Helping Physics Teacher-Candidates Develop Questioning Skills Through Innovative Technology Use

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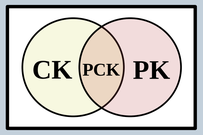
Background

Pedagogical Content Knowledge (PCK)

- A theoretical framework[1,2] for investigating teaching that emphasizes the interplay between different types of knowledge:
  1. **Content Knowledge** (CK): Traditional knowledge of the subject matter, such as *physics*
  2. **Pedagogical Knowledge** (PK): The knowledge of students' difficulties, of various approaches to teaching specific content, and how this knowledge fits within the larger student learning experiences
  3. **Pedagogical Content Knowledge** (PCK): The knowledge of traditional subject matter in the context of teaching it: includes ways of helping students construct a deep meaningful understanding, being aware of what makes subject matter easier/more difficult, and how student conceptual difficulties impact their learning



Technology-Enhanced Pedagogies in Teacher Education[3]

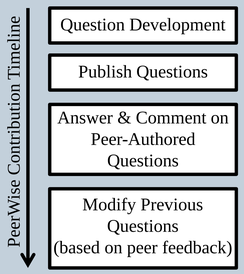
- An extension of the PCK framework includes how technological knowledge interacts with Pedagogical and Content Knowledge[2]
- **Problem:** Few teacher-candidates have experienced student-centered technology-enhanced science or mathematics pedagogies as students during their K-12 or post-secondary education
- **Solution:** Modeling technology-enhanced pedagogies in physics methods courses serves multiple purposes. It helps teacher-candidates to:
  - Experience these pedagogies in two capacities – as students and as future teachers;
  - Identify gaps in their conceptual understanding of physics while offering pedagogical approaches to address these gaps
  - Build skills and confidence in using technology to promote active engagement in physics

PeerWise Online Collaborative Tool[4]

- Developed at the University of Auckland, New Zealand
- Online tool that enables students to create multiple choice questions with an answer explanation
- All questions are shared in a course pool
- Authors can submit questions, add justifications, comment, tag content themes, and augment questions/justifications
- Peers can answer, comment, and rate questions, and make suggestions for augmented questions and solutions

Course Context

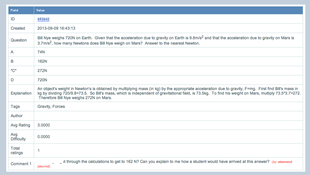
- Ten (10) teacher-candidates at a large research-based university in Canada
- Secondary Physics Methods course in a Teacher Education Program
- As a component of the course requirements, each week students:
  a. Submitted five (5) questions (original or modified from other source)
  b. Included an answer justification for each question
  c. Answered ten (10) questions
  d. Commented on peers questions as appropriate



Sample Questions

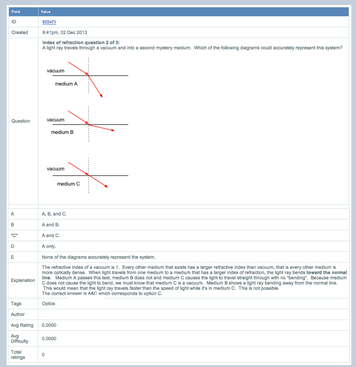
- Question, answer justification, comments, and ratings included
- Indicative of quality from beginning, middle, and end of term

Week 1



Week 6

Week 13



Objectives

Course Goals

Implement the PeerWise system into a secondary physics methods course in a teacher education program

Integrate the PeerWise system with other technology-enhanced pedagogies, such as Peer Response Systems and simulations

Research Goals

Compare the traditional benefits of the PeerWise system with the impacts in a small teacher education course

Investigate the effect of an online collaborative tool on teacher-candidates questioning and commenting skills

Explore teacher-candidates' expressions of PCK:

a) How do these expressions change over the course of a teacher education methods course?
b) How do teacher-candidates' conceptions of the different areas of knowledge interact?

Methods

Questions Ratings

- Course Instructor and Masters Teaching Assistant rated all submitted questions on three scales for Bloom's Taxonomy level[5], distractor quality, and answer justification

SCALES	**Bloom's Taxonomy Level**	**Distractor Quality**	**Answer Justification**
AREA OF RESEARCH INTEREST	Evaluates questions in the context of Bloom's Taxonomy, providing insight into question complexity	Evaluates the quality of distractors and the degree to which they address student difficulties	Evaluates the quality of the answer justification in addressing conceptual knowledge and student difficulties
SUMMARY OF RATING SCHEME	1 – 5 (1 – Knowledge; 2 – Comprehension; 3 – Application; 4 – Analysis; 5 – Synthesis/Evaluation)	1 – 5 (All irrelevant distractors – all distractors are meaningful)	1 – 5 (No answer justification – complete and accurate justification of both correct and incorrect answers)

Comment Ratings

- Course Instructor and two Research Assistants rated all submitted comments on four scales for PK, CK, PCK, and overall quality

SCALES	**Pedagogical Knowledge**	**Content Knowledge**	**Pedagogical Content Knowledge**	**Overall Quality**
AREA OF RESEARCH INTEREST	Evaluates the quality of students' thinking during commenting in terms of PK and CK, respectively		Evaluates the quality of students' integrated PCK during commenting	Provides a secondary measure indicating overall value of students' comments
SUMMARY OF RATING SCHEME	1 – 5 (No demonstration – strong demonstration of PK + addresses student difficulties pedagogically)	1 – 5 (No demonstration – strong demonstration of CK + addresses student content difficulties)	1 – 4 (No PCK overlap – strong PCK overlap)	1 – 5 (No P/CK or PCK value in comment – strong P/CK or PCK value in comment including direct suggestions for improvement)

Results

Summary

	Week 1	Week 13
Number of Questions	51	64
Number of Answers	239 (43 TA, 65 Instructor)	252 (42 TA, 34 Instructor)
Number of Comments	75	120

- Total number of questions, answers, and comments increased
  - Students met course requirements in W1 and exceeded course requirements in W13 for:
    a. Number of questions submitted
    b. Number of answers submitted (allowing instructors to decrease number of answers)

Questions

- Utilized previous tool to assess students' development and demonstration of questions with higher cognitive skill
- Ran ANOVAs to measure significant difference between W1 and W13 on all scales

Bloom's Taxonomy Level

- Statistically significant difference between W1 and W13; $F(1, 118) = 24.204$, $p < .01$

Distractor Quality

- No significant difference between W1 and W13

Answer Justification

- No significant difference between W1 and W13

Comments

- Developed new tool to assess students' development and demonstration of Pedagogical Content Knowledge
- Ran ANOVAs to measure significant difference between W1 and W13 on all scales, after removing instructor comments
- No differences between W1 and W13 were statistically significant

Impact

- Considering question and comments results in tandem:
  - Increase in Bloom's Taxonomy level, demonstrating increased cognitive level of students' questions, with a resulting maintenance of quality of distractors and answer justifications demonstrates an overall shift in students' capacity to question effectively
  - Maintenance of Pedagogical Content Knowledge levels in comments with increasing frequency of comments shows promising results for students' increased capacity to critically evaluate questions
  - Increased number of questions contributed during a one-week period with maintained distractor quality and answer justifications indicates students' ability to efficiently select, critique, and write questions is increased

- Frequency Results
  - Means for questions and comments

Scales		W1	W13
Questions	Bloom's Taxonomy Level	2.3824	2.9219
	Distractor Quality	4.0588	4.2031
	Answer Justification	3.333	3.5859
Comments	PK	3.10448	2.9
	CK	2.9403	2.9167
	PCK	2.41791	2.2417
	Overall Quality	2.94030	2.8083

  - Frequencies of ratings on question and comment scales

	PK					CK					PCK				Overall Quality				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	1	2	3	4	5
W1	11	9	18	34	3	10	23	12	23	7	18	20	25	12	7	17	29	18	4
W13	13	34	37	24	12	17	26	38	28	11	31	45	28	16	4	47	44	18	7

	Bloom's Taxonomy Level					Distractor Quality					Answer Justification				
	1	2	3	4	5	1	2	3	4	5	1	2	3	4	5
W1	20	30	45	7	0	6	4	18	24	50	8	12	33	36	13
W13	6	18	84	20	0	0	7	26	29	66	0	12	55	35	26

Future Directions

1. Course Goals
   a. Revise course requirements and instructions in order to integrate PeerWise efficiently and effectively into the physics methods course, with the goal of developing students Pedagogical Content Knowledge
   b. Develop a process for participating in PeerWise that students will "buy in" to, allowing instructors and students to take advantage of the benefits of PeerWise in an authentic and meaningful way
   c. Develop students skills commenting online in a constructive and thoughtful manner
2. Research Goals
   a. Repeat study in a second cohort, altering course requirements and research questions to reflect our first year experience
   b. Explore the long-term effects of the role of questioning on teacher-candidates practice and PCK
      1. Follow up during long-practicum experience and at the end of the Teacher Education Program through interviews and focus groups

References

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