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Application of the Deans for Impact Report, *The Science of Learning* How Do Students Understand New Ideas?

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This article examines the question, "How do students understand new ideas?" from the Deans for Impact report (2015). Within this paper, applications that address the three cognitive principles identified by the report will be discussed. The strategies recommended include incorporating worked examples into problem solving lessons in order to reduce cognitive load and free working memory, providing multiple opportunities to examine connections during reading instruction, and integrating guided discovery into mathematics instruction. Designing lessons which incorporate different modalities and multiple opportunities for students to make connections to prior learning and understanding during lessons have also been shown to increase opportunities for new learning. Finally, the concepts of developmentally appropriate content and scaffolding are briefly examined.

Keywords: Preservice teachers, *The Science of Learning,* cognitive load, working memory, relational learning, scaffolding, educational research, mathematics

At the time of this publication, there is no uniform standard for the length or intensity of clinical experience in teacher preparation programs. According to Greenberg, Pomerance, & Walsh (2011), only twenty-seven states require teacher candidates to complete a student teaching experience lasting ten weeks or more. Due to this inconsistency, it is important to illustrate the six Key Questions and related cognitive principles from the Deans for Impact (2015) report with concrete examples of application in practice in order to help preservice teachers develop knowledge regarding what the principles can look like in action, and deepen their existing understanding of how students learn, apply, and transfer new knowledge. Discussion about these and other applications can also be helpful to beginning teachers and mentors as part of a high-quality beginning teacher support program. This paper will suggest practical applications for the cognitive principles related to the question, "How do students understand new ideas?" (DFI, 2015).

COGNITIVE PRINCIPLE 1

Students learn new ideas by reference to ideas they already know.

According to Bransford, Brown, and Cocking (2000), referencing new ideas to what students already know is a key to enhancing learning in schools. In order to teach in a manner consistent with new theories of learning and connecting students' prior knowledge to new concepts, extensive learning opportunities for teachers are necessary to enable teachers to develop the abilities to meet students' varied learning needs. The research of Branford et al. (2000) illustrates the importance of the development of quality lessons showing that expert teachers have a deep understanding of the structure and epistemologies of their disciplines, combined with knowledge of the kinds of teaching activities that will help students come to understand the discipline for themselves. Furthermore, Bransford et al. (2000) stated that incorporating students' prior knowledge creates an opportunity for "organizing information into a conceptual framework allows for greater 'transfer'; that is, it allows the student to apply what was learned in new situations and to learn related information more quickly" (Bransford et al., 2000, p.17).

One classroom application to demonstrate the framework of using prior knowledge is incorporating various forms of text application in reading and literacy. To create proficient readers, Keene and Zimmerman (1997) state, "Teaching children which thinking strategies are used by proficient readers and helping them use those strategies independently creates the core of teaching reading." (p. 420). Keene and Zimmerman go on to develop three forms of text relation to incorporate into lessons and classroom discussions; text to self, text to world, and text to text.

- Text to self - The student looks through a book, cover to cover, and takes time to look at the pictures and/or words. After doing so in the allotted time, they then make personal connections to what they looked at in the book.
- Text to world - The student looks through a book, cover to cover, and then makes connections to the world and ideas that they have or knowledge that they have about the world around them.
- Text to text - The student, having made connections to the world and to themselves, will also make connections to previously read literature.

By incorporating these strategies, teachers are able to allow students multiple opportunities to make connections to their prior knowledge. Through modeling, think aloud, and discussion, teachers help students develop into proficient readers who thrive by examining themselves.

COGNITIVE PRINCIPLE 2

To learn, students must transfer information from working memory (where it is consciously processed) to long-term memory (where it can be stored and later retrieved). Students have limited working memory capacities that can be overwhelmed by tasks that are cognitively too demanding. Understanding new

ideas can be impeded if students are confronted with too much information at once.

The Deans for Impact (2015) report states that in order to learn, students must transfer information from working memory to long-term memory, and that one effective way teachers can make this happen is by using "worked examples" as part of their instruction. In using worked examples, the cognitive load on the working memory is reduced. Conventional problem solving creates a heavy cognitive load, which impedes schema acquisition. Therefore, students may benefit if conventional problems were replaced by worked examples.

The Deans for Impact (2015) report explained that the guidance given to students when learning through worked examples should gradually be decreased to over time allow students to become more proficient at solving problems independently. Teachers can make this happen by incorporating appropriately paced explanations, modeling, and worked and/or modeled examples. Von Gog and Rummel (2010) found that worked examples are used to give learners specific steps to work out a problem, and that this works well in math, such as algebra, geometry, and statistics. Students using worked examples are not necessarily focused on learning to solve problems, but on learning the steps to solve problems. Modeling examples may be a more effective way to teach less structured skills such as writing, collaboration, and metacognitive skills such as self-regulation and self-assessment. These concepts can have direct applications in a teacher's classroom instruction.

At most every level of schooling, the teacher using a direct instructional model typically verbally introduces and explains the steps of how to solve a problem. The teacher then demonstrates the method, perhaps numerous times, with the students working to solve the problems along with him/her. Then the students are given guided practice problems to solve under the supervision of the teacher. Finally students solve similar problems independently. If the following day in class the teacher simply provides the students with a worked example of yesterday's lesson rather than asking students to rely on yesterday's lesson, learning may actually be deepened by repetition without cognitive overload. This combined with interleaving over time may produce better learning results.

In an active learning example, middle school beginning band, students are learning to play their particular instruments. The band director must go through step-by-step directions and modeled examples on how to purse one's lips together, blow air through the lips and into the instrument to make a sound. The teacher also gives numerous worked examples to show students the different fingerings of their instruments that must be used in conjunction with the lips and blowing of air - verbally and modeling on the same instrument, many times playing an example and then playing along with the student. In a more advanced high school band, the band director models more subtle or advanced techniques such as staccato, legato and rhythms for students on an instrument. The director also plays along with students through different measures.

When different modalities are incorporated into a lesson, students retain more of the information being taught. Using an example in a fifth grade math class, students learn how to multiply decimals. In teaching the students the process of multiplying, song and dance steps may be incorporated to help the students remember how and when to move the decimal point. First, step-by-step directions are given along with a demonstration on an interactive whiteboard. Students take notes as the explanation and demonstration are given. To help them remember the procedure, students sing and dance/step while they move the decimal point: "To the right, to the right" to move the decimal points in the multiplicand and the multiplier, and then "to the left, to the left" to move the decimal point in the product. Students stand to sing and dance/step when solving the problems.

In order to make Earth Science more realistic to elementary school students, students can create flap books with basic information about the layers of the earth. Older students can extend their previous learning by creating a poster with more detailed information about each layer and draw the layers and label the depths of each layer as their skills progress. As the complexity of the information students are exposed to increases, the expectation for the complexity of the student product also increases, but each product integrates more detailed information that is scaffolded by previous learning and experiences.

COGNITIVE PRINCIPLE 3

No content is inherently developmentally appropriate or inappropriate; content should be scaffolded so that students can connect to concepts where their understanding begins.

Preservice or beginning teachers who lack deep understanding of how concepts develop may initially reject content because they may think that the content is not developmentally appropriate for their students' stage(s) of cognitive development. It is important to realize, however, that no content is developmentally appropriate or inappropriate in and of itself. The structure and presentation of the lesson must be focused on the needs of the learner rather than on the content to be delivered. What matters for students is that they have enough background knowledge or concrete experiences to scaffold new lessons upon. If a lesson is not successful, rather than abandoning the concept as developmentally inappropriate the teacher should consider strengthening the presentation and scaffolding of the concept. Deep and thorough knowledge of content, coupled with knowledge about how students learn, can help teachers adapt their lessons so that students can make connections between complex concepts and their existing knowledge base.

The structure of the lesson itself, the use of modeling and guided practice with concrete manipulatives to build or connect to basic understanding, and the use of worked examples and familiar problem structures are instructional techniques that can help students build fundamental understanding of complex concepts. The goal is not to build comprehensive understanding of a concept, but to build one level of a foundation that will support deeper exploration and learning about the concept in the future.

When beginning a new unit of study it is important to identify prerequisite skills and ensure that those skills are activated and evaluated before new information is presented. In elementary grade math, the study of addition, subtraction, multiplication, and division with decimal numbers should begin with a review of those same operations with whole numbers to ensure that students are proficient. This may necessitate remediation and guided practice for some students who are not strongly proficient with whole number operations to ensure that they increase fluency and will be able to transfer their understanding of the operations to decimal numbers. This can occur during math workshop while proficient students work independently on differentiated areas of need. A review of place value concepts is also necessary so that the information is activated and can be integrated into lessons with decimal operations. Frequent references to how decimal operations are the same as (and how they are different from) whole number operations can help students transfer the information to a different context.

Breaking down problem-solving tasks into clearly defined steps (first we need to …, then we can…, etc.) and working one step at a time helps students focus all of their cognitive effort on each step instead of trying to figure out several things at once. For students who are overwhelmed by a multistep problem with large numbers, using smaller familiar numbers within the math fact families with which they have achieved a level of automaticity already, can decrease the cognitive load. This may be where worked examples may assist with deepening learning while not overloading student working memory. After students have figured out each piece, then they can focus on putting the pieces together in a way that makes sense and evaluate whether the tasks they have done have allowed them to answer the question. Repeatedly using the same problem structure until students build fluency with identifying features, and gradually adding different structures, can help students transfer what they have learned about one type of problem to another problem type.

There are many ways to create worked model types. Using graphic organizers, concrete objects/manipulatives, and drawings to represent the objects and the action of a problem helps students manipulate the information in a way that makes sense. Using story mats to guide younger children helps provide additional structure to guide their interactions with the content. Drawing or representing the action of a word problem with manipulatives helps students see what is happening within the "story" of the problem so that they will eventually be able to represent it abstractly with numbers, expressions, and equations. Developing the algebraic concept of a variable can start as early as kindergarten with the use of different problem structures, such as start unknown and change unknown, as well as total or difference unknown. Algebra also starts in kindergarten with patterning, first with shapes and colors and eventually with numbers and properties of numbers.

During the development of algebraic understanding, the learner moves from concrete to abstract thinking. Henry Borenson's work with fourth graders, who according to cognitive stage theory are generally expected to be in the concrete operational stage, shows that they are able to transition to abstract thinking if they initially experience algebraic principles using concrete manipulatives along with symbolic representations (Borenson & Barber, 2008). An effective instructional strategy begins with transforming the word problem into a concrete or pictorial equation. When the learner becomes proficient with creating and interpreting concrete representations of equations, the teacher can demonstrate how to use that representation to construct an abstract equation using a letter for the unknown. The concrete representation can be used as long as the learner requires the structure, which may be different lengths of time for different students.

By developing an understanding of how content develops and builds upon itself as students progress through educational experiences, teachers can learn how to present new information in manageable chunks so that students can make meaning by connecting to their existing schema. Concrete representations of abstract concepts like fractions, integers, and algebraic expressions with variables can help students build a foundation for future understanding.

CONCLUSION

The discussion of the six Key Questions and their related cognitive principles in the Deans for Impact report is a way to connect cognitive science to pedagogy; however, it is also important to provide examples of practical applications of these principles. Preservice and beginning teachers may have limited experiences and may lack understanding of how these principles can be incorporated in planning, delivering, and reflecting upon the effectiveness of their lessons, and these examples can be used as a springboard for discussion and developing additional strategies. By examining, discussing, and analyzing practical examples of the application of the cognitive principles related to the Six Key questions in the Deans for Impact report, preservice and beginning teachers can begin to consider how to integrate these and other related strategies into their lessons to increase the quality of teaching and learning in their classrooms. They are in essence building upon their own prior knowledge to learn themselves. Administrators can pain beginning teachers with mentors who can use cognitive science principles to strengthen teachers and the entire learning community.

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