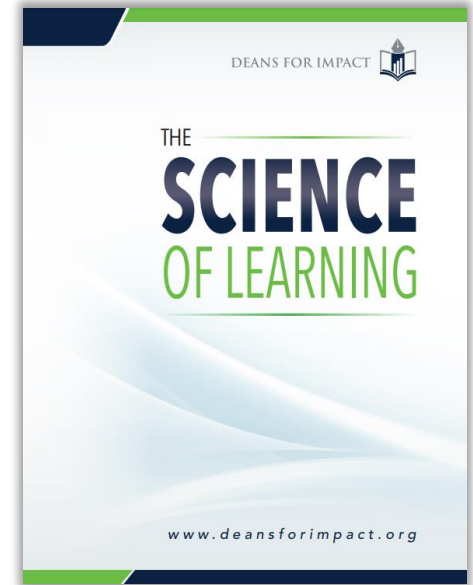


The Science of Learning – Key questions for Educators

The Catalyst teaching approach is informed by the Science of Learning, which is a summary of existing research into how best students learn developed by member deans of Deans for Impact in collaboration with Dan Willingham, a cognitive scientist at the University of Virginia, and Paul Bruno, a former middle-school science teacher.

This document identifies six key questions about learning that should be relevant to nearly every educator. Deans for Impact believes that every teacher should be able to answer the questions in The Science of Learning document, and their answers should be informed and guided by the existing scientific consensus around basic cognitive principles. Further to this, all educators should be able to connect these principles to their practical implications for the classroom.



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Deans for Impact (2015). The Science of Learning. Austin, TX: Deans for Impact.

How do students understand new ideas?



| Cognitive principles | Practical implications for the classroom |
|---|--|
| Students learn new ideas by reference to ideas they already know. | <ul style="list-style-type: none">• A well-sequenced curriculum is important to ensure that students have the prior knowledge they need to master new ideas.• Teachers use analogies because they map a new idea onto one that students already know. But analogies are effective only if teachers elaborate on them, and direct student attention to the crucial similarities between existing knowledge and what is to be learned |
| 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. | <ul style="list-style-type: none">• Teachers can use “worked examples” as one method of reducing students’ cognitive burdens. A worked example is a step-by-step demonstration of how to perform a task or solve a problem. This guidance — or “scaffolding” — can be gradually removed in subsequent problems so that students are required to complete more problem steps independently.• Teachers often use multiple modalities to convey an idea; for example, they will speak while showing a graphic. If teachers take care to ensure that the two types of information complement one another — such as showing an animation while describing it aloud — learning is enhanced. But if the two sources of information are split — such as speaking aloud with different text displayed visually — attention is divided and learning is impaired.⁶• Making content explicit through carefully paced explanation, modeling, and examples can help ensure that students are not overwhelmed.⁷ (Note: “explanation” does not mean teachers must do all the talking.) |
| Cognitive development does not progress through a fixed sequence of age-related stages. The mastery of new concepts happens in fits and starts. | <ul style="list-style-type: none">• Content should not be kept from students because it is “developmentally inappropriate.” The term implies there is a biologically inevitable course of development, and that this course is predictable by age. To answer the question “is the student ready?” it’s best to consider “has the student mastered the prerequisites?” |

How do students learn and retain new information?



| Cognitive principles | Practical implications for the classroom |
|--|--|
| Information is often withdrawn from memory just as it went in. We usually want students to remember what information means and why it is important, so they should think about meaning when they encounter to-be-remembered material. | <ul style="list-style-type: none">• Teachers can assign students tasks that require explanation (e.g., answering questions about how or why something happened) or that require students to meaningfully organize material. These tasks focus students' attention on the meaning of course content.• Teachers can help students learn to impose meaning on hard-to-remember content. Stories and mnemonics are particularly effective at helping students do this. |
| Practice is essential to learning new facts, but not all practice is equivalent. | <ul style="list-style-type: none">• Teachers can space practice over time, with content being reviewed across weeks or months, to help students remember that content over the longterm.• Teachers can explain to students that trying to remember something makes memory more long-lasting than other forms of studying. Teachers can use low- or no-stakes quizzes in class to do this, and students can use self-tests.• Teachers can interleave (i.e., alternate) practice of different types of content. For example, if students are learning four mathematical operations, it's more effective to interleave practice of different problem types, rather than practice just one type of problem, then another type of problem, and so on. |



How do students solve problems?

| Cognitive principles | Practical implications for the classroom |
|--|---|
| <p>Each subject area has some set of facts that, if committed to long-term memory, aids problem-solving by freeing working memory resources and illuminating contexts in which existing knowledge and skills can be applied. The size and content of this set varies by subject matter.</p> | <ul style="list-style-type: none"> Teachers will need to teach different sets of facts at different ages. For example, the most obvious (and most thoroughly studied) sets of facts are math facts and letter-sound pairings in early elementary grades. For math, memory is much more reliable than calculation. Math facts (e.g., $8 \times 6 = ?$) are embedded in other topics (e.g., long division). A child who stops to calculate may make an error or lose track of the larger problem.¹⁸ The advantages of learning to read by phonics are well established |
| <p>Effective feedback is often essential to acquiring new knowledge and skills.</p> | <ul style="list-style-type: none"> Good feedback is: Specific and clear; Focused on the task rather than the student; and Explanatory and focused on improvement rather than merely verifying performance. |



How does learning transfer to new situations in or outside of the classroom?

| Cognitive principles | Practical implications for the classroom |
|---|---|
| <p>The transfer of knowledge or skills to a novel problem requires both knowledge of the problem's context and a deep understanding of the problem's underlying structure.</p> | <ul style="list-style-type: none"> Teachers can ensure that students have sufficient background knowledge to appreciate the context of a problem |
| <p>We understand new ideas via examples, but it's often hard to see the unifying underlying concepts in different examples.</p> | <ul style="list-style-type: none"> Teachers can have students compare problems with different surface structures that share the same underlying structure. For example, a student may learn to calculate the area of a rectangle via an example of word problem using a table top. This student may not immediately recognize this knowledge is relevant in a word problem that asks a student to calculate the area of a soccer field. By comparing the problems, this practice helps students perceive and remember the underlying structure. For multi-step procedures, teachers can encourage students to identify and label the substeps required for solving a problem. This practice makes students more likely to recognize the underlying structure of the problem and to apply the problem-solving steps to other problems. Teachers can alternate concrete examples (e.g., word problems) and abstract representations (e.g., mathematical formulas) to help students recognize the underlying structure of problems. |



What motivates students to learn?

| Cognitive principles | Practical implications for the classroom |
|---|---|
| <p>Beliefs about intelligence are important predictors of student behavior in school</p> | <ul style="list-style-type: none"> • Teachers should know that students are more motivated if they believe that intelligence and ability can be improved through hard work. • Teachers can contribute to students' beliefs about their ability to improve their intelligence by praising productive student effort and strategies (and other processes under student control) rather than their ability. • Teachers can prompt students to feel more in control of their learning by encouraging them to set learning goals (i.e., goals for improvement) rather than performance goals (i.e. goals for competence or approval). |
| <p>Self-determined motivation (a consequence of values or pure interest) leads to better long-term outcomes than controlled motivation (a consequence of reward/ punishment or perceptions of self-worth).</p> | <ul style="list-style-type: none"> • Teachers control a number of factors related to reward or praise that influence student motivation, such as <ul style="list-style-type: none"> • Whether a task is one the student is already motivated to perform; • Whether a reward offered for a task is verbal or tangible; • Whether a reward offered for a task is expected or unexpected; • Whether praise is offered for effort, completion, or quality of performance; and whether praise or a reward occurs immediately or after a delay. |
| <p>The ability to monitor their own thinking can help students identify what they do and do not know, but people are often unable to accurately judge their own learning and understanding.</p> | <ul style="list-style-type: none"> • Teachers can engage students in tasks that will allow them to reliably monitor their own learning (e.g. testing, self-testing, and explanation). If not encouraged to use these tasks as a guide, students are likely to make judgments about their own knowledge based on how familiar their situation feels and whether they have partial — or related — information. These cues can be misleading |
| <p>Students will be more motivated and successful in academic environments when they believe that they belong and are accepted in those environments.</p> | <ul style="list-style-type: none"> • Teachers can reassure students that doubts about belonging are common and will diminish over time. • Teachers can encourage students to see critical feedback as a sign of others' beliefs that they are able to meet high standards. |

What are common misconceptions about how students think and learn?



| Cognitive principles | Practical implications for the classroom |
|--|---|
| <ul style="list-style-type: none">• Students do not have different “learning styles.”• Humans do not use only 10% of their brains• People are not preferentially “right-brained” or “left-brained” in the use of their brains• Novices and experts cannot think in all the same ways• Cognitive development does not progress via a fixed progression of age-related stages | <ul style="list-style-type: none">• Teachers should be able to recognize common misconceptions of cognitive science that relate to teaching and learning. |