Teaching solution design

Foundations for Teaching in Higher Education

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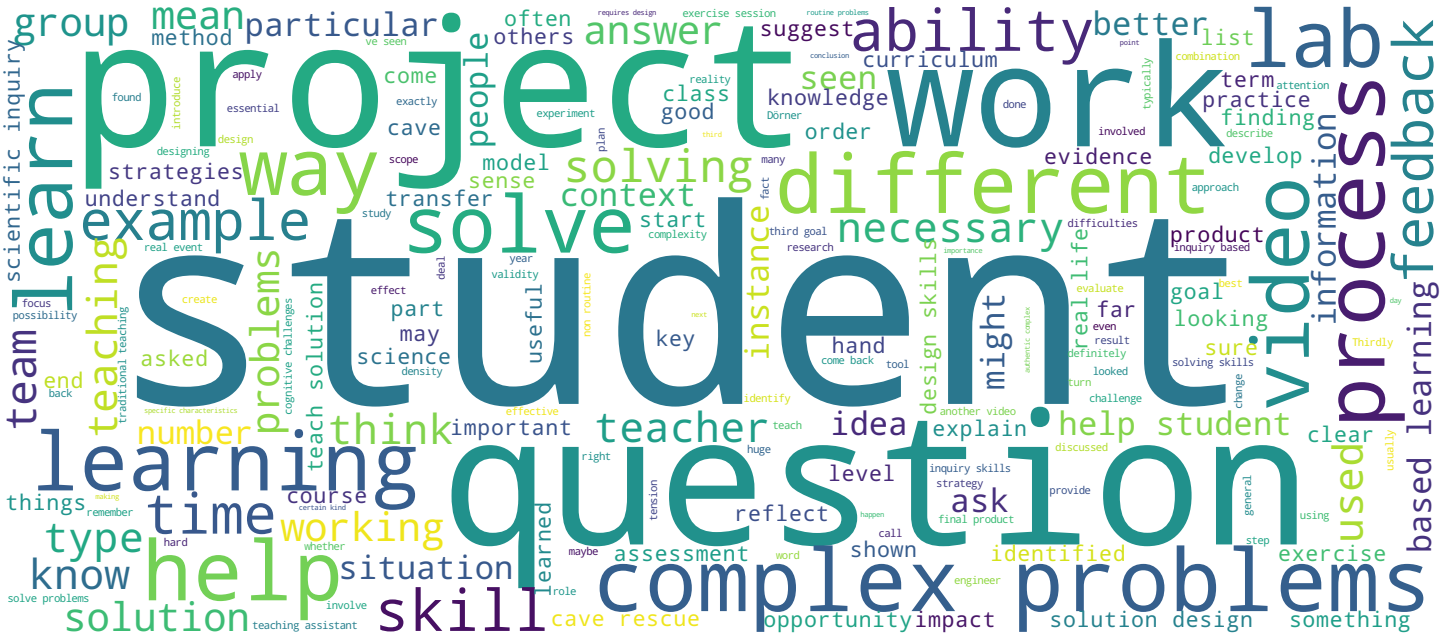


Search MOOC

Video

EPFL

Goals for this video

- List what are the main **skills** students need to work on **complex problems**
- Describe what **solution design** is and how it relates to problem solving and inquiry
- Explain how **projects** can be used to teach solution design
- Present evidence of the **impact** of **projects** on learning

In previous videos, we have discussed how teaching problem solving and scientific inquiry are two big goals in higher education in science and engineering. We are not coming to a third goal which is teaching solution design. At the end of this video you should be able to list what skills are necessary to be to be able to tackle real-life complex problems. You will be able to describe what solution design is and how it relates to problem solving and inquiry. You will also be able to describe how projects can be used to teach solution design. Finally, you will be able to present evidence of the impact of projects on learning.

Notes

Summary

0m 04s

Example problem

(Tham Luang cave rescue, 2018)

12 members of junior a soccer team have gone missing while exploring a cave complex where water is rising at a very alarming pace.

To illustrate the rationale for this third goal, let me introduce an example problem inspired by a real event widely publicized during the summer 2018. The problem is the following: 12 members of a junior football team have gone missing while they were exploring a huge cave complex. Because of heavy rains; the cave has been partially flooded and the water level is rising fast. Now the reason why I chose this problem is that this is a real-life problem. The specialized rescue teams who usually work on this type of problem call upon experts with scientific and engineering background to help them. A situation like this requires knowledge and skills in geology, hydrology, civil engineering, hydraulics, etc., etc. Now I think you would agree with me that this problem is quite different from a typical science problem as we usually see in labs or exercise sessions. So I suggest that you take one minute to compare this problem with a problem that you've seen students solve and to make a list of the differences. Start again the video when you are ready.

Notes

Summary

0m 47s

Example problem

(Dörner and Funke, 2017)

Complex Problem

12 members of junior a soccer team have gone missing while exploring a cave complex where water is rising at a very alarming pace.

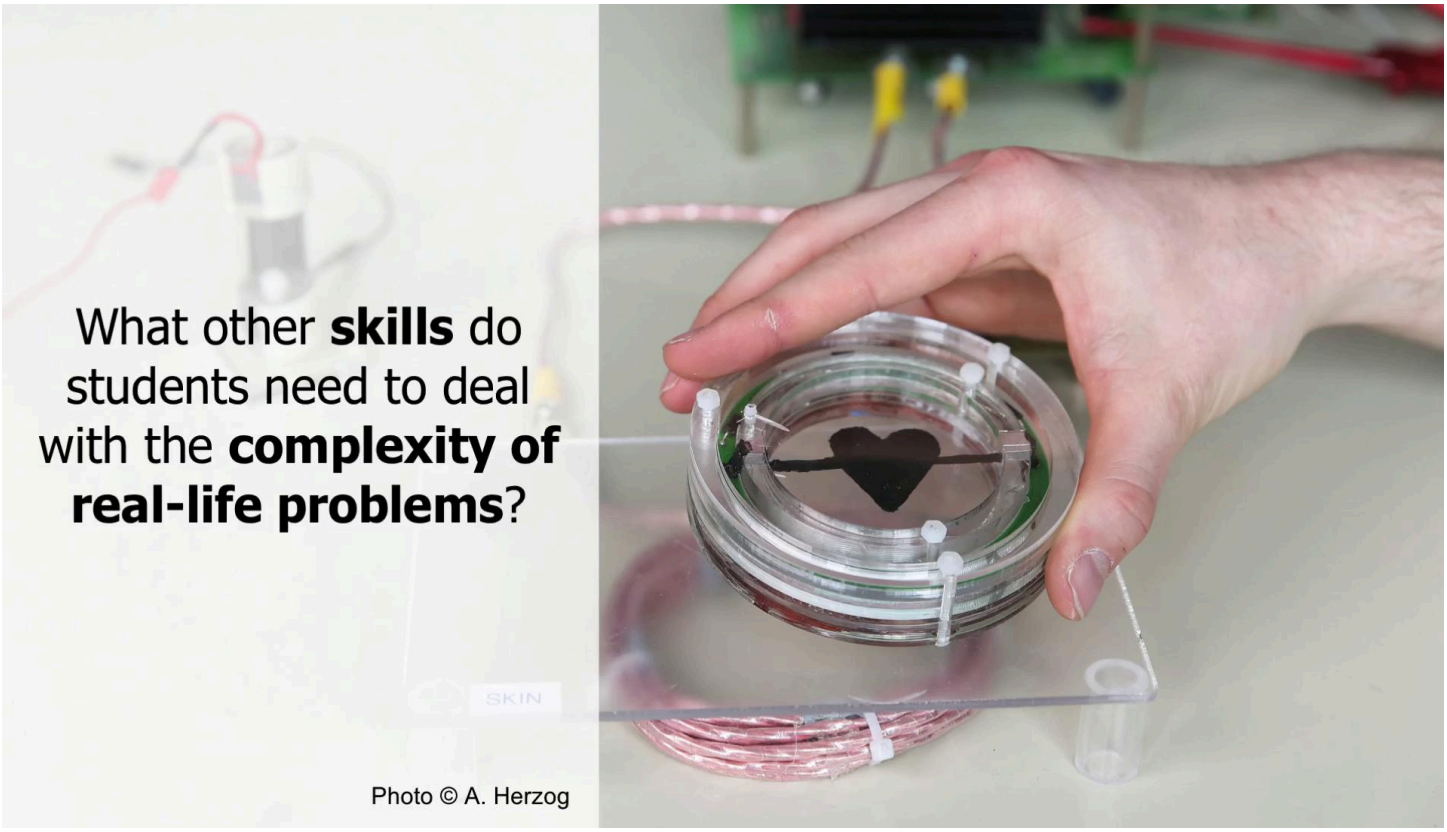
- Undefined starting point
- Multiple aspects
- Dynamic evolution
- No "correct" solution

Okay what are the specific characteristics of the cave rescue problem? First very few information is available and the starting point of the problem is undefined. The location of the group in the cave is unknown as well as their physical condition and the supplies they might have. Finding out this information is actually part of the problem. Second the problem has intricate geological, hydrological, technological and logistical aspects to cite only a few. So it is a multi-disciplinary problem by nature. Third, the problem evolves dynamically in time. The level of water in the cave might change fast and its evolution is hard to predict. The rescuers might have to change their plans multiple times because of the modifications of the constraints. And finally, while the ultimate goal of saving the 12 boys is very clear, it would be very hard to tell what a correct solution to this problem could be. Some solutions would be better than others but they would typically have both advantages and drawbacks. In particular some of the rescue options could involve more risks than others. So these are some of the distinctive features of complex problems.

Notes

Summary

2m 04s



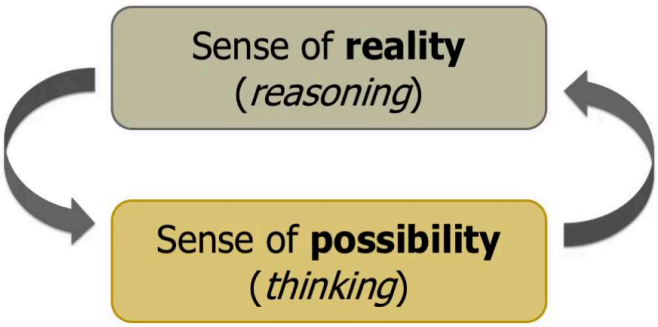
Now how exactly do we solve these problems? And how it is different from what we've seen so far? Let's come back to our cave rescue problem. Such a problem is definitely a non-routine ill-defined problem. As you have seen in another video being able to transfer what has been learned in other context in hydraulics and fluid dynamics, for instance, would definitely be necessary but the situation of this cave in this country with this weather and this number of people to rescue imposes so many specific constraints that the standard methods in the field cannot be applied directly. So adaption is essential. Of course, methods of scientific inquiry will be very useful to work on the problem. Looking at other cave rescue operations and collecting data to figure out what's going on in the cave, is necessary. But if you want to evaluate if a solution could work, there are so many variables involved that the simple principle of vary one thing at a time cannot be applied here. So what is the missing piece? What should we teach our students so that they would be able to tackle such challenges?

Notes

Summary

3m 33s

Complex problem solving skills



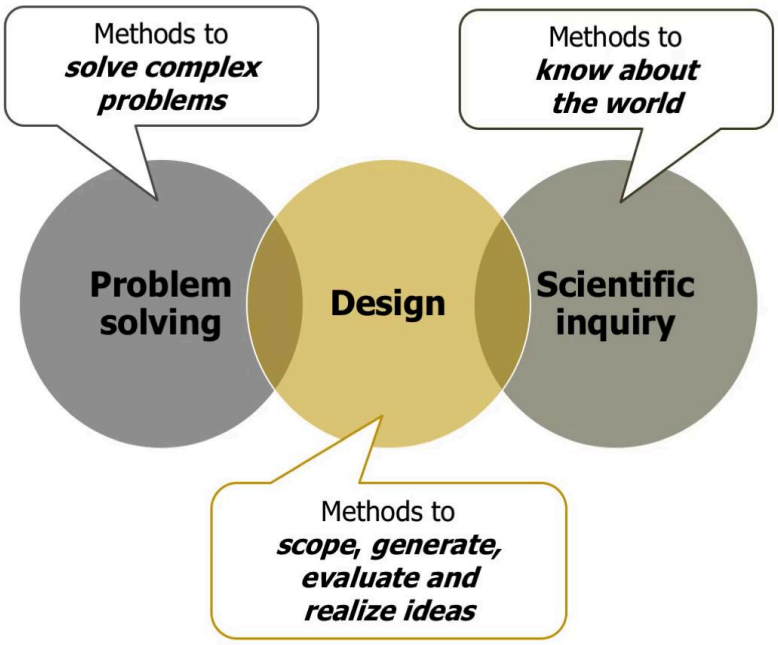
(Dörner and Funke, 2017)

The processes involved in the resolution of complex problems have been widely studied. But because the problems considered are complex, the processes to solve them are also very complex. In their recent summary of the research from the topic, Dörner and Funke have identified two key competences that complex problem solvers have. First, they have the ability to make acute and exact deductions based on evidence. These reasoning skills are also called sense-of-reality because they are the source of pragmatic and realistic actions. But to deal with uncertainty, complexity and openness, another category of skills is necessary. When working with incomplete or ambiguous information, you need the ability to fill the gaps. This requires a certain kind of imagination. Imagining possible solutions that have not yet been considered also requires a certain kind of creativity and this is what Dörner and Funke called the sense of possibility. It is the ability to imagine what “might be” based on your current knowledge of “what is”. Now they argue that to solve complex problems, it is necessary to constantly switch between our sense of possibility and our sense of reality.

Notes

Summary

4m 57s



(Sheppard et al., 2006 ; Dym et al., 2005)

If we come back to our two previous big skills which are problem-solving and scientific inquiry actually what Dörner and Funke describe is a mix of the two plus a third important ingredient which is design. Sometimes called design thinking, design is the ability to scope, to generate, to evaluate and to realize ideas. Design is a skill that goes across disciplines. Biologists or mathematicians needed as much as architects or engineers, for instance. Actually, design is tightly integrated with problem solving and inquiry. Solving problems for which solution does not yet exists, requires design skills to create the solution. And designing a solution requires problem-solving skills. Investigating scientific questions requires design skills to create an investigation protocol and designing a research protocol requires inquiry skills. So if you think about it, the ability to generate new ideas is ubiquitous in the work of scientists and engineers. But contrary to the popular opinion, the ability to design is not innate. It is a skill that we can learn.

Notes

Summary

6m 28s

Learning by...

Working on authentic **problems**

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As you may have already guessed, a learning-by-doing approach is best to provide an experience of the specific features of complex problems. So a key to the approaches to teach solution design is, therefore, to give students the opportunity to work on authentic complex problems.

Notes

Summary

7m 45s

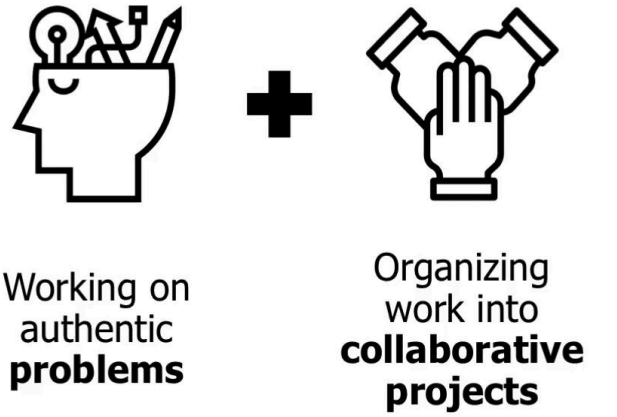
Now if you think about the cave rescue problem, finding one single person who has all the knowledge and skills that are necessary to address all the aspects of the situation, is clearly impossible. Actually the real event involved more than ten thousand people, which is huge but the problem was huge too. So teams do not need to be overly big but teams are necessary to solve most complex problems. This is why the ability to collaborate is a very important skill to develop.

Notes

Summary

8m 03s

Learning by...



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So methods to teach solution design by practice generally combine the opportunity for students to work on authentic complex problems with the opportunity to organize their work into collaborative projects. The goal is that they develop a combination of design skills, teamwork skills and project management skills.

Notes

Summary

8m 41s

Teaching using problems / projects

- Projects in the context of courses
- Semester projects
- Bachelor/Master projects

Importance of the **final product**

(Prince and Felder, 2006)

As Prince and Felder explain in their review - projects using teaching may vary significantly in scope and scale. As a teaching assistant you might be asked to help students to work on a project as part of a course or you might have to supervise semester projects or you could also be involved in Master or Bachelor projects. The complexity of the problem, the duration of the project and the size of the student team will, therefore, vary. A big difference between projects at the beginning of the curriculum and graduation projects, is generally the importance given to the final product. In industry sponsored projects for instance, the pressure associated with arriving at a viable solution is much higher than if the project is only a simulation of a real situation.

Notes

Summary

9m 04s

Balance product / process

(Hmelo et al., 2000 ; Barron et al., 1998)

One specific challenge of projects comes from the tension between two different outcomes. The final product or the final solution on one hand and student learning on the other hand. In general, students quickly become so product- focused that they lose sight of the learning goals of the project. The problem is that what students can reuse in future projects is rarely the product. It is what they have learned from the process of working on the project. We have already seen that for students to learn from doing, they need to reflect on what they are doing and projects make no exception. This is one of your essential roles as a teaching assistants to help students to balance their attention between the product and the process. We will discuss how to do this in practice in another video.

Notes

Summary

10m 01s

Challenges when dealing with complex problems

- "Emergency reaction" leading to **lower ability to step back**
- Irrationality leading to an **increased potential for failure**
- Strong influence of context leading to **lower ability to transfer**

Importance of appropriate supervision with **feedback**

(Dörner and Funke, 2017)

But this tension between the product and the process is further complicated by the nature of the problems on which students have to work. Research on complex problem-solving has shown that people have to deal with three major cognitive challenges during the process. The first challenge is that when confronted with the pressure of complexity, the way we process information changes. Because of what researchers called the emergency reaction we are less able to step back and to reflect on what we do. The second challenge is that we become less rational and this affects our ability to plan, to control and to decide. So researchers have identified that this can lead to what they call an increased potential for failure. Finally it has been shown that the context has a stronger influence in complex problems than your other types of problems. And as a consequence, we have more difficulties transferring what we know from other contexts. So for all these reasons, supervision plays a crucial role in student projects. If we want students to learn from working on the complex problems, we have to help them focus on the process and overcome these three cognitive challenges. Feedback is a tool that has been shown to be particularly effective in this context.

Notes

Summary

11m 02s

What does the evidence say?

- Capstone/Cornerstone projects
  (Howe, 2010 ; Grimheden, 2007)
- Problem-Based Learning (PBL)
  (Kolmos, De Graaf and Du, 2009 ; Savery, 2006)

Now what does the evidence say about the impact of projects on learning? Many studies relate to projects that are called capstone projects. This term is used to refer to the projects coming at the end of the curriculum as a way to integrate learning and to prepare students for the professional world. These studies show that these projects generally improve employer satisfaction and employment ratios but also student motivation and retention. This is also why a number of institutions have then chosen to introduce this type of project in first year as a way to expose students to real-life experiences earlier in the curriculum. To continue with the metaphor these projects have been called “cornerstone projects”. Two teaching models are usually associated with these projects. In one students attend lectures in parallel of the project and then they apply the knowledge to solve the problem. In the other model, students start by working on the project and it is the question that they have to solve that drive them to learn what they need. This specific approach is called problem-based learning.

Notes

Summary

12m 40s

Impact of Problem-Based Learning

(Hattie, 2009)

No effect or negative effect on surface learning

- Breadth of knowledge (d = -0.78)
- Understanding of concepts (d = -0.04)

Positive effects on **deep learning**

- Ability to apply (d = 0.40)
- Understanding of the structure underlying concepts (d = 0.75)

Positive effects on **skills** (d = 0.66)

Hattie has included a review of existing meta-analyses on problem-based learning in his book “Visible Learning”. As he explains, the results show two main trends. The first is that problem-based learning has an effect which is comparable or even slightly worse than traditional teaching on surface learning. This means that problem-based learning does not really help students to acquire more knowledge or to understand better the concepts. Instead, problem-based learning has a positive impact on deep learning. Concretely this means that it helps students to understand how the concepts relate to each other. It also means that students are better at applying what they have learned to new problems and new situations. Overall it has been shown that problem-based learning has a much better impact than traditional teaching on the skills of students, in particular, on their ability to solve problems and I'm sure you can see why.

Notes

Summary

14m 04s

Summary

- Solving complex problems requires problem solving + inquiry skills **+ design skills**
- Solution design can be taught using **project-organized problem-based learning**
- Supervision is essential to help students **learn from the process**

So let's summarize what we have seen so far. After discussing the specific characteristics of complex problems we have seen that solving these type of problems requires a combination of three different sets of skills. Problem-solving skills, inquiry skills and design skills. We have also discussed how projects can be used to teach how to design solutions to complex problems. Finally, we have introduced the idea that helping students to learn from the process of working on a project is essential, in particular, given the cognitive challenges posed by complex problems.

Notes

Summary

15m 12s