Pedagogical Content Knowledge: Can a successful program of research exist without scientific-based research?

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ABSTRACT

This study represents an attempt at determining if a construct, rather than an instructional method, is supported by scientifically-based research. The purpose of this study was to examine the credibility of evidence-based claims underlying the literature related to Pedagogical Content Knowledge (PCK) (Shulman, 1986). Using a hybrid cross-validation method, and criteria from the No Child Left Behind Act (NCLB, 2001), the National Research Council (NRC, 2002), and the Education Sciences Reform Act (ESRA, 2002), the study analyzed and evaluated 51 published journal articles containing PCK in the title. Findings indicate that PCK can be labeled a "successful program of research" and represent the intent of the "scientifically-based research standards"; however, no single published article meets all the criteria for "scientifically-based research." Thus, PCK as a construct defined by this sample of literature is not based upon scientifically-based research. This finding calls into question the application of PCK within the NCATE accreditation evaluation criteria and the applications of PCK within teacher education. Questions raised and implications for teacher education are addressed. Further, recommendations for re-examining both the ideology underlying PCK, as well as SBR, is presented.

INTRODUCTION

> "Given the times, PCK rather quickly and with minimal disturbance slipped into teacher educator rhetoric. Today, the concept is almost taken for granted as though representing common sense" (Bullough Jr., R.V., 2001).

> "Without methods courses to learn pedagogical content knowledge, novices are unlikely to provide quality instruction" (Laczko-Kerr & Berliner, 2003, p. 35).

Since its introduction in the literature base in 1986, the construct known as "pedagogical content knowledge," (Shulman, 1986) otherwise referred to as PCK, has become commonplace in education vernacular. So much so, Bullough (2001), acknowledged PCK's new status when he wrote that the concept, "is almost taken for granted as though representing common sense" (Bullough Jr., R.V., 2001). Further, by 2003, often times the phrase "PCK" no longer needs reference to Shulman and appears in literature as an established variable in a causal relationship. For example, Laczko-Kerr & Berliner (2003) write, "Without methods courses to learn pedagogical content knowledge, novices are unlikely to provide quality instruction" (p. 35).

This simple claim, learning PCK is linked to quality instruction; hence, student achievement, may or may not be justifiable given the current research-base underlying PCK. Further, PCK has entered into a very political arena. In their Spring 2003 revisions, the National Council for Accreditation of Teacher Education included PCK as part of the evaluation criteria for Standard 1 (NCATE, 2002). NCATE lists the first standard for assessing potential teacher candidate's performance as:

> **Standard 1:** *Candidate Knowledge, Skills, and Dispositions*
>
> Candidates preparing to work in schools as teachers or other professional school personnel know and demonstrate the content, pedagogical, and professional knowledge, skills, and dispositions necessary to help all students learn. Assessments indicate that candidates meet professional, state, and institutional standards (NCATE, 2002, http://www.ncate.org/standard/unit_stnds_ch2.htm#stnd1).

Recently, as documented as "Spring 2003 Revisions," NCATE updated the rubric for assessing institutions alignment with Standard 1. Although the phrase "pedagogical content knowledge" is not listed in Standard 1 above, the revised rubric includes criteria to evaluate institutions effectiveness of "Pedagogical Content Knowledge for Teacher Candidates." More specifically, for the highest rating in the rubric, otherwise known as the "target," the NCATE web-site states the following criteria:

> **TARGET**
>
> Teacher candidates reflect a thorough understanding of *pedagogical content knowledge* delineated in professional, state, and institutional standards. They have in-depth understanding of the subject matter that they plan to teach, allowing them to provide multiple explanations and instructional strategies so that all students learn. They present the content to students in challenging, clear, and compelling ways and integrate appropriately (http://www.ncate.org/standard/unit_stnds_ch2.htm#stnd1) (italics added).

Given that the original document (i.e., Shulman, 1986) delineated between two types of knowledge bases, pedagogical knowledge and pedagogical content knowledge, the following question arises: Does the "pedagogical" listed in Standard 1 above mean the same thing to NCATE as the "pedagogical content knowledge" used in the evaluation rubric? The actual answer to this question is not of importance here, the simple fact that the phrase "pedagogical content knowledge" has snuck into a very political environment before a critical examination of the research base underlying the construct was conducted is problematic.

In short, in only sixteen years, PCK has grown from the first introduction into the literature base, to the global label for the 'what' teacher education students *potentially* learn in methods courses, to being related to quality instruction, to becoming evaluation

criteria for NCATE. With the political nature of PCK established, the question arises: is the research base underlying PCK sound?

Along side the development of PCK, in a mere two years, 2001 and 2002, three different sets of guidelines were published defining scientific-based research. Although each set uses much of the same terminology, each set is unique to a certain degree.

With the advent of No Child Left Behind Act (NCLB) of 2001, "scientifically-based research" (SBR), has also become a popularized phrase in education vernacular. Referencing NCLB, Olson & Viadero (2002) provide the following definition of SBR as it appears in the 2001 act:

> The term 'scientific-based research' means
>
> (A) research that involves the application of rigorous, systematic, and objective procedures to obtain reliable and valid knowledge relevant to education activities and programs; and
>
> (B) research that:
>
> - employs systematic, empirical methods that draw on observation or experiment;
> - involves rigorous data analyses that are adequate to test the stated hypotheses and justify the general conclusions drawn;
> - relies on measurements or observational methods that provide reliable and valid data across evaluators and observers, across multiple measurements and observations, and across studies by the same or different investigators;
> - is evaluated using experimental or quasi-experimental designs in which individuals, entities, programs, or activities are assigned to different conditions and with appropriate controls to evaluate the effects of the condition of interest, with a preference for random-assignment experiments, or other designs to the extent that those designs contain within-condition or across-condition controls;
> - ensures that experimental studies are presented insufficient detail and clarity to allow for replication or, at a minimum, offer the opportunity to build systematically on their findings; and
> - has been accepted by a peer-reviewed journal or approved by a panel of independent experts through a comparably rigorous, objective, and scientific review" (p. 1)

In response to SBR, the National Research Council presented *Scientific research in education* (NRC, 2002). Given the timeframe of SBR, and NRC's report, a recent *Educational Researcher*, 31(8), November 2002, devoted an entire themed issue to "Scientific Research in Education."

As central participants in crafting the NRC report, Feuer, Towne, and Shavelson (2002) were asked to provide the opening article for the *ER*. In it, they outline the National Research Council report's Principles of Scientific Inquiry. The author's write:

> Although no universally accepted description of the principles of inquiry exists, we argue nonetheless that all scientific endeavors
>
> - Pose significant questions that can be investigated empirically,
> - Link research to relevant theory,
> - Use methods that permit direct investigation of the questions,
> - Provide a coherent and explicit chain of reasoning,
> - Yield findings that replicate and generalize across studies, and
> - Disclose research data and methods to enable and encourage professional scrutiny and critique.
>
> These principles need to be understood not as an algorithm, checklist, or how-to guide but rather as norms of behavior that reflect expectations for how scientific research will be conducted. It is very unlikely that any one study would possess all of these qualities although a successful program of research is likely to embody all of them (p. 7).

Although SBR and principles of successful research entered the landscape, the Education Sciences Reform Act of 2002 also proposed a third set of definitions and/or criteria outlining scientifically based research. The act proposes the following "scientifically based research standards":

(A) The term "scientifically based research standards" means research standards that
- Apply rigorous, systematic, and objective methodology to obtain reliable and valid knowledge relevant to education activities and programs; and
- Present findings and make claims that are appropriate to and supported by the methods that have been employed.

(B) The term includes, appropriate to the research being conducted –
- Employing systematic, empirical methods that draw on observation or experiment;
- Involving data analyses that are adequate to support the general findings;
- Relying on measurements or observational methods that provide reliable data;
- Making claims of causal relationships only in random assignment experiments or other designs (to the extent such designs substantially eliminate plausible competing explanations for the obtained results);

- Ensuring that studies and methods are presented in sufficient detail and clarity to allow for replication or, at a minimum, to offer the opportunity to build systematically on the findings of the research;
- Obtaining acceptance by a peer-reviewed journal or approval by a panel of independent experts thought a comparably rigorous, objective, and scientific review; and
- Using research designs and methods appropriate to the research question posed (Education Sciences Reform Act, 2002).

With the establishment of SBR (NCLB, 2001), principals of successful research programs (NRC, 2002), and scientifically based research standards (ESRA, 2002), no study was found to date that represented an attempt at examining a construct from within the field of Education to determine if the construct met the intent of any or all of these research guidelines.

DATA SOURCES

The selection of data sources was guided by a purposeful sampling umbrella and used a combination of "homogeneous sampling," and "maximal variation sampling" techniques (Creswell, 2002).

Using the phrase "pedagogical content knowledge" for a keyword search in both the ERIC (FirstSearch) and ArticleFirst search engines, over 600 hits occur; further, 349 hits list PCK as a subject header to identify the paper.

Creswell (2002) defines homogeneous sampling as, "purposeful samples individuals or sites based upon membership in a subgroup that has defining characteristics" (p. 196). To increase the effectiveness of homogeneity sampling, the defining characteristic for the subgroup was articles that contain PCK in their title. This sampling technique reduced the initial group of 349 down to 83. Further, and due to SBR requiring a peer-review, the sample of 83 was narrowed to only 51 articles that were published in a recognized peer-reviewed journal.

The maximal variation sampling technique is considered the range of research questions, methods, and subject disciplines represented within the data set. Creswell (2002) defines maximal variation sampling as, "a purposeful sampling strategy in which the researcher samples cases or individuals that differ on some characteristic" (p. 194). The purpose, research question, participants, and content field represented by the each of the individually published articles are all examples of the maximal variation within the sample.

METHOD/ANALYSIS

This study combined techniques appropriate for historical analysis and cross-validation to create a hybrid historical cross-validation method. In particular, the method was to conduct an "internal criticism" (Borg & Gall, 1989, p. 822-4) as a means for cross-

validating the literature base. Although cross-validation is typically concerned with re-sampling and/or replication, this study attempts to use a more holistic method of cross-validating to examine a population of articles.

The internal criticism "involves evaluating the accuracy and worth of the statements contained in a historical document" (p 822). Whereas the task of the historian conducting an internal criticism is, "to combine one or more witnesses' accounts, admittedly subjective, and to interpret them (admittedly, also a subjective process) in an attempt to discover what actually happened" (p. 823). Thus, the accuracy and worth was determined by evaluating the data sources against the criteria for SBR, successful program of research and the research standards.

Given this study, the data sources are actual published articles that which represent the historical documents. The witnesses' accounts, therefore, are the conclusions represented within the published articles given the research questions and methods used to garner evidence underlying the implications and conclusions.

More specifically, the methods included after collecting the data sources, each article was examined in light of how, if at all, the article met the intent of the criteria outlined by SBR, successful program of research or the research standards (See Appendix A for sample check-sheet).

Next, each article was sub-categorized into appropriate data sets. For example, all articles were dissected into the following sections: a) purpose; b) research questions; c) methods; d) participants; and, e) implications/conclusions (for example see Appendix B). Then, each sub-category was evaluated to determine if the sub-category meet the criteria for SBR, successful program of research, and/or the scientifically based research standards. In other words, I literally analyzed what was in the published text against the established criteria.

Lastly, using the heuristic PCK-3D model (Holder & Cochran, 1998 – see Appendix C), categorical analyses were conducted on each data set as a whole to determine the overall nature of the data set. For example, all research questions were analyzed and categorized to determine which component of PCK the question was addressing in an attempt to determine if, or which, component of PCK was being addressed through the study research questions. This was done to determine if the successful program of research criteria, "Yield findings that replicate and generalize across studies" was being met. In other words, did similar studies pose similar research questions relating to similar components of PCK?

RESULTS/CONCLUSIONS

Descriptive results for the 51 articles published in journals that contain PCK in the title are:

(a) when examined as a whole, the collection of 51 articles meet the criteria and can be labeled a "successful program of research" (i.e., given all the articles, all the criteria for successful program of research have been met);
(b) that no single article can be labeled "scientific-based research";
(c) that they appear in 34 different peer-reviewed Journals;
(d) they utilize the following method type:

Type or Method:	Number (percent of total)
Qualitative	34 (66.7%)
Conceptual/historical analysis	11 (21.6%)
Mixed Methods	2 (3.9%)
Book Review	1 (1.9%)
Construction of Assessment Items	1 (1.9%)
Textbook Content Analysis	1 (1.9%);

(e) that only 12 of the 51 (i.e., 23.5%) contain clearly stated Research Question(s);
(f) they collectively have utilized 855 participants; and,
(g) and that they represent the following content domains (listed in order from most studies published): Science, Mathematics, Physical Education, English, Social Studies, Communication Education, Educational Psychology; Business, Visual and Performing Arts, Linguistics, Computer Science, and Political Science.

QUESTIONS RAISED

Initial analysis and results have prompted many questions. Three of which are:

1. The phrase PCK is used in a very broad sense with multiple interpretations and operational definitions as what the construct represents; thus, the generic defining questions arise: What is Pedagogical Content Knowledge? And, how does PCK develop?

2. The collective "Conclusions" and "Implications for Teacher Education" sections included in the 51 articles propose overwhelming support for more research needed in this area and widespread agreement that PCK is fundamental to successful teacher education; however, generic implication questions arise such as: How can PCK most effectively be utilized by teacher educators? And, what is the connection between PCK and classroom student achievement?

3. This study was confounded by the nature of the data sources selected. Given a reasonable attempt was made to collect a sample of studies, only studies that contained PCK in their title were chosen. One obvious question arises: Do the results of this study, based upon only 51 articles, generalize to the population of

studies (i.e., over 600) that use PCK as a descriptor phrase in the data sources section?

IMPLICATIONS FOR TEACHER EDUCATION

The educational significance for teacher education and of this study are twofold:

Contribution to the development of PCK: This study continues to define the boundaries of what PCK was, how it has been examined, where it currently is, and provides possible areas for future studies. Thus, as a whole, this study contributes greatly to the development of current and future understandings of PCK.

Contribution to the field: Albeit quietly, PCK has become a very political construct in the field of teacher education. Given the NCATE revision of Standard 1's evaluation criteria, with only 12 studies actually involving a research question and 0 (zero) studies utilizing experimental designs, the results of this cross-validation call into question whether PCK is scientifically-based and asks if PCK really is what authors claim it to be.

CONCLUDING THOUGHTS

A major contribution of this paper is an immediate call for a re-examination of current ideology underlying PCK. Further, this call also asks how the field of Education will respond to constructs as popular as PCK that appear as Successful Programs of Research yet are not based upon NCLB's definition of Scientific-Based Research. Lastly, as constructs such as PCK enter the political dimension of teacher education accreditation and become criteria for programs to be evaluated against, one must ask, is it really scientifically based research we are after or is appropriate to make decisions based upon only a successful program of research?

Regarding PCK, perhaps Shulman describes it best when he wrote, "The teacher comprehends which aspects of the content will be likely to pose the greatest difficulties for the pupil's understanding. The most crucial to learn is not always the most difficult; the most difficult is not always the most crucial" (Shulman, 2004, p. 353). SBR, and in particular, experimental or quasi-experimental research are generalizably the 'rule' and not the exception. However, for a teacher to apply their own PCK, they are contextually working with a group or even an individual student – generalizably the 'exception'. Thus, the question arises: Given this study, and that PCK does not meet the criteria for SBR, is PCK the exception to the rule?

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Appendix A
Criteria Check Sheet for SBR

- CRITERIA 1: employs systematic, empirical methods that draw on observation or experiment;
- CRITERIA 2: involves rigorous data analyses that are adequate to test the stated hypotheses and justify the general conclusions drawn;
- CRITERIA 3: relies on measurements or observational methods that provide reliable and valid data across evaluators and observers, across multiple measurements and observations, and across studies by the same or different investigators;
- CRITERIA 4: is evaluated using experimental or quasi-experimental designs in which individuals, entities, programs, or activities are assigned to different conditions and with appropriate controls to evaluate the effects of the condition of interest, with a preference for random-assignment experiments, or other designs to the extent that those designs contain within-condition or across-condition controls;
- CRITERIA 5: ensures that experimental studies are presented insufficient detail and clarity to allow for replication or, at a minimum, offer the opportunity to build systematically on their findings; and
- CRITERIA 6: has been accepted by a peer-reviewed journal or approved by a panel of independent experts through a comparably rigorous, objective, and scientific review" (p. 1)

	C1	C2	C3	C4	C5	C6
Amade-Escot, C. (2000)						
Barnett, C. (1991)						
Barrett, K.R. & Collie, S. (1996)						
Bullough Jr., R.V. (2001)						
Carlson, R. E. (1990)						
Carpenter, T. P., Fennema, E., Peterson, P.L., & Carey, D.A. (1988)						
Clermont, C. P., Borko, H., & Krajcik, J.S. (1994)						
…						

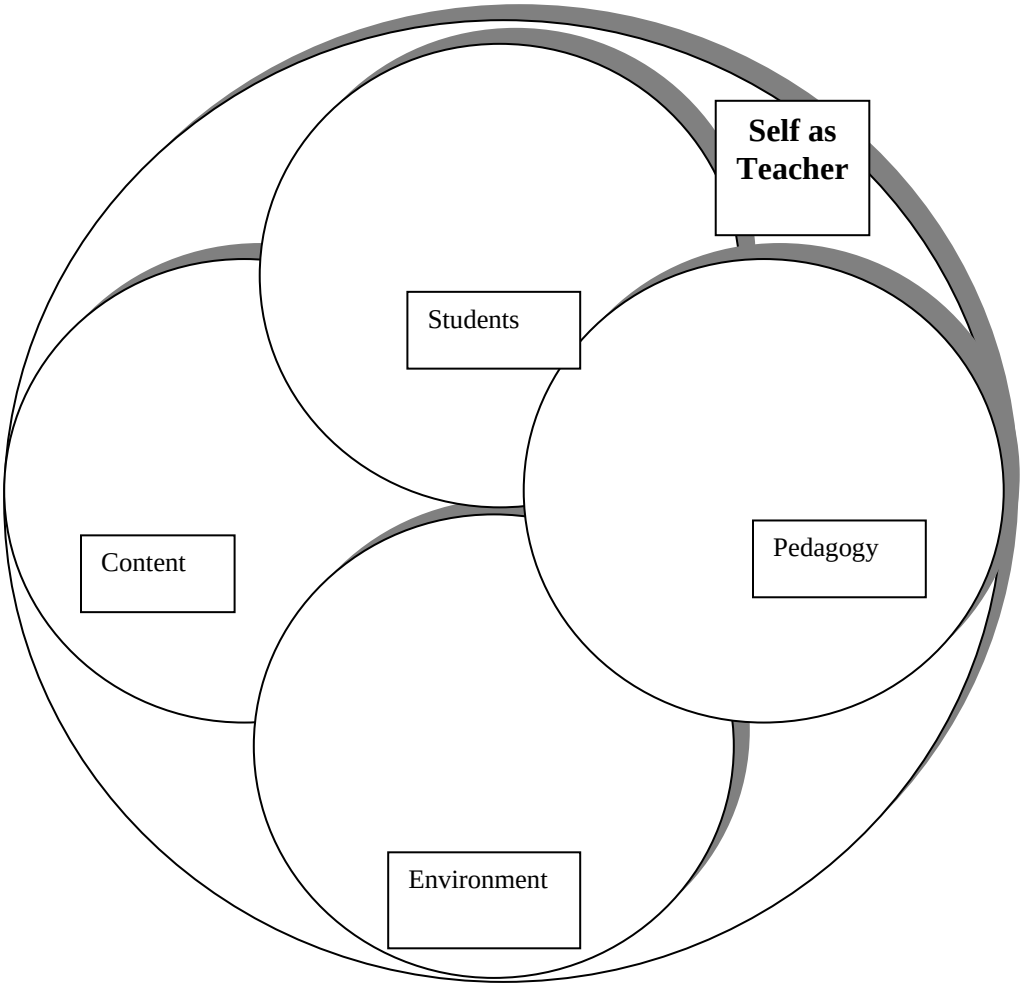
Appendix B

PCK RESEARCH QUESTION(S) CHART

Article Identification #	Stated Research Question
2	What do expert teachers know about their subject matter that novice teachers do not (p. 59)?
4	1. What do teachers know about the distinctions between different addition and subtraction problem types? 2. What do teachers know about the strategies that children use to solve different problems? 3. How successful are teachers in predicting their own students' success in solving different types of problems and in identifying the strategies used by children to solve problems of different types? 4. What is the relation between different measures of teachers' pedagogical content knowledge and their students' achievement (p. 389)?
5	1. If pedagogical content knowledge is an important component of the knowledge base of teaching, does professional education, in fact, transmit this area of professional knowledge? 2. How can strong subject-specific teacher preparation coursework influence how beginning teachers develop pedagogical content knowledge? 3. What happens when people enter teaching without professional preparation? 4. Does strong subject matter knowledge alone provide the pedagogical understanding of a subject necessary for teaching (p. 25)?
15	How do teachers develop pedagogical thinking processes (p. 263)?
16	Two questions guided the research: (a) what knowledge did the preservice teachers describe as salient?; and (b) how did this knowledge develop (p. 70)?
23	This study addresses the question, What are the essential features of the modern concept of function (p. 95)?
34	In this sense, important questions arise, such as: How do professors transcend their status from "subject matter knowers" to "subject matter teachers?" (Berliner, 1986, pp. 9-10). How do professors structure and implement generic PCK (p. 296)?
54	(How) do the characteristics of the lesson preparation method stimulate pre-service teachers to show their (ability to develop) pedagogical content knowledge (p. 15)?
61	For example, what do preservice teachers believe about how scientists

	work or how learners come to understand scientific ideas? What do we know about their backgrounds in learning science? What do they bring in their conceptions of learning to teach science? How would knowledge of our students' entering beliefs and knowledge be helpful for science teacher educators (p. 30)?
68	1. How much (and what kind of) content knowledge do teachers need in order to have a rich discussion about hard pedagogical content questions such as: what makes this particular science easy or hard for students to learn? And what are successful ways of making challenging science ideas comprehensible to young learners? 2. To what extent does an integrated teaching case contribute to the content and richness of teachers' discussions? To what extent does an integrated case influence how teachers talk about science and the pedagogical decisions related to teaching that science (p. 268)?
74	1. What do preservice teachers learn about students' difficulties with slope, and how is this knowledge reflected in their lesson plans and in their teaching? 2. What do preservice teachers learn about various representations for teaching slope, and how is this knowledge reflected in their lesson plans and in their teaching? Specifically, how do they use real-world representations – physical and functional situations involving slope (p. 210)?
76	What exactly is the significance of the quality of prospective teachers' understanding of subject matter? What effect, if any, does teachers' initial knowledge state (SMK) have on the quality of their instructional explanations? Or, put another way, what is the consequence of prospective teachers' understanding and beliefs for their subsequent pedagogy (PCK) (p. 52)?

Appendix C
Pedagogical Content Knowing – The Third Dimension (PCKg—3D)



KNOWING SELF AS TEACHER	
• Educational Philosophy • Professional Development – Reform or Conform? • Philosophy of Life	
KNOWING CONTENT	KNOWING PEDAGOGY
• Substance (ideas) / Structure (representation) / Syntax (construction & verification) • Creating new/verifying old • Inter-conceivability – across/within	• Teacher/Student Relationship • Instructional Strategies • Assessment/Motivation/Learning–Relationship • PCK
KNOWING ENVIRONMENTS	KNOWING STUDENTS
• Learning Community – School/Classroom • Social/Political/Cultural • Relationship b/w policy and implementation	• Individual Differences • Prior Conceptions about Content/School/etc. • Needs – school or go hunting?