



University of  
Zurich<sup>UZH</sup>

Institute of Education & Faculty of Science

# “Trickle Up” Improvement of University Science Teaching

## Evaluation of PCK-based training for PhD students

Sara Petchey  
Kai Niebert

Science and Sustainability Education  
University of Zurich



Teaching Science  
at University

## What is the problem?

**High drop out rates in STEM**

= 45% at 4-year US institutions (NSF, 2012)



Lecture hall 1940 - University of Wisconsin Archives

<https://news.wisc.edu/newsphotos/aghall.html>

The continued use of lecturing is the “pedag

8320)

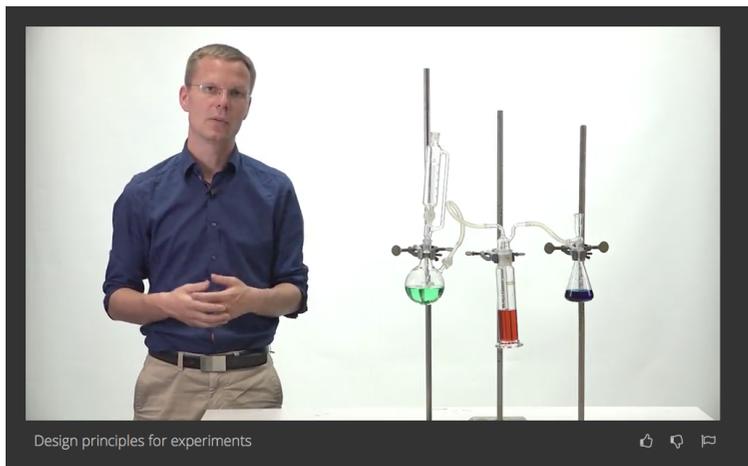
## What is the problem?

PhD students are asked to teach with little or no training

What makes someone a good instructor?	Vital
Explains clearly	97%
Fair	77%
Approachable to students	74%
Expertise in the subject matter	72%
...	
Promotes active student participation	51%
Gives students regular feedback on their learning	50%
Asks students about their prior learning	28%

How confident are you to...	Not so confident
Manage a class full of students with varying ability?	46%
Use a variety of teaching techniques (e.g. group work, collecting and giving feedback, discussions, etc.)?	38%
Promote student participation in your course?	34%
Determine final grades for a course?	34%
Plan learning activities (e.g. a series of lectures, a lecture then lab, homework, etc.)?	28%
...	
Answer students' questions and explain material clearly?	15%
Stand and teach in front of an audience?	10%
Create a positive learning environment?	10%

# Teaching Science at University – MOOC format



Have a question? Discuss this lecture in the week forums. >

- Downloads
- Lecture Video mp4
  - Subtitles (English) WebVTT
  - Transcript (English) txt

Interactive Transcript

Search Transcript  English

0:05 In the 1920s, German psychologists developed theories to describe how visual perception and understanding belong together. In the 1950s, Rudolf Arnheim published a very famous book, The Creative Eye, that describes how we are grouping things together and separating things in our understanding based on our visual perception.

0:31 We'll it's worth reading this books I will sum up the six most important Gestalt principles from this theories for your experimental set ups and lab classes and lectures. The first and foremost important Gestalt principle is the figure ground principle.

TEACHING SCIENCE AT UNIVERSITY KNOWLEDGE-TO-PRACTICE BRIEF #5

### BIG IDEAS IN SCIENCE

How can I help my students bring cohesion into their understanding?

University graduates, even those from respected places such as Harvard or Cambridge, often hold misconceptions about science-based phenomena, such as how an acorn becomes an oak tree. One explanation is that students don't often see the big picture in their fields' body of knowledge or understand the relationships between the topics they cover in different courses.

To help students understand the often highly specialized and isolated knowledge elements of your courses in relation to other content, introduce them to the big ideas of your field.

**This brief will...**

- Describe what a 'big idea' in science is.
- Describe how you can identify big ideas for your courses.
- Provide examples of big ideas used for several disciplines.

**Why use it?**

**What is a 'big idea' in science?**

There is an enormous range of possible content lectures, labs, and seminars. However, no one can read all textbooks. So how do we select the knowledge we hold needs to be placed in a Students and instructors need to know when that what they are doing helps to explain this.

The Nobel Laureate Richard Feynman has an understanding the big ideas of a discipline understanding the physical world:

The world looks so different after learning than the world of an ignorant. When they look back on what they learned, they realize that the world which was bound to be different.

In the scientific endeavor ideas can seem very reading Darwin's The Origin of Species. They have said "I don't expect of me not to have this, phenomena studied in the Large Hadron Co project are understandable at some level by idea that all material is made of small particles consist genetic material which helps determine.

A big idea in science is a key concept that is understanding scientific explanations. It acts organizer for the knowledge in your field and link the different areas of disciplinary content because they provide students with connect tools that can enrich their application of your understanding of core ideas.

Find our MOOC at: [www.coursera.org/learn/teaching-science](http://www.coursera.org/learn/teaching-science)

TEACHING SCIENCE AT UNIVERSITY KNOWLEDGE-TO-PRACTICE BRIEF #13

### TEACHING WITH MODELS

Without models, science is neither teachable nor learnable.

**Key role of models in science teaching**

When you were in school, did you ever have to make a 3D model of a cell? This activity probably took time and energy, but did it really develop your understanding of how a cell functions? After an assignment like this, we can only say that our students know how to make a replica of a cell. We cannot say that they know how to use the model to describe, test, and predict cellular phenomena.

Models in our teaching take various forms - physical replicas, diagrams, drawings, computer simulations, analogies, for example. No matter what form you use, the key is to engage students in making explanations and predictions with that model.

**Students and scientists perceive models oppositely**

Often students have a very limited understanding about models and the modeling process. Some see models as miniatures of real life objects, and they do not see models as instruments in the scientific method.

Scientists, on the other hand, see models as explanations, a means to organize observations, a way to bring structure to complex processes, or tools for visualizing abstract concepts.

This means a lecturer might present a model developed from understanding at the end of a process, and students see this same model as the beginning of a learning process in which they must reconstruct the observations of real life underlying it.

**Developing a model**

**Perceiving a model**

**This brief will...**

- Explain the different roles models play in science teaching and in scientific discovery.
- Introduce the different levels of competence students have in understanding and working with models and how this impacts teaching of individuals.

**Why do it?**

Using models or modeling in your lessons gives students...

- Visual tools to understand invisible phenomena and abstract concepts
- A means of organizing their observations
- A tool to simplify complex processes

However, models also have limitations, so it is very important to not only use the model but also talk about its strengths and weaknesses.

Find our MOOC at: [www.coursera.org/learn/teaching-science](http://www.coursera.org/learn/teaching-science)

## 5 modules

Evidence-based teaching strategies

Conceptual Change

Teaching with Analogies

Teaching with socio-scientific issues

Teaching science in the lab

Lecture

Transcript

Briefs

Assignment

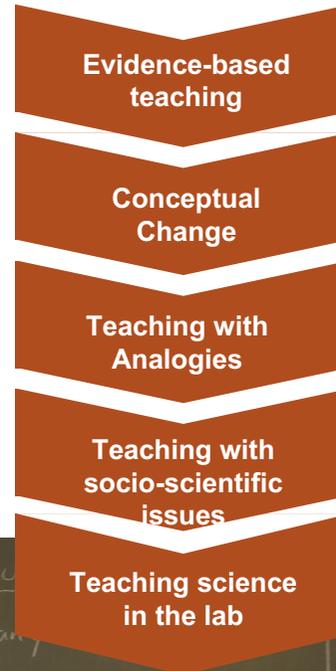
Feedback

## Blended format

Open to all PhD students

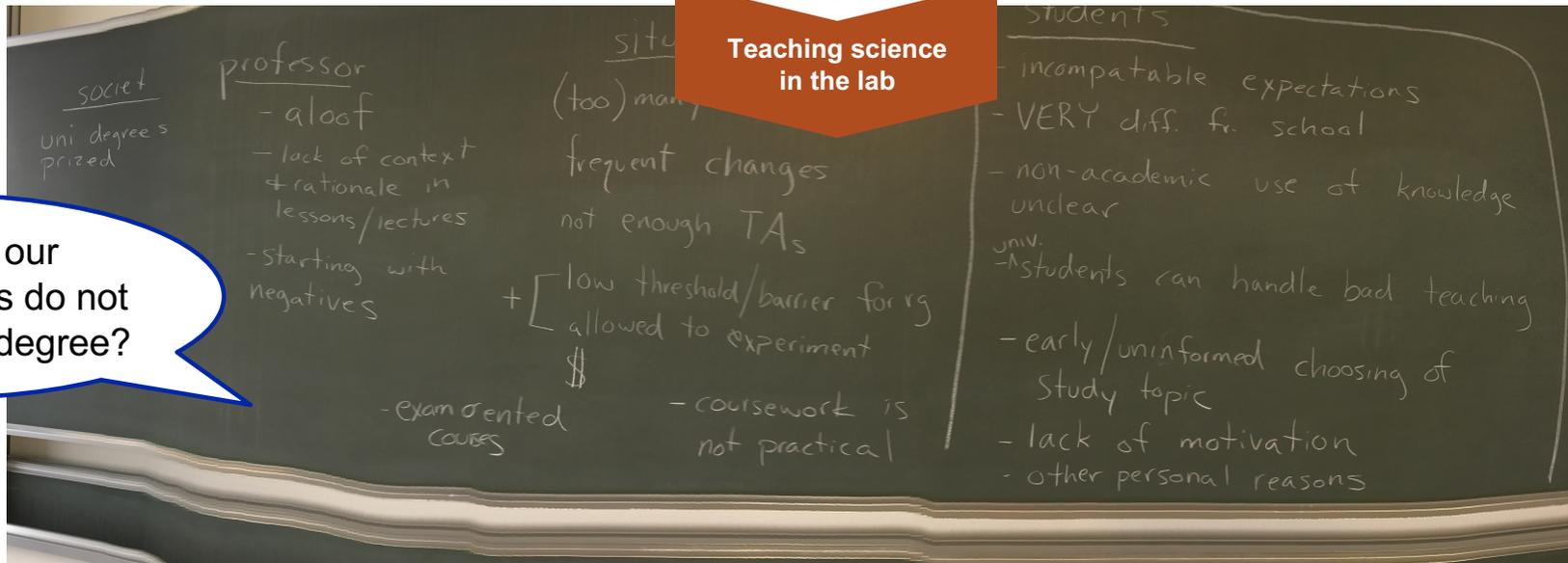
- In-person Day 1:**
- (Pre-course survey)
  - Critical reflection on orientation to teaching
  - Conceptual change basis

### 5 online modules



- In-person Day 2:**
- Reflections on teaching experience & orientation
  - Post-course survey

What % of our undergraduates do not complete their degree?



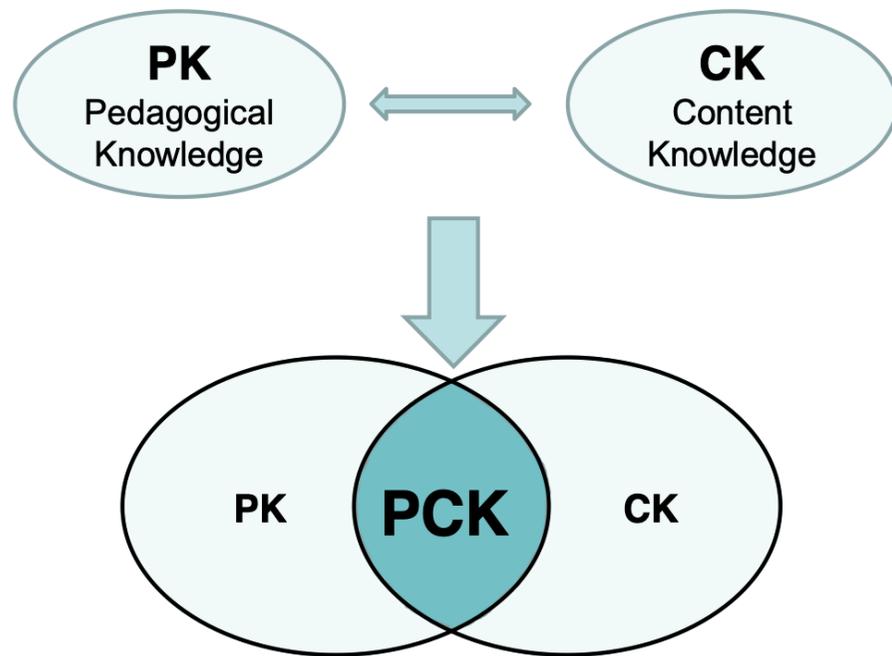
## Does our intervention work?

**Research question: How does a course on teaching science in higher education influence the teaching abilities and beliefs of PhD students?**

### **Methodology**

- Abilities? —> qualitative content analysis of assignments (n=63)
- Beliefs? —> pre/post survey analysis (n=100)

# Pedagogical Content Knowledge



## What is PCK?

- subject matter knowledge for teaching- “embodies the aspects of content most germane to its teachability” (Shulman, 1986, p.9)
- knowledge base for planning and delivering topic- and audience- specific teaching (Gess-Newsome, 2015)

## Why focus on PCK?

- positive effect on instructional quality (e.g. Kunter et al., 2013)
- “reliable predictor” of teacher ability and action in the classroom (Park et al., 2010, p.254)

## How to focus on PCK

- authentic practice (Putnam & Borko, 2000)
- individual and collective reflection (Van Driel & Berry, 2012)

## Effects of the course I: Demonstration of PCK

### Conceptual Change

#### Assignment questions:

1. Identify concept to teach
2. Identify relevant student everyday conceptions
3. Identify learning demands
4. Design a conceptual change intervention
5. Self Reflection

#### Peer review prompts:

1. Anything missing and why might this matter?
2. Most important preconception?
3. Will it improve student learning?

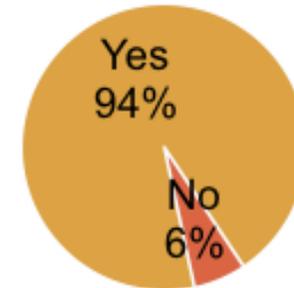
## Effects of the course I: Demonstration of PCK

### Conceptual Change

#### Assignment questions:

1. Identify concept to teach
2. Identify relevant student everyday conceptions
3. Identify learning demands
4. Design a conceptual change intervention
5. Self Reflection

Is this different from how you have taught before or were taught as a student?



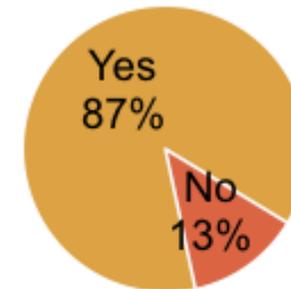
## Effects of the course I: Demonstration of PCK

### Conceptual Change

#### Assignment questions:

1. Identify concept to teach
2. Identify relevant student everyday conceptions
3. Identify learning demands
4. Design a conceptual change intervention
5. Self Reflection

Grain size of topic appropriate for a single intervention?



e.g. Newton's Laws of Motion vs. friction

## Effects of the course I: Demonstration of PCK

### Conceptual Change

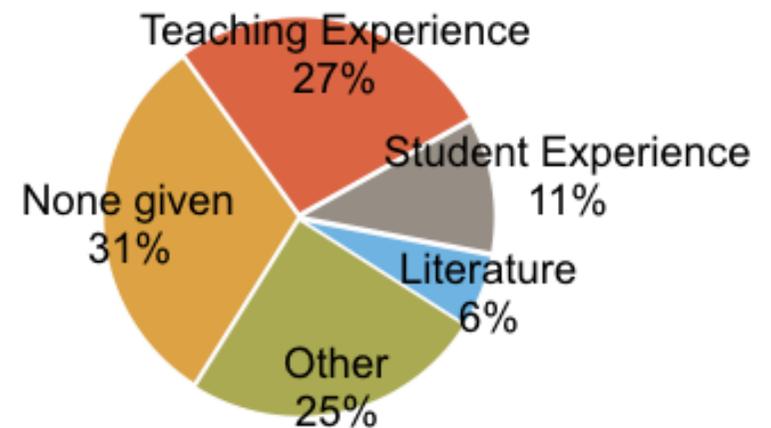
#### Assignment questions:

1. Identify concept to teach
2. Identify relevant student everyday conceptions
3. Identify learning demands
4. Design a conceptual change intervention
5. Self Reflection

Relevant conceptions?

e.g. Students think that objects with no forces acting upon them naturally come to rest.

Source of awareness?



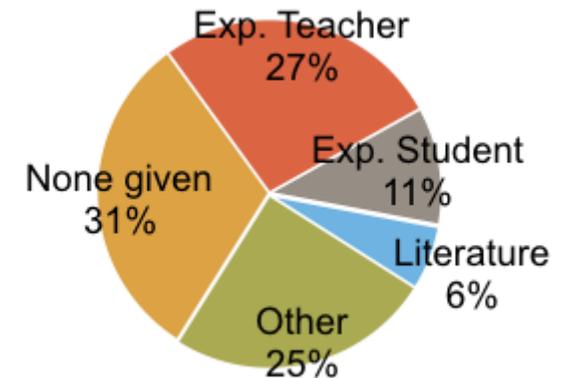
## Effects of the course I: Demonstration of PCK

### Conceptual Change

#### Assignment questions:

1. Identify concept to teach
2. Identify relevant student everyday conceptions
3. Identify learning demands
4. Design a conceptual change intervention
5. Self Reflection

#### Source of awareness?



#### Breakdown by cohort:

Experience as a teacher:

Coursera 34%, Blended 18%

Experience as a student:

Coursera 0%, Blended 24%

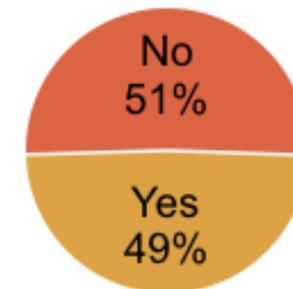
## Effects of the course I: Demonstration of PCK

### Conceptual Change

#### Assignment questions:

1. Identify concept to teach
2. Identify relevant student everyday conceptions
3. Identify learning demands
4. Design a conceptual change intervention
5. Self Reflection

Included cognitive conflict in intervention plan and in what form?



44% Afford a student experience/inquiry  
e.g. experiments with collisions on  
air hockey table

50% Information transmission

## Effects of the course II: Changes in orientation to teaching

### 1. Increased metacognition about teaching

*“I had **never thought the actual act of giving feedback**, and I believe being conscious of it while doing it may help me provide more insightful feedback.”*

*“I have never thought of raising socioscientific issues using frames... Probably, it’s very intuitive, but **I never managed to actively put a name to it**”*

### 2. Shift in attitude towards teaching

*“I think our work as TAs is not appreciated during our PhD. After this course, I feel that it is actually important for others... **It was pleasant to feel satisfied with my teaching and not just see that as “unproductive” time during my PhD.**”*

*“I used to think that that histology and embryology could not be taught in a motivating, engaging way. But now I think **it can be fun for me as a professor and for the students as well**, elevating the possibilities that the knowledge that the students build will be more significant and last longer.”*

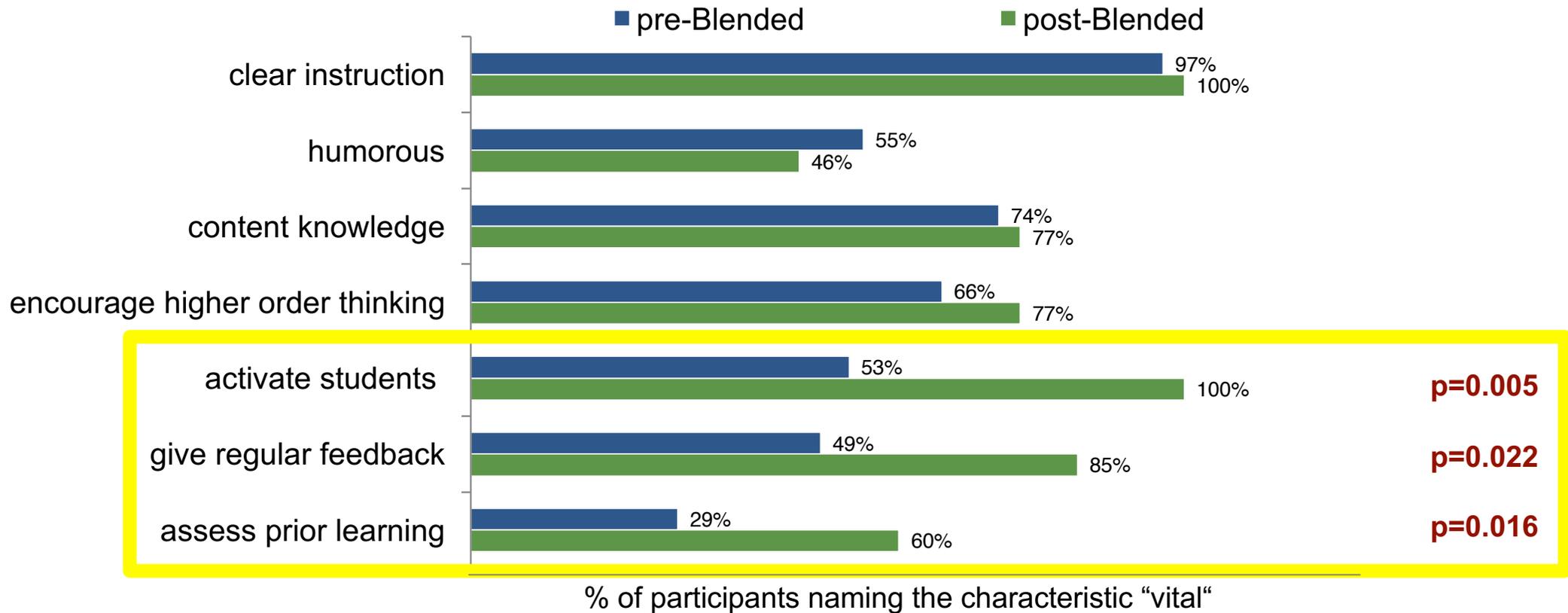
## Effects of the course II: Changes in orientation to teaching

### 3. Shift of focus towards students and their learning

*“I used to think ... learning objectives are a **formality**. Now I think, ... learning objectives **genuinely guide student learning** to give them confidence.”*

*“I used to think of **how I would teach** and the clarity of how/what to deliver, but now I think more from what is more **important for the students and what they struggle understanding the most.**”*

## Pre/Post Survey: What makes someone a good instructor?



n=37 blended, Participants were able to rate any/all as "vital," "somewhat important" or "less important."

## Conclusions

- TSAU offers transformation, not just a few more tricks.
- Most participants report teaching differently, and in a way that is:
  - more PCK- and student- oriented
  - more able to identify and use student preconceptions
  - more confident
- All PhD students should receive similar training.

How confident are you to...	PRE Not so confident	POST Not so confident
Manage a class full of students with varying ability?	46%	14%
Use a variety of teaching techniques (e.g. group work, collecting and giving feedback, discussions, etc.)?	38%	0%
Promote student participation in your course?	34%	7%
Determine final grades for a course?	34%	14%
Plan learning activities (e.g. a series of lectures, a lecture then lab, homework, etc.)?	28%	7%
...		
Answer students' questions and explain material clearly?	15%	3%
Stand and teach in front of an audience?	10%	7%
Create a positive learning environment?	10%	0%

# Thank you!

## Citations:

- Gess-Newsome, J. (2015). A model of teacher professional knowledge and skill including PCK: Results of the thinking from the PCK Summit. In: Berry, A., Friedrichsen, P. & Laughran, J. (eds) *Re-examining Pedagogical Content Knowledge in Science Education*. New York: Routledge.
- Kunter, M., Klusmann, U., Baumert, J., Richter, D., Voss, T. & Hachfeld, A. (2013) Professional competence of teachers: Effects on instructional quality and student development. *Journal of Educational Psychology*, 105(3), 805–820. <http://dx.doi.org/10.1037/a0032583>
- National Science Foundation. (2012). *Science and Engineering Indicators 2012*. Arlington, VA: National Science Foundation. <https://www.nsf.gov/nsb/sei/edTool/data/college-10.html>
- Park, S., Jang, J.-Y., Chen, Y.-C. & Jung, J. (2010) Is pedagogical content knowledge (PCK) necessary for reformed science teaching? Evidence from an empirical study. *Research in Science Education*, 41(2), 245–260.
- Putnam, R. T., & Borko, H. (2000). What do new views of knowledge and thinking have to say about research on teacher learning? *Educational Researcher*, 29(1), 4–15.
- Shulman, L.S. (1986). Those who understand: knowledge growth in teaching. *Educational Researcher* 15, 4–14.
- Van Driel, J.H. & Berry, A. (2012). Teacher Professional Development Focusing on Pedagogical Content Knowledge. *Educational Researcher*, 41(1), 26-28.
- Wieman, C. (2014). *Improving how Universities Teach Science: Lesson from the Science Education Initiative*. Cambridge, MA: Harvard University Press.

Sara Petchey, Kai Niebert  
University of Zurich  
[sara.petchey@uzh.ch](mailto:sara.petchey@uzh.ch), [kai.niebert@uzh.ch](mailto:kai.niebert@uzh.ch)  
[www.coursera.org/learn/teachingscience](http://www.coursera.org/learn/teachingscience)



# Teaching Science at University



## Top Tip

Narrative, formative peer review feedback, **especially when well curated**, leads to better exchange between participants than rubric-based, summative feedback.

### Version 1

**Does the writer has a realistic feeling for how students will respond to the teaching strategy.**

*47% Retention*

Poor – The writer did not reasonably address the student perspective. - 0

Fair – The writer anticipates student response to the strategy, but I think it could be more realistic. - 1

Good – The writer seems to really understand how students would respond to this strategy and shows realistic insight into student learning and behavior in this situation. - 2

### Version 2

**How realistic is the writer's sense of how students will respond to the teaching strategy?**

*71% Retention*

## Change in confidence

PRE

	PRE Not so confident	POST Not so confident
Manage a class full of students with varying ability?	46%	14%
Use a variety of teaching techniques (e.g. group work, collecting and giving feedback, discussions, etc.)?	38%	0%
Promote student participation in your course?	34%	7%
Determine final grades for a course?	34%	14%
Plan learning activities (e.g. a series of lectures, a lecture then lab, homework, etc.)?	28%	7%
...		
Answer students' questions and explain material clearly?	15%	3%
Stand and teach in front of an audience?	10%	7%
Create a positive learning environment?	10%	0%

POST

	Not so confident
Manage a class full of students with varying ability?	14%
Determine final grades for a course?	14%
Stand and teach in front of an audience?	7%
Promote student participation in your course?	7%
Plan learning activities (e.g. a series of lectures, a lecture then lab, homework, etc.)?	7%
Support and encourage students who are having difficulty learning?	7%
Be sufficiently knowledgeable in the subject matter?	3%
Answer students' questions and explain material clearly?	3%
Assess student understanding?	3%
Encourage higher level (independent, critical, creative) thinking?	0%
Use a variety of teaching techniques (e.g. group work, collecting and giving feedback, discussions, etc.)?	0%
Create a positive learning environment?	0%

## Participant numbers

Coursera

*Participant numbers to date:*

- 23 sessions
- 3500 enrollments
- 154 completers

Blended

*Participant numbers to date:*

- 3 sessions
- 42 enrollments
- 37 completers
- 2 ECTS

## Blended format II

TAs for a specific course

**In-person Day 1:**

- Intro and logistics by course leader
- Top 10: most challenging content
- Top 10: most challenging teaching situations

**In-person Day 2:**

- Reflections on teaching experience
- Top 10 strategies from TSAU online
- Group development of teaching tools

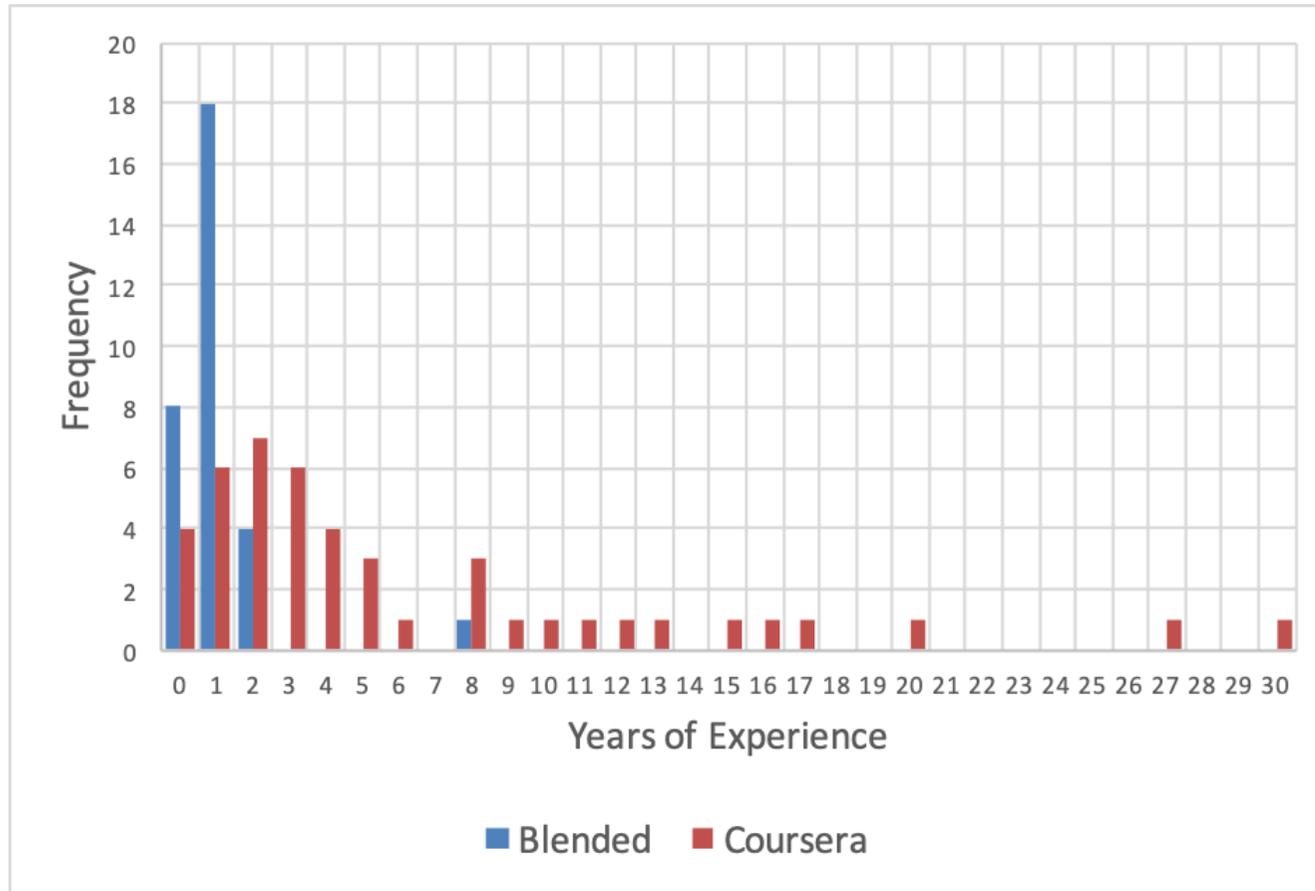


How can I improve my 1-to-1 work with students?

Have you learned this before?

"I'm not sure about .... but here's what I DO know..."

## Two distinct cohorts



### Previous training?

Coursera 50%

Blended 15%

### Pedagogy certificate/degree?

Coursera 13%

Blended 0%

### “Very confident” to stand and teach in front of an audience?

Coursera 80%

Blended 21%

### Survey numbers

Coursera n=61

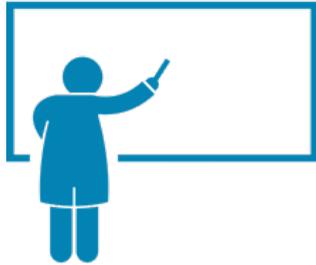
Blended n=39



## Course Completion

	Version 1	Version 2
	12 SESSIONS	4 SESSIONS and going
	Peers = summative graders	Peers = critical peers
	<b>TOTAL ASSIGNMENTS SUBMITTED</b>	<b>TOTAL ASSIGNMENTS SUBMITTED</b>
1 Evidence-based teaching strategy	219	46
2 Initiate a conceptual change	153	33
3 Develop an analogy	137	31
4 Reframe your teaching	124	29
5 Foster students' inquiry skills	104	29
<b>AVG retention (%)</b>	<b>48%</b>	<b>63%</b>

## Teacher-centered



What scientific content will you teach?

Describe an experiment you teach.



## Student-centered



Describe the typical everyday conceptions of your students on the topic.

Think how this concept, method, or experiment has a relevance for your students' everyday life.

How will you know if students are learning?

### Five modules

Evidence-based teaching strategies

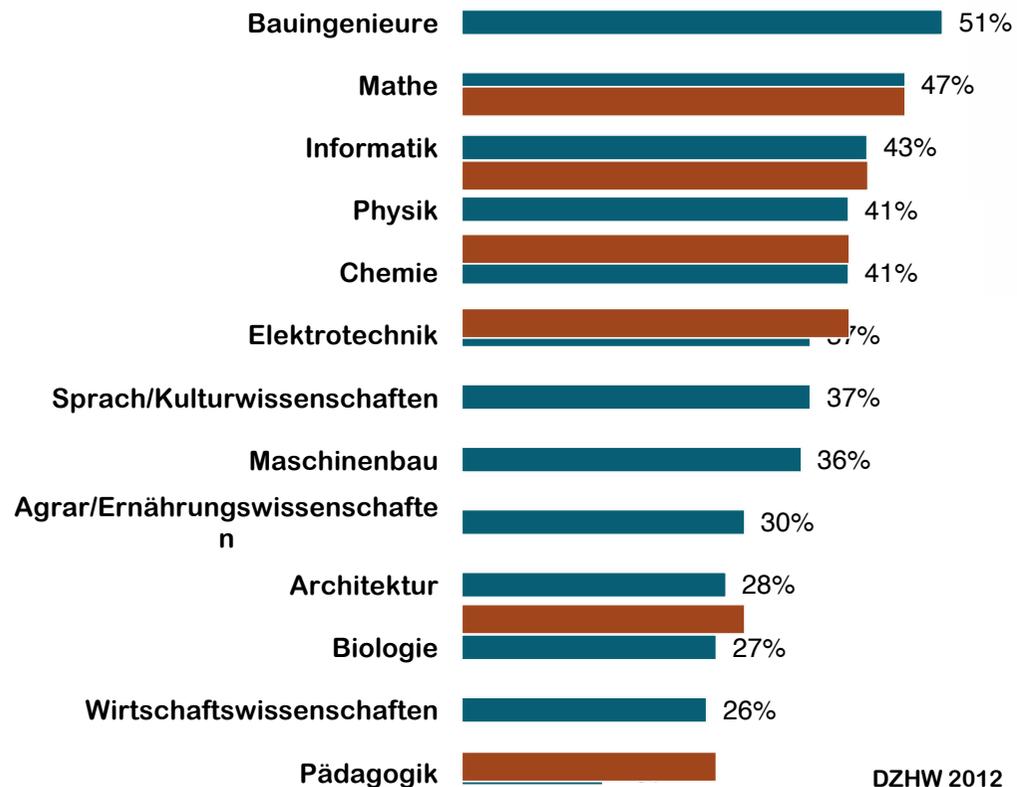
Conceptual Change

Teaching with Analogies

Teaching with socio-scientific issues

Teaching science in the lab

# Dropouts and their reasons



DZHW 2012

## Studienabbruch und Studienfachwechsel in den mathematisch-naturwissenschaftlichen Bachelorstudiengängen der Humboldt-Universität zu Berlin

Autorinnen: Wenke Seemann und Maika Gausch

Berlin, Januar 2012

80%) und niedrigere Absolventenquoten von teilweise nur 10 bis 20 Prozent aufweisen und demnach besonders stark von dem Phänomen betroffen sind.

Die Ergebnisse der Onlinebefragung von Studienabbrechern und Studienfachwechslern mathematisch-naturwissenschaftlicher Bachelorstudiengänge machen deutlich, dass aus der Sicht der Befragten insbesondere Gründe, die mit den Studienbedingungen und Leistungsanforderungen der Fächer zusammenhängen, für das vorzeitige Verlassen eines mathematisch-naturwissenschaftlichen Studiengangs entscheidend sind. Leistungsprobleme und ein als zu hoch empfundener Zeit- bzw. Arbeitsaufwand sind nach Angaben der Befragten Hauptursache für den Studienabbruch, wobei diese Faktoren durch zu wenig Betreuung und eine als unzureichend eingeschätzte didaktische Qualität der Lehre flankiert werden. Darüber hinaus wird ein vorzeitiges Beenden eines mathematisch-naturwissenschaftlichen Bachelorstudiengangs häufig mit falschen Erwartungen hinsichtlich der inhaltlichen Ausrichtung und einem fehlenden Praxisbezug begründet, während Aspekte der beruflichen Neuorientierung oder persönliche Gründe im Allgemeinen eine eher untergeordnete Rolle spielen. Für die Mehrheit der Befragten ist mit dem Studienabbruch kein Abschied aus dem Hochschulsystem verbunden, denn 57 Prozent der befragten Studienabbrecher haben zum Zeitpunkt der Befragung wieder ein Studium aufgenommen.

## Training teachers versus training scientists

Differences in expectations, priorities and professional identity:

### SCHOOL TEACHERS

- Assume a heterogeneous audience
- Smaller classes – more personal contact with students
- Care more for affective aspects of student performance (personal development, norms, values)
- **Career goal = Excellence in teaching**

### UNIVERSITY TEACHERS

- Assume a (more) homogeneous audience
- Focus on training content specialists
- “Sink or swim” mentality - more likely to think student effort/ability underlies course failure
- **Career goal = Excellence in research**

*“University teachers apparently consider themselves first and foremost not teachers but members of a certain discipline.”*

*(p. 594, Oolbekkink-Marchand, van Driel & Verloop, 2006)*





## Improving peer feedback

**BEFORE**

### RUBRIC

**Give one point** if at least one similarity and one dissimilarity are described.

**Give two points** if at least three similarities and two dissimilarities are described.

**Give no points** if nothing is described.

Give a short feedback to explain your decision.



Peer 1

“Very good attempt. But in question 1 the student's pre-conception has not been addressed.”



Peer 2

“Great job! Very elaborate response and a very illustrative analogy”



Peer 3

“Very good description”

**SUMMATIVE  
RUBRIC-BASED  
EVALUATION**

**AFTER**

### Criterion – Instructional Strategy

How well did the writer analyze the strengths and weaknesses of his/her analogy? What important strength or weakness did s/he leave out?



### Criterion – Student understanding

Are you convinced that students will be familiar with the source domain? Why or why not?

**FORMATIVE,  
NARRATIVE  
EVALUATION**

