Expert Blind Spot: When Content Knowledge Eclipses Pedagogical Content Knowledge

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The importance of content knowledge on proficiency in teaching practices is well documented (Borko et al., 1992; Shulman, 1986). But is this statement completely unimpeachable? Are there drawbacks for teaching that are specifically due to subject matter expertise? In this paper we draw on evidence from mathematics and language arts education to show ways that advanced knowledge in a content area can lead to notions about learning that are in conflict with students' actual developmental processes. This underscores the need for empirically based theories of instruction, and for teachers to integrate assessment practices in their classroom curricula that have the potential to challenge their assumptions about mathematical development in their students.

THE NATURE OF EXPERTISE

Before the launching of the cognitive science research program in the 1950's, experts were considered to be a different breed from others. They were regarded as more intelligent, with greater memory capacity, and superior intellectual resources (Ericsson & Smith, 1991). However, careful research into the reasoning processes of experts as they performed both familiar tasks, and related but unfamiliar tasks, has shown that experts function with the same internal constraints as non-experts. Elevated performance levels were shown to be due to the acquisition of vast amounts of well-organized, domain-specific knowledge; intense, long-term practice within a narrow field; and exploitation of regularities of familiar tasks (Ericsson & Smith, 1991). Even so, demystifying expertise does not undermine its allure for education, and many prominent researchers argue that expert performance should guide our educational efforts (Hatano & Inagaki, 2000; Sternberg, 1996).

Expertise is not without its problems, however. Think aloud reports from experts and novices show that experts are less likely to have access to memory traces of their cognitive processes when engaged in tasks within their domain of expertise (Ericsson & Simon, 1984). This appears to be due to the automatization of certain cognitive processes in experts. Among novices, these processes are deliberate and stepwise, and so they leave a memory trace which is more likely to be inspectable and verbalizable.

It has also been shown that that subjects with a large amount of domain knowledge may actually be at a disadvantage when compared to novices on certain tasks (e.g., Wiley, 1998). Expertise can act as a mental set (*Einstellung*).

Within mathematics education settings, this can lead domain experts to focus on known efficient and effective representations and procedures for solving problems. But it can make them blind to the processes of novices who are struggling to understand new ideas during their constructive learning process.

EXPERT BLIND SPOT IN MATHEMATICS EDUCATION

We consider two arenas for *expert blind spot* (EBS) – areas where, because of their advanced content knowledge in mathematics, people with greater expertise tend to make assumptions about student learning that turn out to be in conflict with students' actual performance and developmental propensities. The first example looks at the so-called "New Math" movement of the 1950's in the USA. The second looks at teachers' intuitions regarding students' mathematical development. These examples shows how advanced knowledge of mathematical content leads experts to believe that, like themselves, learners will find symbolic formalisms of quantitative relations and mathematical concepts most accessible because of their relative parsimony (Nathan & Koedinger, 2000a). However, studies of middle, high school and college students has revealed that novices struggle with abstract representations and formal procedures, and generally acquire new domain knowledge through informal and concrete forms of representation and reasoning (e.g. Case, 1991).

New Math. In the 1950's, the state of mathematics achievement, interest, and instruction in the United States was scrutinized. The declining enrollment in mathematics education that began prior to WWII continued, despite the growing importance and marketability of a technical education. The popular press of the time declared that the content of public school mathematics courses had been determined by professional educators for too long. Academicians turned their attention to school curricula (NCTM, 1970) and argued for the need to base mathematics education on the same foundational concepts that were being used to organize the domain of mathematics for university study – set theory and number theory. Thus, the "New Math" movement was born.

Critics of the New Math curriculum saw as an over-emphasis on the formal structure and notation (NCTM, 1970a). They argued that the pedagogy was poor; that it did not motivate students; and it failed to develop students' intuitive notions of mathematics. They also criticized the lack of staff development for teachers, noting that teachers needed to be better informed about the curricular structure and goals.

The New Math program failed because the concepts that formed the foundation had been designed by mathematicians to highlight the organization of the domain, with little regard to how that domain was to be learned or taught. They believed that, by revealing the logical foundation of mathematical structure to the learner, understanding and learning would naturally follow as it did in the Ivory Tower. Their expertise in mathematics made them blind to the struggles experienced by novice students and non-expert teachers.

Views of algebra development among teachers. In the second example, Nathan & Koedinger (2000b) compared algebra students' problem-solving performance to teachers' expectations about problem difficulty. Participating elementary, middle and high school teachers ($n = 105$) ranked a set of problems from easiest for their students to solve, to most difficult. The problems given in the ranking task can be organized in six categories: The problems were either arithmetic (with the result as the unknown) or algebraic (with a starting quantity as unknown) along one dimension, and in one of two verbal forms (story or word-equation), or a symbolic format.

Recent research on the problem-solving performances of ninth grade students in two samples ($n_1 = 76$, $n_2 = 171$; Koedinger & Nathan, 1999) who had completed a year of formal algebra instruction has shown that they generally find symbolically presented problems to be *harder* than verbally presented problems. Students' performance on equations is less than 30%, while verbal problems are solved correctly over 50% of the time, leading to statistically significant advantages for verbal problems in both samples ($p < .01$).

When asked to judge the relative difficulty of the problems, the pattern of responses given by teachers was clear. First, arithmetic problems were generally considered to be easier than algebra problems. Second, among high school teachers ($n = 39$), verbal problems (word and story problems) were considered to be more difficult for students than symbol problems. In fact, high school teachers considered algebra story problems to be the most difficult for students to solve. High school teachers reasoned that symbolic problems would be easiest for students because they were written in "pure math," while verbal problems needed to be translated to equations before being solved, and this required understanding the language on top of the mathematics.

In contrast, middle school teachers ($n = 30$) with less post-secondary mathematics education predicted that students would find story and word problems to be easiest. These teachers held students' intuitions in higher regard, and believed students were more likely to invent effective problem-solving methods that were not symbol based. Middle school teachers were very accurate in predicting student performance, $\tau(6) = .733$, $p = .034$. However, the ranking provided by high school teachers was not related to student performance at all, $\tau(6) = 0$, providing further support for the EBS hypothesis.

EXPERT BLIND SPOT IN LANGUAGE ARTS EDUCATION

Additional evidence for the EBS Hypothesis comes from Grossman's (1990) comparative case study of six secondary English teachers who were all strong in subject matter knowledge but differed in their teacher preparation. Three teachers were graduates of a professional teacher education program and three were not. All 6 had a high level of subject matter knowledge in literature and grammar. Grossman's comparative analysis shows how strong subject matter knowledge that is not off-set by well-developed pedagogical content knowledge can lead to domain-centered views of instruction characteristic of the EBS Hypothesis that inadvertently neglects the learning needs of students.

A major pattern that emerges from the case studies of those teachers who had no formal teacher education is how they used their subject matter knowledge as the lens on English instruction. As Grossman's interviews divulge, these teachers promoted a *text-centered* view of English instruction that emphasize detailed textual analysis as the path toward comprehension. While this is a powerful perspective, pedagogically it is a poor match for most high school students. The lessons developed from this critical view were often too analytical, insufficiently engaging, and quite disconnected from students' own personal experiences and their pre-conceptions of reading.

For example, we learn that Jake's notions of high school instruction came directly from his experiences as an English major in college. "He did not distinguish between his conception of English as a discipline and his conception of English in secondary school" (Grossman, 1990, p. 25). Similarly, Lance's goals for his students "had their roots in his understanding of literature, rather than any specific understanding of ninth graders." (p. 37).

In contrast, the 3 teachers who graduated from a formal teacher education program, all with high levels of content knowledge, emphasized a student-centered approach. Literary analysis and grammar still played a central role in the English classrooms taught by the teacher education graduates. However, the focus of instruction was not exclusively on the text itself, but on the relationship of the student to the text. Thus, while those without professional teacher education prepared for class by *reviewing* literary material, the teacher education graduates used their planning time to *re-structure* material to connect it to students' current knowledge and developmental levels.

Comparative Analysis

For a hypothetical ninth grade General Literature class, teacher education graduates chose 78% of their readings from among "adolescent literature," texts considered to be of great interest and relevance to youth, with the remaining 22% chosen from among "canonical texts" that had great literary importance. In contrast, the teachers with no formal education classes chose mostly (72%) canonical texts. "As successful students themselves, they expected their students to be as knowledgeable and as interested in literature as they remembered themselves being" (Grossman, 1990, p. 107).

CONCLUSIONS

The literature teachers with no formal education classes slipped into the same predicament as many of the high school mathematics teachers. Their vast knowledge was a valuable organizing principle for themselves. But their own domain-centric lens served as the primary guide for their pedagogical decisions. Like the mathematics educators who placed a premium on formal representations, the text-centered view of literature instruction reflects the view of the domain commonly found among literary and linguistic scholars at the university level, but inappropriate and off-putting to many students.

The cognitive science community must be aware of the power of well-developed content knowledge in influencing pedagogy in potentially harmful ways. Advanced content knowledge without well-developed knowledge of the learning and teaching of novices can lead to expert-based views of curricula that are at odds with the learning process. While we seek to advance learners' abstract reasoning within mathematics and language, we must also recognize that students often do not develop these abstract representations easily, and that formal reasoning may in fact trail and depend upon the development of informal reasoning (e.g., Case, 1991).

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