Teaching Problem Solving

Foundations for Teaching in Higher Education

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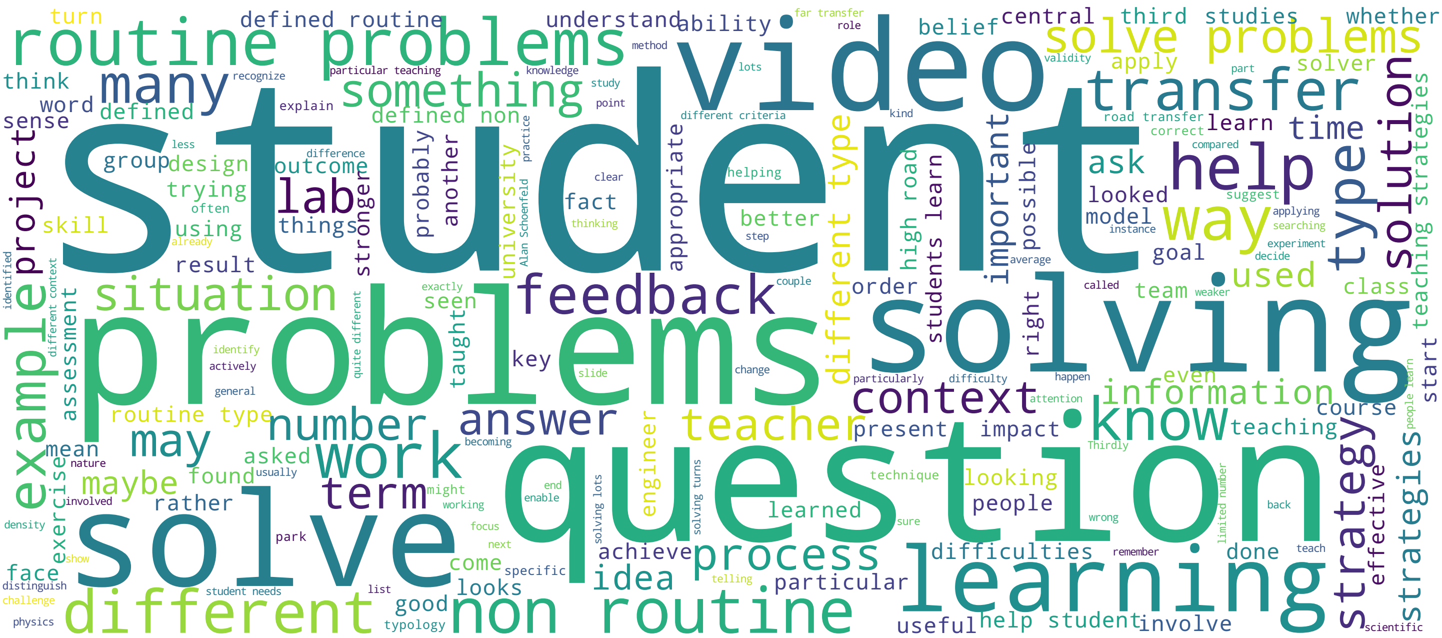

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Video

EPFL

Goals of this video

You should be able to:

- Describe research evidence about the impact of **teaching problem solving**
- Categorize problems in terms of how **routine** they are and how **well-defined** they are
- Identify how student **beliefs** about problems impacts on problem solving success
- Define what is meant **transfer** in problem solving and distinguish between **near** and **far** transfer

Problem-solving is central to becoming an engineer or becoming a scientist. When we look at what activities we ask students to do in university, it turns out that in scientific degrees, about two-thirds of the activity students do, are solving pen-and-paper problems. And that's probably no surprise because problem solving is also central to these disciplines in professional practice. What it is that engineers do is solve problems. In this video we'll be looking at how it is that we can help students learn to solve problems. So we know that people can learn to solve problems but actually can they be taught to solve problems? Do people learn to solve problems simply by solving lots of problems? Or are there particular teaching strategies that can work that can be demonstrated to be effective? In order to help people solve problems it's useful to understand the different types of problems which are involved and so one of the things we look for you to do in this video is be able to distinguish between different types of problems. One of the ways in which different types of problems impact upon problem-solving is because it impacts upon the beliefs students have about how to solve problems.

Notes

Summary

0m 04s

Goals of this video

You should be able to:

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- Categorize problems in terms of how **routine** they are and how **well-defined** they are
- Identify how student **beliefs** about problems impacts on problem solving success
- Define what is meant **transfer** in problem solving and distinguish between **near** and **far** transfer

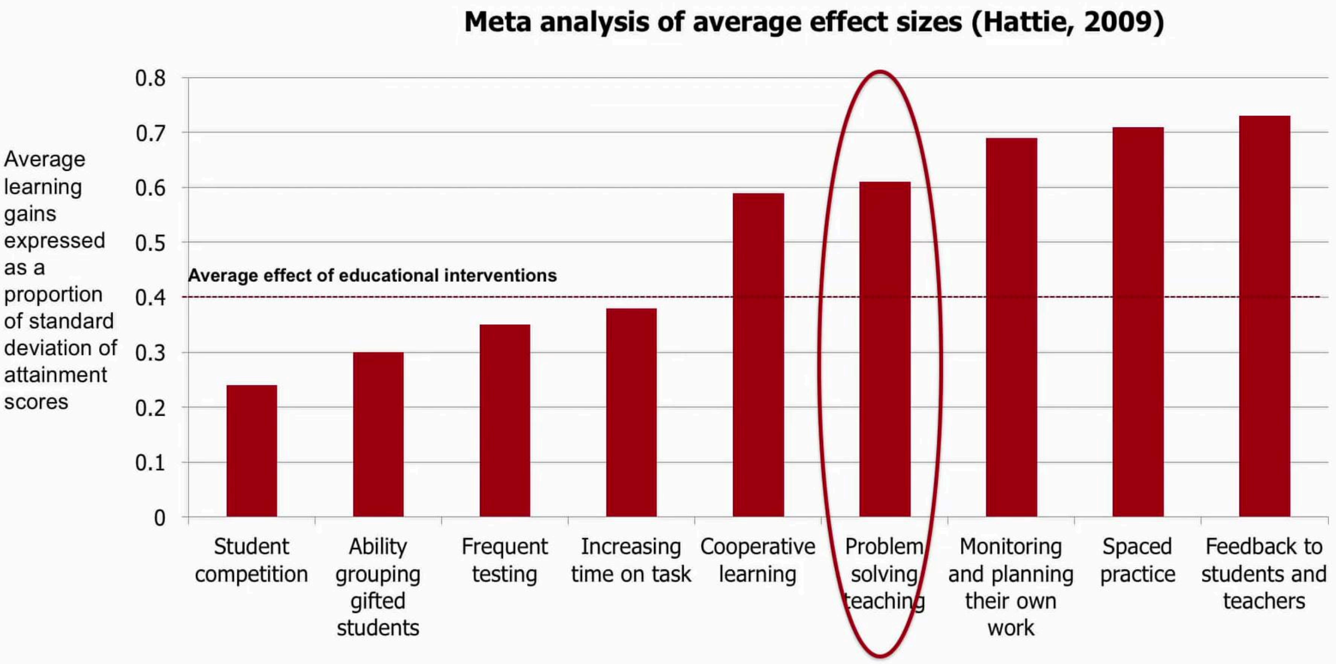
And so we'll also look at the beliefs which students hold about problems. And then finally, solving problems is about taking strategies which you've learned in one context and using them in another. This is what's called 'transfer' and in this video we'll also look at this question of transfer and in particular how we can transfer from one situation to a different situation which on the surface of it looks quite different.

Notes

Summary

1m 18s

Teaching problem solving



So our first question is whether or not problem-solving can be taught? Do people learn to solve problems just by solving lots of them or are there particular teaching strategies that work? Can these teaching strategies be shown to be effective? Now this is a slide you've seen before from other videos. It is a slide which compares different teaching strategies in terms of their effectiveness and what you can see here is that actually teaching people problem solving turns out to have a strong positive impact on learning. It certainly has an impact on learning which is stronger than average. In particular, teaching problem-solving turns out to be more associated with learning than simply giving people practice problems. Secondly, it's notable that the impact of teaching problem-solving tends to be stronger in older students, that is, high school students and university age students as compared to for younger students. So, therefore, the research evidence supports the idea that rather than just giving students problems to solve we should actively try to teach them strategies for solving these problems. Okay.

Notes

Summary

1m 44s

A typology of problems

	Defined Problems	Ill-defined Problems
Routine problems	Student has learned a procedure for calculating a Fourier series. The problem is "Find the Fourier series for the periodic function f(x) defined by $f(x) = e^x$ for -1<x<1 on the fundamental interval [-1,1]"	
Non-routine problems		

Based on: Richard Mayer & Merlin Wittrock (1986) *Problem Solving Transfer*

I've used the word “a problem” numerous times in this video so far but what exactly is a problem? Well, problem is defined by Alan Schoenfeld, one of the writers who's done a lot of work in this area as: “trying to achieve some outcome where there was no known method for the individual trying to achieve that outcome, to achieve it.” In other words, we need to distinguish between situations in which we know how to solve the problem in which case it's not really a problem, it's more of an exercise and situations in which we actually don't know how to solve it. And this begins to suggest the typology for looking at different types of problems. The reason this typology will be useful is that it turns out that many of the problem students have is that they use strategies which are appropriate for one type of problem when trying to solve a different type of problem. So let's look at this typology in a little bit more detail. Ok. Let's start with routine problems or exercises which are clearly defined. So in this type of problem, all of the required information that the student needs is actually present in the problem and usually there is no additional information.

Notes

Summary

2m 54s

A typology of problems

	Defined Problems	Ill-defined Problems
Routine problems	Student has learned a procedure for calculating a Fourier series. The problem is "Find the Fourier series for the periodic function f(x) defined by $f(x) = e^x$ for -1<x<1 on the fundamental interval [-1,1]"	
Non-routine problems		"How many parking spaces and of which dimensions should be included in a 200 by 300 metre car park if the goal is to maximise the number of spaces and minimise damage to cars arising from accidental collisions (e.g. a car door banging against an adjacent car)"

Based on: Richard Mayer & Merlin Wittrock (1986) *Problem Solving Transfer*

To solve this problem the student will need to apply a limited number of well-structured rules. The problem will probably have a limited number of answers and one or a couple of those will be correct but it will be pretty clear whether the answer is right or wrong. In this it doesn't really matter how complex the problem is. This problem here which involves the student in calculating a Fourier series actually is of a reasonable level of complexity. They'll need to do some integration. They'll need to decide whether or not the function is odd or even. So it will involve a number of different complex tasks but the problem itself is still routine and defined because they're applying a technique which they have already learned in class. So let's compare that with a problem which is ill-defined and non-routine. So in this problem the student is asked to define how many spaces should be in a car park of given size. They have a number of different criteria to use in this. Number one that should have as many car parking spaces as possible and number two they should minimize accidental collisions such as people banging a car door against the car next to it.

Notes

Summary

4m 08s

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Non-routine problems	The student is asked to solve a problem for which they do not already have a procedure.	"How many parking spaces and of which dimensions should be included in a 200 by 300 metre car park if the goal is to maximise the number of spaces and minimise damage to cars arising from accidental collisions (e.g. a car door banging against an adjacent car)"

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So there's lots of information that the student needs which they don't have. They don't know about the design or optimal layout of lanes in a car park. They don't know how many family-friendly spaces they need. How many spaces for drivers with a disability? They don't know how many large cars, medium cars, small cars use this car park. There's lots of unknown information. The student will have to identify unknown information. They'll have to scope out the problem and there are multiple different criteria against which the outcome can be judged. In fact, there are multiple different solutions which are possible in this case. So this type of problem is obviously quite different from the first one. This is much more like a real-world problem that maybe an engineer will have to solve. In this video we won't particularly look at this kind of problem. We will have other videos which look at the design process which can be used in terms of solving a problem like this. A third category of problem is problems which are defined in the sense that all of the information required where the student is present in the problem statement but non-routine in the sense that the student will not be able to solve the problem by just applying a strategy that they've already seen and already learned.

Notes

Summary

5m 24s

A typology of problems

	Defined Problems	Ill-defined Problems
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So this type of problems, defined non-routine problems, make up many and possibly most of the problems students will face in university. They will make up many of the type of problems that students will face in examinations. This is the type of problem that students need to be able to solve. Unfortunately, these problems look a lot like defined routine problems. They look very similar. They have similar surface features with these more routine type problems and that means students can misunderstand the nature of this problem. Students can try to solve this problem, defined non-routine problems, using strategies which are more appropriate for defined routine type problems. One such strategy is pattern matching, where the student looks at the question and tries to use a technique that they've seen work in another problem. That may very well work well in defined routine problems but will probably not work at all in defined non-routine problems. Alan Schoenfeld in his research with student problem solving found that about 60% of the student attempt to solve this type of problem, defined non-routine problems, were essentially look at the problem, decide very quickly what strategy to use and then keep using that strategy whatever happens.

Notes

Summary

6m 44s

A typology of problems

	Defined Problems	Ill-defined Problems
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In other words, students were not analyzing the problem. They were just matching a strategy to a similar looking problem as maybe they would have done with a defined routine type problem.

Notes

Summary

8m 05s

- Thomas Litzinger and colleagues
- Pennsylvania State University

- What difficulties do students have in solving statics problems and do they differ between strong and weak students?

A Cognitive Study of Problem Solving in Statics

Thomas A. Litzinger, Peggy Van Meter, Carla M. Firetto, Lucas J. Passmore, Christine B. Masters, Stephen R. Turns, Gary L. Gray, Francesco Costanzo, and Sarah E. Zappe

The Pennsylvania State University

Background

Even as expectations for engineers continue to evolve to meet global challenges, analytical problem solving remains a central skill. Thus, improving students' analytical problem solving skills remains an important goal in engineering education. This study involves observation of students as they execute the initial steps of an engineering problem solving process in statics.

Purpose (Hypothesis)

(1) What knowledge elements do statics students have the greatest difficulty applying during problem solving? (2) Are there differences in the knowledge elements that are accurately applied by strong and weak statics students? (3) Are there differences in the cognitive and metacognitive strategies used by strong and weak statics students during analysis?

Design/Method

These questions were addressed using think-aloud sessions during which students solved typical textbook problems. We selected the work of twelve students for detailed analysis, six weak and six strong problem solvers, using an extreme groups split based on scores on the think-aloud problems and a course exam score. The think-aloud data from the two sets of students were analyzed to identify common technical errors and also major differences in the problem solving processes.

Conclusions

We found that the weak, and most of the strong problem solvers relied heavily on memory to decide what reactions were present at a given connection, and few of the students could reason physically about what reactions should be present. Furthermore, the cognitive analysis of the students' problems solving processes revealed substantial differences in the use of self-explanation by weak and strong students.

Keywords

cognitive, metacognitive, problem solving

I. Introduction

We conducted this study because of the central importance of problem solving in engineering. Even as the characteristics expected of young engineers continue to evolve, analytical problem solving remains central. The National Academy of Engineering (NAE) report, *Engineer 2020*, gives the first attribute of an engineer of 2020 as: "*will possess strong analytical skills*" (NAE, 2004). The second attribute is practical ingenuity of which the report notes, "*Using science and practical ingenuity, engineers identify problems and solve them.*" In many cases successfully solving problems requires engineers to use their analytical skills. Therefore, the development of strong analysis and problem solving skills remain central to the education of students who will become engineers of 2020.

The study was conducted with students taking statics because it is one of the first courses where students encounter an engineering problem-solving process. In this study we paid particular attention to the early steps in problem solving when students "model" the system being studied to create a set of equations describing the system. The problems used in the study are typical of problems found in introductory statics textbooks, consisting of a short problem statement and a figure. Such problems can be classified as well-structured and knowledge rich (Bhaskar and Simon, 1977; Lovett, 2002; Mayer and Wittrock, 1996). As the students solve these problems, they typically read the problem statement and then create a model of the system: the free-body diagram that contains all of the salient forces on the body. Next, based on the free-body diagram, they create a mathematical model of the system: the equilibrium equations.

The goal of the present study is to better understand students' difficulties as they learn to solve problems in statics in order to inform the design of an instructional intervention (cf. Lesh and Zawojewski, 2007). Our research questions are:

1. What elements of knowledge do statics students have the greatest difficulty applying during problem solving?
2. Are there differences in the elements of knowledge that are accurately applied by strong and weak statics students?
3. Are there differences in the cognitive and metacognitive strategies used by strong and weak statics students during analysis?

In this research, we collected verbal protocols from strong and weak statics students as they completed analysis problems while thinking aloud. Students' written work was scored to reveal knowledge-based technical errors and verbal protocols were coded to identify differences in the cognitive and metacognitive strategies used by the two groups of students. The "fine-grained analysis" (see Tuminaro and Redish, 2007) of these data sources was carried out in an effort to identify potential targets for instruction.

II. Relationship to Previous Work

The work described in this paper has much in common with extensive studies of problem solving that have been conducted in mathematics, physics, and chemistry. In this section, we summarize results from studies with an emphasis on two areas: the role of knowledge and the use of cognitive and metacognitive strategies in

Similar findings emerged from other studies of student problem solving at university level. For example, this paper from the Journal of Engineering Education looked at the difficulties which students have in solving statics problems and looked at whether or not those difficulties were different between strong and weak students. What they found is that many of the difficulties that students have emerge from spending insufficient time analyzing the problem. They also found that students relied very heavily on memory to decide how to solve a problem rather than actually trying to understand the nature of the problem and the given reactions that were happening within it.

Notes

Summary

8m 20s

Learning to transfer

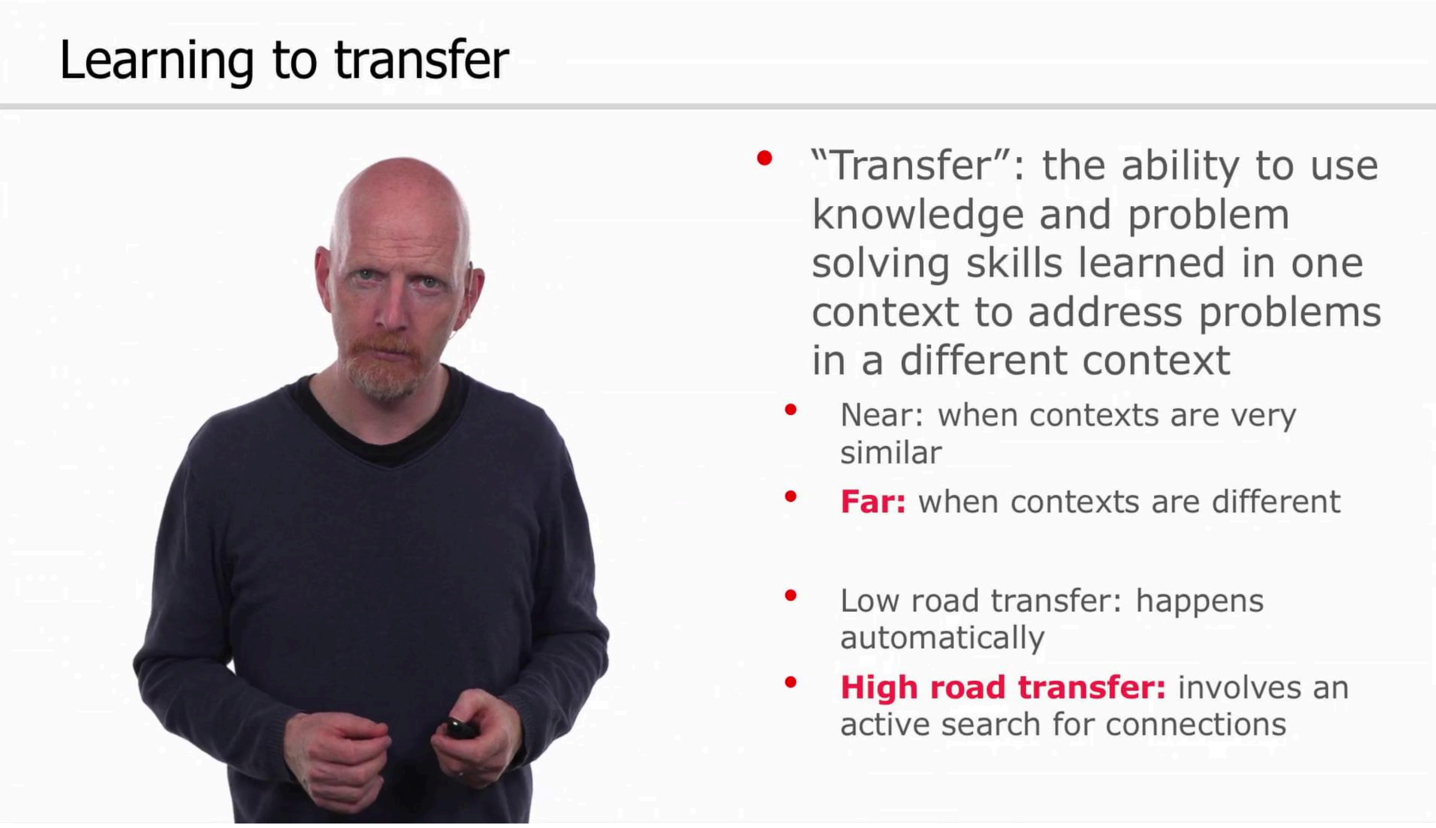
- "Transfer": the ability to use knowledge and problem solving skills learned in one context to address problems in a different context
  - Near: when contexts are very similar
  - Far: when contexts are different
  - Low road transfer: happens automatically
  - High road transfer: involves an active search for connections

So the difference between routine and non-routine problems is that, in routine problems you've seen something like this before, in non-routine problems you need to take something you've learned from one context and apply it in a different one. So this is what cognitive scientists call the problem of 'transfer'. Transfer is the ability to use knowledge in problem-solving skills learned in one context to address problems in a different context. And transfer is going to be central to their ability to solve non-routine problems. Learning scientists distinguish between two different types of transfer. What they call "near transfer", that is, transfer when the contexts are very close to each other. This is what we find in solving routine problems. And "far transfer", where you need to take something from one context and use it in what looks on the surface of it like a very different context. This is maybe more likely to be the case in non-routine problem-solving.

Notes

Summary

9m 04s



Learning scientists also make a distinction between two different processes of transfer what they call "low load transfer", which happens more or less automatically - when you look at something you recognize a similarity implicitly, you have an intuition that this strategy will work - And what they call "high road transfer", which involves an active process of searching for similarities or searching for patterns which will enable you to transfer the information from one context to another. Obviously you can imagine that high road transfer is linked to far transfer and it's high road transfer and far transfer which will be of use to students in terms of solving non-routine problems.

Notes

Summary

10m 04s

Helping students learn to transfer

In class student has derived equations of motion under constant acceleration:

$$v = v_i + a * t$$

$$x = x_i + t * v_i + \frac{1}{2} a * t^2$$

Exercise: A ball is vertically into the air from a height of 1.5 m with an initial vertical velocity of 10 m s^{-1}. What is the maximum height that the ball will reach? (Take the magnitude of acceleration to be 10 m s^{-2}).

- Explicit abstraction - Make the process or underlying principle explicit:
  - "Where you have two unknowns and two equations, these can be solved using simultaneous equations"

David Perkins and Gavriel Salomon (1992) *Transfer of Learning*

So how do we help students learn to transfer. Let's look at this in terms of an example. This is a relatively simple example compared to many of the ones that students will face in their university studies. In this case the teacher has, in class worked with the students to derive a number of different equations which apply in circumstances where a body is moving and acceleration is constant, such as a situation where something is dropped on planet earth and the only acceleration force involved is that of gravity. And so in this case the student is asked to solve a problem in which something is thrown into the air and then it falls down again. The difficulty for the student is that neither one of these formula will by themselves solve the problem. What strategies can you as a doctoral assistant use to help students solve this problem in a way that they will be able to transfer their learning from this situation to another problem when they face it? Well, one way of doing that is what's referred to as “explicit abstraction”, that is helping them to make the process or underlying principle explicit. In order to solve this problem, the student will eventually use simultaneous equations.

Notes

Summary

10m 50s

Helping students learn to transfer

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- Explicit abstraction - Make the process or underlying principle explicit:
  - "Where you have two unknowns and two equations, these can be solved using simultaneous equations"
- Active self-monitoring – Checking if a strategy is working

David Perkins and Gavriel Salomon (1992) *Transfer of Learning*

They have two different unknowns and they have two different equations. Recognizing that as a principle which can be used to solve problems in general, will be useful for the student and so either you telling them or them telling you that where you have two unknowns and two equations these can be solved using simultaneous equations recognizing that general principle will be of value to the student in helping them make the transfer. A second thing that will help the students learn to make transfer is to actively self-monitor during the process of solving the problem. That is, continually checking in with themselves to see 'is this strategy working?' In fact, their Litzinger et al., study which we mentioned earlier identified that this is one of the key differences between stronger problem solvers and weaker problem solvers. When they went from an easy question to a more difficult question, stronger problem solvers increasingly activated self-checking strategies. They asked themselves more frequently whether or not their strategy was working. That wasn't the case with weaker problem solvers.

Notes

Summary

12m 09s

Conclusion

- Problem solving can be explicitly taught and learned
- Students are well-versed in routine problem solving strategies
- Beliefs may be aligned with routine problems
- May need help to:
  - Recognize non-routine problems
  - Think in ways appropriate to non-routine problems
  - Think in ways that promote transfer

In this video we've looked at a couple of key ideas. First of all, problem-solving can be taught. Students will often learn problem-solving better if it is taught than if they are just given a bunch of problems to work through. Secondly, students don't come to university as a blank slate. They are already very well-versed in solving problems but maybe in a particular type of problem, that is, routine problems. As a result of this many students have already developed beliefs about problem solving and one such belief is a belief that they should be able to a very quickly identify a solution to a given problem. So students may need your help. They may need your help to recognize when the problem they are faced with is a non-routine type of problem. They may need your help to change their belief system so that they are approaching the problem in a way that is appropriate for non-routine types of problems. And they may also need your help to think about problems in ways that will enable them to transfer solutions from one problem to a problem which looks very different.

Notes

Summary

13m 19s