e.g., carefully sequencing content, explaining a task and modeling a skill, and providing guided practice with corrective feedback), but they also may be implemented across days for more complex content (e.g., summarizing information text might require multiple days of teacher models before students are ready for guided practice; Archer & Hughes, 2011).

> When too much information is presented at once, or when processing demands are too great, working-memory functioning can become overwhelmed.

Examples of Explicit and Systematic Instruction

Consider an example in which Ms. Oratio is teaching her group to identify the main idea of an expository text from supporting details. Identifying the main idea in one sentence can be challenging for many students. The aforementioned features of explicit and systematic instruction can be applied to more readily teach students to identify the main idea using details from text (see Dissen et al., 2013, for a comprehensive description of teaching steps for identifying the main idea of information text). To strategically select and sequence examples, Ms. Oratio considers that in previous lessons, she modeled finding details for her students. She thinks that her students are ready to find the details with her guided support but that they still will need modeling of how to find the main idea. She also carefully chooses the text to use to avoid overwhelming students' focus on the instructional target. Because her students are in the initial stages of learning the strategy,

Figure 1. Features of Explicit and Systematic Instruction

she chooses text with clear supporting details without distracting information.

Ms. Oratio starts the activity by explaining and modeling the task, telling the group, "Now we will find the details and figure out the main idea of text. Remember, the details are the important parts of information. The main idea tells all of the details in just a few words. I will read to you this time. Follow along with your finger." Ms. Oratio reads the text aloud (see Figure 2) and the students follow along, using their fingers to track. Next, Ms. Oratio tells the students, "What is one detail that you learned? Turn to your partner and tell one detail that you learned. Start with, 'One detail I learned is....'" Ms. Oratio leans in to listen to the partner responses and writes accurate details on the whole-group organizer (see Figure 3) that she has displayed on a clipboard in front of the group. Ms. Oratio monitors closely and provides corrective feedback if students provide inaccurate details. When Charlotte is not able to identify a detail, Ms. Oratio says, "Let's look back at the text. Put your finger on one detail. Yes, that's a detail. Now say it in a sentence." Later, Ms. Oratio hears Charlotte correctly identify a new detail and says, "Yes, Charlotte, one detail is that some animals can get trapped." Ms. Oratio writes Charlotte's correct detail on the graphic organizer. Ms. Oratio then says, "We found the details. Let's review what we found." She then shows students the graphic organizer and reads the details aloud. Then she says, "Remember the main idea tells about all the details in just a few words. All of these details tell us why a tide pool can be a dangerous place for sea animals. So, I can say that the main idea is, 'A tide pool can be a dangerous place for sea animals.'" Ms. Oratio then writes the main idea on the graphic organizer for students to see. As Ms. Oratio plans future activities for teaching the main idea, and as students become more independent, she will reduce her support by having the students independently identify the main idea. The focus of this activity is on identifying the main idea, but when the focus is on reading accuracy and writing, Ms. Oratio may have the students read the text or write the details on their own. Over time, Ms. Oratio will also choose more challenging text that includes a greater variation of details, including some details that are not clearly related to the main idea, based on her students' readiness to handle greater complexity.

Ms. Oratio also can apply the explicit and systematic instruction features during her third-grade math instruction. For example, she can use

Figure 2. Example Read-Aloud Text

Let's take a close look at what can happen in a tide pool. Waves crash into the shore when the tide is high and can damage organisms. Most of the water goes back out at low tide and some animals can get trapped. The sun shines down on the tide pool and can make the water too warm for some animals. Seagulls, and other shore birds, eat many of the animals that live in tide pools.

the features to teach her group how to represent categorical data on a scaled picture graph. Given that Ms. Oratio has modeled and explained how to design the picture graphs, during the third lesson she can directly show her students how to use the graphed data to solve "compare" word problems with the difference unknown. On future days (Lessons 4 and beyond), she can provide more guided practice with immediate feedback and less explanation as she reduces her support.

Ms. Oratio begins the third lesson by reminding students about the structural features of comparing word problems (i.e., a comparison between two things using a common unit). This reminder helps prompt her students to retrieve known information about these problem types. Next, using data from Figure 4, Ms. Oratio poses the following: "I want to find out how many more cows live on the Garcia ranch than on the Lewis ranch." She explains that this is a "how-many-more" word problem and that she will need to subtract to find the missing difference.

To help her students work with how-many-more problems, Ms. Oratio verbalizes aloud how to solve the targeted problem, explaining that she plans to break the problem down into more manageable parts. Her reason for doing this is twofold. First, she wants to avoid overloading students' working-memory capacities. Second, she wants to promote students' early success with accurately recognizing and effectively implementing the mathematical structures of comparing word problem types that ask how-many-more questions (Gersten et al., 2009).

She tells the class, "This graph indicates that each picture represents 100 cows. Count with me by multiples of 100 to find out how many cows live on the Garcia ranch. 100, 200, 300 … 900. Nine hundred cows live on the Garcia ranch. So I will write 900 on the

Figure 3. Graphic Organizer for Teaching the Main Idea

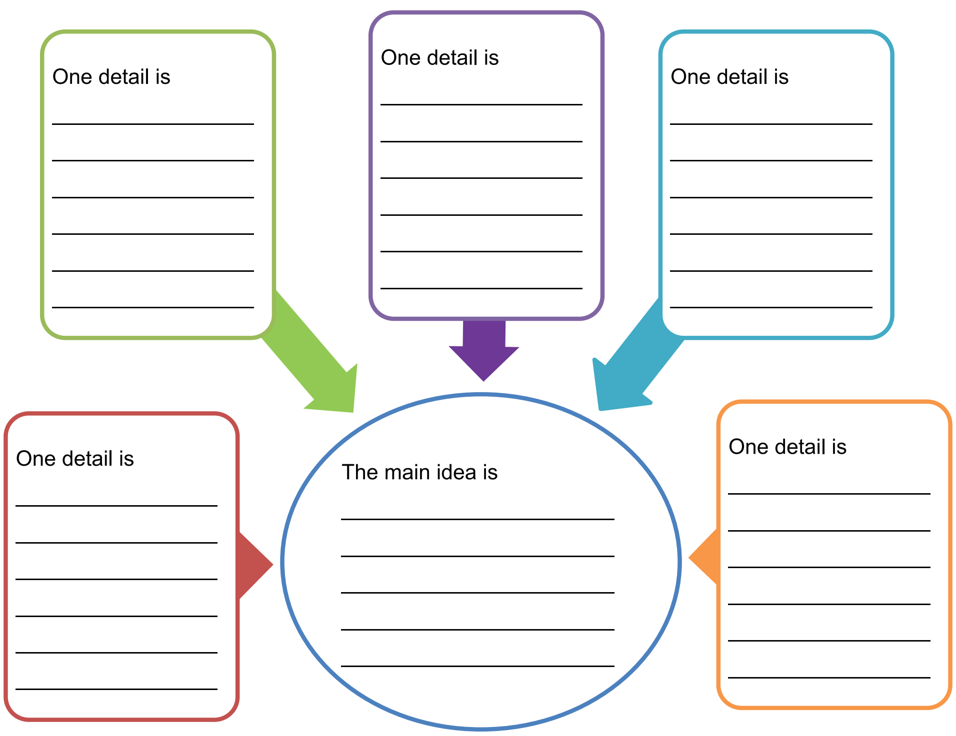
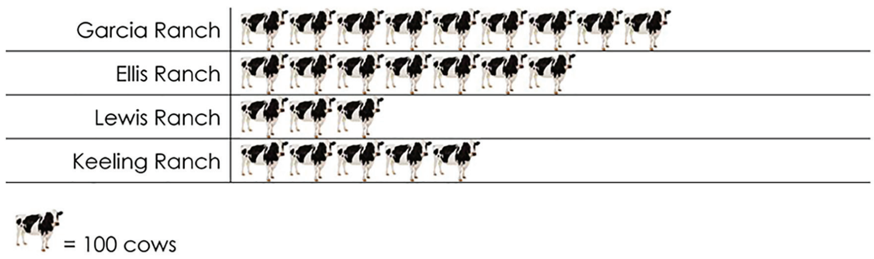


Figure 4. Visual Representation of the Word Problem



board." Next, she asks Charlotte to count how many cows live on the Lewis ranch. Charlotte counts 300 cows and then Ms. Oratio writes 300 below 900 on the board. She then states, "Because I want to find how many more cows live on the Garcia ranch compared to the Lewis ranch, I will need to subtract 300 from 900." Ms. Oratio completes the subtraction problem and then states, "Nine hundred minus 300 equals 600. Six hundred more cows live on the Garcia ranch than the Lewis ranch."

Both of these examples demonstrate how the features of explicit and systematic instruction can be applied to instruction to help students manage implicit working-memory demands. In addition to the four features just described, recommendations for organizing a classroom environment to support optimal working memory include:

- eliminating background noise (specifically speech and talking) that can interfere with working-memory processing,
- displaying materials to reduce what must be remembered (e.g., steps in routines, the classroom schedule, classroom rules and expectations),
- arranging space so that the teacher can move easily around the room for monitoring student work and providing quick feedback during practice,
- having extra instructional materials on hand (e.g., sharpened pencils) to keep students' attention to the task and not to items that may be forgotten or broken, and
- teaching routines and expectations (e.g., what to do when arriving to the group) to minimize distracting behaviors that may undermine task engagement and make unnecessary processing demands.

By managing working-memory load during instruction, teachers like Ms. Oratio can support students in focusing on the objective of the lesson, engaging fully in the activity, learning from their mistakes, and feeling confident in the learning process.

Conclusion

Students are frequently expected to complete multistep tasks within a range of academic or classroom routines and to do so independently. Students' ability to complete these tasks successfully may vary as a consequence of both their working-memory capacity and the conditions under which they are expected to learn. Crucial features in the design or "architecture" of tasks, coupled with how tasks are staged and delivered, can influence a learner's working-memory ability to perform the initial tasks. Although students with learning disabilities are particularly vulnerable to mental overload during learning, all students can benefit from intervention approaches that strategically manage their processing efforts during instructional activities. Explicit and systematic teaching is an evidence-based practice that contains elements particularly well suited for supporting crucial working-memory processing needed for learning.

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