



Durham  
University

# **Chemistry teacher knowledge: teaching successfully by knowing what you don't know**

Professor Vanessa Kind  
Durham University  
School of Education

# Introduction

What knowledge is held by trainee science teachers?

A strategy for improvement: A diagnostic test on chemical reactions

What professional knowledge is required of teachers?

Conclusions





“Teachers are one of the most influential and powerful forces for equity, access and quality in education and key to sustainable global development”

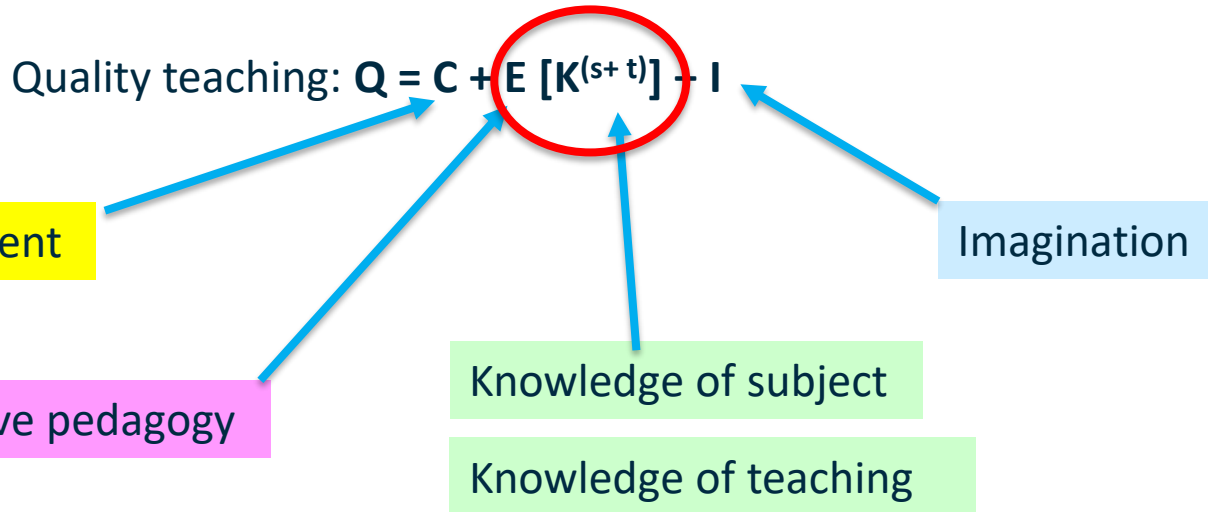
Eric Falt, UNESCO, New Delhi Director

World Teachers Day, 2019



# Teacher/ing quality matters

“..the most important school-related factor in pupil learning: the answer is teaching.” (Husbands, 2013)





Durham  
University

# What knowledge is held by trainee science teachers?

A study using open-ended vignettes

## Context and sample

239 PSTs enrolled on a one-year initial teacher education programme for teaching 11 -16 science at Durham University between 2005 – 2010

All PSTs had:-

- a Bachelors degree in a science subject
- 16+ qualifications in English, Mathematics and Science
- 18+ qualifications including at least one science subject
- passed a “suitability for teaching” interview

# Chemistry vignette

A teacher showed a class of 11 -12 year olds magnesium burning in air. There was a bright white light, smoke, and white ash remained. The teacher asked, “Where did the white stuff come from?”

Student responses included:-


- Inside the magnesium
- It is carbon/ soot
- It is ash left over from burning

Correct answer: It was a new substance formed in a chemical reaction.



What would you do to help students learn the scientifically correct answer?

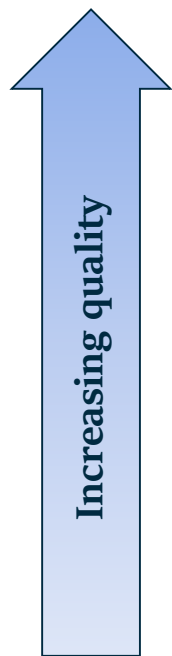
# Chemistry content knowledge



Quality	Example	%
Correct relevant complete	Magnesium oxide (MgO) new substance; oxygen from air; elemental magnesium	6.3
	Metals and oxygen react to produce oxides	14.6
Correct incomplete / irrelevant	Product named magnesium oxide / Equation for reaction	26.7
	Thermodynamic response	1.7
	Experimental procedure description	4.2
Incorrect	A mixture forms	13.0
No content knowledge		29.3
No response		4.2



# Chemistry pedagogical knowledge



Quality	Type	Example	%
Relevant	Demonstrate	Repeat experiment, Discuss MgO product	6.3
	Explain	State magnesium oxide is formed	11.7
	Illustrate	Draw particle diagrams	5.0
	Misconceptions	Use students' responses	12.6
Relevant incomplete / Irrelevant	Demonstrate	Show mass increases	10.0
	Explain	Burning produces oxides	26.4
	Illustrate	Model reaction with Lego® bricks	2.5
	Demonstrate	Repeat with another gas	4.6
	Explain	CO <sub>2</sub> not supporting combustion	7.5
	Analogy	It's like mixing paint / making a cake	4.2
No response			5.9

# Poor

- Correct relevant incomplete CK
- Correct, irrelevant PK

Student learning impact:  
LOW

“Try an experiment where Mg was burnt in different pure gases, e.g. N, O, He. Pupils could compare products with original experiment to see if there was (sic) any comparable results. Pupils could also be taught about the principles of combustion with oxygen, e.g. burning other materials in the gases to reinforce this idea.”

Biologist, Aged 23, Female, some science teaching

## Good

- Complete relevant correct CK
- Relevant PK

Student learning impact:  
HIGH

MSci Chemistry, PhD, Age 27, Female,  
Prior science-based teaching experience

“The white stuff is magnesium oxide. Explain that the oxygen in the product comes from the air. Say ‘If I cut open the Mg strip, will there be oxygen in there?’ Answer, ‘No, only Mg.’ Mg strip contains only Mg atoms, so when it burns the product will contain Mg and atoms from the other reactant. The other reactant is oxygen. Ash/soot comes from burning carbon containing species.”

# Summarising teacher knowledge

Pedagogy	Content	Quality
Correct relevant	Incorrect	Poor
Correct irrelevant	Irrelevant	
None	Correct relevant complete	
Correct relevant	Correct relevant incomplete	
Correct irrelevant		
<b>Correct relevant</b>	<b>Correct relevant complete</b>	<b>Good</b>



Durham  
University

# A strategy for improving chemistry knowledge: A diagnostic test on chemical reactions

400 MCQs on aspects of chemistry,  
graded for knowledge expected of  
11-14s, 14-16s and 16 – 19s

# Sample

Age			
	Frequency	Percent	Cumulative Percent
<b>11-15</b>	79	46.5	46.5
<b>16-20</b>	51	30.0	76.5
<b>21-25</b>	8	4.7	81.2
<b>26-30</b>	6	3.5	84.7
<b>31-35</b>	6	3.5	88.2
<b>36-40</b>	8	4.7	92.9
<b>41+</b>	12	7.1	100.0
<b>Total</b>	170	100.0	

Highest level of chemistry studied			
	Frequency	Percent	Cumulative Percent
<b>11-14</b>	59	34.7	34.7
<b>14-16 GCSE</b>	38	22.4	57.1
<b>16-19 Alevel/UG</b>	66	38.8	95.9
<b>BSc</b>	2	1.2	97.1
<b>PhD</b>	3	1.8	98.8
<b>Other</b>	2	1.2	100.0
<b>Total</b>	170	100.0	

**When magnesium ribbon is burned in air, a bright, white light is produced and white stuff is left over. Where did the white stuff come from?**

A It was inside the magnesium

B It is ash, which is always left over from burning something in air

**C It was formed in a reaction between magnesium and air**

D It is carbon from burning the magnesium in air

# Response pattern

Response	Age							Total
	11-15	16-20	21-25	26-30	31-35	36-40	41+	
	NR1	0	0	0	0	0	0	
A (inside)	0	3	0	0	0	0	0	3
B (ash)	16	5	0	0	0	1	1	23
<b>C (new substance)</b>	<b>49</b>	<b>43</b>	<b>7</b>	<b>6</b>	<b>6</b>	<b>7</b>	<b>11</b>	<b>129</b>
D (carbon)	13	0	1	0	0	0	0	14
Total	79	51	8	6	6	8	12	170



# Which of these statements is the best definition for a chemical reaction?

A A substance changes physical state, e.g. from solid to liquid

B The appearance of a substance changes, e.g. colour

**C A new substance is made that was not there before**

D A change to a different state that is not easily reversed

# Response pattern

Response	Age							Total
	11-15	16-20	21-25	26-30	31-35	36-40	41+	
No response	3	0	0	0	0	0	1	4
A (Physical change)	2	3	0	0	1	0	0	6
B (Appearance)	0	10	0	0	0	0	0	10
<b>C (New substance)</b>	<b>50</b>	<b>36</b>	<b>8</b>	<b>6</b>	<b>4</b>	<b>8</b>	<b>10</b>	<b>122</b>
D (Not reversed)	24	2	0	0	1	0	1	28
Total	79	51	8	6	6	8	12	170

## Which statement best describes what occurs when a chemical reaction takes place?

- A Bonds are broken between particles in reactants
- B Energy is released, as reactions are exothermic
- C Bonds are broken and new bonds made**
- D Bonds are made, creating a new substance

# Response pattern

Response	Age							Total
	11-15	16-20	21-25	26-30	31-35	36-40	41+	
Response	1	0	0	0	0	0	0	1
A (bonds broken)	1	2	1	0	1	0	0	5
B (energy)	6	5	0	0	0	0	0	11
<b>C (broken &amp; made)</b>	<b>45</b>	<b>42</b>	<b>3</b>	<b>6</b>	<b>5</b>	<b>6</b>	<b>9</b>	<b>116</b>
D (bonds made)	26	2	4	0	0	2	3	37
Total	79	51	8	6	6	8	12	170

# Diagnostic questions may be useful

For probing students' knowledge pre-and post-teaching

For establishing knowledge levels in pre-service teachers, particularly those working out of field

But they need to be good questions

Attention needs to be paid to the answers students give





Durham  
University

# What professional knowledge is required of teachers?

Document analysis of teacher education requirements in five nations

# Document analysis

Teacher education documents from  
Singapore, Finland, US, England, Australia

Thematic analysis

- Known aspects of teacher professional knowledge
- Emergent aspects of teacher professional knowledge



# Nations

Nation	2018 PISA ranking	2015 TIMSS ranking science 8 <sup>th</sup> grade	GNI per capita 2019 \$
Singapore	2	1	57900
Finland	7	No data	49580
United States	13 (Average)	11	65760
England	14	8	42370 (UK)
Australia	16	17	54910



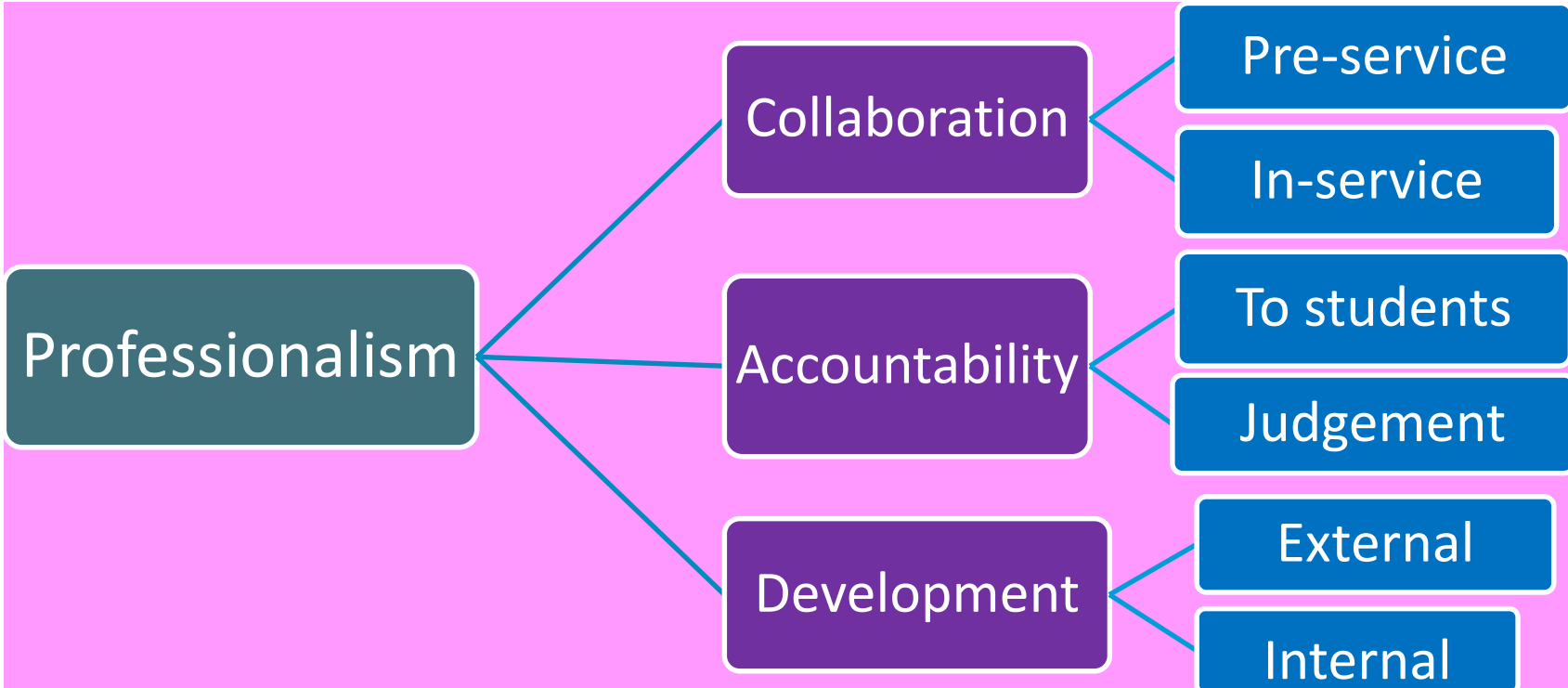
# Document analysis for aspects of teacher professional knowledge

- Strong alignment
  - major heading in standards documents
  - other equivalent emphasis in documents / other literature
  - emphasised in teacher progression / qualification
- Weak alignment
  - sub-/ minor heading in standards documents
  - inference from documents / other literature
  - aspirational rather than actual

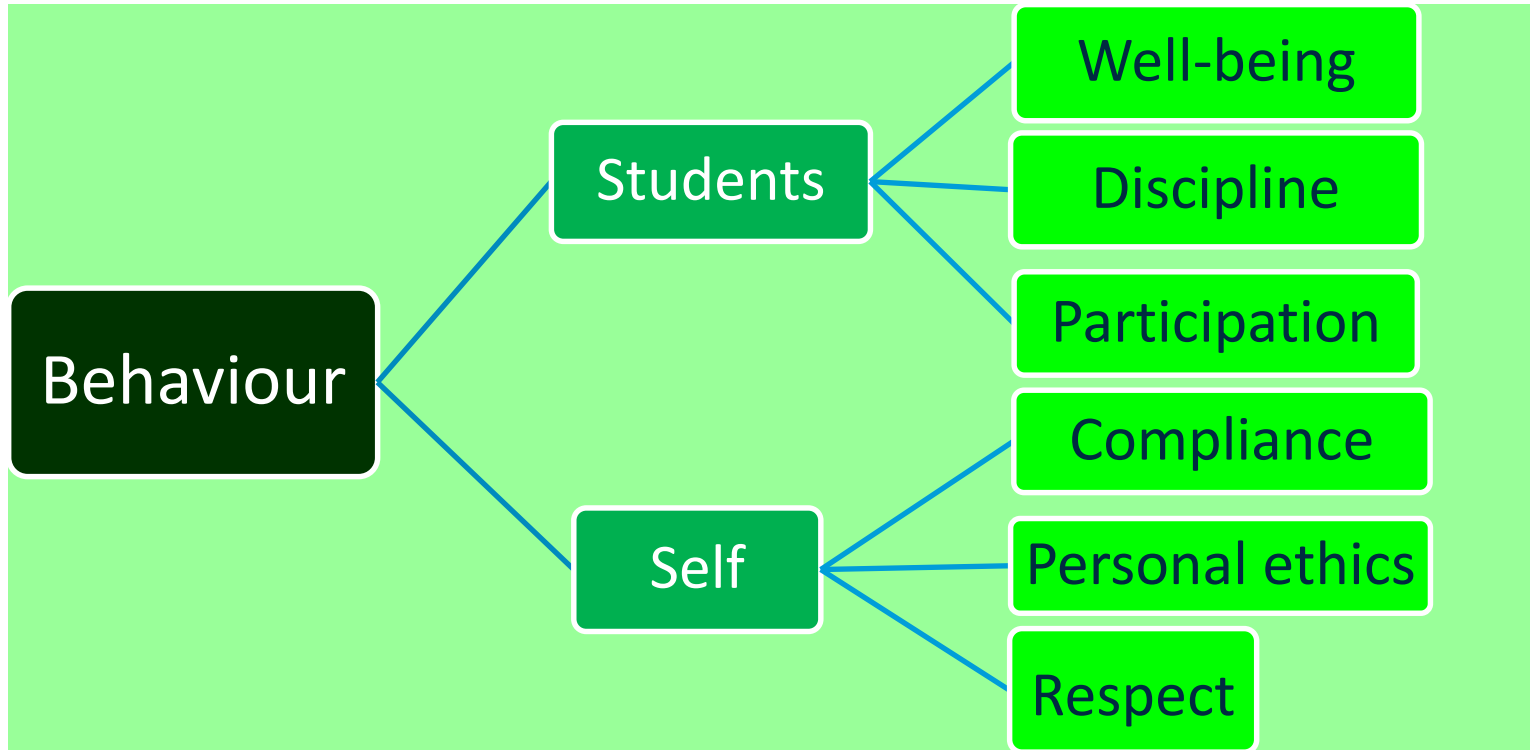
# Aspects of professional teacher knowledge in international teacher education

Knowledge	Singapore	Finland	England	US	Australia
Content	Strong	Strong	Strong	Strong	Strong
Pedagogy	Strong	Strong	Strong	Weak	Strong
External Assessment	Weak	Weak	Strong	Strong	Strong
Students	Strong	Strong	Weak	Weak	Strong
Specific subject knowledge	Strong	Strong	Weak	Weak	Strong
Curriculum	Weak	Strong	Weak	Strong	Weak
Teacher beliefs	Strong	Weak	Strong	Weak	Weak

# Emergent aspects of teacher knowledge: professionalism



# Emergent aspects of teacher knowledge: teacher behaviours





Durham  
University

# Conclusions



# Comparing teacher education policies

Higher performing nations emphasise  
Content knowledge and Topic-specific  
knowledge

**Pedagogy – knowledge of students’  
learning needs**

**Teacher accountability as judges of  
student performance**

**Teachers as collaborative, high status  
professionals**

Lower performing nations emphasise  
content, pedagogy and

**External assessment –  
teachers prepare students for exams**

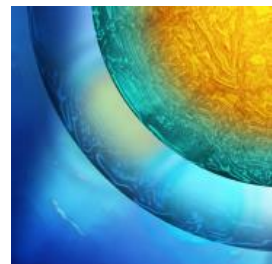
**Teacher behaviour – personal ethics  
and beliefs**

# Content and pedagogical knowledge data show

- When both are high quality, positive impact on student learning is possible
- When pedagogy is low quality, but content is correct positive impact on student learning is unlikely and students may not learn anything meaningful/ rote learn
- When pedagogy is good, but content is incorrect OR When both are low quality, negative impact on student learning is likely and students may learn irrelevant or incorrect material

# Teacher knowledge research

- Enables precise strategies to be identified
- Permits development of PCK over time
- Should identify explicit pedagogical practices that impact positively on student achievement
- Agree a teacher knowledge model for a majority of situations to support policy development





# To teach and train teachers successfully

- Focus ruthlessly on knowledge that impacts student progress and develop teacher professional knowledge that includes
  - awareness of individual students' learning needs
  - misconceptions / subject-specific difficulties
  - teaching strategies for addressing these
- Emphasise teachers are professionally accountable for developing effective practice
  - focus on improvement
  - support teachers making changes to practice
  - use the best teachers to educate the next teacher generation

# Thank you!

Professor Vanessa Kind  
School of Education  
Durham University, UK

[Vanessa.kind@durham.ac.uk](mailto:Vanessa.kind@durham.ac.uk)

