Evidence about Learning (Part I)

Foundations for Teaching in Higher Education

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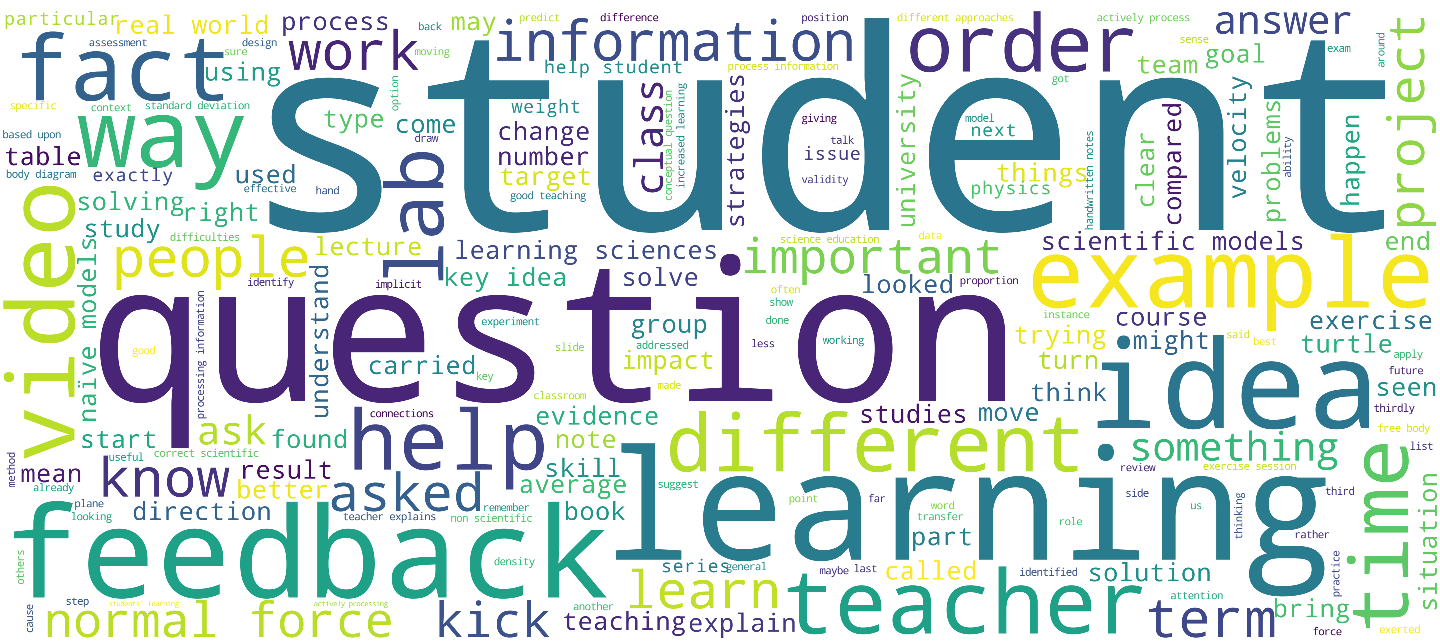

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Video

EPFL

Goals of this video

You should be able to describe what research evidence says about the role of the following things in learning:

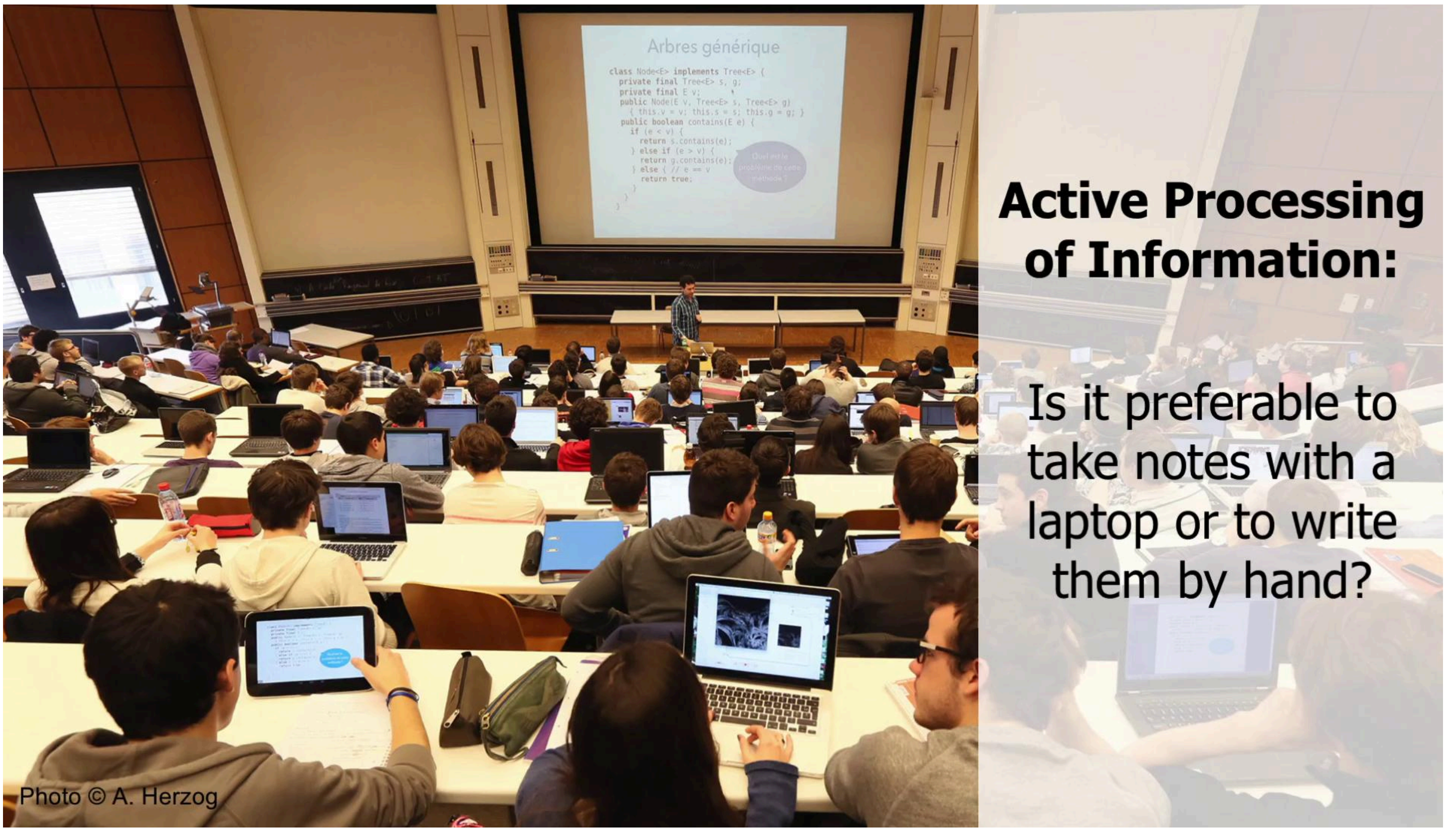
- **Active processing** of information
- Making **conections** between models and the real world
- **Feedback** about performance

What constitutes good teaching? Many people have lots of ideas as to what constitutes good teaching but how do we know? Well, the best way would be to use evidence and in this video and the next we'll cover some of the ideas which come from learning sciences, some of the evidence about learning. We’re gonna cover six ideas. Three in this video, three in the next. In doing so we'll look at various studies, which are classic studies in the learning sciences. Although we look at specific studies, in fact these represents really ideas which are well based upon a multitude of studies across the field. So the goals of this short video are to look at three key ideas. First of all, to look at this idea of active processing of information. What does that mean? The second is to look at the way in which people learn by making connections between ideas and real-world scenarios. This turns out to be particularly important in science education and a third area we will look at is feedback.

Notes

Summary

0m 05s



So the first of these three areas is this idea of active processing of information. In order to look at this, I'm going to use a particular study which was done just a few years ago. Which asked the question as to how people should take notes in class.

Notes

Summary

1m 12s

Research Article

aps
PSYCHOLOGICAL SCIENCE

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The Pen Is Mightier Than the Keyboard: Advantages of Longhand Over Laptop Note Taking

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Abstract
Taking notes on laptops rather than in longhand is increasingly common. Many researchers have suggested that laptop note taking is less effective than longhand note taking for learning. Prior studies have primarily focused on students' capacity for multitasking and distraction when using laptops. The present research suggests that even when laptops are used solely to take notes, they may still be impairing learning because their use results in shallower processing. In three studies, we found that students who took notes on laptops performed worse on conceptual questions than students who took notes longhand. We show that whereas taking more notes can be beneficial, laptop note takers' tendency to transcribe lectures verbatim rather than processing information and reframing it in their own words is detrimental to learning.

Keywords
academic achievement, cognitive processes, memory, educational psychology, open data, open materials

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The use of laptops in classrooms is controversial. Many professors believe that computers (and the Internet) serve as distractions, detracting from class discussion and student learning (e.g., Yamamoto, 2007). Conversely, students often self-report a belief that laptops in class are beneficial (e.g., Barak, Lipson, & Lerman, 2006; Mitra & Steffensmeier, 2000; Skolnick & Puzo, 2008). Even when students admit that laptops are a distraction, they believe the benefits outweigh the costs (Kay & Lauricella, 2011). Empirical research tends to support the professors' view, finding that students using laptops are not on task during lectures (Kay & Lauricella, 2011; Kraushaar & Novak, 2010; Skolnick & Puzo, 2008; Sovern, 2013), show decreased academic performance (Fried, 2008; Grace-Martin & Gay, 2001; Kraushaar & Novak, 2010), and are actually less satisfied with their education than their peers who do not use laptops in class (Wurst, Smarkola, & Gaffney, 2008).

These correlational studies have focused on the capacity of laptops to distract and to invite multitasking. Experimental tests of immediate retention of class material have also found that Internet browsing impairs performance (Hembrooke & Gay, 2003). These findings are important but relatively unsurprising, given the literature on decrements in performance when multitasking or task switching (e.g., Iqbal & Horvitz, 2007; Rubinstein, Meyer, & Evans, 2001).

However, even when distractions are controlled for, laptop use might impair performance by affecting the manner and quality of in-class note taking. There is a substantial literature on the general effectiveness of note taking in educational settings, but it mostly predates laptop use in classrooms. Prior research has focused on two ways in which note taking can affect learning: encoding and external storage (see DiVesta & Gray, 1972; Kiewra, 1989). The encoding hypothesis suggests that the processing that occurs during the act of note taking improves learning and retention. The external-storage hypothesis touts the benefits of the ability to review material (even from notes taken by someone else). These two theories are not incompatible; students who both take and review

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"The Pen is mightier than the Keyboard" *Psychological Science (2014)*

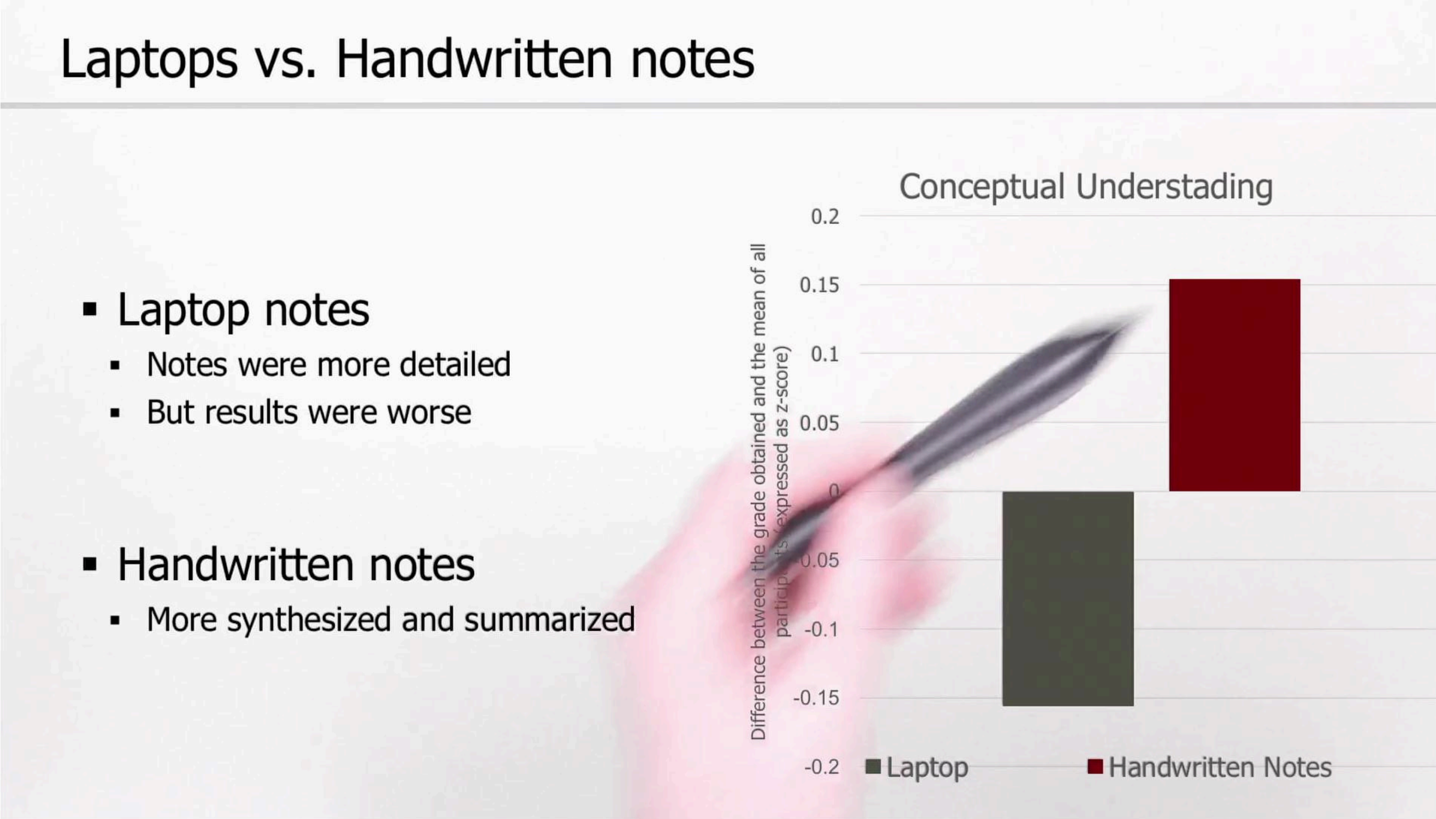
- Pam Mueller, Princeton University
- Daniel Oppenheimer, UCLA

This was exactly the question that was addressed in this study which was carried out in 2014 by Pam Mueller from Princeton and Daniel Oppenheimer from UCLA. Their question was, is it best to take notes on a laptop or by hand. In fact, we already know from a multitude of studies that simply listening in the lecture is not the optimum strategy.

Notes

Summary

1m 27s

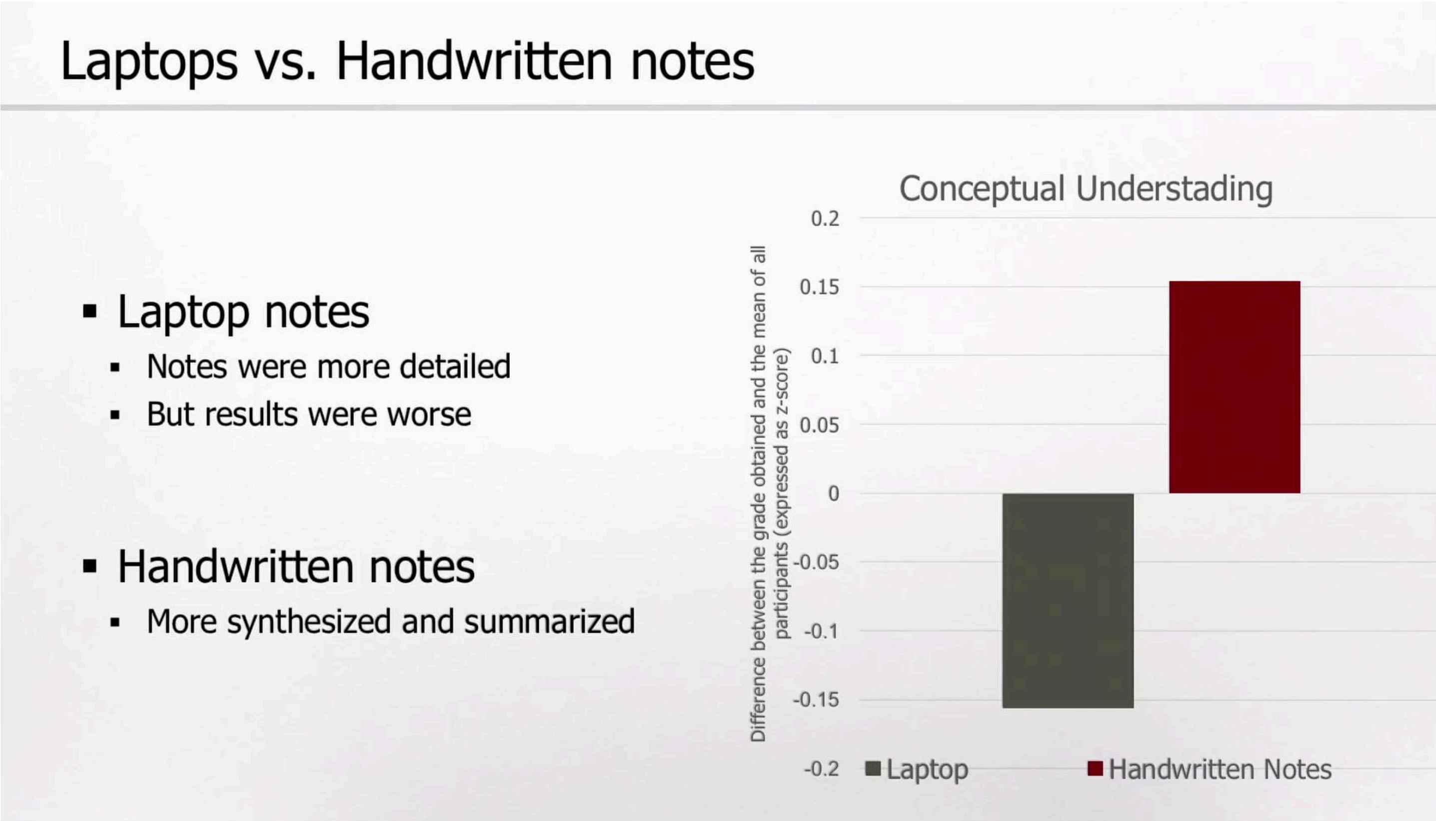


Mueller and Oppenheimer conducted multiple studies but we're gonna look at just one here as an example. In this particular experiment they had 67 participants. They were undergraduates in Princeton. They watched lectures, in this case five different TED Talks that they had not previously seen. They were given either a laptop or a notebook and they were asked to use their normal note-taking strategy. At the end of watching the videos, there was a 30-minute break, when they were asked to do other things and then they had an exam. The exam had both factual questions and also some conceptual questions, which asked them to apply the ideas that they had seen in the videos to different scenarios. Here's the results of that study in relation to the conceptual questions, so the second of these type questions. The way in which the results are presented here, is that first of all they took an average of the whole population and that average score is zero here and then they compared each of the groups in terms of how the average of that group compared to the average for the whole population and so that's represented here in terms of a proportion of the standard deviation and what you can see is that the laptop group performed significantly worse on the conceptual questions as compared to the handwritten notes group.

Notes

Summary

1m 50s



Now this is just one of the examples, one of the experiments which Mueller and Oppenheimer carried out. This finding was found to be repeated across multiple experiments. Mueller and Oppenheimer were interested as to what was the cause of this difference and so they looked at the notes which people took. In fact people taking notes with laptops took more detailed notes. They had more verbatim transcriptions of what the lectures actually said when compared to those who took notes by hand. People who took notes by hand tended to have more synthesis and more summaries of what was said but despite the fact that the laptop notes contained more information, the results were worse.

Notes

Summary

3m 16s

Learning requires active processing of information

- "…synthesizing and summarizing content rather than verbatim transcription can serve as a desirable difficulty…"

Pam A. Mueller & Daniel M. Oppenheimer (2014) The Pen Is Mightier Than the Keyboard: Advantages of Longhand Over Laptop Note Taking *Psychological Science* DOI: 10.1177/0956797614524581

- "The acquisition of complex knowledge and skills demands the investment of considerable learner energy and strategic effort"

Lambert, N. M., & McCombs, B. L. (Eds.). (1997b). *How students learn: reforming schools through learner-centered education.* Washington D.C.: American Psychological Association.

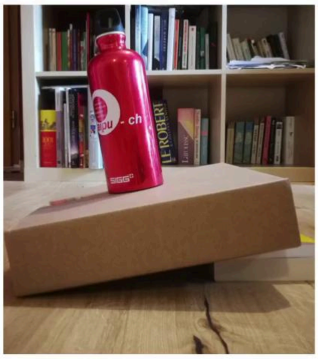
Mueller and Oppenheimer concluded that the process of synthesizing and summarizing, which people had to do when they were taking handwritten notes because they can't handwrite as quick as they can type was what was actually causing the increased learning. When people were handwriting, they were being forced to process the information as they went and it was this information processing which is leading to the increased learning. In fact this is found in Mueller and Oppenheimer's study but it's actually a much more generally recognized finding from the learning sciences literature. In fact when the American Psychological Association did a review of the learning sciences literature back in the 1990s, they concluded pretty much exactly the same thing. They noted that the acquisition of complex knowledge and skills demands the investment of considerable learner energy and strategic effort.

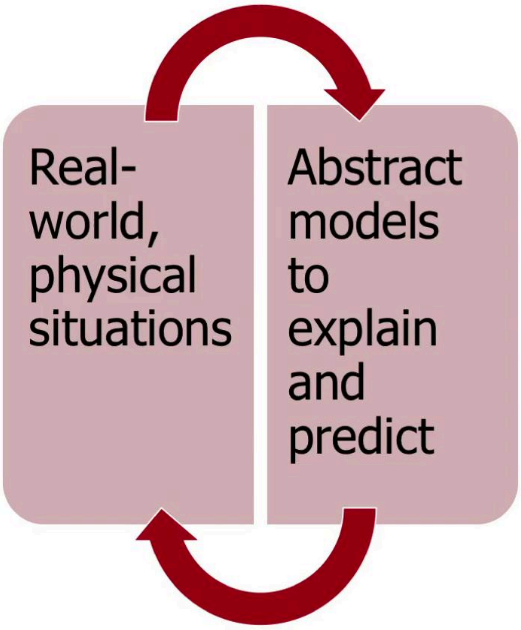
Notes

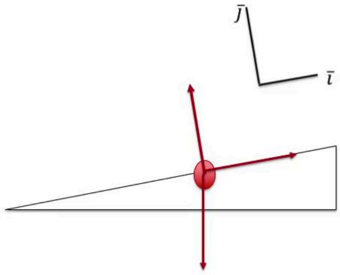
Summary

4m 01s

Scientific Knowledge







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So one of the first questions we should ask ourselves is who's doing the work, in any given situation. Is it the student who's actively processing information or is it the teacher. If it's not the student then that's something we might need to address. Our first key finding is that students need to actively process information. Our second relates to the nature of scientific knowledge. Scientific knowledge can be thought of as being about how we model real world physical situations in abstract ways in order to explain and predict what's going on. In the example on the slide, here we see on one side a bottle perched on a slope and that's represented in an abstract way on the other side of the slide in terms of a free body diagram but also in terms of a mathematical model. Using more abstract representations like the free body diagram or the mathematical model, we can explain and predict the world. But students don't just come to university with no abstract models in place.

Notes

Summary

4m 57s

“Unlearning Aristotelian Physics” ***Cognitive Science (1982)***

- Andrea DiSessa, MIT

COGNITIVE SCIENCE 6 37–75 (1982)

Unlearning Aristotelian Physics: A Study of Knowledge-Based Learning*

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A study of a group of elementary school students learning to control a computer-implemented Newtonian object reveals a surprisingly uniform and detailed collection of strategies, at the core of which is a robust "Aristotelian" expectation that things should move in the direction they are last pushed. A protocol of an undergraduate dealing with the same situation shows a large overlap with the set of strategies used by the elementary school children and thus a marked lack of influence of classroom physics training on this student's naive physics. The data from these two studies are pooled and elaborated into a "genetic task analysis" of how one might come to understand Newtonian dynamics as a more or less natural evolution from the naive state.

1. INTRODUCTION

For problem solving in domains like physics, no one disputes an important role for prior, domain-specific knowledge. For learning, however, it is easy to overlook the naive knowledge state in favor of a focus on general learning mechanisms, or on the representation and function of knowledge in already competent systems. This paper aims specifically at charting the naive knowledge state and its implications in learning. In particular, we make an analysis of the naive knowledge which students can bring to bear on a standard college curriculum subject (Newton's laws), including some aspects of vector algebra that are necessary to understand the laws.

What we are after is something like a task analysis—what does it take to operationally understand Newton's laws? But given the developmental

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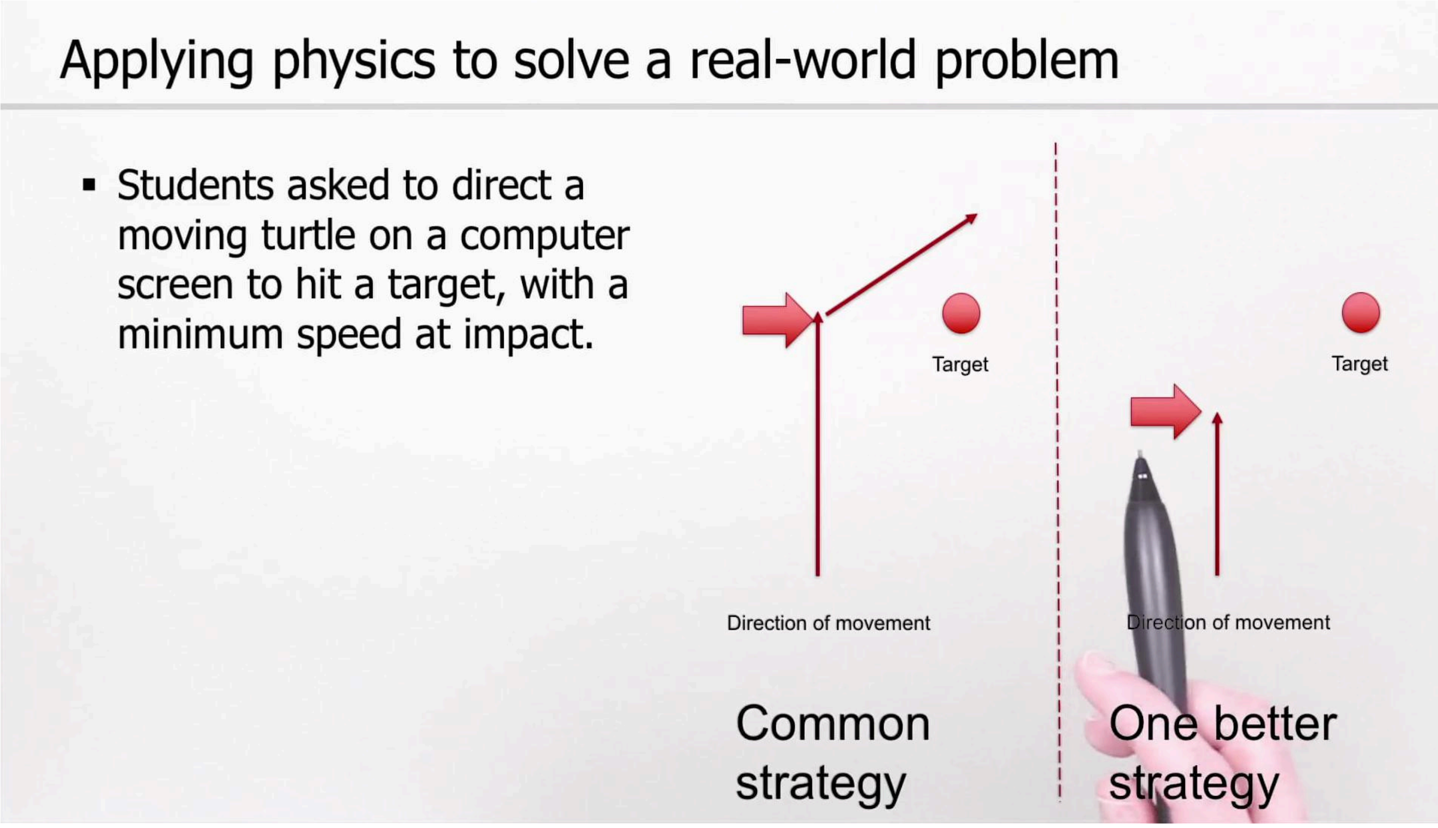
*I am grateful to John Seeley Brown and Allan Collins for careful reading of a previous version of this paper which had considerable impact on its final form. I would also like to thank S. Papert, H. Sinclair and J. Richards for insightful comments.

In fact they've already got a long experience of the physical world and therefore they've already developed informal non-scientific and what we might call naïve models of the world and so one of the issues which is faced in science education at university level is how we interact with students naïve, implicit or informal non-scientific models of the world. This issue was addressed in a study which is carried out in 1982 by Andrea DiSessa from MIT which she called Unlearning Aristotelian Physics.

Notes

Summary

6m 02s

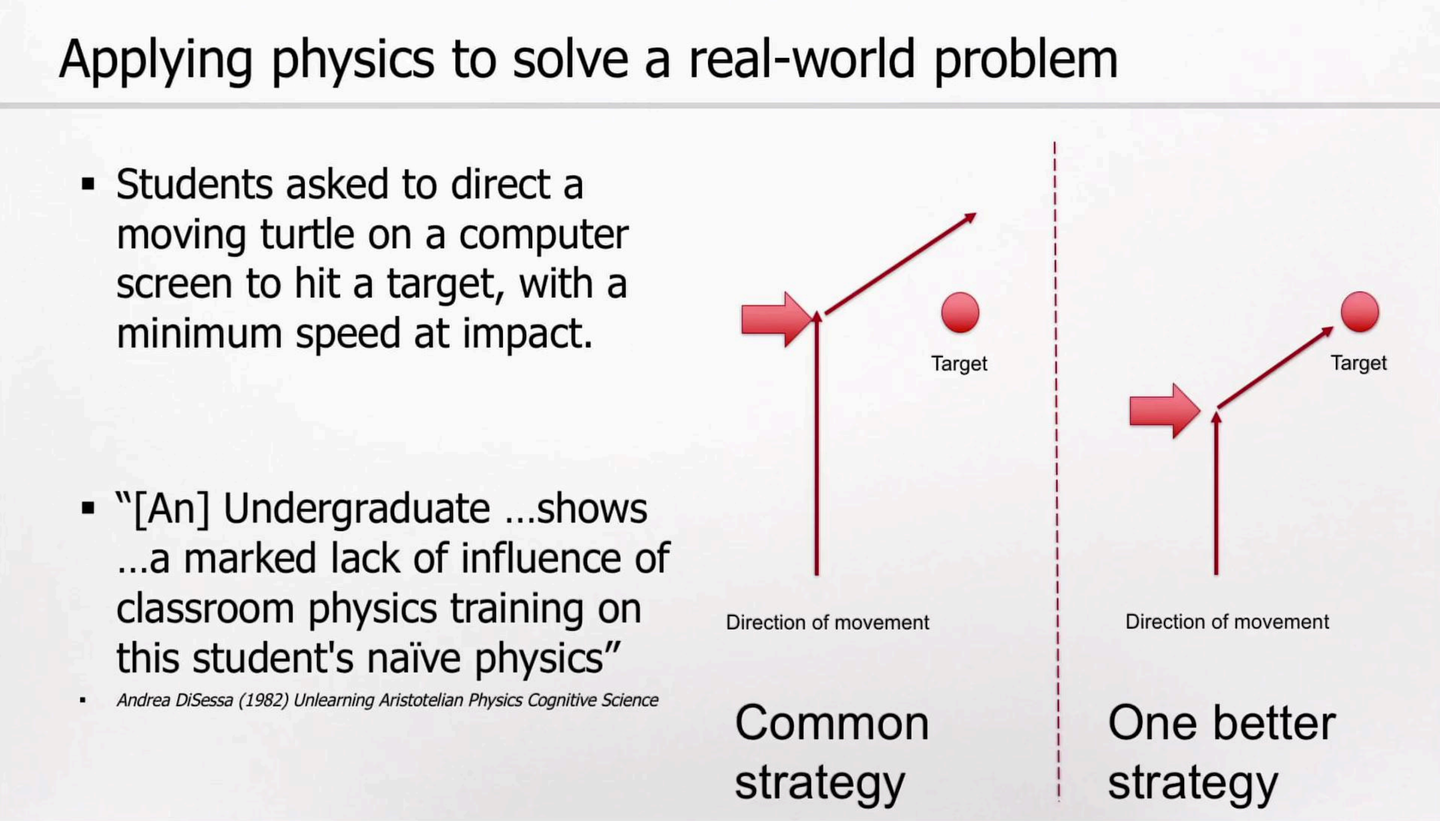


In this study DiSessa asks students to direct a moving turtle on a computer screen in order that it would hit a target with the idea that it would have a minimum speed at impact. They could move the turtle by giving a kick to the turtle so the turtle was moving and they could give it a kick which would change where the turtle was going. One common strategy people had was to assume that when they gave the turtle a kick it would move in the direction in which it was kicked so, for example, if the turtle was moving in this direction, they would give it a kick here with the idea that it would then move this direction towards the target. In fact the turtle missed the target because it already had a velocity in this direction and the kick gave it a change in velocity not a direct change in position. So this is why she called her study Unlearning Aristotelian Physics. This is the physics model which people had before Isaac Newton and Isaac Newton identified that force is associated with acceleration that is with change in velocity not simply change a position. Okay. So what would a better strategy look like? A better strategy would look like, for example, recognizing that the force is going to change the velocity and so is going to change the direction.

Notes

Summary

6m 39s



So you give a kick here and that will cause it to hit the target. A second option would be to allow it to continue to here and then stop it with a kick this way and then give it a kick this way to move it this way. These second approaches, these better strategies would take into account a Newtonian approach to physics. Now what Di Sessa found was that actually students typically used the first strategy. In other words they had an implicit Aristotelian model of the world. This was true not just for primary school students but actually she found the same thing with undergraduate students and so this was interesting because the fact that people had learned physics in a classroom didn't impact upon the way in which they behaved when asked to apply that physics to a real-world problem.

Notes

Summary

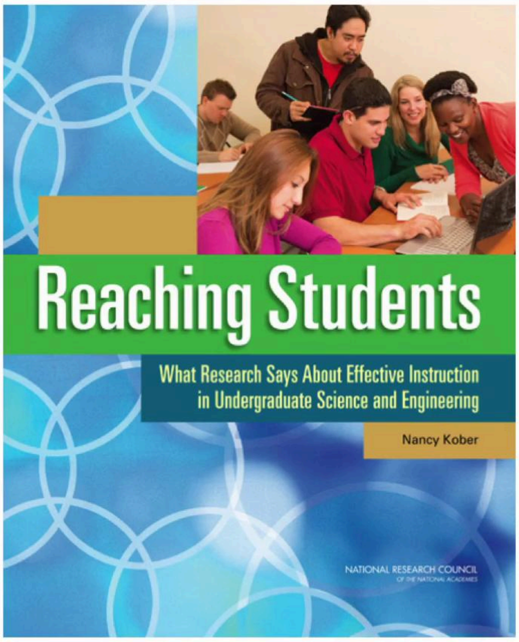
8m 11s

Address (Implicit) Prior Misconceptions

"Misconceptions can persist through the undergraduate years, even when students have been taught accurate explanations in their earlier science classes…

Rather than simply telling students the right explanation, good instructors …elicit students' prior knowledge and use it to help students construct a more complete and accurate understanding"

Reaching Students: What Research Says About Effective Instruction in Undergraduate Science and Engineering. (2015). Washington, D.C.: National Academies Press. Retrieved from http://www.nap.edu/catalog/18687



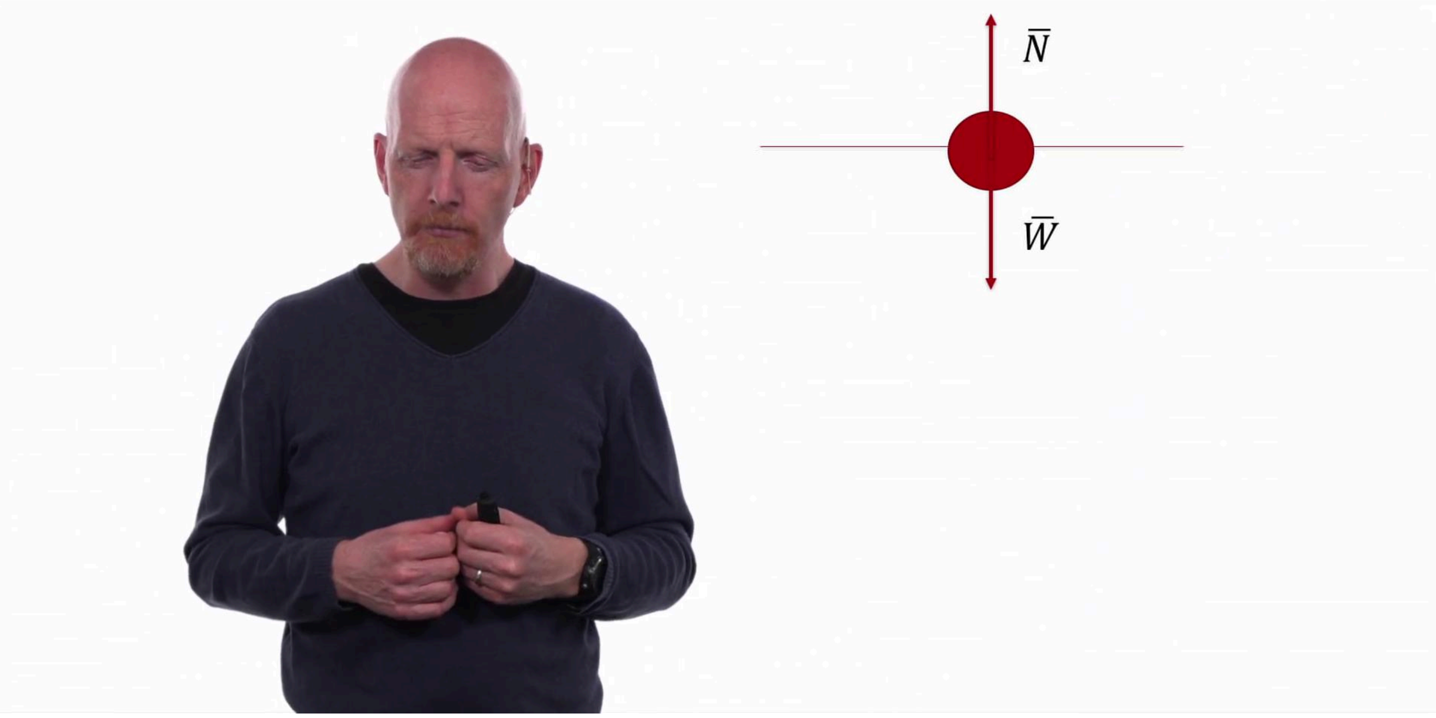
In the last few years the National Research Council in the US has carried out a review of evidence about science and engineering learning in university. What they've identified is that these misconceptions can persist throughout the undergraduate years, even though people are studying physics and studying chemistry, even though they're actually studying the formally correct scientific models. One implication of this is that it's not enough to give people the formerly correct scientific models. If we give them that, they may keep that disconnected from their real-world, implicit or naïve models. In fact we've got to make people make connections between these formal models and real-world scenarios. We've got to get them to question the implicit or naïve models that they bring to their higher education experience.

Notes

Summary

9m 06s

Need for Feedback



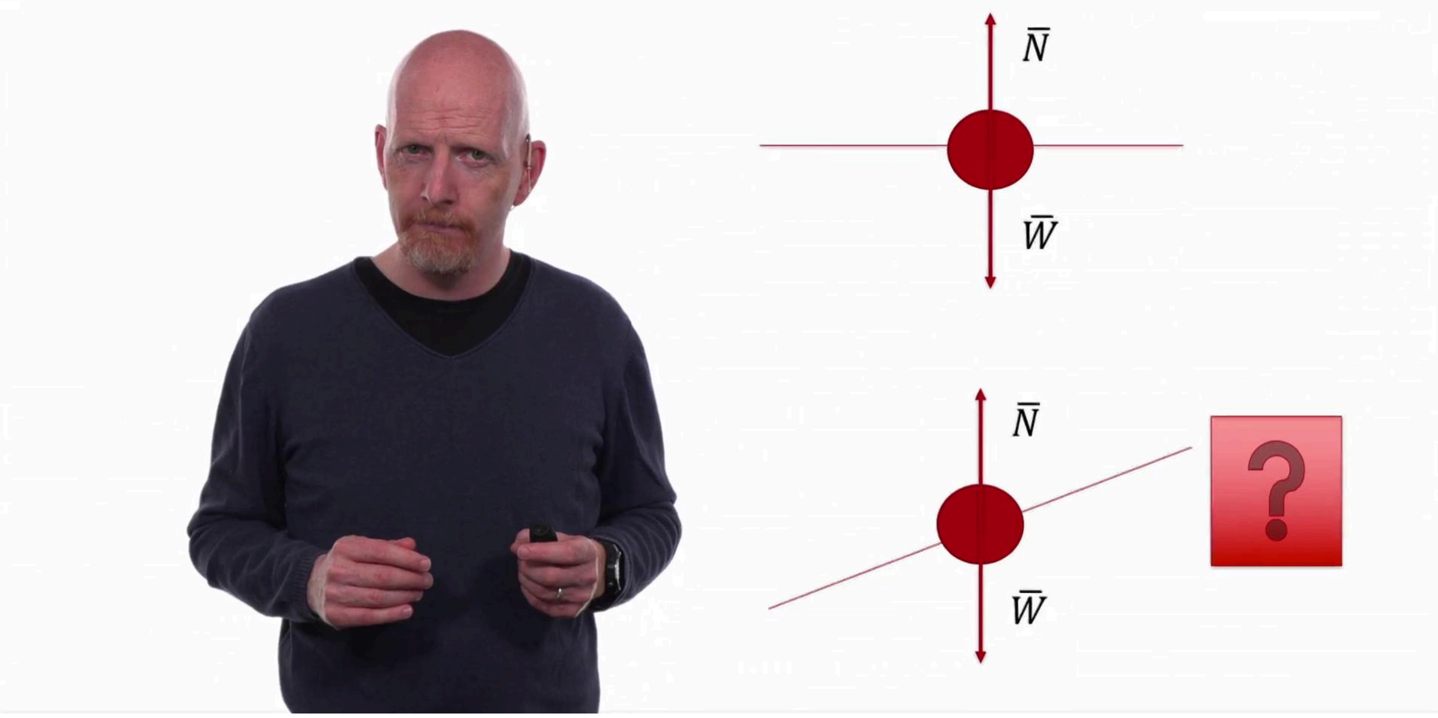
So far we've looked at two key ideas. First that students need to actively process information and second in actively processing information students need to make connections between formally correct scientific models and the implicit or naïve models they bring with them into University. A third key idea we want to look at is that of feedback. So let's imagine a situation. A student is sitting in a lecture and the teacher is explaining to them the basics of Newtonian mechanics and the teacher has an example much like the one on the screen here. So there is a book, it's on the table and the teacher explains that there is a force being exerted on that book which is weight and the teacher explains that because there is a reaction in the opposite direction, for every action there is an opposite reaction, there is also a normal force exerted by the table on the book and the normal force, the teacher explains, is called a normal force because it's exerted in a direction which is normal to the plane of the table.

Notes

Summary

10m 01s

Need for Feedback

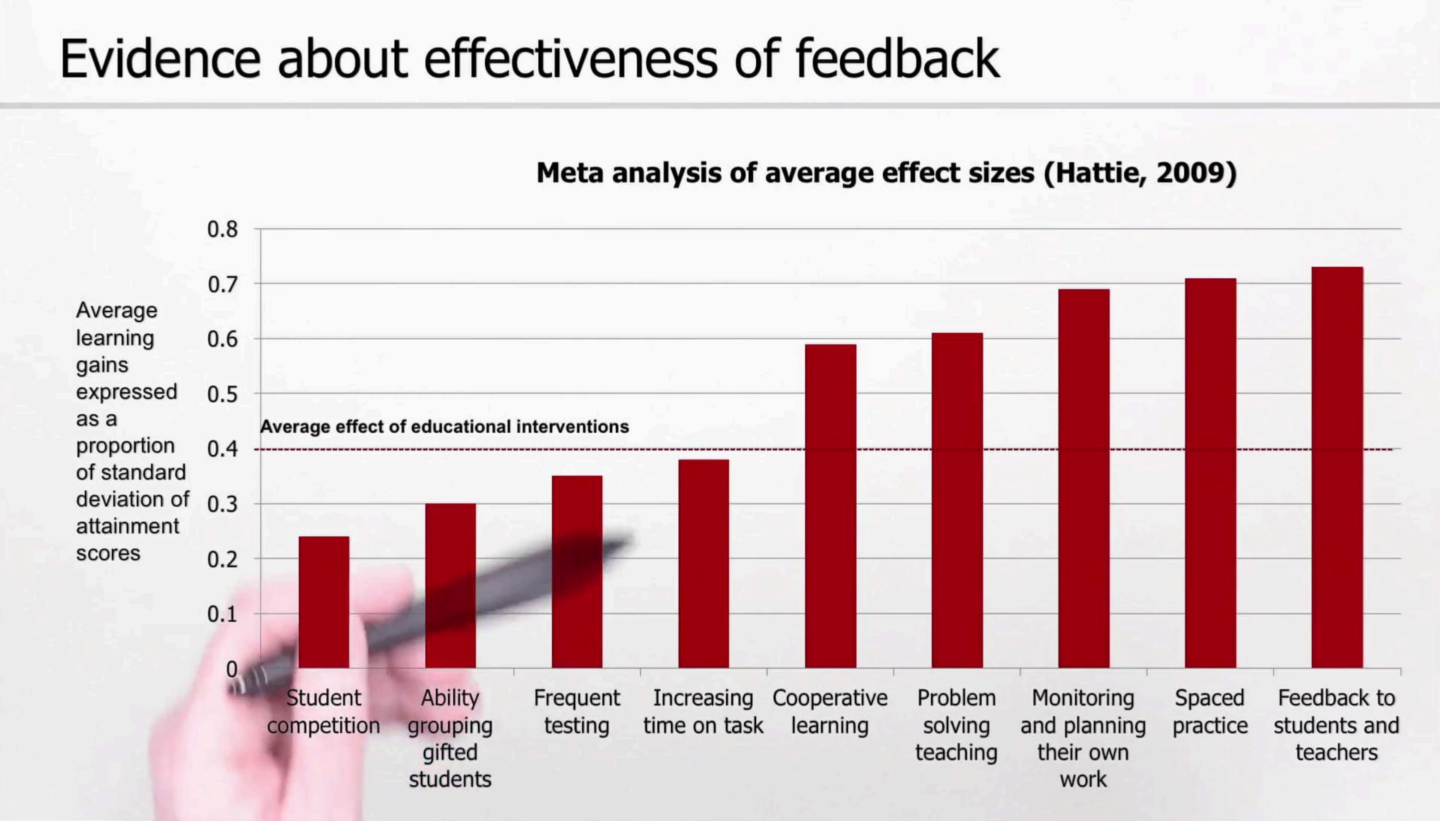


So the student is listening to this and students writing their notes and this student is trying to synthesize and trying to summarize and trying to get it right and when the teacher say something like "it's exerted in a direction normal to the plane of the table" The student wonders what does that mean, they know that weight is operating downwards and they can see from the image that the normal force is operating upwards and so they write down "weight down, normal force up". Okay, the student then moves into the exercise session. What happens at this point? They have an exercise which is slightly different. This time the plane is not flat but rather it's an inclined plane and the student is trying to figure out how to model this. So weight goes down, what happens with a normal force? They look at their notes and they see in their notes that weight goes down and the normal force goes up. Okay, the student has made a mistake. It's a perfectly reasonable mistake. Many students will make it. What happens next?

Notes

Summary

11m 06s

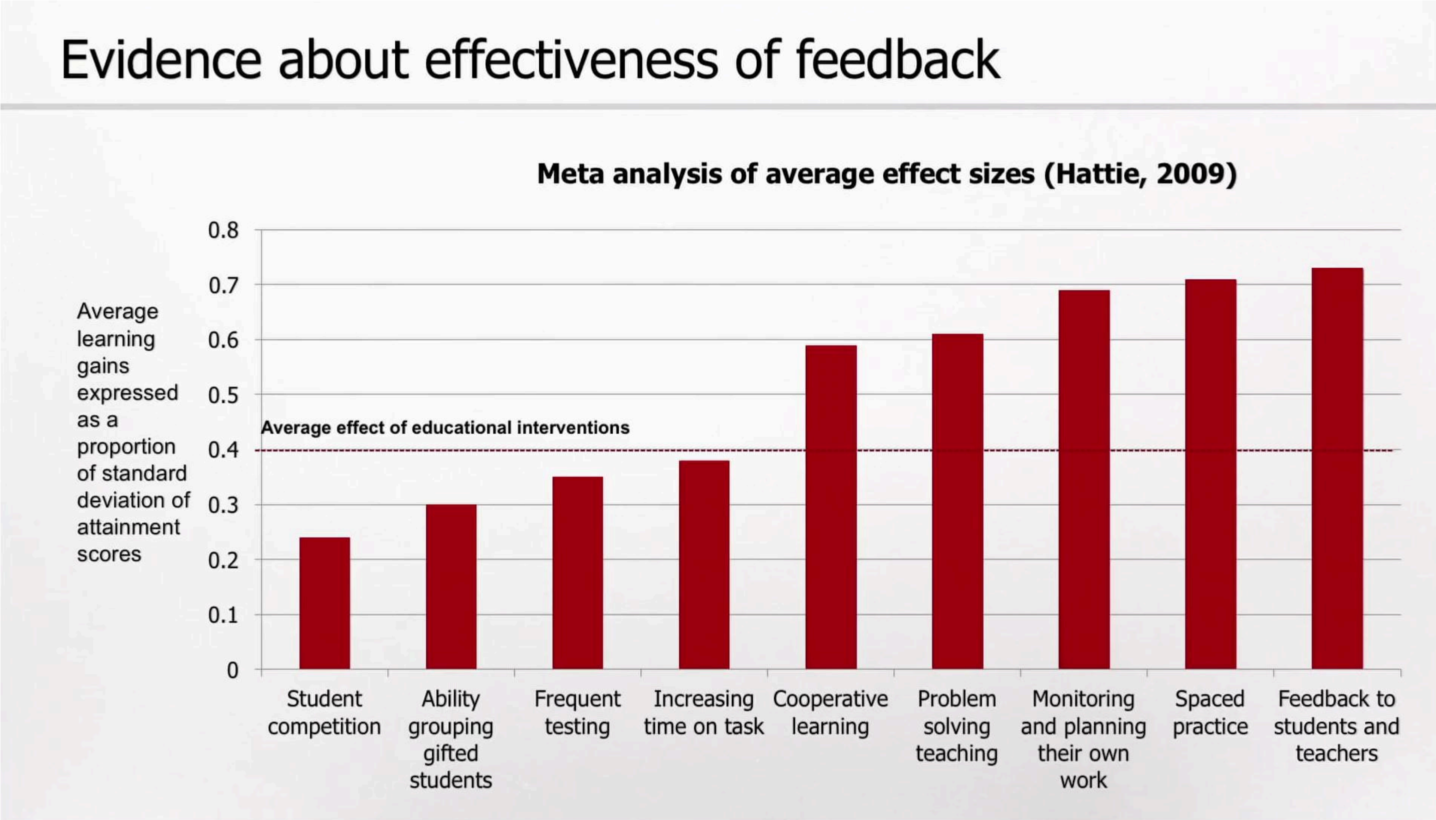


In an ideal world the student will get some feedback on their error and this will help them to get it right in future. But how important is feedback? Here we have data from a study which was carried out by John Hattie in 2009. Hattie collected a series of meta-analysis of studies of learning? In fact he collected over 800 meta-analyses. And with this, he was able to compare different approaches to learning, different approaches to teaching, to see what impact they had on students' learning. So you'll see this slide a number of times in the course of this series. We have here a series of different approaches to teaching as you can see, and they are ranked in terms of the learning gains expressed as a proportion of the standard deviation of attainment scores. So the average effect of educational interventions that Hattie found was 0.4. That is, on average, teaching increased the learning of a class by about four tenths of a standard deviation. And we can see that some things are less impactful than others. So getting students to compete with each other, it does have an impact on learning but less than the average of all educational interventions.

Notes

Summary

12m 17s



Frequent testing also has an impact on learning but it's only around the average. And then over at this end we have some other things. Spaced practice which we'll talk about later on, problem-solving teaching which we'll also talk about in this video series, but let me draw your attention to this one here because it turns out that feedback to students and to teachers is one of the education interventions which has the strongest positive impact on students' learning.

Notes

Summary

13m 41s

Conclusion

- The student should be the one **actively processing** information
- New information may not always help: we have to engage with and question **implicit misconceptions**
- **Feedback** plays a crucial role in learning

So here we have three key ideas which come from the research on learning sciences. First of all in order to learn students have to actively process information. Secondly in order to do so part of that will involve making links between the formal scientific models they learn and their real-world experience and their naïve or implicit scientific models which they bring with them, and thirdly in order to do that, feedback will be crucially important. In the next video we look at three other key ideas which emerge from the learning sciences.

Notes

Summary

14m 14s