Conceptions of Pedagogical Content Knowledge: An Empirical Perspective

Presented at NARST Annual Conference
28 March 2012

Janet Carlson, BSCS
Colorado Springs, Colorado, USA

Julie Gess-Newsome, Willamette University
Salem, Oregon, USA
Overview

1. Hypothesis
2. Assumptions
3. Theory of Action → Intervention
4. Data Collection
5. Impact of the Intervention
6. Discussion and Conclusions
7. Summary
We hypothesized that academic content knowledge (ACK), general pedagogical knowledge (GenPK), and content-specific PCK are related to each other and influence teacher practice to become more inquiry-oriented, resulting in greater student achievement.
Knowledge Bases for Teaching

- Philosophy, goals, and objectives
- School contexts
- Curriculum
- Learners and learning (Context)
- Pedagogy – general (Pedagogy)
- Subject matter (Content)
- Pedagogical Content Knowledge (PCK)

PCK exists on a continuum.
PCK can be improved.
Assumptions

Connection to student learning...

PCK

High → High

Low → Low

Student Learning
Assumptions

Connection to educative materials

Educative Materials -> PCK -> Student Learning

High -> Low

High

Low
Assumptions

Connection to transformative PD...

Educative Materials → PCK → Student Learning

Transformative PD → PCK

High → High

Low → Low
Theory of Action: Intervention

A sustained intervention based on two theoretical frameworks would increase all knowledge bases:

1. Long-term use of educative curriculum materials
2. Transformative professional development designed to challenge current beliefs, knowledge, and practice
Characteristics of Educative Curriculum Materials

Support for teachers in thinking about:

a) content beyond the level suggested for students
b) underlying pedagogy
c) developing content and community across time
d) students
e) the broader community

Transformative Professional Development

1) create cognitive dissonance to disturb the equilibrium
2) provide time, contexts, and support for teachers to think and revise their thinking;
3) connect professional development to teachers’ students and contexts;
4) provide a way for teachers to develop practices that are consistent with their new understandings
5) provide continuing help in the cycle of issue identification, new understanding, changing practice, and recycling

Intervention Time Line

**Cohort 1**
- Spring 05
- Summer 05 (2 wks)
- School Year 05-06
- Summer 06 (3 wks)
- School Year 06-07

**Cohort 2**
- Spring 06
- Summer 06 (2 wks)
- School Year 06-07
- Summer 07 (3 wks)
- School Year 07-08

40 HS biology teachers in Arizona, USA
Data Collection

- Academic content knowledge test
- Student content pre/post-test
- PCK written reflections
- Video record of daily teaching
- PCK interview
- End of project interview(s)
Our Model: Theoretical Paths of Influence
• Major Field Test in Biology
  – Developed by Educational Testing Service
  – Designed for undergraduate biology majors at the time of graduation
  – 150 multiple choice questions
  – Possible scores ranged from 120-200
Mean Posttest
Mean Baseline

\[ p < 0.001 \]
\[ \text{Effect size} = 0.88 \]
Topic-specific Analysis

• Percentage correct across the five subscales varied as much as by 61% and as little as 8% ($X=32.17\%$, $sd=12.77\%$).

• Subscales:
  – Evolution
  – Homeostasis
  – Matter, Energy, Organization
  – Genetics
  – Ecology
Impact of Intervention

General Pedagogical Knowledge

- **Baseline**
  - Mean = 7.78
  - SD = 4.28

- **Year 1 & 2 Average**
  - Mean = 12.89
  - SD = 2.72

- **p < 0.001**
- **Effect size = 0.88**

*RTOP: Video*
Impact of Intervention

General Pedagogical Knowledge

• Significant increase from baseline to average of Years 1 & 2 teaching
• Non-topic-specific aspects of pedagogy:
  – Active learning
  – Teacher as facilitator & resource rather than authority

Data source = classroom videotapes
Pedagogical Content Knowledge
Pedagogical Content Knowledge

• Factor analysis indicated 2 factors or components

• PCK-PK and PCK-CxK items loaded together on one factor

• Thus, model simplified to describe two components of PCK: PCK-CK and PCK-PK
Pedagogical Content Knowledge

- Factor analysis indicated 2 factors or components
- PCK-PK and PCK-CxK items loaded together on one factor
- Thus, model simplified to describe two components of PCK: PCK-CK and PCK-PK
Impact of Intervention

PCK: Content Knowledge Component

Mean = 4.52
SD = 1.57

Mean = 7.11
SD = 1.55

p < 0.001
Effect size = 1.66

Reflections
Impact of Intervention

PCK – Content Knowledge

• Significant increases from baseline to highest subsequent score for both Content Knowledge & Pedagogical Knowledge components

• Teachers consistently noted Content Knowledge (CK) as prerequisite for excellent teaching

• Did not feel PRIME had large impact on their CK

• Described CK more similarly to ACK than PCK-CK

• Did note gains in making connections among topics and considering conceptual flow

Data sources = written reflections and interviews
Impact of Intervention

PCK: Pedagogical Knowledge

<table>
<thead>
<tr>
<th>Time</th>
<th>Mean Score</th>
<th>SD</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseline</td>
<td>2.24</td>
<td>1.22</td>
</tr>
<tr>
<td>Highest Subsequent</td>
<td>4.19</td>
<td>1.30</td>
</tr>
</tbody>
</table>

$p < 0.001$
Effect size = 1.59

Reflections
Impact of Intervention

PCK - Pedagogical Knowledge

• Teachers indicated they were not accustomed to reflecting on teaching strategies

• Noted that following PRIME they gave more attention to student prior conceptions and opportunities for metacognition

• Perceived greater growth in PK than CK

• Actual results indicated greater growth in CK

Data sources = written reflections and interviews
**Impact of Intervention**

**Teacher Practice**

- **Mean = 15.72**
- **SD = 6.86**

- **Mean = 23.87**
- **SD = 3.98**

$p < 0.001$

Effect size = 0.71

RTOP: Video
Impact of Intervention

Teacher Practice

- Significant increases in inquiry-based practices from baseline to average of Years 1 & 2 teaching
  - Involving students in active exploration of the content
  - Generating hypotheses, examining multiple representations of data
  - Connecting content knowledge to other understandings

Data source = classroom videotapes
Impact of Intervention

Student Achievement

Significant increases in all content areas, although interpretation is limited because there was no comparison group.
# Impact of Intervention

<table>
<thead>
<tr>
<th>Knowledge Base or Classroom Practice</th>
<th>df</th>
<th>t</th>
<th>p</th>
<th>Effect Size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Academic content knowledge (ACK)</td>
<td>33</td>
<td>5.114</td>
<td>&lt; 0.001</td>
<td>0.88</td>
</tr>
<tr>
<td>General pedagogical knowledge (GenPK)</td>
<td>17</td>
<td>1.441</td>
<td>&lt; 0.001</td>
<td>0.88</td>
</tr>
<tr>
<td>PCK-Content knowledge component (PCK-CK)</td>
<td>26</td>
<td>6.094</td>
<td>&lt; 0.0001</td>
<td>1.66</td>
</tr>
<tr>
<td>PCK-Pedagogical knowledge component (PCK-PK)</td>
<td>26</td>
<td>5.645</td>
<td>&lt; 0.0001</td>
<td>1.59</td>
</tr>
<tr>
<td>Teaching practice</td>
<td>17</td>
<td>1.210</td>
<td>&lt; 0.0001</td>
<td>0.71</td>
</tr>
</tbody>
</table>
Component 1: Impacts of Intervention
## Correlation Matrix of Teacher Variables

<table>
<thead>
<tr>
<th></th>
<th>ACK</th>
<th>Gen PK</th>
<th>PCK-CK</th>
<th>PCK-PK</th>
<th>Practice</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACK</td>
<td>-</td>
<td>.354</td>
<td>.672**</td>
<td>.237</td>
<td>.451</td>
</tr>
<tr>
<td>Gen PK</td>
<td>-</td>
<td></td>
<td>.522**</td>
<td>.190</td>
<td>.727**</td>
</tr>
<tr>
<td>PCK-CK</td>
<td>-</td>
<td></td>
<td></td>
<td>.503**</td>
<td>.299</td>
</tr>
<tr>
<td>PCK-PK</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>.092</td>
</tr>
<tr>
<td>Experience</td>
<td>.339</td>
<td>.420</td>
<td>.207</td>
<td>-.008</td>
<td>.242</td>
</tr>
</tbody>
</table>

** Correlation is significant at the 0.01 level (2-tailed)
* Correlation is significant at the 0.05 level (2-tailed)
N=40
## Multiple Regression of Teacher Variables to Practice

<table>
<thead>
<tr>
<th></th>
<th>B</th>
<th>T-ratio</th>
<th>p-value</th>
<th>Direction</th>
</tr>
</thead>
<tbody>
<tr>
<td>ACK</td>
<td>.091</td>
<td>.797</td>
<td>.426</td>
<td>+</td>
</tr>
<tr>
<td>Gen PK</td>
<td>.537</td>
<td>4.178</td>
<td>.000</td>
<td>+</td>
</tr>
<tr>
<td>PCK-CK</td>
<td>-.223</td>
<td>-.769</td>
<td>.443</td>
<td>-</td>
</tr>
<tr>
<td>PCK-PK</td>
<td>.011</td>
<td>.045</td>
<td>.964</td>
<td>+</td>
</tr>
</tbody>
</table>

95% CI for Gen PK: [0.279 < -------> 0.795]
Component 2: Relationships among Teacher Variables

Component 1
- Intervention
- Gen PK
- PCK-CK
- PCK-PK

Component 2
- ACK
- Teacher Practice

Component 3
- Student Achievement
Relationships of Teacher Variables to Student Achievement

Level 1: Student Achievement - POST$_{ij} = \beta_{0j} + \beta_{1j} \text{(Student Achievement PRE)} + e_{ij}$

Level 2: $\beta_{0j} = \gamma_{00} + \gamma_{01} \text{(ACK)} + \gamma_{02} \text{(GenPK)} + \gamma_{03} \text{(PCK-CK)} + \gamma_{04} \text{(PCK-PK)} + \gamma_{05} \text{(Teacher Practice)} + \mu$
Key findings:

• ACK was the most influential on student achievement (t=1.91, p=.064).

• The relationship between teacher Practice and Student Achievement is not statistically significant at the 0.05 level.
Empirically Tested
Theoretical Path of Influence
Discussion & Conclusions
1. Educative curriculum materials combined with transformative professional development results in significant increases in teacher knowledge, skills, and practice.
   – PCK exists on a continuum and can be strengthened
   – Educative materials can support growth.
   – Facilitation via PD may be critical.
Discussion & Conclusions: Relationships between Knowledge and Practice

2. Relationships exist in teacher knowledge and practice
   - ACK to PCK-CK
     • Support for development but not direction
   - PCK-CK to PCK-PK
     • Empirical validation of the construct
   - GenPK to PCK-CK
     • Topic specific nature of teaching
   - GenPK to Practice
Discussion & Conclusions

3. Teacher knowledge, skills, and practice as defined by PCK did not predict student achievement
   – Substantial relationship of ACK maybe related to the coherent nature of the instructional materials
   – Nature of student exams versus negative direction of PCK-CK
   – RTOP was not predictive of student achievement
Participants made positive and significant gains in all of the knowledge bases across the program.

ACK did have a positive relationship with Student Achievement (SA).

PCK-CK increased from the baseline to later time points and was positively and significantly related to classroom practice, but not SA.
Empirically Tested
Theoretical Path of Influence

Key:
Solid lines = statistically significant relationship
Dashed lines = positive trend, not statistically significant
Acknowledgements

BSCS Project Research Team:
April L. Gardner
Molly A.M. Stuhlsatz
Joseph A. Taylor
Christopher D. Wilson

Additional Contributors to the Project:
Kristin Andersen, NAU
Vanessa Kesler, NAU
Sharon Cardenas, NAU
Susan Kowalski, BSCS
Kenric Kesler, NAU
Jane Larson, BSCS

This work was funded by grant ESI-0455846 from the National Science Foundation. The opinions expressed are those of the authors.
Thank you

Slides are available at bscs.org/sessions
For more information contact the authors:
  Janet Carlson
  jcarlson@bscs.org
  Julie Gess-Newsome
  jgessnewsome@willamette.edu