DEEPENING Meaning and Learning

How future teachers are putting learning science into action to support all students

DEANS FOR IMPACT

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EXECUTIVE Summary

"DO YOU KNOW IF WHAT YOU ARE DOING AT DEANS FOR IMPACT IS MAKING A DIFFERENCE IN HOW TEACHERS WILL TEACH?"

An education journalist asked us this question a few months ago. It's tough but fair, and in many ways his question gets at the core challenge of education. Learning is the result of cumulative actions, and it's very hard (though not impossible) to measure. Six years ago, Deans for Impact launched with a vision of bringing scientific insight into teaching practice, but it was just that—a vision. In the time that's passed, the question remains: is what we're doing having any impact?

WE NOW HAVE THE ANSWER: YES.

Before providing evidence to support that claim, a quick recap of our organizational journey. Two years ago, we launched the Learning by Scientific Design (LbSD) Network to begin the vital—albeit challenging—work of redesigning how teachers are prepared. This effort is informed by principles of learning science and taking place in what is now a network of 10 educator-preparation programs across the country. More than 70 faculty are working with us to change the arc of experiences that teacher-candidates receive as they prepare to become teachers.

Despite the challenge of a global pandemic, the programs participating in the LbSD Network pressed ahead with changes we designed together. Over the past academic year, these programs—which collectively graduate about 2,100 teachers each year—helped their teacher-candidates to explore and practice the principles of learning science. As far as we know, it's the largest—and perhaps only—effort of this type to ever occur in schools of education.

Is it working? Let's start with the empirical data. In Spring 2020, just over 1,000 teacher-candidates enrolled in programs in the LbSD Network took our **assessment** that covers six key principles of learning science.[1] As we might expect, given that these candidates had received no special instruction in learning science, their scores were modest.

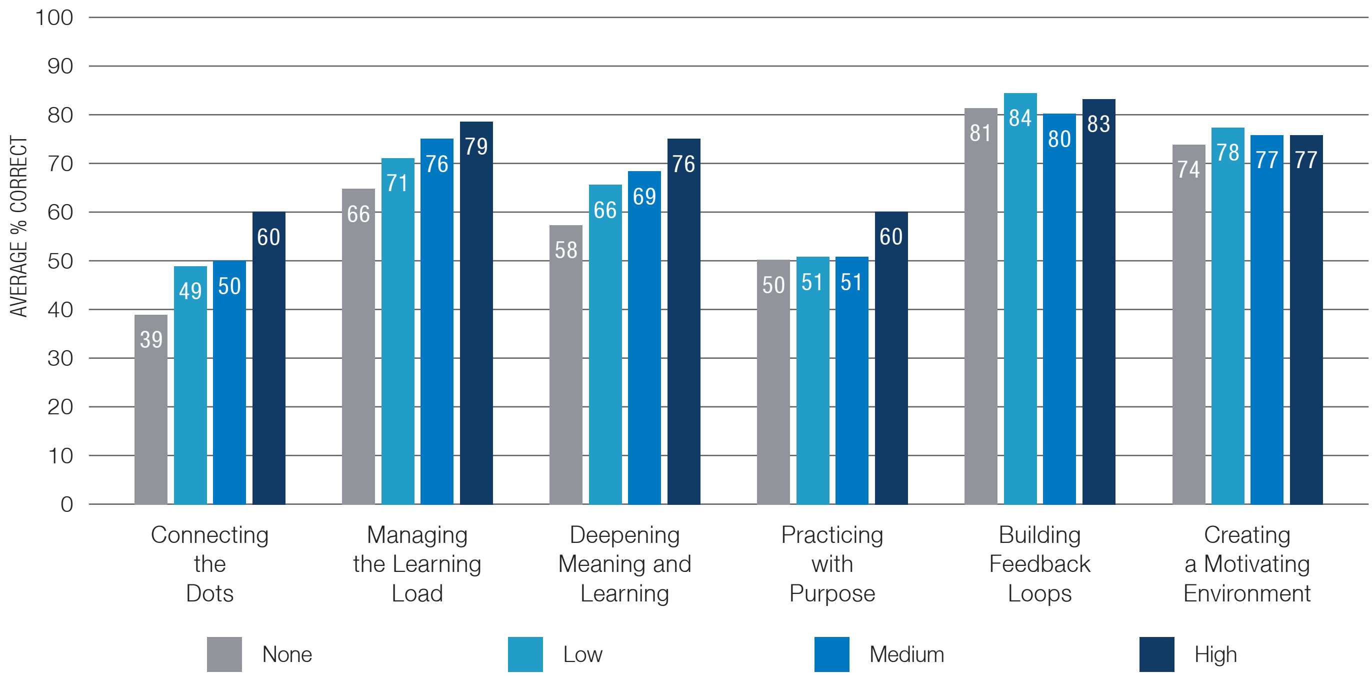
One year later, and after programs implemented new sequences of practice-based learning experiences focused on learning science, we assessed approximately 750 teacher-candidates on their understanding of

[1] For more on the LbSD Assessment and these key principles, see our **Learning by Scientific Design report** from Spring 2020.

key learning-science principles. The candidates in this group did not all receive the same amount of training on these ideas; instead, the amount of learning-science instruction ranged from "none at all" to sustained, explicit learning-science instruction for a full academic year. The following chart shows how their scores vary—and vary significantly—depending on the amount of learning-science instruction they received (none, low, medium, high):[2]

Differences in teacher-candidates' understanding of learning-science principles

LbSD | Spring 2021



So what do these results tell us? First, redesigning teacher preparation works. At Deans for Impact, we are often told we should refocus our efforts because, "it's too hard to make shifts in teacher preparation." These results—and the timeline over which they occurred—directly counter this claim. Put simply, we see sizable differences between the scores of teacher-candidates who had access to learning-science-focused learning opportunities, and those who did not.

Second, focus matters. We have long stressed that depth is more important than breadth. Accordingly, we encouraged programs in the LbSD Network to focus deeply where they saw the highest area of need. All six chose to work on Deepening Meaning and Learning—which is why we've made that principle the focus of this report.

Finally, the quality of experiences matter too. The more opportunities teacher-candidates were given to unpack learning-science principles and apply them in their teaching, the higher they scored on the assessment. If that sounds like an obvious outcome, keep in mind that all too often, efforts spent on improving teacher learning do not lead to measurable increases in teacher knowledge and skills. This effort did, and these results underscore the impact that well-designed teacher preparation can have.

[2] For more information on the assessment, analyses, dosage groups, and additional principles that programs focused on, see the Technical Appendix.

Further, these increases are consistent across *all* demographic groups, suggesting that programs in the network are successfully equipping the future teachers involved to be more effective.

So that's one piece of empirical evidence supporting the impact of this work. But these are numbers, and teaching is a human endeavor. Over the past several months, as we have spoken to the soon-to-be teachers in the LbSD Network, we have been inspired by how they have reimagined their teaching in ways that align with scientific principles and provide meaningful learning opportunities to all students. This is evidence of impact as well—powerful evidence.

This report thus highlights stories and data that answer the questions at the heart of the network: What does it look like when a teacher uses learning science to design instruction and build relationships with students? How does a teacher create an environment where all students receive equal access to learning?

We begin with an overview of the cognitive principles and teaching actions that animate the LbSD Network. We will examine data, and hear the voices of teacher-candidates and teacher-educators, as we explore three key components of this principle:

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1. **How teachers can use questions and tasks that require students to focus their attention on the meaning of content.**

2. **How teachers can use questions and tasks to require students to engage in effortful thinking.**

3. **How teachers can prompt students to connect examples and contrasting non-examples.**

And we conclude with a look at how this principle supports all students to receive rigorous instruction.

Dr. Meixia Ding

"We know that there can be a cycle of inefficiency between teaching and learning. The literature shows that poor teaching contributes to poor learning, and a lot of that is due to teachers' lack of knowledge. To break this cycle, working with pre-service teachers is a great entrance point."

- Dr. Meixia Ding,

Associate Professor of Math Education at Temple University

Programs in the LbSD Network

TCU
American University, Washington, DC
Temple University
Sam Houston State University
UNC Charlotte
UMSL
LRCE Louisiana Resource Center for Educators
UAF University of Alaska Fairbanks
Endicott College
National Louis University

UNDERSTANDING learning science

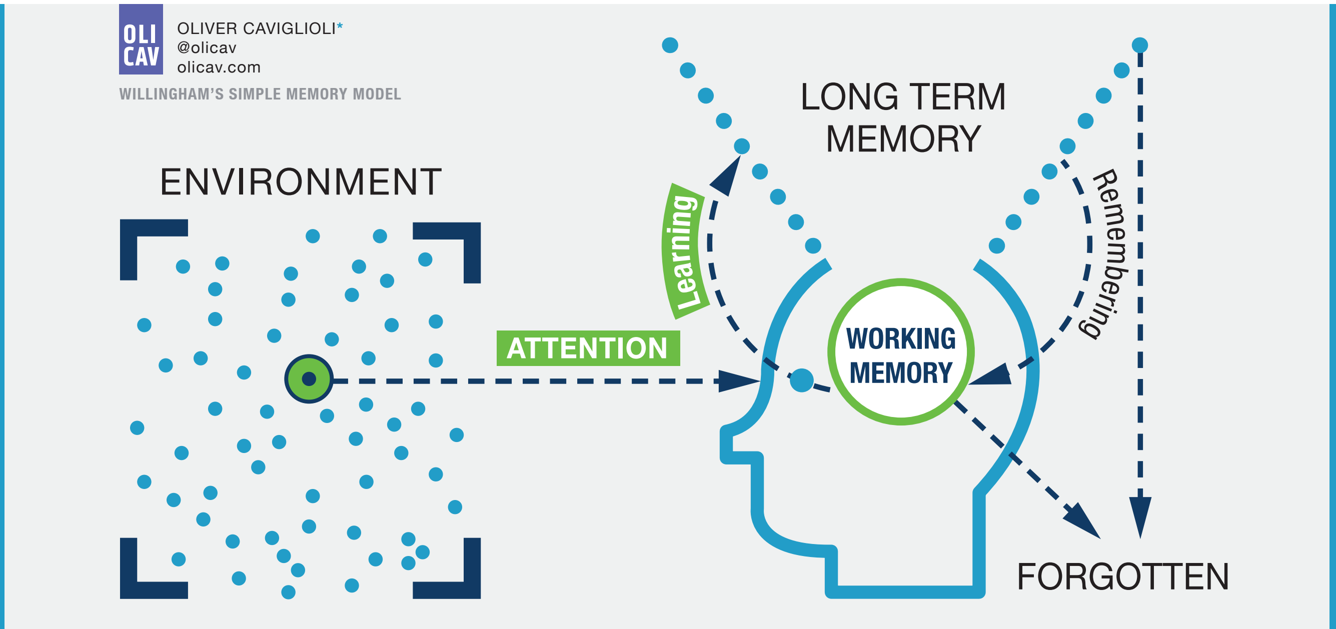
The framework that guides the LbSD Network is built on the core cognitive science research that we outlined in our first publication, ***The Science of Learning***. From this, we have identified six key principles that are important for future teachers to understand and specified what it looks like when teachers put those principles into action. We use this framework:

Learning Science Principles and Teacher Actions

Connecting the Dots	Managing the Learning Load	Deepening Meaning and Learning	Practicing with Purpose	Building Feedback Loops	Creating a Motivating Environment
Students learn new ideas by reference to ideas they already know.	Learning can be impeded if students are confronted with too much information at once.	Students should think about meaning when they encounter to-be-remembered material.	Practice is essential to learning, but not all practice is equivalent.	Effective feedback is essential to acquiring new knowledge and skills.	Students will be motivated to learn in environments where they feel safe and valued.
Teachers prompt students to call up important prior knowledge and explicitly connect it to new ideas	**Teachers intentionally sequence tasks to include opportunities to build foundational concepts before moving on to more advanced tasks** **Teachers scaffold student understanding through carefully designed instruction that includes modeling, explanation, thinking aloud, and worked examples**	**Teachers' questions and tasks require students to focus their attention on the meaning of content** **Teachers' questions and tasks require students to engage in effortful thinking** **Teachers prompt students to connect (and distinguish) varied examples and contrasting non-examples**	**Teachers space and interleave practice opportunities to assist students in building automaticity**	**Teachers provide students targeted practice opportunities with specific feedback on their work** **Teachers foster an orientation toward improvement, not performance**	**Teachers surface the voices, ideas, and opinions of all their students and show that these are valued**

We encourage programs in the LbSD Network to focus on a few principles where they see the best opportunity to support teacher-candidate learning. Six programs redesigned their coursework over the last two years, and the bulk of their redesign work focused on the principle of **Deepening Meaning and Learning**: ***Students should think about meaning when they encounter to-be-remembered material.***

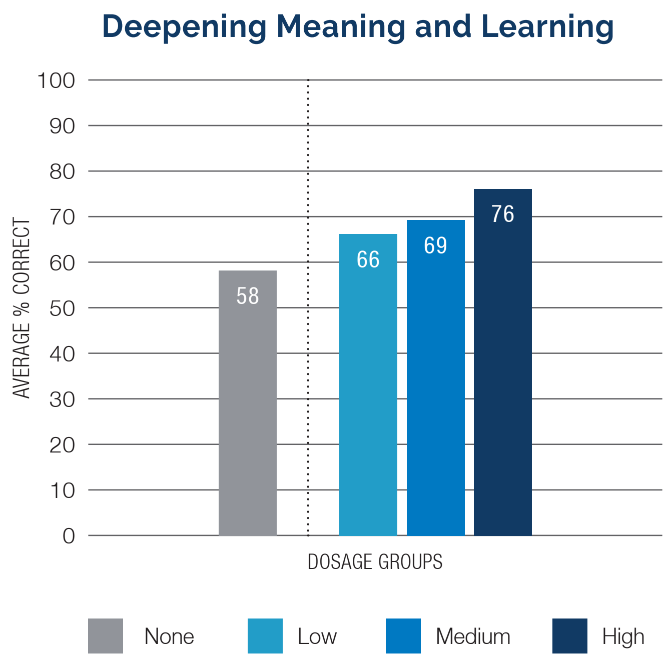
If you don't have a background in cognitive science, you may be wondering—what does that really mean? To help explain, here's the "simple model of the mind" posited by scientist Dan Willingham that describes how the mind processes new information:



* This graphic is used under a Creative Commons Attribution-Non Commercial **license**. We modified the color scheme. Original available **here**.

To learn something new, a student must pay attention to the new idea. It's easier to do this if a teacher directs the student's attention towards exactly what the student must learn—the "to-be-remembered" content. This is **the first action** that we recommend teachers take to put this principle into practice: Teachers need to ask questions and design tasks that focus on the key concept, not distracting or tangential content.

By paying attention to the new information, the student brings it into their working memory—the workshop of the mind. Here, they grapple with new ideas, and the more they turn them about, the more likely they are to move the information into long-term memory, the warehouse of the mind. This is where **the second action** comes into play: teachers should ask questions and design tasks that require students to engage in deep or "effortful" thinking. This prompts robust processing that allows students to remember information long term. Finally, to help students add nuance to their understanding and refine their mental maps (also known as *schema*), teachers can give examples and non-examples to show the boundaries of a new concept—**the third teacher action**.



This section of the assessment presented teacher-candidates with a series of classroom vignettes designed to illuminate their approach to instructional decisions. Candidates who received sustained learning and practice opportunities scored 18 points higher on the assessment items related to Deepening Meaning and Learning than a comparison group. This data indicates that these future teachers are better equipped to provide instruction to K-12 students that is in line with our best scientific understanding of learning.

FOCUSING STUDENTS' ATTENTION

on the most important content

Think back to high school. Imagine being in class right before lunch. Your stomach rumbles, and the smell of food wafts down the hallway, distracting you from listening to your teacher reading from *Romeo and Juliet*. Instead of thinking about the Capulets and the Montagues, your mind wanders to chicken nuggets and mac-and-cheese.

It's hard to pay attention in an environment filled with distractions. Sometimes teachers inadvertently design lessons that focus students' attention on something other than the key concept to be learned. Instead of creating an environment where students can think critically about ancient Greece, they ask them to paper-mache a Grecian urn instead. Is it fun? Yes. Do students learn the content as the standard requires? No. They're thinking about glue and newspaper instead of Socrates.

The first teacher action that stems from the principle of Deepening Meaning and Learning is this: ***Teachers should focus students' attention narrowly on the to-be-remembered content.*** Activities can be fun, but engagement should never come at the expense of focusing attention on challenging content.

Acqualyn Polk

LIGHTBULB MOMENTS IN LOUISIANA

On a bright winter day in a classroom 30 miles north of the Louisiana coast, a class of third-grade students listened carefully as their teacher, Acqualyn Polk, explained the difference between "like" and "as."

"Now, I'm going to read a passage," she told the class. "Raise your hand when you hear the simile."

As she started to read, hands shot up across the room. Something was wrong—she hadn't actually read a simile yet. She skimmed back over the text and saw the problem sentence: "George *likes* ice cream."

"It dawned on me that I didn't stress the part about comparing two things using 'like' or 'as'—they were focused more on the *words* 'like' and 'as,'" she said later. "I had to backtrack and go back and get their focus on comparing."

Understanding she needed to focus her students' attention on the key concept with similes—comparison—was a direct result of her training through the

Louisiana Resource Center for Educators, a nonprofit alternative teacher-certification program. For the last two years, LRCE has worked with Deans for Impact to employ learning science in how they prepare future teachers. This work has empowered Polk to teach differently, and more effectively, using scientific principles.

So that's what she did. She explicitly taught her students that similes are comparison, and then read the same passage to them again. A little boy named Jaden raised his hand excitedly.

"I got one, Ms. Polk!" he said, as he correctly identified the simile. "You know what that is?"

"An 'aha' moment?" Polk asked, beaming with pride.

"Yes! The lightbulb just turned on in my head!" Jaden said.

These changes to her instruction based on learning science have resulted in significant changes in her students' comprehension, Polk said.

"My students' passing scores have gone way up now because I know what I need to focus on," she said. "Before I knew about these things, I would be like, the students are just staring at me, no one is answering questions. Now I realize that they weren't answering because they weren't understanding. I had to learn a new way to teach so that everyone is understanding what I'm teaching.

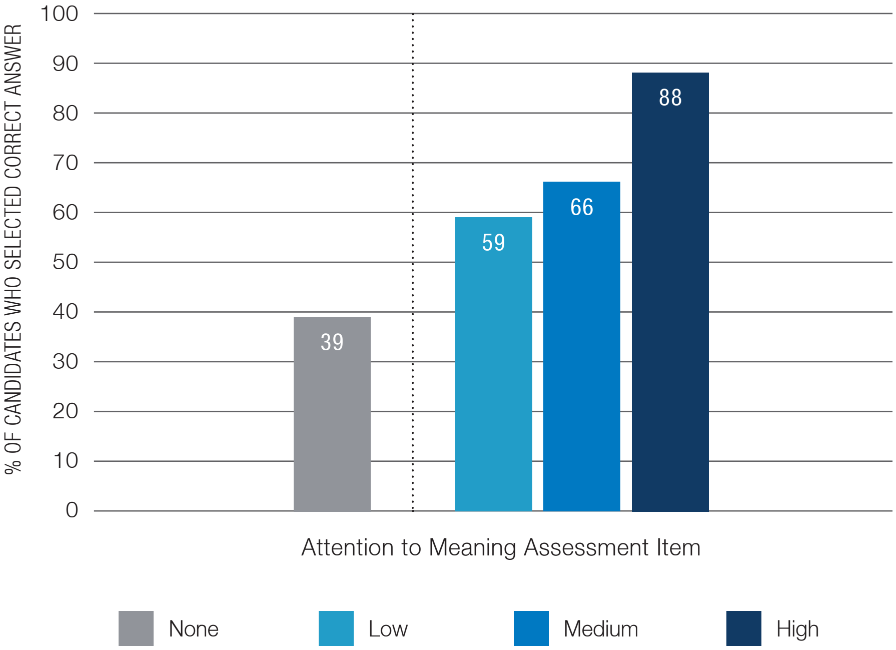
"I didn't know anything about the science of learning before, and now that I know, I'm making the changes I need to make, and doing things that I know are going to help my students master the content."

Jody Hagen-Smith

"The candidates are being thoughtful about the activities they're choosing to enact. They're asking questions that will get their students thinking deeply and engaging with the content, and they're making sure that the entire lesson focuses on the to-be-remembered content and not something else. The heart of this is that we are preparing teacher-candidates who will provide high-quality instruction to each and every student in their class, thinking about their students from an assets perspective, and not limiting what they think some students might be capable of."

- Jody Hagen-Smith,
Adjunct Instructor
at American University

Identifying Attention to Meaning in Practice



This chart shows how teacher-candidates responded to a question on the LbSD Assessment about directing students' attention to the important details of the content they are learning. 49% more candidates who received sustained learning and practice opportunities selected the correct answer than their peers who received no learning opportunities. This data indicates that these future teachers are more likely to prioritize rigorous thinking and learning in their instruction over simplistic or unaligned activities.

DIVING DEEP with effortful thinking

How we make sense of the world depends on our vantage point. Consider snorkeling versus scuba diving: both allow you to observe the ocean, but the latter gives you greater range to explore underwater depths.

Effortful-thinking questions are like scuba-diving gear for learners. They provide the means by which to "dive deep" on a new concept or idea. Such questions make students think hard about new ideas, making it more likely that they will remember what they've thought about. They include questions such as: *Why might ___ be true? Why would this be true of X and not Y? How might this be different if…? How did you figure that out, and why did you take those steps?*

This is the second teacher action that stems from the principle of Deepening Meaning and Learning: *Teachers' questions and tasks should require students to engage in effortful thinking.*

Roxanne Biedermann

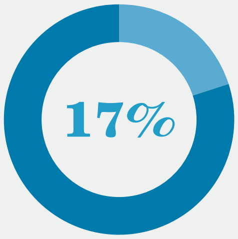
SETTING THE FOUNDATION FOR FUTURE LEARNING

Making a career change isn't easy, but Roxanne Biedermann sees teaching as a way to create a more just world. After spending two decades in finance and at home with her children, she entered Temple University's educator-preparation program to launch a second career as an early elementary teacher. There, she's learned about how to use high-quality questions to prompt effortful thinking.

"It is so important to use research-based practices in your teaching. Learning science is a proven, effective method for students to have deeper understanding and more long-term memory," she said. "By encouraging them to think deeply in the early years, you set the foundation for all future learning."

Last year, Biedermann completed her practicum in an under-resourced school in Philadelphia. The school's science curriculum was scarce, and teachers were making up lessons or getting them off of sites like *Teachers Pay Teachers*. Biedermann employed learning science to ensure her students were prompted to do the deep thinking she knew they were capable of.

"With effortful-thinking questions, you can make those lessons ten times better," she said. "It's free, and you don't need an expensive curriculum. Even if you don't have a ton of resources, you can still ask questions that encourage deep thinking and processing."



Before participating in LbSD-related preparation, only 17% of the candidates we observed consistently prompted for effortful thinking.

After the redesign, more than 60% of candidates we observed did. (For more information, see the technical appendix.)

Dr. Hilary Dack

"Every child needs to have access to rigorous instruction that requires scuba diving and not just snorkeling, and research tells us that's not what's happening across American public schools. This is the 'why' of what we are studying. This is not just nice stuff to throw in your lesson when your principal observes you. This has really high stakes for K-12 learners, and it's our responsibility as individual middle-school teachers to do something about it. We can change this if we understand what we need to do differently. Learning science is going to teach us what we need to do differently."

- Dr. Hilary Dack,
Associate Professor of Middle Grades Education at UNC Charlotte

Understanding how to prompt effortful thinking

One of the LbSD Assessment items evaluates whether teacher-candidates recognize how a teacher would respond during a math lesson to prompt effortful thinking in students. In the scenario, a fourth-grader named Alicia is explaining to the class how she solved an addition problem. Here are two representative responses. First, a candidate with a background in learning science:

"The answers that I selected were effortful-thinking questions which will deepen their schema. Instead of asking just Alicia how she got that answer, these responses will prompt the teacher into asking the entire class to also think deeply about the answer in order to store the information in their long-term memory."

Teacher-candidate from UNC Charlotte

Compare that to a response from a candidate who did not have the opportunity to engage with learning science in their preparation:

"I tried to think about ways to support all learners. For example, I picked responses that support students verbally, kinesthetically etc...so all learners can be supported."

Teacher-candidate who did not learn about learning science (There is almost no empirical support for learning styles.)

CONNECTING IDEAS through examples (and non-examples)

Cognitive science reveals that one helpful way to build a student's understanding of a new concept is to give examples that illustrate what the concept is, and to present non-examples that show what it isn't. For instance, to learn a new swim stroke, you don't just hop in the water and start racing. First, perhaps you'd watch examples of good practice—a coach demonstrating the stroke, or an Olympic athlete winning a race—from all angles. Then, you'd watch examples of someone swimming the stroke incorrectly. Learning abstract concepts works the same way.

This is the third teacher action that stems from the principle of Deepening Meaning and Learning: *Teachers prompt students to connect (and distinguish) varied examples and contrasting non-examples.*

Ben Mueller

USING LEARNING SCIENCE TO CUT FAT AND FLUFF

Every morning, when future teacher Ben Mueller turns on the light in his bedroom, his fingers brush against a taped-on index card that reads, *"Memory is the residue of thought."*

The phrase stuck with him after a seminar at the University of Missouri—St. Louis (UMSL) on how to prompt deep thinking in students.

"If memory is the residue of thought, then for students to understand the to-be-remembered content, they are going to have to think super hard. The more they process, the longer they remember," he said.

To foster this learning, Mueller designs lessons to include examples and non-examples that help students to understand the boundaries of a concept—what it is and isn't. Though it may seem straightforward, this teaching strategy is actually a powerful tool to help students access deeper learning.

"It's really shifted the foundation of my lessons. I almost always start with **detailed examples and non-examples** now in lessons so that students can frame what I'm talking about," he said.

During his high-school English practicums, he has used this approach to orient students towards the underlying thematic structure of texts and what it looks like to compare themes across texts, helping them avoid distracting surface-level features of the plot or characters.

For instance, if he's asking students to compare Edgar Allen Poe's short story *William Wilson* to *Dr. Jekyll and Mr. Hyde*, he will push his students to make meaningful comparisons between texts. An example of a meaningful comparison? Both texts are about doppelgangers and duality. A non-example? Both stories are set in England.

"When you ask students to compare two stories, there's a lot available for them to compare. I'm asking them to look for a quality observation—something worthwhile and insightful. Using varied examples allows me to draw an outline, to sketch a border around what they're looking for," he said.

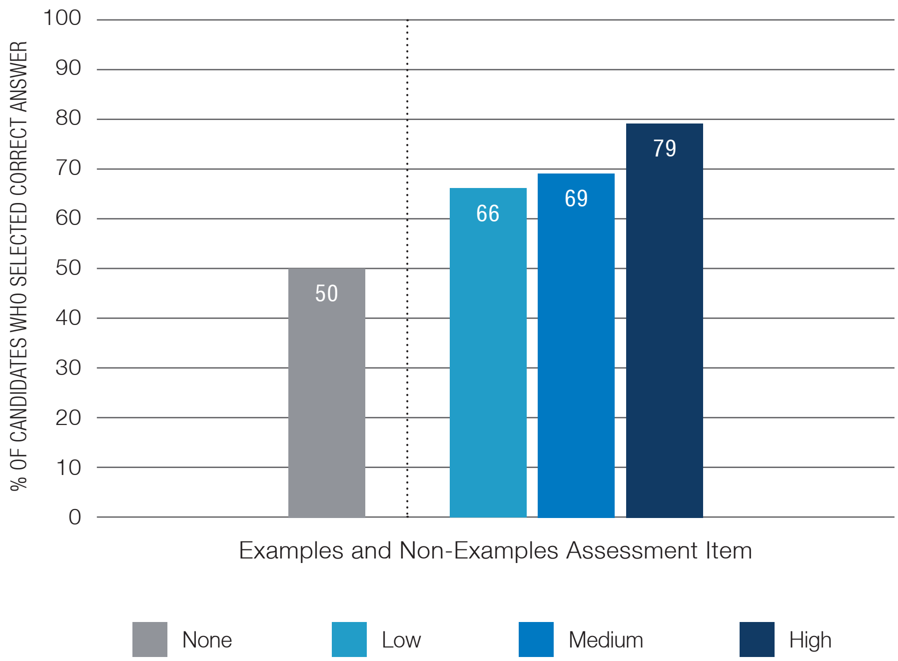
In contrast, "when I separate non-answers, it shows them what I'm not looking for, and helps them avoid landmines. Seeing non-examples helps them understand that comparisons such as two stories being set in England exist outside of the boundary of what I'm looking for.

"It cuts away the fluff and fat of the lesson."

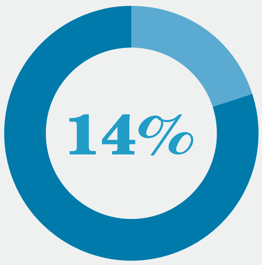
"When teachers use examples and contrasting non-examples they help students understand how examples are connected and why they belong to a group, and how non-examples are different. This helps students build schema and fills in knowledge gaps."

- Dr. Sandy Rogelberg,
Research Assistant Professor at UNC Charlotte

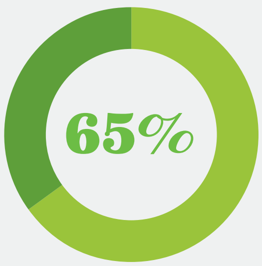
Identifying Examples and Non-Examples in Practice



This chart shows how teacher-candidates responded to a question on the LbSD Assessment about using examples and non-examples. 29% more candidates who received sustained learning and practice opportunities selected the correct answer than their peers who received no learning opportunities. This data indicates that these future teachers are better equipped to provide instruction that builds students' schema and facilitates transfer to new situations.



Before programs changed how they prepared teachers as part of the LbSD Network, only 14% of candidates we observed used examples and non-examples in classroom instruction.



After one year of preparation using learning science, 65% of candidates we observed did this.

USING LEARNING SCIENCE to support all students to access rigorous instruction

Questions of how to prepare novice teachers to ensure they are engaging every student in rigorous, affirming instruction have long challenged educator-preparation programs.

Many teacher-educators have grappled with the balance between wanting to help teacher candidates be responsive to students' different backgrounds and experiences, while also focus on their locus of control, their classroom instruction. Too often candidates seem to emerge with a grab-bag of knowledge and instructional moves—provide students with books about different life experiences, celebrating cultural holidays—that are valuable in fostering understanding of differences, but insufficient. Too many enter the classroom without a deeper lens through which to consider how they might facilitate learning experiences that affirm and challenge all of their students. Our work with Learning by Scientific Design Network programs has focused on addressing this last gap: to provide novice teachers with opportunities to connect theory to their own classroom practice, to think critically about how to effectively reach and engage all students in every instructional decision.

INTENTIONAL DECISION-MAKING IN EVERYDAY INSTRUCTION

Through thoughtful coursework redesign, programs have begun supporting candidates to consider how their instructional choices can impact the extent to which every student is able to rigorously engage with learning experiences. Every one of these decisions can affect students' learning experiences: the tasks they design, the questions they ask, of whom and how they ask them—even down to the examples they choose.

Candidates reflect about the core activities in their lesson plans and whether or not they challenge students to think deeply about ambitious content, understanding that they must hold high expectations for all students by offering every student the opportunity to engage with challenging tasks and be asked rigorous questions.

"It's very empowering for novice teachers to recognize the degree to which they have control…through their teaching practice," said Dr. Hilary Dack, Associate Professor of Middle Grades Education at UNC Charlotte.

"Each time I present a learning science principle, I also present what we know from research about [differences] in students having access to instruction that learning science tells us is effective. This is the 'why' of what we are studying. This is not just nice stuff to throw in your lesson when your principal observes you. This has really high stakes for K-12 learners, and it's our responsibility as individual middle school teachers to do something about it. Learning science is going to teach us what we need to do differently."

So often, we see both novice and veteran teachers lean into common misconceptions about teaching and learning—myths like learning styles or the idea that effective differentiation involves offering a simplistic "lower level" text to readers with unfinished learning. Yet with opportunities to link knowledge about the basic mechanics of the mind with instructional choices, and unpacking these choices through a critical lens, even early stage teaching candidates show the possibility of making more accessible lessons for all their students.

"Teachers who are focusing their instruction on the to-be-remembered content, and giving all students an opportunity to engage with high-level thinking, are providing… access to all of their students," said Jody Hagen-Smith, adjunct instructor at American University. "We really want candidates to think about differentiation in terms of scaffolding and building up background knowledge. We want to make sure that we're not limiting the content or the rigor that we're expecting from every student. In that way, all students can access the grade-level content, rather than allowing some students to fall short of that because they might not be quite 'ready', which we know would then limit their opportunity to learn."

IMPLICATIONS FOR STUDENTS

These everyday instructional decisions are all the more important given the reality that shortcomings in the preparation of new teachers have impacted students from low-income communities the most. Decades of research have found novice teachers placed in more under-resourced schools and in the classrooms of students with the most unfinished learning.

The Learning by Scientific Design Network is working to combat this issue, by providing novice teachers with a clear understanding of how students learn, and by weaving a critical lens into the fabric of their instructional decision-making.

One of the LbSD Assessment items evaluates whether or not teacher-candidates can recognize when a teacher denies her students fair access to a high-quality learning opportunity.

"Ms. Chambers' plan does not promote [fairness] in the classroom. To ensure that students are growing and learning, we must provide students with the right to-be-remembered information and the opportunity to deeply process that information. All students in the class should be given this opportunity, not just a few."

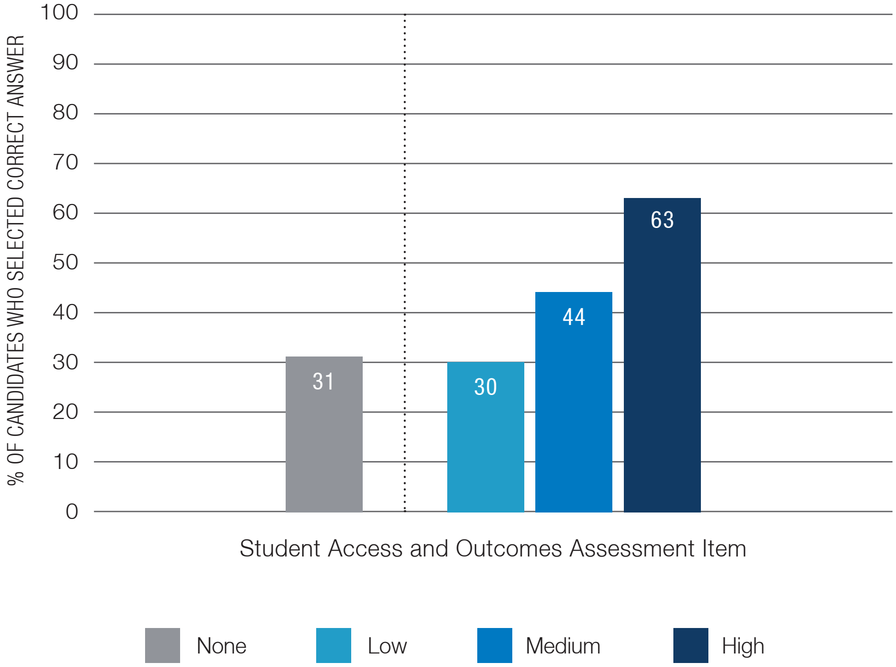
Received LbSD support

- **"The teacher should not use Ms. Chambers' materials, because they show a deficit mindset toward the students. They deny the students the opportunity to think deeply about the topic and instead replace it with memorization and activities that distract from the important information."**
- **Ms. Chambers' plan does not promote [fairness] in the classroom. To ensure that students are growing and learning, we must provide students with the right to-be-remembered information and the opportunity to deeply process that information. All students in the class should be given this opportunity, not just a few."**
- **"Ms. Chambers is not challenging her students and is reducing her expectations of them. Even though her class may struggle with reading, it does not entitle her to expect less of them and dumb down her instruction."**

Did not receive LbSD support

- **"I think this helps students understand and master the topic. Also, students come from different backgrounds and some cultures are better at open-ended questions."**
- **"Yes, because it makes sure that the students are listening because they need to fill in the blanks."**
- **"Because it is an easy hands-on activity that they can do as groups to help learn in a different setting than they are used to."**

Assessing for access in practice



This chart shows how teacher-candidates responded to the question on the LbSD Assessment described on the previous page about creating rigorous and affirming learning environments. 32% more candidates who received sustained instruction on learning-science principles selected the correct answer than peers who received no such opportunities. This data indicates that these future teachers are more likely to provide instruction that provides all students with access to high-quality learning.

Chanua Ross

> **"Focusing on Deepening Meaning and Learning gives us the tools to develop our teachers so that all students have a quality teacher who can prepare them to think critically about the content that they're learning."**
>
> ***– Chanua Ross,***
>
> *Senior Program Producer, Department of Professional Learning & Innovation, University of Missouri—St. Louis*

"After intentionally honing in on the deepening meaning and learning principle, we've seen that candidates are looking at standards differently. They're looking at standards to find the most important to-be-remembered content to learn, and then asking, *'How do I then think about the questions I'm going to ask my learners?'*" said Dr. Natalie Bolton, Associate Professor at the University of Missouri—St. Louis. "We're seeing really exciting changes in such a short amount of time. We can see learning science has transformed their teaching vocabulary and their teaching practice."

This kind of thinking is not the only work that teacher-candidates need to do to ensure all students access rigorous and affirming learning experiences. But it is an essential part of the equation—so that from the outset of their careers in the classroom, new teachers understand that both their lesson plans, and the way those lessons are delivered, are critical in meaningfully reaching and engaging every student.

CASE STUDY:
Alignment in Louisiana educator preparation

What does science tell us is the most effective way for people to learn?

That's the question that drove the Louisiana Resource Center for Educators (LRCE)—one of the state's oldest and largest teacher-preparation programs—to join the Learning by Scientific Design (LbSD) Network in 2019. The network is a collaborative of 10 educator-preparation programs working to help future teachers understand that question and its implications for instruction.

"It's tempting when you first engage with the learning science framework to say, 'Oh that's just good teaching, that's what we do,'" Executive Director Kyle Finke said. "But it's worth a pause to really think deeply about how what you're doing might be different, and the value of everybody approaching what they're doing in the exact same way."

In the pause that the LbSD Network provided, the team discovered that they had some work to do to create greater alignment between curriculum, instruction, and coaching. As they began to share the language of learning science, a framework emerged through which to harmonize various aspects of their program.

First, instead of having multiple adjuncts write disparate bits of curriculum, the team centralized writing responsibilities with Adam Gordon, Director of Training and Instruction, which allowed him to align and scaffold the presentation of learning science principles within coursework.

"Deans for Impact has transformed how we approach course design. Not only does our coursework focus on teaching learning science principles; we now design our courses with learning science principles in mind so we can prompt our practitioners to effortfully think and ensure learning sticks," Gordon said. "We now have a framework for both how to design courses and the content of courses. This has led to greater congruence within the coursework we have, and allows practitioners to connect the dots."

Second, the team implemented a new model for coaching, in which the course instructor also serves as the coach for teacher-candidates. These faculty received robust training on learning science and a new coaching observation rubric to help them observe and uplift the principles in practice.

"It's been really exciting to see where our practitioners are landing with their instruction," said Teryn Bryant, Director of Training and Instruction. "This shift is helping us to improve the congruence of our coaching and our instruction."

And they're already seeing results. Teacher-candidates demonstrated 17% higher proficiency in their understanding of cognitive science principles after a year of redesign work.

Helping candidates understand Deepening Meaning and Learning

The LRCE team focused their work around the principle of Deepening Meaning and Learning: the idea that teachers should prompt deep thinking in students in order to help them better remember new information.

"We want students in Louisiana to encode knowledge into their long-term memory and to retrieve that information for years to come. Learning requires students to effortfully think. Promoting effortful thinking is one of the hardest skills for novice teachers to implement in the classroom. Through DFI, we have been able to develop a framework to enable us to emphasize effortful thinking and make a difference in the lives of students," Gordon said.

When LRCE joined the network, they assessed their teacher-candidates' understanding of learning science using DFI's LbSD Assessment. Items on the assessment evaluate whether future teachers understand the principles of learning science and how to apply them in practice. Initially, only 53% of teacher-candidates correctly identified what it looks like to deepen meaning and learning. After the redesign, this increased to 75%[3] able to correctly identify this principle in practice.

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[3] Data is taken from teacher-candidates who received high intervention, meaning that they participated in all of LRCE's redesigned coursework.

Along with the quantitative data that show significant increases in candidates' understanding, the qualitative data demonstrate their fluency in using the common language of learning science to justify their instructional decision-making.

For example, on one of the assessment items that measures candidates' understanding of how to direct students' attention to meaning, 88% of candidates selected the correct answer after intervention, compared to just 35% before. In addition to this impressive 53 percentage point increase, their rationale in open-ended responses reveals a sophisticated understanding of the principle:

> ***"Not only are there more opportunities for practice in [the option I selected], the to-be-remembered information is the bigger focus. This option requires students to think about multiplication problems in multiple ways so they have deeper processing than simply recall."***

On another assessment item that measured candidates' ability to understand how to use examples and non-examples, 74% of candidates could identify a teacher doing this successfully, compared to just 39% before. Responses prior to the program redesign betray deficit thinking about students:

> ***"My students are more visual and would comprehend and enjoy puzzles rather than written instructions as most of our students' reading level isn't where it should be before they get into middle school or high school."***

But after the redesign, candidates demonstrated high expectations for their students:

> ***"The rigor of the learning activity is much, much higher in [the option I selected] and puts the cognitive effort on the student to process and analyze."***

This is one way in which candidates began to more deeply understand how learning science is intertwined with fair outcomes for children. After redesign, approximately two-thirds of candidates could identify how a teacher might deny students access to a rigorous and affirming learning environment in her classroom.

"When we attend to effective learning science, then we tend to teach in the most [fair] way possible," Finke explained. "We often see a link between how a candidate is utilizing some of these fundamental skills of learning science and high expectations for their student population…asking 'How do we approach, with very little bias, how we deliver instruction to a wide variety of students in our classroom?'"

Building a statewide movement around learning science

As the team celebrates their early wins, they're continuing to iterate and improve upon their approach. Ultimately, they hope to create a systemic change within Louisiana's schools by better equipping novice teachers with a research-based understanding of learning.

"One of the reasons why learning science is so important is that it authenticates our profession as a whole," Bryant said. "In education, we're always trying to fight to show why our work is important. In a state such as Louisiana, where we have struggled being 50 out of 50, and struggled to figure out how to elevate our education system, I think that we're on a really good pathway with this."

As they've created greater coherence within the program using the learning science framework, teacher-candidates have benefited. "Teachers coming through the program definitely feel a higher level of coherence now. Things make a lot more sense at every point along the arc of their training and development when we're able to center on a common understanding of what it looks like to deliver high-quality teacher instruction," Finke said.

They hope to extend that common understanding into every school in Louisiana. The team collaborates with master teachers working in the state to provide coaching to their teacher-candidates, and they see this professional development as another avenue to broaden the conversation within education about learning science.

"We've been able to provide professional development and training to some of the best teachers in the state on what this is," Bryant said. "We're training over 200 teachers a year on learning science in Louisiana. We're hoping this can help change the landscape of how we're teaching teachers to teach kids to think."

CASE STUDY:
Fighting folk pedagogies with science at UNC Charlotte

Imagine you're observing a third-grade classroom. The teacher has just finished a multiplication lesson, and is walking down the rows of desks, passing out a little handful of Cheerios to each student.

"Okay," the teacher says as she walks to the front of the room. "We are going to use Cheerios to show multiplication. I want you to glue the cereal onto the paper, creating four rows with five Cheerios each." She wants the students to understand that multiplication can be used to find the total number of items in a collection of equally sized groups or rows.

Papers rustle and the sound of crunching fills the air as students munch on their cereal. You think back to the classroom you just visited, on the other side of town, where students completed a lesson focused on the same objective. In that classroom, students were provided a series of multiplication expressions, and then asked to generate other mathematical representations, including diagrams and story problems, for each.

In one classroom, students were thinking deeply about the concept of multiplication, and making an effort to process through the new information. In another classroom, students were chomping and gluing.

So what makes a teacher pick the critical-thinking problems over the Cheerios? We believe educator-preparation plays a vital role. And we are seeing that firsthand at UNC Charlotte's Cato College of Education.

At UNC Charlotte, 100% of teacher-candidates who experienced two semesters of coursework that explained the science of learning identified the correct answer: the math problems where students were asked to generate multiple representations. Only 42% of teachers in a control group did. In their explanations of why, candidates in the control group cited mythology such as the idea that people learn best by doing:

> *"Hands-on activities are more likely to be remembered."*

In contrast, the first group's responses revealed a deep understanding of the scientific basis for learning new information:

> *"I choose the activity that will allow students to focus on to-be-remembered information. Since students will focus on this to-be-remembered information, it will encode into their long-term memory."*

"Results from data we have collected show big improvements in candidates' ability to differentiate between 'hands-on' activities—that at face value look really appealing, fun, and engaging versus 'minds-on' activities—activities that align with standards and help students learn," said Dr. Sandy Rogelberg, Research Assistant Professor at UNC Charlotte. And candidates are not just making the right decisions—they're articulating complex reasoning for why.

"We found that the candidates who have engaged in the learning science coursework—compared to our control group—were much more articulate in their rationale for why they were making the instructional decisions they made. They were using the language and approach of the information processing model in their thinking," Associate Dean Dr. Paul Fitchett said.

Modeling to help candidates learn—and unlearn

These differences in thinking are the direct result of participating in the LbSD Network. For the last two years, UNC Charlotte faculty members Dr. Rogelberg and Dr. Hilary Dack have redesigned three courses: a foundational educational psychology class in the elementary education program, and two courses that comprise the foundational methods block of the middle grades education program.

"I find that candidates are very surprised when they learn about learning science, not only because they haven't learned about it before and are surprised they haven't, but because so much of the teaching practices that we talk about in our course that align with learning science are not necessarily prevalent in the K-12 classrooms that they experienced as learners," Dack said. "They are often surprised by the degree to which choices made by teachers are not actually aligned with what we now know is the way that people learn."

That was the case for teacher-candidate **Emilee Strohl**, who entered the program believing in the common neuromyth of learning styles, having had the mythology passed down to her by a teacher years prior.

"I used to believe in learning styles. I learned that from a teacher who made us do a test to determine if we were kinesthetic, auditory, or visual learners," Strohl said. "My approach to instruction has changed a lot since I entered the program."

Situations like this present an opportunity and a challenge. "If candidates are not coming into my class with a bank of images of what this looks like in practice, then my job is to help them build as clear an image as possible of what this can look like in a middle school classroom," Dack said. For example, she utilizes "teaching time-outs," where she stops class to explain what she did and why, or what she could have done differently to better align with learning science.

"I'm constantly looking at my own practice to see if it aligns to learning science. Every aspect within my control aligns to what I am teaching candidates," Dack said.

In Rogelberg's classes, candidates have opportunities to rehearse using learning science, which helps them get the hang of a new approach that may not be intuitive. During classes about using effortful-thinking questions, teacher-candidates first practiced writing the questions into lesson plans, **then they collaborated with peers to enact asking the questions** during instruction in a mock classroom setting.

"Participating in the LbSD Network provided a bridge from theory to practice," Rogelberg said. "Now, I'm better able to directly link theory to the nitty-gritty of the practice of teaching. In class, candidates develop teaching skills as the skills relate to theory, which is a powerful combination that will help them remember why they are doing what they do."

These moments train the future teachers to think metacognitively about their own practice, and the data is clear that the redesign is working. By the end of one semester, nearly 30 percent more teacher-candidates in Rogelberg's course could correctly identify student/teacher dialogue that prompted effortful thinking. On an LbSD Assessment question that probed students' understanding of using examples and non-examples, 89% of candidates who received high intervention identified the teacher action correctly, compared to just 64% in the comparison group.

"Rather than just falling back on anecdotes from their own experience or this pervasive folkish way of thinking about teaching, our teacher-candidates are moving to something more complex and scientific," Fitchett said. "They're privileging the scientific nature of teaching—that it's complex, not just passing down an idea from one teacher to the next."

Providing all students access to high-quality Instruction

These changes have real implications for students, as the professors often remind their teacher-candidates.

"The major destination for candidate learning is always the outcomes we're trying to achieve for K-12 learners—that's the driving force behind everything," Dr. Dack explained. "We frame all of our teaching with candidates around that. We ask them to imagine that they're a middle school student or pull in an example of a learner they've worked with. We want them to think about how their instructional decisions will make an impact on real kids that they're responsible for teaching."

Think back to the classrooms working with math problems versus Cheerios. While it may seem like a small moment, these instructional decisions—and opportunities to think deeply or shallowly—accumulate over the course of a child's educational career, laying groundwork that makes it easier or more difficult for them to learn later on.

"What is implicit to the LbSD content is the importance of developing critical thinking skills in all students—so that all students are college ready," Rogelberg said.

TECHNICAL APPENDIX

ASSESSMENT BACKGROUND

The Learning by Scientific Design Assessment

The LbSD Network supports programs in preparing novice teachers with a deep understanding of learning science principles, and the ability to apply that knowledge when teaching. This report summarizes data from the six programs involved in the first two years of the network. In order to benchmark progress, each of the participating institutions administered the 30-minute online Learning by Scientific Design Assessment at multiple time points. The assessment's three domains are designed to show a candidate's skills and knowledge of learning science principles both theoretically and practically, as well as candidate beliefs about the importance of those principles (see table below for assessment structure and scoring information).

ASSESSMENT OVERVIEW

Domain / Principles	Scoring
DOMAIN 1: Understanding learning science principles *Can you describe core learning science principles and explain how/why they work?*	**13 items**
DOMAIN 2: Identifying, understanding, and evaluating learning science principles in practice *Can you identify exemplary practice, explain why it is exemplary (how it supports students' learning), and distinguish between gradations of practice?*	**46 items**
▸ Learning can be impeded if students are confronted with too much information at once.	9 items
▸ Students learn new ideas by reference to ideas they already know.	3 items
▸ Students should think about meaning when they encounter to-be-remembered material.	8 items + 3 open-ended
▸ Practice is essential to learning new facts, but not all practice is equivalent.	10 items
▸ Effective feedback is essential to acquiring new knowledge and skills.	8 items
▸ Students will be motivated to learn in environments where they feel valued.	5 items
▸ Ensuring all students access high-quality learning opportunities	1 item + 1 open-ended
DOMAIN 3: Beliefs about learning science principles *Do you believe you can and should enact learning science principles in your work with students? Do you feel this is worth prioritizing?*	**11 items**

* Each domain and subscale score represent the percentage of items correct out of the total number of items on that scale (e.g., 9 correct out of 10 items = 0.90).

The assessment was first developed in the summer of 2019. (A detailed explanation of the piloting of the assessment in fall of 2019 is available **here**.) After the pilot, we performed a series of analyses to examine validity evidence. This included exploratory factor analysis to examine its structure and, to test whether items over-privileged respondents from particular backgrounds, differential item functioning (DIF) analyses for each item by race and gender. The results from our exploratory factor analysis suggested that Domains 1 and 2 each function as individual scales as hypothesized. They also indicated that Domain 3 items could be broken into two scales—beliefs about instruction and beliefs about learning. The results of our DIF analyses showed one item in Domain 2 appeared to be over-privileging white respondents. We replaced it with a new item that we piloted through a series of cognitive interviews with teachers and teacher-candidates. This revised assessment was used in Spring 2020 and Spring 2021.

Administration and Sample

Programs benchmarked progress using a cross-sectional design. The first administration occurred in the spring of 2020, pre-implementation. One year later, after embedding learning opportunities aligned to the network's learning science principles in coursework and clinical experiences, programs administered the assessment to a new cohort of candidates. Because we asked institutions to assess all currently enrolled teacher-education candidates at each timepoint, this cohort included candidates who were enrolled in coursework and clinical experiences where implementation occurred and candidates who were not.[1] For example, if an EPP focused their redesign on the middle grades program, we also assessed candidates in the elementary and secondary programs as a robustness check. We call these three groups Spring '20 Pre-Implementation, Spring '21 Implementation, Spring '21 No Implementation. The hypotheses underlying this approach are as follows:

- There should be no significant differences in the scores of candidates in the Spring '20 Pre-Implementation group and candidates in the Spring '21 No Implementation group, given that both groups received no implementation.
- If our improvement effort was successful, candidates who received implementation should score significantly higher than their counterparts in the Spring '20 Pre-Implementation group and candidates in the Spring '21 No Implementation group.

Due to the effects of COVID-19, the dosage of implementation varied within and across programs. To account for this in our analyses, we broke the Spring '21 Implementation group into dosage groups according to the following criteria:

- **High:** At least four teacher actions (all three Deepening Meaning and Learning teacher actions plus one or more additional teacher actions) and multiple pedagogies[2] for each Deepening Meaning and Learning teacher action
- **Medium:** Multiple pedagogies for at least two Deepening Meaning and Learning teacher actions
- **Low:** Multiple pedagogies for one Deepening Meaning and Learning teacher action OR only one pedagogy for multiple Deepening Meaning and Learning teacher actions

We coded these dosage groups at the candidate level based on course enrollment. Three of the institutions included data from multiple dosage groups (e.g., in a single program, some candidates experienced medium dosage while others received sustained dosage because of the particular courses they were enrolled in). The High category included candidates from two institutions, the Medium category included candidates from five institutions, and the Low category included candidates from two institutions. The number of candidates in each dosage group is listed in the Spring 2021 column of the table on the next page.

[1] Administration varied within and across programs. In some cases taking the assessment was voluntary; in others it was a course assignment.

[2] Pedagogies refer to four primary ways we develop teacher-candidates' knowledge and practice related to each teacher action: Understand (introduction to learning science principle and teacher action); Analyze (opportunities to analyze instructional vignettes or video through lens of the teacher action); Modify (opportunities to modify instructional tasks or lesson plans through lens of the teacher action); Rehearse (opportunities to rehearse lesson segments focusing on the successful enactment of a teacher action).

LEARNING BY SCIENTIFIC DESIGN NETWORK

Spring 2020 - 2021 Sample

SAMPLE DEMOGRAPHICS	Spring 2020		Spring 2021	
	Reported Sample	Freq.	Reported Sample	Freq.
EPP	750		785	
American University		70		91
Endicott College		43		66
Louisiana Resource Center for Educators		124		109
Temple University		101		79
University of Missouri-St. Louis		321		262
UNC Charlotte		91		178
Network-Level Dosage Group	750		781	
None		750		300
Low				249
Medium				131
High				101
Program Pathway	700		776	
Alternative certificate-only		147		143
Alternative degree-granting		49		46
Traditional certificate-only		12		47
Traditional degree-granting		492		540
Online/In-person	694		776	
In-person		579		507
Online		115		269
Transfer Status	687		779	
Non-transfer student		378		467
Transfer student		309		312
Grade Level	706		778	
Early childhood		181		113
Elementary		248		287
Middle		68		51
Other		79		183
Secondary		130		144
Race/Ethnicity	750		785	
Asian		13		20
Black/African American		100		92
Hispanic/Latino		19		26
Race not specified		100		84
Other		46		22
Two or more races		28		17
White		444		524
Gender	687		780	
Female		559		658
Male		128		122
Total number of teacher-candidates:	750 (Spring 2020)		785 (Spring 2021)	

ASSESSMENT RESULTS

In the report, we only included data from the Spring 2021 administration of the assessment. In this technical appendix, we present data from the Spring 2020 and Spring 2021 administrations, broken out by dosage group.

Principles in Practice Scores by Dosage Group

The graph below shows the raw averages, broken out by dosage group, for the six principles in practice assessed in Domain 2 of the assessment.

Principles in Practice Averages by Dosage Groups

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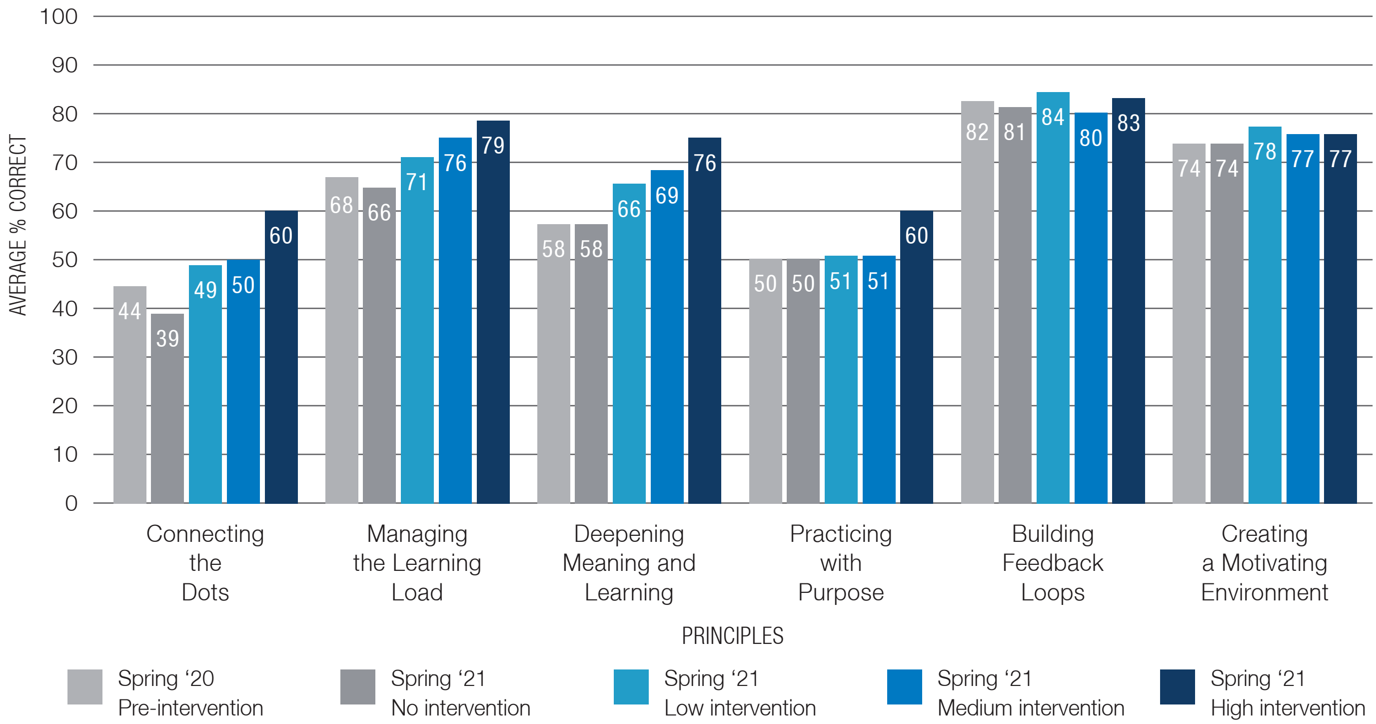

While all programs focused on Deepening Meaning and Learning, three programs took on additional principles and teacher actions. Three took on Managing the Learning Load, two took on Connecting the Dots, and one took on Practicing with Purpose. The data shows that where programs focused, they saw the most growth. It also shows that the more implementation candidates received, the higher they scored.

Results from our regression analysis, designed to test whether these results for Deepening Meaning and Learning held when we controlled for a vector of program and candidate characteristics, are shown below.[3] Note that even though we included a subset of data in the report, the results hold in the full dataset and our hypotheses were met. Holding program and candidate characteristics constant, there were no significant differences between the scores of candidates in the Spring '20 Pre-Implementation and Spring '21 No Implementation groups. Candidates in the Low, Medium, and High implementation groups all scored significantly higher *($p < 0.001$)* than candidates in the Spring '20 Pre-Implementation group.

[3] In this and all subsequent analyses we dropped program fixed effects because of collinearity with other variables. This did not change our findings. For example, in this model, point estimates remained the same and the r-squared value changed by only 0.003 when fixed effects were excluded from the model.

Principles in Practice Results

Spring 2020 and Spring 2021 Comparisons

	Learning Load	Connect	Meaning	Practice	Feedback	Motivation
Spring '21 No implementation	−0.68 (1.22)	−4.83** (2.26)	−0.86 (1.57)	0.69 (1.13)	−2.19 (1.48)	0.11 (1.55)
Spring '21 Low dosage group	5.01*** (1.30)	6.00** (2.37)	6.02*** (1.68)	0.91 (1.22)	−0.15 (1.41)	6.17*** (1.53)
Spring '21 Medium dosage group	7.58*** (1.58)	5.37* (3.08)	8.86*** (2.29)	1.22 (1.60)	−3.18* (1.89)	3.94** (1.87)
Spring '21 High dosage group	9.35*** (1.73)	14.12*** (3.30)	16.17*** (2.30)	9.46*** (1.82)	−0.66 (1.92)	5.44** (2.21)
Program pathway: Alternative certificate-only	4.32*** (1.25)	2.77 (2.75)	−3.92** (1.80)	−3.25** (1.35)	−0.15 (1.54)	−0.26 (1.63)
Program pathway: Alternative degree-granting	0.62 (1.94)	7.82** (3.58)	−1.39 (2.31)	1.76 (1.88)	0.75 (2.18)	−0.41 (2.28)
Program pathway: Traditional certificate-only	0.53 (2.44)	3.24 (4.90)	−0.40 (3.20)	−4.06 (2.55)	−0.68 (3.04)	4.26 (2.99)
Online	1.56 (1.30)	1.67 (2.49)	5.20*** (1.72)	1.14 (1.29)	3.83** (1.51)	−3.67** (1.60)
Transfer student	0.21 (1.05)	−1.76 (1.99)	−1.18 (1.34)	0.31 (0.99)	−1.38 (1.21)	−2.62** (1.28)
Early childhood	−1.29 (1.41)	−8.76*** (2.83)	−4.69** (1.94)	−4.30*** (1.37)	−1.95 (1.66)	−2.24 (1.84)
Elementary	−0.95 (1.21)	−5.56** (2.44)	−2.54 (1.63)	−1.58 (1.19)	−2.06 (1.45)	0.78 (1.52)
Middle school	−2.08 (1.59)	1.30 (3.48)	−1.68 (2.25)	2.99* (1.77)	−0.43 (1.87)	0.82 (2.08)
Other grade level	−3.51** (1.48)	−4.96* (2.87)	−5.44*** (1.85)	−2.10 (1.39)	−0.52 (1.72)	−0.20 (1.76)
Asian	−0.57 (2.26)	−1.69 (5.98)	2.67 (3.75)	5.96** (2.69)	−5.44 (3.89)	1.60 (3.36)
Black/African American	−5.21*** (1.30)	−6.75*** (2.50)	−7.71*** (1.76)	−0.56 (1.23)	−6.97*** (1.59)	−2.31 (1.65)
Hispanic/Latino	−5.57** (2.37)	−1.86 (4.67)	−0.04 (3.14)	0.71 (2.26)	−3.55 (2.61)	−0.41 (2.54)
Race not specified	−2.97 (1.94)	−6.78** (3.33)	−1.87 (2.43)	−4.30** (1.95)	1.87 (2.39)	−2.80 (2.26)
Other race	3.13 (1.95)	4.94 (4.14)	0.17 (3.08)	2.34 (2.07)	0.22 (2.29)	1.03 (3.19)
Two or more races	1.55 (2.39)	6.16 (4.10)	0.74 (2.69)	−1.52 (2.15)	−1.41 (2.86)	1.37 (3.26)
Male	−1.82 (1.22)	2.93 (2.25)	0.87 (1.45)	−0.70 (1.13)	−2.77** (1.34)	−3.66** (1.50)
Constant	68.49*** (1.32)	47.97*** (2.81)	62.60*** (1.86)	51.95*** (1.32)	85.13*** (1.72)	75.95*** (1.77)
Observations	1,385	1,375	1,360	1,355	1,353	1,369
R-squared	0.10	0.07	0.10	0.06	0.04	0.03

*** p<0.01, ** p<0.05, * p<0.1.
Robust standard errors in parentheses. Reference groups: Network-level dosage groups = Spring 2020; Program pathway = traditional degree-granting; Online/In-person = in-person; Transfer status = non-transfer student; Grade level planning to teach = secondary education; Race = White; Gender = female.

Results from the Deepening Meaning and Learning Items

Results from our logistic regression analysis, designed to test differences in the likelihood of selecting the correct answer choice for each individual item under the Deepening Meaning and Learning principle, are shown below. Results for the Attention to Meaning and Examples and Non-Examples items were similar to those in previous analyses. When we controlled for a vector of program and candidate characteristics, there were no significant differences in the likelihood of answering the items correctly between the Spring '20 Pre-Implementation and Spring '21 No Implementation groups. Candidates in the Low, Medium, and High implementation groups all were significantly more likely to answer correctly *($p < 0.001$)* than candidates in the Spring '20 pre-implementation group. The Effortful Thinking item included six answer choices and asked candidates to "select all that apply." These results show the likelihood of not selecting an incorrect answer (choices A, C, D, and E) and of selecting a correct answer (choices B and F). There was more variability in the effortful thinking responses. For example, the Spring '21 No Implementation cohort was significantly less likely *($p < 0.001$)* to answer correctly for answer choices B and C than their counterparts in the Spring '20 Pre-Implementation group.[4]

Deepening Meaning and Learning Item-Level Results

Spring 2020 and Spring 2021 Comparisons

Likelihood of answering each item correctly (coefficients presented as odds ratios)

	Effortful Thinking A	Effortful Thinking B	Effortful Thinking C	Effortful Thinking D	Effortful Thinking E	Effortful Thinking F	Attention to Meaning	Examples & Non-Examples
Spring '21 No implementation	1.08 (0.19)	0.61*** (0.10)	0.64*** (0.10)	0.73* (0.12)	0.68* (0.14)	3.16*** (0.52)	0.91 (0.15)	0.96 (0.15)
Spring '21 Low dosage group	1.12 (0.22)	0.78 (0.13)	0.67** (0.11)	0.71* (0.13)	0.76 (0.17)	4.68*** (0.83)	2.86*** (0.51)	1.75*** (0.31)
Spring '21 Medium dosage group	1.11 (0.27)	0.67* (0.14)	1.09 (0.23)	0.75 (0.17)	1.35 (0.44)	4.99*** (1.12)	3.01*** (0.67)	1.85*** (0.42)
Spring '21 High dosage group	2.74*** (0.92)	0.91 (0.23)	1.36 (0.33)	0.80 (0.20)	1.02 (0.35)	4.96*** (1.28)	12.12*** (4.11)	3.22*** (0.90)
Program pathway: Alternative certificate-only	0.63** (0.13)	1.70*** (0.34)	0.59*** (0.11)	0.83 (0.16)	0.69 (0.17)	1.23 (0.24)	0.65** (0.13)	0.80 (0.16)
Program pathway: Alternative degree-granting	0.76 (0.21)	1.16 (0.29)	0.86 (0.21)	0.76 (0.20)	1.82 (0.70)	0.94 (0.24)	0.87 (0.22)	1.04 (0.26)
Program pathway: Traditional certificate-only	0.52* (0.19)	1.10 (0.37)	0.61 (0.20)	1.02 (0.38)	1.53 (0.78)	1.80* (0.63)	1.30 (0.45)	0.85 (0.29)

[4] Odds ratios less than one indicate the group is less likely than the reference group to answer the question correctly. Odds ratios greater than one indicate the group is more likely than the reference group to answer the question correctly.

	Effortful Thinking A	Effortful Thinking B	Effortful Thinking C	Effortful Thinking D	Effortful Thinking E	Effortful Thinking F	Attention to Meaning	Examples & Non-Examples
Online	1.50** (0.31)	0.84 (0.15)	1.39* (0.25)	2.05*** (0.39)	2.07*** (0.54)	0.74 (0.14)	1.11 (0.21)	1.62*** (0.30)
Transfer student	1.07 (0.17)	0.96 (0.13)	1.00 (0.14)	1.35** (0.19)	1.48** (0.27)	0.64*** (0.09)	0.61*** (0.09)	1.06 (0.15)
Early childhood	0.65** (0.14)	1.12 (0.22)	0.84 (0.16)	0.67** (0.14)	0.70 (0.18)	1.12 (0.23)	0.72 (0.15)	0.69* (0.14)
Elementary	0.88 (0.17)	1.42** (0.24)	0.91 (0.15)	0.80 (0.14)	0.78 (0.18)	1.07 (0.19)	0.59*** (0.10)	0.85 (0.15)
Middle school	0.94 (0.26)	0.91 (0.22)	1.18 (0.27)	0.68 (0.17)	1.07 (0.36)	1.01 (0.25)	0.75 (0.19)	1.06 (0.26)
Other grade level	0.90 (0.20)	0.90 (0.18)	1.10 (0.21)	0.53*** (0.11)	0.68 (0.18)	0.81 (0.17)	0.61** (0.12)	0.79 (0.16)
Asian	1.01 (0.45)	2.00 (0.85)	1.23 (0.47)	1.22 (0.49)	3.38 (2.52)	1.09 (0.44)	1.06 (0.43)	0.72 (0.29)
Black/African American	0.51*** (0.09)	0.84 (0.15)	0.92 (0.16)	0.63*** (0.11)	0.77 (0.17)	1.09 (0.20)	0.65** (0.12)	0.51*** (0.09)
Hispanic/Latino	0.80 (0.28)	1.09 (0.35)	1.06 (0.33)	1.51 (0.55)	0.83 (0.34)	0.52* (0.18)	1.42 (0.48)	0.87 (0.28)
Race not specified	1.13 (0.34)	1.39 (0.36)	1.33 (0.33)	1.21 (0.33)	0.80 (0.26)	1.06 (0.27)	0.37*** (0.10)	0.52** (0.13)
Other race	0.60* (0.18)	1.30 (0.40)	0.79 (0.22)	0.76 (0.22)	1.62 (0.73)	1.07 (0.32)	1.31 (0.41)	0.76 (0.24)
Two or more races	0.65 (0.22)	1.48 (0.51)	1.29 (0.41)	0.72 (0.23)	0.82 (0.34)	1.14 (0.38)	1.22 (0.39)	0.94 (0.31)
Male	0.84 (0.15)	1.06 (0.17)	1.38** (0.21)	1.01 (0.16)	1.54* (0.36)	0.88 (0.14)	0.86 (0.14)	1.10 (0.18)
Constant	3.72*** (0.81)	1.63** (0.31)	1.15 (0.22)	2.50*** (0.50)	5.17*** (1.36)	0.57*** (0.11)	1.34 (0.27)	1.34 (0.26)
Observations	1,410	1,410	1,410	1,410	1,410	1,410	1,370	1,361

*** p<0.01, ** p<0.05, * p<0.1.
Robust standard errors in parentheses. Note that the effortful thinking item included six answer choices and asked candidates to "select all that apply." These results show the likelihood of not selecting an incorrect answer (choices A, C, D, and E) and of selecting a correct answer (choices B and F). Reference groups: Network-level dosage groups = Spring 2020; Program pathway = traditional degree-granting; Online/In-person = in-person; Transfer status = non-transfer student; Grade level planning to teach = secondary education; Race = White; Gender = female.

In Spring 2021 we added an item to assess whether candidates could identify an instructional decision that would result in not all students being able to access high-quality learning opportunities. Results from our logistic regression analysis, designed to test differences in the likelihood of selecting the correct answer choice, are shown below. When we controlled for a vector of program and candidate characteristics, there were only significant differences in the likelihood of answering the item correctly between the Spring '21 No Implementation and Spring '21 High implementation groups (*p < 0.001*). Candidates in the low and medium groups were no more likely to answer correctly than candidates in the Spring '20 Pre-Implementation group, suggesting that sustained learning opportunities may be of particular importance to efforts focused on increasing all students' access and outcomes.

Supporting a Strong Teacher Pipeline

One of our goals at the start of the network was to ensure that implementation effectively supported all teacher candidates. To examine this, we analyzed differences in item-level responses from the Spring '21 data. Controlling for a range of candidate and program characteristics, our results indicate no significant differences in the likelihood of selecting a correct response on any of the Deepening Meaning and Learning items, except the Effortful Thinking item. This item had six answer choices and candidates were directed to "select all that apply." Candidates identified as Black/African American were significantly more likely to select Option A, one of the four incorrect answer choices. They were significantly less likely to select Option B, one of the two correct answer choices. Similarly, there were no significant differences in the scores of candidates identified as white and those identified as Hispanic/Latino

Student Access and Outcomes Item Results

Spring 2021

Likelihood of answering each item correctly (coefficients presented as odds ratios)

	Student Access
Low	1.36 (0.35)
Medium	1.61* (0.45)
High	2.97*** (0.92)
Program pathway: Alternative certificate-only	1.37 (0.53)
Program pathway: Alternative degree-granting	1.02 (0.37)
Program pathway: Traditional certificate-only	1.09 (0.52)
Online	1.15 (0.44)
Transfer student	0.57** (0.13)
Early childhood	0.70 (0.23)
Elementary	1.09 (0.27)
Middle school	1.44 (0.53)
Other grade level	1.23 (0.33)
Asian	0.67 (0.37)
Black/African American	0.73 (0.20)
Hispanic/Latino	1.21 (0.55)
Race not specified	0.44* (0.20)
Other race	1.18 (0.59)
Two or more races	2.17 (1.20)
Male	0.90 (0.21)
Constant	0.50** (0.14)
Observations	733

*** p<0.01, ** p<0.05, * p<0.1.
Robust standard errors in parentheses. Reference groups: Network-level dosage groups = no-implementation; Program pathway = traditional degree-granting; Online/In-person = in-person; Transfer status = non-transfer student; Grade level planning to teach = secondary education; Race = White; Gender = female

on any of the Deepening Meaning and Learning items except on the Effortful Thinking item. In this instance, candidates identified as Hispanic/Latino were less likely to select Option F, one of the correct answer choices. There were no significant differences in scores on any of the Deepening Meaning and Learning items between candidates identified as white and candidates identified as "other race," "Asian" or "two or more races."

Deepening Meaning and Learning Results

Likelihood of answering each item correctly (coefficients presented as odds ratios)

	Effortful Thinking A	Effortful Thinking B	Effortful Thinking C	Effortful Thinking D	Effortful Thinking E	Effortful Thinking F	Attention to Meaning	Examples & Non-Examples	Student Access
Low	1.22 (0.32)	1.34 (0.31)	1.29 (0.30)	1.07 (0.25)	1.15 (0.34)	0.98 (0.23)	2.84*** (0.69)	2.24*** (0.54)	1.36 (0.35)
Medium	1.13 (0.34)	1.24 (0.33)	1.87** (0.50)	1.02 (0.28)	1.69 (0.63)	1.33 (0.36)	3.08*** (0.86)	2.10*** (0.58)	1.61* (0.45)
High	2.43** (0.97)	1.61 (0.49)	2.15** (0.65)	0.96 (0.30)	1.20 (0.49)	1.52 (0.48)	13.09*** (5.12)	3.32*** (1.11)	2.97*** (0.92)
Program pathway: Alternative certificate-only	1.29 (0.56)	1.66 (0.62)	0.50* (0.19)	1.06 (0.40)	0.76 (0.38)	0.57 (0.22)	0.59 (0.24)	0.91 (0.36)	1.37 (0.53)
Program pathway: Alternative degree-granting	0.79 (0.31)	1.61 (0.57)	0.94 (0.32)	0.61 (0.21)	2.00 (0.97)	1.30 (0.48)	0.86 (0.31)	1.09 (0.39)	1.02 (0.37)
Program pathway: Traditional certificate-only	1.21 (0.65)	1.12 (0.51)	0.74 (0.34)	1.22 (0.58)	1.41 (0.91)	0.85 (0.40)	0.99 (0.47)	1.21 (0.57)	1.09 (0.52)
Online	0.79 (0.34)	0.97 (0.35)	1.77 (0.64)	1.57 (0.58)	2.37* (1.14)	1.39 (0.52)	1.43 (0.56)	1.65 (0.63)	1.15 (0.44)
Transfer student	0.88 (0.22)	0.98 (0.21)	0.87 (0.19)	1.02 (0.22)	1.37 (0.37)	0.86 (0.19)	0.79 (0.18)	1.05 (0.23)	0.57** (0.13)

	Effortful Thinking A	Effortful Thinking B	Effortful Thinking C	Effortful Thinking D	Effortful Thinking E	Effortful Thinking F	Attention to Meaning	Examples & Non-Examples	Student Access
Early childhood	0.76 (0.25)	1.34 (0.40)	1.01 (0.29)	0.60* (0.18)	0.72 (0.27)	0.57* (0.18)	0.36*** (0.12)	0.52** (0.16)	0.70 (0.23)
Elementary	1.35 (0.36)	1.14 (0.26)	0.72 (0.16)	0.72 (0.17)	0.92 (0.30)	0.59** (0.15)	0.45*** (0.12)	0.82 (0.20)	1.09 (0.27)
Middle school	1.41 (0.64)	0.89 (0.31)	1.50 (0.53)	1.08 (0.41)	1.23 (0.65)	0.77 (0.29)	0.55 (0.22)	1.17 (0.47)	1.44 (0.53)
Other grade level	1.16 (0.35)	0.83 (0.21)	1.30 (0.33)	0.57** (0.15)	0.61 (0.21)	0.41*** (0.11)	0.52** (0.14)	1.08 (0.29)	1.23 (0.33)
Asian	0.98 (0.54)	2.12 (1.13)	0.91 (0.44)	1.73 (0.88)	2.50 (1.92)	1.09 (0.54)	1.79 (0.92)	1.42 (0.71)	0.67 (0.37)
Black/African American	0.57** (0.16)	0.53** (0.13)	1.20 (0.30)	0.67 (0.17)	0.76 (0.25)	0.94 (0.24)	0.64 (0.18)	0.74 (0.20)	0.73 (0.20)
Hispanic/Latino	1.28 (0.67)	0.85 (0.35)	1.82 (0.77)	1.73 (0.80)	1.12 (0.64)	0.38** (0.16)	1.69 (0.76)	1.00 (0.43)	1.21 (0.55)
Race not specified	2.14 (1.11)	1.13 (0.46)	0.89 (0.36)	1.39 (0.59)	0.71 (0.36)	1.16 (0.49)	0.28*** (0.13)	0.34** (0.15)	0.44* (0.20)
Other race	0.62 (0.32)	1.28 (0.62)	2.10 (1.00)	2.58* (1.49)	3.17 (3.31)	1.17 (0.57)	1.07 (0.55)	1.26 (0.69)	1.18 (0.59)
Two or more races	0.69 (0.39)	1.16 (0.61)	1.39 (0.72)	1.01 (0.54)	0.58 (0.36)	1.14 (0.64)	1.59 (0.93)	0.71 (0.39)	2.17 (1.20)
Male	0.82 (0.20)	1.05 (0.23)	1.46* (0.32)	0.94 (0.21)	1.81* (0.61)	0.83 (0.19)	0.72 (0.17)	1.21 (0.29)	0.90 (0.21)
Constant	2.96*** (0.93)	1.04 (0.28)	0.65 (0.17)	1.99** (0.56)	3.38*** (1.19)	3.06*** (0.89)	1.47 (0.43)	1.05 (0.30)	0.50** (0.14)
Observations	755	755	755	755	755	755	740	739	733

*** p<0.01, ** p<0.05, * p<0.1.
Robust standard errors in parentheses. Reference groups: Network-level dosage groups = no-implementation; Program pathway = traditional degree-granting; Online/In-person = in-person; Transfer status = non-transfer student; Grade level planning to teach = secondary education; Race = White; Gender = female.

We also wanted to look beyond just the Spring 2021 outcome data and explore whether changes in candidates' scores from Spring 2020 to Spring 2021 were similar across different racial groups. To do this, we disaggregated the data by race and compared changes in candidate scores pre-implementation (Spring 2020) to those who received implementation (Spring 2021).[5] The figure below, which reports changes in raw averages for the Deepening Meaning and Learning principle, shows that scores for Asian, Black/African American, and Hispanic/Latino candidates in the network increased more than for candidates identified as white from pre-implementation to post-implementation.[6]

Average Deepening Meaning and Learning Scores by Race

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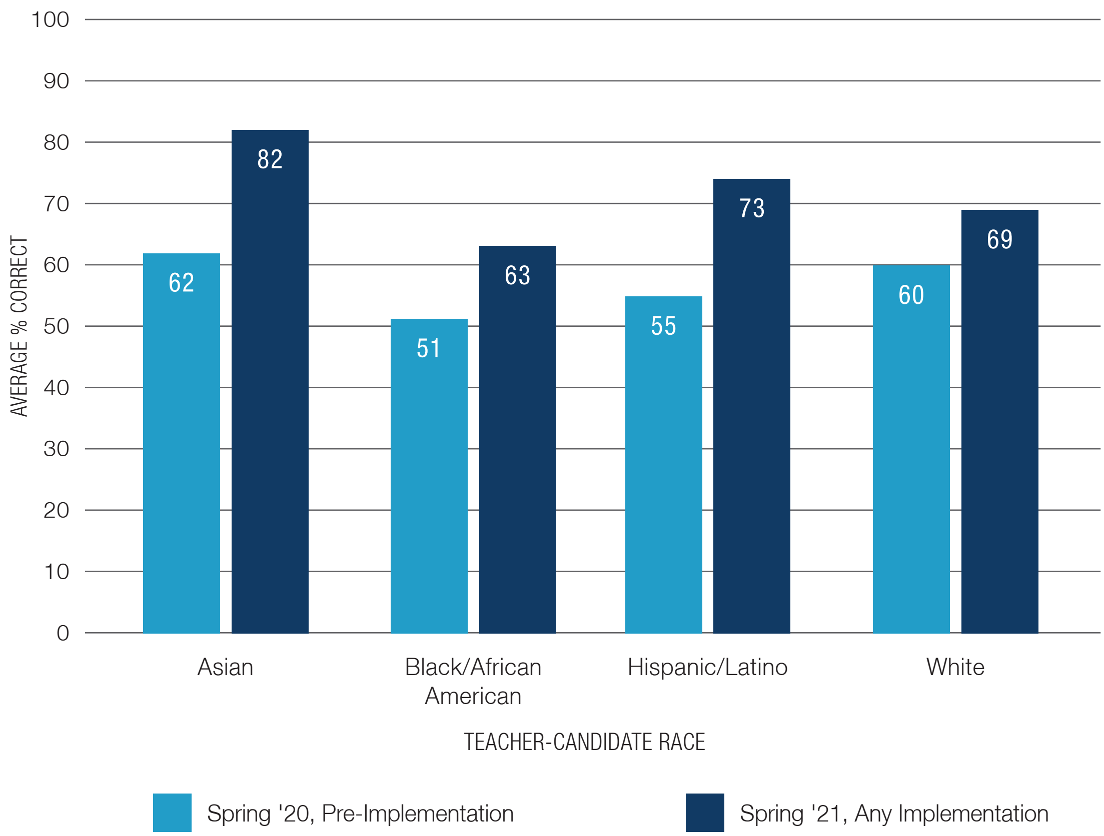

[5] When we broke results out by race and dosage group, several of the cell sizes were very small (< 5), so we collapsed the groups to Spring 2020 Pre-Implementation and Spring 2021 Any implementation (all dosage groups combined).

[6] Because of a low sample size, we do not report differences in scores for candidates who were reported as "Other" and "Two or More Races."

OBSERVATIONS OF CANDIDATE PRACTICE

To add texture to the assessment data, we also conducted teaching observations of a small sample of candidates at each institution in Spring 2020 and Spring 2021.[7] Due to the outbreak of COVID-19, this sample was smaller than originally intended—we were only able to observe between three and seven candidates at each institution at each timepoint. The observation protocol included a set of descriptive guidelines for each Deepening Meaning and Learning teacher action, with observable markers delineating the low, mid, and high range of practice.

A group of at least three program faculty and one Deans for Impact staff member observed each candidate. Prior to the observations, faculty completed an online, asynchronous observation training. During the observations, raters were asked to take notes on classroom discourse and observed behaviors. After the observations, raters were given time to individually score each observation. Then, observers came together and normed on their observation scores, debriefing until they reached consensus for each teacher action, resulting in the following data:

Deepening Meaning and Learning Observations

	Attention to Meaning		Effortful Thinking		Examples Non-Examples	
	Spring '20	*Spring '21*	*Spring '20*	*Spring '21*	*Spring '20*	*Spring '21*
High	3 (10%)	7 (30%)		2 (8%)		3 (13%)
Medium	12 (41%)	13 (57%)	5 (17%)	12 (52%)	4 (14%)	12 (52%)
Low	14 (48%)	3 (13%)	25 (83%)	9 (39%)	25 (86%)	8 (35%)

[7] Due to the outbreak of COVID-19, we were not able to observe candidates at Temple University in Spring 2020.

NOTES

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