Research Fact Sheet

Counter-intuitive Findings from the Science of Learning

Research in the science of learning tries to understand how students learn, by analyzing the processes of learning, in the context of learning large authentic bodies of (often complicated) knowledge, such as those taught in schools. It differs from other strands of learning-related work that directly applies robust findings to learning in a classroom learning context. By analyzing the processes of learning (such as the products students produce while learning or the dialogue and questions they pose to their peers and teachers), research in the science of learning can uncover not only a variety of phenomena about the challenges of learning, but also findings that contradict what is shown from laboratory studies. Below are several examples.

The benefit and cost of prior knowledge: Uncovering misconceptions

- *Traditional Assumption:*
  Prior knowledge is beneficial, such as in the context of research on expertise for both adults and (Chase & Simon, 1973) children (Chi, 1978), or in the context of reading comprehension (Recht & Leslie, 1988). Findings from decades of laboratory studies typically show that students with greater prior knowledge learn and remember more than students with less prior knowledge about a topic.

- *Evidence from the Science of Learning:*
  Research in the science of learning reveals that prior knowledge is often misconceived, thus preventing students from having accurate understanding of new concepts and phenomena. Four decades of research, especially in science education, show the prevalence of misconceptions about concepts in a variety of areas that stem from prior knowledge (Chi, 2013; Chi, Slotta & deLeeuw, 1994; Confrey, 1990; and see the latest volume on conceptual change by Vosniadou, 2013).

The benefit and cost of teachers providing correct explanations to students: Self-explaining

- *Traditional Assumption:*
  Teaching involves finding the best way to present correct information, perhaps requiring that the information not only be correct, but structured and sequenced in the proper order.

- *Evidence from the Science of Learning:*
  Even if learning materials are inadequate (such as not perfectly sequenced, with much missing information), students can learn, in fact even more effectively, if they try to explain the materials to themselves. Doing so allows them to infer the missing information, synthesize the presented information even if it's out-of-sequence, and so on. This has been coined the self-explanation effect (Chi, et al. 1989, 1994). Such findings mean that we can worry less about how to optimize the experts'/teachers' explanations, or how to optimize how curriculum materials are organized. Instead, we want to encourage students to explain materials to themselves, even if they explain with errors. By explaining to themselves, students are being constructive.

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The benefit of asking students to generate ideas: Being constructive

- *Traditional Assumption:*
  To facilitate better learning, teachers should help students connect ideas, principles, and examples, or text and graphical representations, by explicitly pointing out the relationships between them (Richland, Zur, & Holyoak, 2007). The idea is that teachers should do all the work in helping and scaffolding students to understand.

- *Evidence from the Science of Learning:*
  Students can learn more if they constructively connect ideas, principles, and examples, or text and graphical representations without having teachers scaffold these connections. For example, when two kinds of representations are provided (such as a text and a diagram), or when two contrasting examples are provided, students can benefit from them if they engage in integrating the text and the graphical representation themselves (Butcher, 2006; Schwartz, Chase, Oppezzo, & Chin, 2011). The more often they refer to the text and the diagrams cyclically, thus constructing and integrating the two representations themselves, the more they will learn.

The mismatch between teachers' understanding and students' understanding: Shallow vs. deep understanding

- *Traditional Assumption:*
  It is best for teachers or someone who has more expert knowledge to explain ideas and concepts to students, because we assume that such expertise is needed to correctly convey relevant knowledge.

- *Evidence from the Science of Learning:*
  Because their understanding is deep, based on either the underlying principles or structure of a domain or topic, expert teachers cannot always explain in a manner that allows students to integrate their explanations in a meaningful and helpful way. This is true because the students' understanding is shallow, based mostly on superficial surface features of a concept, problem or phenomena (Chi, Feltovich & Glaser, 1981). Thus, there is a lack of correspondence between the ideas and concepts referred to by the expert teachers and the superficial concepts and entities that students refer to in their understanding.

The benefit and cost of asking students to work together: Cooperate vs. collaborate

- *Traditional Assumption:*
  The benefit of pairing students to work together is mixed: sometimes it may enhance learning, but at other times it diminishes learning. The benefit of collaboration, when it occurs, may be due to the multiple effect of having two heads, two memories, compounding the benefit of two sets of knowledge.

- *Evidence from the Science of Learning:*
  The cooperative view of working in pairs masks the real benefit of collaborative learning for students, arising from each partner building on the contributions of the other (Chi & Menekse, 2014; Hogan, Nastasi, & Pressley, 1999; Webb, 1989). Thus, studying the processes of collaboration allows researchers in the science of learning to understand what contributes to enhanced learning from collaboration, instead of assuming that the benefit arises from each partner holding half of the knowledge needed to complete a task.

Students can engage in different forms of active learning regardless of how teachers teach: The Interactive Constructive Active Passive (ICAP) theory.

- *Traditional assumptions*
  Active learning means that students should be actively doing something in class; paying attention is adequate for learning; and lecturing is bad.

- *Evidence from the Science of Learning:*
  Active learning can actually be divided into three modes of student activities: (1) manipulating the instructional materials such as underlining a text sentence (which can be referred to as being *active*), (2) generating some new inferences by posing questions or integrating a text and a diagram (which can be referred to as being *constructive*), and (3) collaborating with a peer in a way that responds to the peer's comments (which can be referred to as being *interactive*).

  These three active modes of student learning behaviors produce different levels of learning, with the *interactive* mode having the potential of being the best. All three active modes are better for learning than the *passive* mode, which is equivalent to paying attention.

  Any mode of instruction, whether it is lecturing or showing students how to solve a problem on the whiteboard, can be salvaged if teachers make the effort to ask students to be more generative/constructive, or collaborate with a peer in a co-constructive way in which they build on each other's knowledge. It is not how teachers teach per se that limits students' learning; rather, it is what the students themselves do that can enhance or not enhance their own leaning.

  Thus, a teacher lecturing can be very productive if the student at the same time takes notes that synthesize the content of the teacher's explanation, or poses questions for the teacher. In short, for the student to be constructive or interactive with another student can contribute substantially to learning despite the fact that the teacher is merely lecturing (Chi, 2009; Chi & Wylie, 2014).

Key Takeaway

Evidence from the science of learning not only contributes to a better understanding of learning, but also challenges many traditional assumptions about how students learn, as well as what interventions might be helpful or harmful to students.

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