Making Models of Working Memory
A Teaching and Assessment Tool

Casey Hord & Benjamin Wiles

Abstract

This study is a qualitative analysis of the work of preservice special education teachers on an activity during which they had to design a game that represented the concept of working memory. The study draws from the framework of model-eliciting activities that require students to develop structural representations of concepts that can be used to demonstrate their understanding of a topic. In this study, the students' models were useful tools for discussing and demonstrating the concept of working memory, which provided the instructor with valuable opportunities for formative and summative assessment. The researchers discuss the connection between the data in this study and the work on model-eliciting activities in other fields and how this research can inform the teaching of preservice special education teachers.

Introduction

Students with learning disabilities (LD) often struggle in school in a variety of subjects (e.g., Andersson, 2008; Graham et al., 2017). Special education teach-

Casey Hord is an associate professor in the Department of Special Education in the School of Education at the University of Cincinnati, Cincinnati, Ohio. Benjamin Wiles is chief data officer with an affiliate faculty appointment in the Department of Engineering & Science Education in the College of Engineering, Computing, and Applied Sciences at Clemson University, Clemson, South Carolina. Email addresses: casey.hord@uc.edu & bwiles@clemson.edu

ers face the responsibility of teaching students with LD the concepts and skills they will need to perform at levels comparable to students without disabilities on high-stakes, standardized tests, as mandated by the Individuals With Disabilities Education Improvement Act of 2004 and the Every Student Succeeds Act of 2015. If students with LD do not advance through high school courses and succeed with end-of-course exams, they may be unable to access some educational and occupational opportunities (Achieve, 2015; Ysseldyke et al., 2004). Teachers also face consequences if their students do not score as proficient or higher on high-stakes exams (Croft et al., 2016). Therefore special education researchers need to search for ways to prepare teachers for this high-pressure environment in which they (and their students) will face consequences if the students do not pass standardized tests and advance through gatekeeper courses (Croft et al., 2016; Ysseldyke et al., 2004).

Approaches for Meeting the Needs of Students With LD

Students with LD often face anxiety and difficulties with working memory, which is the processing, storing, and integration of information (Baddeley, 2003; Nelson & Harwood, 2011; Swanson & Siegel, 2001). For example, working memory can be overloaded when students struggle with remembering information in short-term memory as they focus on processing new information and connecting it to information they have already processed and are trying to retain in short-term memory (Baddeley, 2003). Anxiety can exacerbate difficulties with working memory (Ashcraft & Krause, 2007). Students with LD may have difficulty focusing their attention on processing, storing, and integrating information in a problem if they are distracted by worries of failure and consequences of failure on that task (Eysenck et al., 2007; Nelson & Harwood, 2011).

Students with LD tend to struggle with multistep tasks either due to a predisposition to struggle with working memory or due to working memory–related struggles related to task difficulty (Swanson & Beebe-Frankenberger, 2004). When a task has multiple steps, students with LD may have more trouble with keeping track of information in short-term memory as they process multiple pieces of information and, eventually, try to combine all of the information to form a solution (Swanson & Beebe-Frankenberger, 2004). Students with LD tend to have more difficulties with working memory in situations when a topic is new or difficult for them (Hord et al., 2016). More challenging or unfamiliar topics tend to overload working memory more so than simpler, familiar tasks (Barrouillet et al., 2007). If any of the pieces of information are particularly perplexing, students may have to devote a disproportionate amount of attention to that particular piece of information, possibly leading to them forgetting what they are attempting to store in short-term memory (Barrouillet et al., 2007).

When special education researchers have addressed this situation, using tables and diagrams as tools for storing and organizing information on paper (e.g., van

Garderen, 2007; Xin et al., 2005), students with LD have succeeded in multistep situations. In these studies, students were able to offload information (i.e., temporarily store information on paper rather than in short-term memory; Risko & Dunn, 2015), refocus on processing what is next in the problem, store the next step on paper, and eventually combine information to solve the problem. This technique allows students to devote more attention to thinking critically about the problem rather than having to divide their attention between remembering information in short-term memory and thinking critically about the rest of the information in the problem they need to process, store, and integrate.

Special education teachers would presumably benefit from understanding this process. In some cases, students need to offload information, which can make challenging tasks more accessible for them (van Garderen, 2007; Xin et al., 2005). In other cases, teachers may need to realize that certain parts of problems are a little too difficult for students based on their current level of understanding of the topic and make strategic modifications to parts of the task or provide extra prompts to keep students moving forward (Hord et al., 2016). Sometimes teachers may need to realize that anxiety is making it difficult for students to think clearly and must adjust prompting or task difficulty accordingly (Hord et al., 2018). Special education teachers are likely to be more successful if they can be sensitive to and aware of these possible challenges and potential solutions.

Possible Solutions for Teacher Preparation

Strategies for improving teacher knowledge of working memory and its application to instructional practice are embedded within existing literature. Relevant work includes perspectives on both the knowledge teachers need and on instructional strategies for building knowledge of abstract concepts for use in practical applications in general. Regarding what teachers need to know, Shulman (1986) emphasized the need for teachers not only to understand content and pedagogy but also to conceptualize individualized models of students' knowledge and learning processes as part of the framework for pedagogical content knowledge. Cohen et al. (2003) extended this notion further to the teachers' ability to understand and attend to complex instructional dynamics involving the triadic, reciprocal relationships between teacher, student(s), and content as well as the environment in which these interactions take place. Specific to the present study, an understanding of working memory contributes to teachers' ability to model students' interactions both with content and with the teacher within an educational environment. These models created individualized frameworks for promoting student learning through instruction.

Regarding how to build teachers' knowledge, instructional strategies for developing models of abstract concepts and how they manifest in practical activities have been investigated within domains like mathematics, science, and engineering. These instructional strategies could provide a template for ways to develop preservice teachers' understanding of abstract concepts like working memory, motivation, cognition, or emotion. Specifically, model-eliciting activities (MEAs; see Lesh & Doerr, 2003) are a well-established instructional tool for facilitating the development of structural representations of abstract mathematical concepts in elementary and secondary-level students for the purpose of application of those models in practice and to eventually formally operationalize and further develop those representations (Lesh & Caylor, 2007). During these activities, students are immersed in situations that are strategically designed to provide opportunities to represent meaningful problems; self-evaluate; and improve the nature, complexity, and accuracy of their representations. Students iterate upon and document drafts of models toward a generalizable simplest solution (Lesh et al., 2013). A simplistic MEA might involve giving students a fixed amount of money and having them perform scaffolded experiments involving the different meals they could buy at a restaurant. The purpose of this MEA would be to work toward more complex models about how money, budgets, expenses, and income are related and how they can be applied to situations more broadly. Well-documented examples of how MEAs are implemented in the K–12 classroom are available within the practitioners' literature (see Bostic, 2013; Magiera, 2013).

It is worth noting some parallels between undergraduate programs for teacher education and those for other professional disciplines, such as engineering. For instance, in the mid-1980s university physicists came to acknowledge that, after a semester of introductory physics, top-performing engineering undergraduates could achieve proficiency at recall of information related to concepts like force, momentum, and velocity but could not apply those concepts in novel situations or discuss how they are related (Hestenes et al., 1992). This led to the development of teaching activities and assessments, similar to MEAs, that led to students needing to create a product that could be assessed to determine deeper levels of understanding of the topic as well as a basis for quality discussions on those topics (Hestenes et al., 1992; Saul et al., 2000). Similar approaches have been developed for undergraduate calculus since the mid-1980s, when mathematics professors were struggling with developing necessary levels of understanding of mathematics among future engineers (Bressoud & Zorn, 2018; Epstein, 2013; Steen, 1988). MEAs have also been applied in undergraduate engineering methods courses for the purpose of applying science and mathematics to authentic engineering problems to teach undergraduates how to "do" engineering (for an early example, see Moore & Diefes-Dux, 2004). Furthermore, the specific use of MEAs in engineering methods courses has been established as a way of connecting and improving research on the learning of mathematics and of engineering methods (Hamilton et al., 2008). In the present study, we examine MEAs as an instructional tool for undergraduates in teacher education programs, not for the teaching of mathematics or science, but for teaching about working memory. The use of MEAs with adults has a great deal of support and may be able to be translated (along with its tenets) to foster the understanding of working memory and how it functions within instructional settings for students with disabilities. Teachers may apply this knowledge in the classroom and further refine their understanding of memory and processing (Murataa & Kattubadi, 2012; Sevinc & Lesh, 2018). Additionally, use of MEAs in the preservice teacher education classroom allows future special educators to consider applying MEAs in their own classrooms and has been successfully used in preparing elementary school teachers in the context of mathematics (Stohlmann, 2013). MEAs serve as a vehicle through which teachers can closely monitor students' progress and help students with LD develop reasoning and representational skills (Lesh et al., 2013). When teachers facilitate students' creation of their own representations, teachers are likely to become more informed of students' individualized needs as they create those representations (Flevares, 2010). In short, MEAs may be a valuable addition to the portfolio of instructional practices related to preservice teacher training.

Purpose of the Study and Research Questions

The stakes are high for both special education teachers and their students in the current educational environment due to standardized testing and end-of-course exams students must pass to advance through gatekeeper courses (Croft et al., 2016; Ysseldyke et al., 2004). Special education teacher educators are responsible for preparing special education preservice teachers to succeed in this environment. A potentially useful tool is MEAs as a teaching method to assess students' understanding of the concept of working memory and how this relates to teaching students with LD. The research question of this study is as follows: How can a model-eliciting activity be used to teach and assess understanding of working memory?

Method

We conducted a qualitative analysis of preservice teachers' work on a model-eliciting activity designed to develop and assess their understanding of working memory. This project was designed to provide insight into how preservice teachers can develop and demonstrate their understanding of working memory and how teacher educators can use MEAs to teach and test the understanding of the concept of working memory. We obtained permission to conduct this research from the institutional review board of the first author's university, and we followed the approved protocol.

Participants, Setting, and Procedure

The learning and assessment activity (i.e., the working memory game MEA) took place on the last day of a teacher preparation course for special education preservice teachers in their junior year of college. The course was designed to cover the assessment and teaching of students with mild to moderate disabilities. Owing to the tendency of many students with mild disabilities to struggle with working memory, such as students with LD and students with mild intellectual disability (Schuchardt et al., 2010; Swanson & Siegel, 2001), a significant portion of this course was devoted to teaching preservice teachers how to informally assess when and how their students may be struggling with working memory and how to alleviate these difficulties.

The participants were all in their junior year of college in a special education preservice teacher preparation program. In this class, there were 24 White females and six White males. The students worked in small groups to design a working memory game (see Figure 1 for game directions) that would overload the game player's working memory by presenting information in a way that was difficult to process, store, and integrate. After the game player struggled to complete the game, the participants were charged with the task of making a modification to the game to make it easier by providing a way for the game player to offload information or by making pieces of the task easier to process and manage (e.g., changing one of the steps in a way that it taxed working memory less). During and after the process of demonstrating the game, the instructor and the students discussed the concepts represented by the game. After demonstrating their game, students were directed to write and/or draw a representation of their game that would be understandable to someone who was not present during their verbal explanation of the game and who had not had an opportunity to play the game with the students. During all game demonstrations, the game player was the course instructor.

The instructor and the class worked together to bring possible materials to the class that could be used to make the working memory games. Groups used

Figure 1
Game Directions

Working Memory: Model-Eliciting Activity

- Create a "model" of working memory in the form of a game that you can manipulate to overload the working memory of a participant and then modify to not overload working memory.

- It may help you to think of students you've seen struggling with school work. For example, many times at local schools, I've seen a situation like this: A student with LD was having trouble with his algebra homework because of having trouble subtracting. I'm serious about this. He understood the algebra (or at least was on his way to understanding it), but subtracting integers was causing his working memory to get overloaded. A tutor gave him a number line to use to help him with subtraction, and he started excelling with the algebra problems.

- Your assignment is to create a game using the available materials to simulate a situation like this. Please summarize your game below (bullet points are fine) and demonstrate your game to me.

materials like playing cards, math facts flashcards, balls, balloons, construction paper, computer paper, markers, crayons, and colored pencils. Students watched an example of a working memory game called Space Mines Patrol (Cogmed, 2019) to show them how a game can be designed to vary in difficulty by changing the amount of information students need to process, store, and integrate and in some cases change the difficulty of some of the pieces of information that needed to be managed. We discussed how others in the room could help the game player offload information by keeping track of information for the student who was playing the game and reminding them of things when they needed to connect this information to new information as it was presented during the game.

Data Collection and Analysis

We video-recorded the demonstrations and discussions of each of the 10 groups in the class and collected the written explanations of the games from each group. We searched through the written representations of games from all of the 10 groups in the class to identify well-crafted and easy-to-understand games that represented working memory successfully. Some of the games were well crafted but quite complex and potentially difficult to describe in a journal article without a game player having an opportunity to learn the game by playing it. On the basis of these considerations, we purposefully sampled four videos. All 10 of the examples of student work were similar in structure. The excluded examples were useful for teaching and assessment, yet these examples were not conducive to being explained in words in a journal article with a necessary and mandatory page limit.

During data analysis, we watched and transcribed these four sessions, coded the data, and searched for emerging themes. First, we transcribed the data and created data tables with columns for time of session, transcript, subjective comments, and codes. Then, we searched through the transcripts for trends to create a list of open codes to document our initial interpretation of the data set and establish a priori codes for the next round of data analysis (Strauss & Corbin, 1998). We used a priori codes, such as demonstrations of working memory in general, offloading, anxiety-related factors, quality discussions, and quality assessment (Stake, 2010). Then, in a separate document, we put the coded data into "patches" to search for emerging themes that we eventually agreed upon during meetings (during which we worked toward consensus) about trends in the data (Brantlinger et al., 2005). We then communicated with an external auditor (another researcher not involved in this study) about our interpretation of our findings (seeking consensus) to monitor interpretive validity (Maxwell, 1992). The first author and the external author corresponded through email about their interpretations of the findings. The findings that we and the external auditor agreed upon are presented in the next section using sequences of dialogue to provide a detailed description of the demonstrations and discussions that took place to provide a basis for our inferences and conclusions (Brantlinger et al., 2005).

Results

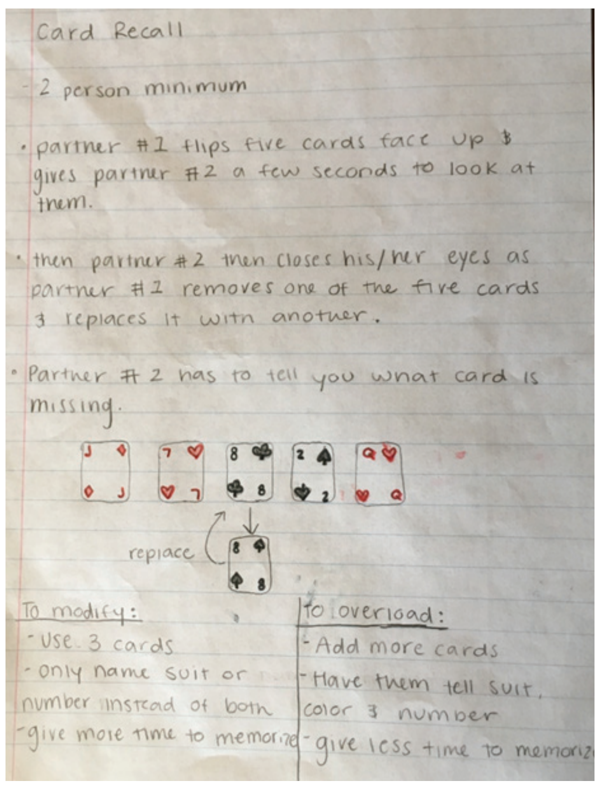
During data analysis, two major themes emerged. The working memory game was a valuable tool for assessing student knowledge of working memory. Also, the game served as a useful tool for stimulating discussions about working memory, which provided learning opportunities for the students. In the following section, we describe how the students were able to demonstrate and discuss the concept of working memory as well as how they could manipulate the load on working memory the game player experienced by changing the demands of the tasks in the game or providing extra support for the game player.

Card Recall Game

A group of students demonstrated their understanding of working memory successfully by designing and demonstrating a game they called the Card Recall Game (see Figure 2). In the first step of the game, the game player was presented

Figure 2

Card Recall Game



five playing cards for a few seconds. The player had to memorize the cards and then close his eyes. The students then replaced one of the cards, and the player had to then recognize which card had been replaced. This game represented the storing of information when the player had to store which cards were presented in short-term memory. It represented the combining of information when the player had to connect what he had in short-term memory from the first set of cards to what he saw in the second set of cards. To succeed with this task, the game player had to store a first set of information in short-term memory, process a second set of information, and connect (by comparing) those two sets of information to determine which card had been changed. These students also demonstrated their knowledge of working memory, regarding how they could avoid overloading working memory, by making the task easier by decreasing the amount of information the player would need to process, store, and integrate (e.g., lowering the number of cards; see Figure 2).

In addition to providing information for assessment, the Card Recall Game provided the instructor with opportunities to expand upon how the game demonstrated the concept of working memory. For example, after the students explained the game, they laid these cards on the table: nine of hearts, nine of spades, 10 of spades, six of hearts, and eight of spades. Then, the player covered his eyes, and the students replaced the nine of hearts with a three of diamonds and scrambled the order of the cards. The game player, who by his own account tends to struggle considerably sometimes with remembering things, was able to name the new card correctly. Explaining how he succeeded by chunking information (e.g., grouping the cards into easy-to-remember groups), the instructor said, "There were two faces and one was in sequence. That gave me a chance. I was able to make five into two groups or I wouldn't have had a chance." Rather than five pieces of information, the game player had to remember only two pieces of information: a sequence of spades (eight, nine, 10) and 96 hearts (for a nine and six of hearts). This provided a foundation for a discussion we had about how, if there are fewer pieces of information, the demand on working memory is decreased (Barrouillet et al., 2007).

When they were prompted to show how they could make the game less taxing on working memory, the students then laid down three cards: a three of spades, a seven of spades, and a six of diamonds. The instructor said, "If I have three cards, all I have to remember is spades and diamonds and a three, seven, and six, there is less I have to remember. There is less I have to hold in short-term memory while I'm connecting things." In this situation, the instructor was able to discuss working memory with the students referencing a game they had just created and played with their instructor. In the context of the students demonstrating and discussing their game, the instructor had the opportunity to make the concept of working memory more accessible and to deepen their understanding of working memory.

Combining Mathematics and Catching a Ball

Another group demonstrated and discussed the concept of working memory with a game that involved mathematics and catching a ball. The game involved three tasks: solving an addition problem using two playing cards, matching up that sum with the sum of one of five addition flashcards, and then immediately catching a ball from the right or left depending on whether the sum was odd or even. For example, a game player could face a scenario in which she had to match sums, such as the two of diamonds and four of hearts equals six with a flashcard that said three plus three, and then immediately catch a ball coming from her right because the sum was even. When doing the addition and matching the cards, the player would need to keep refreshing left–odd, right–even in her mind. The player had to hold where the ball will come from in her short-term memory while processing and integrating information about the sums of the cards and then combining information about the sum (odd or even) with left or right to face the right direction to catch the ball. In short, information is being stored for later and then combined to succeed with the task. After the instructor completed the game, he asked the group members to explain how this game made things difficult with regard to working memory.

> STAN: It was hard because you were doing one math problem based on the two-card combination. You are already doing one math problem. After you did that math problem, all the while looming above you, you had to worry about the ball coming at you. You had that looming above you I assume. The two-card combination here is one math problem. You had to do that problem. Do this [*pointing to the flashcards*] problem. Match them up. Catch a ball. Basically, we tried to get so much stimulation that it acted as an overload.

> JACK: You had the third aspect of working memory remembering if it is even or odd to know what side.

> STAN: Yes. Good point.

> AUSTIN: Exactly.

> INSTRUCTOR: OK. What was I having to hold in short-term memory while I was combining things?

> JACK: The math problem [*pointing to the flashcards*] and the math problem [*pointing to the playing cards*].

> STAN: This one [*pointing to the playing cards*]. Would this one be short-term memory? The two-card combo before he matched it.

> JACK: Yeah.

> AUSTIN: All of them would be.

> BRENT: That would also be [*pointing to the flashcards*] because you can see that before he lays them [the playing cards] down. You already know what these are

before [*pointing to the flashcards and listing of the sums*] four, six, three, seven, and 10. So, you already know that. That's short-term [memory]. Then, you have to match this [*pointing to the playing cards*] with the other.

STAN: That's right. Because you probably looked at these [*pointing to the flashcards*] before we even started and did the math problems.

INSTRUCTOR: No, I didn't. I probably should have. [*laughs*]

STAN: But, if you had, that would be short-term memory, right? If the student looked at these five cards [*pointing to the flashcards*] before we even started and he did the math problems in his head, he would access those as short-term memory while he was matching them.

INSTRUCTOR: Yeah. I'm holding it in storage in my short-term memory. Other stuff is coming in. The ball, literally. . . . As other information is coming in and I'm connecting it, what kind of memory is that?

AUSTIN, BRENT, and STAN: Working . . .

INSTRUCTOR: Yeah. Processing, storing, and integrating. . . . I have to process what is happening and store it in short-term memory. And, to succeed, I have to integrate all of that information. It's all of that at once. Processing, storing, and integrating is working memory.

This discussion provided the instructor with a chance to teach content and to see how the students were differentiating between a sequence of tasks that involves only short-term memory (which can be difficult but is not a representation of working memory) and a sequence of tasks that represents working memory, which requires the game player to combine information in short-term memory with new information that needs to be processed and combined with older information to succeed in the game.

Kinesthetic Math Game

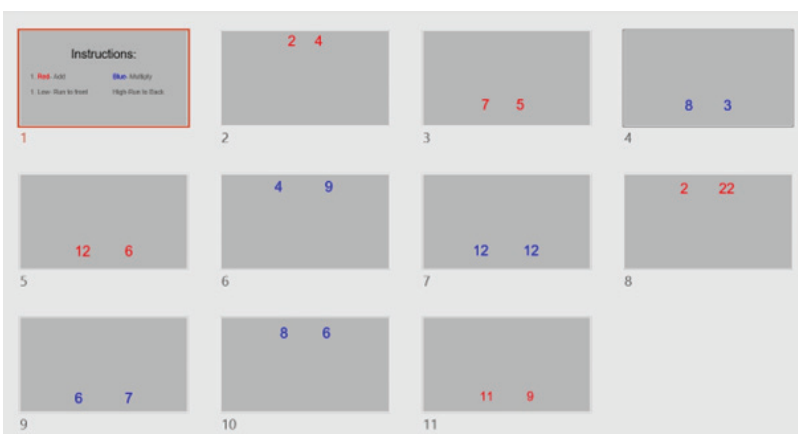
In another scenario, a pair of students successfully demonstrated working memory and how cognitive load could be overwhelming and also addressed how anxiety could be a factor in students' chances of successfully processing, storing, and integrating information (see Figure 3 for the PowerPoint slides they developed for the game). The students designed a game in which the players had to remember that red print meant they needed to use addition and blue print meant they needed to use multiplication. All the while, the game player needed to keep in mind that a problem presented at the top of the slide meant that the player needed to get to the back of the room and touch the wall before answering, with the goal of doing this before his competitor. Problems at the bottom of the slide meant that students needed to go to the front of the room and touch the wall before answering. Interestingly, one of the students purposefully chose to make the location of the problem and its corresponding direction less intuitive (top-to-back rather than top-to-front) to make it more cognitively demanding for the game player. Her partner said to the instructor, after describing how the student's partner wanted to set up the game this way, that she told her partner, "I don't think we'll even be able to play our own game," which demonstrated some of her understanding of cognitive load.

As the students explained the rules, the instructor said, "I have to keep all of that in my mind while thinking about something else." One of the students said, "You got that?" and the instructor replied, "Probably not, but that's the idea, right?" On the first attempt, the instructor did the wrong operation and went to the wrong part of the room and commented, "This is really hard." The other game player went to the right part of the room but did the wrong operation. The instructor said, "It's a lot of things to keep track of at one time. We are trying to do math while we are stressed and keeping track of other things. It transfers very well to real-life situations." On the second attempt, the instructor and other game player did both things correctly. The instructor used this situation to explain how practice or familiarity with a task can make thing easier with regard to working memory (see Barrouillet et al., 2007; Ericcson & Kintsch, 1995): "With practice, it is getting easier. It is in long-term memory now that we've done it." On the third attempt, both game players completed the task correctly. The teacher said, "There's a lot to keep track of. Adding all of these elements together made this more stressful." To demonstrate their knowledge of how lessening anxiety could make the working memory game easier, one of the students said,

> We can take back one of the rules and just make it about blue and red and having multiplying and adding. Other things we could do is make it less stressful—not a game, but just something that we are working on with one student individually and not in front of the whole class.

Figure 3

Kinesthetic Math Game



Then, the students and teacher discussed games they had played as children that were competitive, such as math races. We discussed examples of how anxiety can exacerbate difficulties with working memory, especially in situations in which students have a lot to process, store, and integrate and when they are stressed (Ashcraft & Krause, 2007).

Operation 99

The concept of working memory, as well as offloading, was demonstrated successfully by another group with a game called Operation 99, which involved the game player taking three playing cards and using addition, subtraction, multiplication, and/or division to get an answer that was as close to 99 as possible without going over 99. In this scenario, in addition to keeping track of other parts of the game (see Figure 4), the game players had to keep track of a lot of information in their working memories as they considered different combinations of numbers and operations. After demonstrating the game, the instructor asked the students how they could make the game easier to play regarding the load on working memory.

> LISA: We have scratch paper so you can write out your process of how you are going to get to 99.
>
> INSTRUCTOR: OK. So, I can write stuff down. How does that benefit you?
>
> LISA: To write out your process of how you are going to try to get to 99 in a visual representation.
>
> ALLY: It puts it on paper versus keeping it in your mind.
>
> SANDRA: When we were getting this ready, we played a round. You only have 30 seconds and you are looking at your three cards and you are trying to figure out, Am I going to do 10 times 7? Then, add 5. What am I going to do? And, that's a lot. Because you have to remember all four of the operations you could use. But, if I could use the paper instead and write out 10, 7, and 5 and write out a couple of possibilities, that helps.

In this case, the working memory game activity worked well for providing an opportunity for the students to show their overall understanding of working memory and to discuss ways they could change the game to tax working memory less by using scratch paper to offload information.

Discussion

The data showed the nature of the learning opportunities for students and how well the students understood working memory in general as well as how anxiety, familiarity with a topic, offloading, and fluctuations in the quantity of information that needs to be dealt with can affect working memory (Ashcraft & Krause, 2007; Barrouillet et al., 2007; Ericcson & Kintsch, 1995; Risko & Dunn, 2015). The activity provided the instructor with opportunities to conduct formative and summative assessments of his students and discuss working memory in the context of a game they had created, which was likely to make the concept more accessible. The instructor was able to give students feedback on their current levels of under-

Figure 4
Game That Demonstrated Offloading

Operation 99

- The goal is to use any of the four operations to get your cards at equal to, or get as close to, 99 as you can.

To Start the Game

- The dealer will deal out three cards to each player face down at the beginning of the round. Each player will look at them individually and use the operations to have their numbers equal 99 or get as close as possible.
    - Jack = 11
    - Queen = 12
    - King = 13
    - Ace = 1
    - No jokers are used
- The players will have 30 seconds to come up with the number and operation combination that gets them as close to 99 as possible.
    - The Price Is Right rules: If you go over 99, you lose the round.
- Each player has three flip cup wild cards throughout the duration of the game. If you win a round by getting exactly a 99, the player receives an extra flip cup wild card.
- If two players get the same winning number, they will play a round of flip cup. Whoever wins flip cup, and can land the cup first, will win the cards. The two players will keep playing flip cup until someone can land the cup right side up. That player wins the round.
- When you win the round, meaning you were able to get the highest number, you collect the cards. These cards are in the trash pile, and then whoever has the most cards when the deck is out is the winner of the game.

Supports

- Players will be able to have scratch paper to work with the numbers that they were distributed.
- Players normally will have 30 seconds to come up with their solutions. As a support, players can have an extra 30 seconds (1 minute total).
- Supply a times table for players.
- Create a visual of the rules that they could easily reference during the game.
- Play a practice round to be able to model the game.

standing of working memory based on what they had displayed by creating and demonstrating their games. Using information from the assessment, the instructor gained valuable insight about what the students knew to stimulate discussions on the topic and how working memory is related to other aspects of learning.

This experience and the discussions that followed are possibly one step in the process of preservice teachers gaining knowledge of working memory that can serve as a foundation for making sound decisions about teaching strategies that address the challenges students with LD may face with working memory. For example, situations in the created games during which working memory was overloaded may help preservice teachers think about how students can be overwhelmed with multistep situations or being faced with new and difficult concepts. And, in the discussions of these concepts with the preservice teachers, the first author often helped his students make these connections.

As with the preservice teachers in this study, other teachers may benefit from developing a high level of understanding of working memory. Students with LD tend to struggle with working memory and will rely on their teachers to notice when they are struggling and find ways to strategically modify task difficulty to avoid overloading students' working memory and support their thinking processes (Hord et al., 2018; Swanson & Siegel, 2001). Teachers will also need to teach students with LD to support their own thinking processes with strategies like offloading information onto paper (Risko & Dunn, 2015). Students with LD are likely to be especially in need of support for working memory from their teachers when they are anxious, which is likely to occur frequently due to the tendency of students with LD to struggle with anxiety (Ashcraft & Krause, 2007; Nelson & Harwood, 2011). To succeed with teaching students with LD, teachers need to be equipped with a deep understanding of working memory and a skill set for making good teaching decisions based on their understanding of working memory. To provide this needed training, teacher educators can utilize MEAs designed to help preservice teachers develop and demonstrate their understanding of working memory. These experiences for preservice teachers can provide some of the training that students with LD will need their teachers to have to address these challenging teaching situations.

In addition to anxiety, there are many interconnected concepts, in addition to working memory, that special educators need to understand about students' cognitive and noncognitive functions, including information processing, emotional regulation, motivational regulation, attention, and reasoning (Council for Exceptional Children, 2015). Our findings suggest that MEAs may be a useful tool for building a more complete picture of students' psychological characteristics and interactions in the classroom. Yet, addressing the complexities of students with LD is no small task, and finding parts of the solution to this challenge may require special education researchers to consider how other fields have addressed challenges that have been problematic in preparing undergraduates in their respective disciplines. As with how we utilized MEAs from STEM fields, special education researchers may need to consider work in other disciplines, such as psychology, sociology, or anthropology, and consider how undergraduates are prepared in these fields as well as find other ways to apply knowledge from these fields in general for addressing the challenges that special educators face.

Limitations and Implications for Future Research and Practice

We conducted analysis of only four groups of students from one class. Also, transcripts were not member checked with participants, which would have strengthened the study. Although the findings from this study shed light on the use of a MEA with one class of students with regard to the topic of working memory, future research studies should be targeted toward the work of more groups of students and potentially other topics, such as motivation, cognition, and emotion. Students with LD can have fluctuating levels of emotions during the process of solving challenging problems (Hord et al., 2018), and preservice teachers could be more prepared to deal with emotional components of struggling in school if they have a deeper understanding of the relationship between emotion and learning. Within the broad concept of working memory, there are also possibilities for further investigating related concepts, such as anxiety. Anxiety is common among students with LD (Nelson & Harwood, 2011) and warrants attention from special education researchers.

Special education researchers should also consider how preservice teachers may be able to transfer their own learning experiences with MEAs to their own teaching of students with LD regarding the academic content they need to teach their students and study skills their students with LD need to develop. For example, in relation to teaching students study skills and strategies for solving multistep word problems, teachers could use MEAs to show their students how to offload information onto scratch paper so that they have better opportunities to succeed in these situations. By teaching students about how their working memory can be overloaded, either through a MEA about something like a card game or simply in the context of solving a multistep word problem, teachers can show their students the value of offloading to make challenging problems easier to manage.

In relation to teaching academic content to students with LD, special education teacher educators could consider using a MEA, such as the activity described in this study, with a group of preservice teachers to teach about something like working memory but also as a springboard for teaching preservice teachers how to design their own MEAs for teaching academic content to students with LD. Once preservice teachers are introduced to the structure of MEAs, teacher educators have a potentially better opportunity to help preservice teachers develop their own MEAs for challenging elementary and secondary academic concepts. In addition to creating their own MEAs, teachers could access existing MEAs, possibly through assigned readings (e.g., Bostic, 2013; Magiera, 2013), for future use in their own classrooms or for further discussion in teacher preparation courses. These MEAs could be valuable tools for preservice teachers in their careers. Providing teachers with these tools may help them avoid the consequences they may face if their students do not succeed on high-stakes tests (Croft et al., 2016). Most importantly, this learning and growth of teachers may empower them to provide the teaching their students will need for accessing opportunities that are not available if students do not succeed on high-stakes tests (Ysseldyke et al., 2004).

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