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A meta-analysis of comparative studies on Chinese and US students' mathematics performance: Implications for mathematics education reform and research

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ABSTRACT

US and China are reforming mathematics teaching by shifting from students' attainment of facts and procedures toward development of competencies in reasoning, communication, connections, and problem solving, and application of these in real life contexts. Differences in students' overall performance, curricula, and teachers' knowledge and instruction between US and Eastern Asian countries are often used to support US reform with two obvious limitations. First, their performance has not been delineated into specific areas which raise questions about whether overall higher Asian mathematics performance over US is also evident in the specific US reform competencies. Second, Asians are often used as an indiscriminate group with inattention to different schooling and non-schooling factors between countries that might contribute differently to performances. This meta-analysis examines US and Chinese student mathematics performance studies and identifies the strengths and weaknesses in overall and specific competencies. It raises questions about theoretical assumptions, discusses limitations of research designs, and proposes research that may lead to a critical understanding of the quality of mathematics learning.

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The establishment of curriculum standards (NCTM, 1989, 1991, 2000) and the development of teachers' subject-specific pedagogy (INTASTC, 1992; NBPTS, 2002; NCTM, 1989) are two US policy initiatives designated to improve all students' mathematical reasoning, communication, connections, representation, and problem solving (Romberg, 1992). These initiatives elicited considerable debate in the academic and policymaking arenas in which opponents argued that the prescribed curriculum standards could dampen US students' creativity and independence (Hayness & Chalker, 1997), reasoning skills (Bracey, 1997a), and critical social awareness (Apple, 1992; Cheung & Muse, 1998). These criticisms were often based partly on the assumption that standardized curricula would exert a constraining and convergent force on mathematics learning and partly on the unexamined images of teaching and learning in countries where curriculum and teaching were centralized, such as those in East Asian countries. These assumptions and images are often used as if they are empirically based.

Alternatively, proponents presumed that common curriculum standards can propel teachers to inter-depend on each other and create a teaching culture that would nurture both professional exchanges and establish a knowledge base for effective teaching (Ball & Cohen, 1996; Hiebert, Gallimore, & Stigler, 2002; Romberg, 1997, 1999). Several lines of comparative studies are often used to support this assumption. First, East Asian students perform substantially better than their US counterparts (Mullis et al., 1997, 1998, 2000; Mullis, Martin, & Foy, 2005; Mullis, Martin, Gonzalez, & Chrostowski, 2004; PISA, 2004a;

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Stevenson & Stigler, 1992). Second, US school mathematics curriculum materials are less focused and more repetitive in light of content coverage, instructional requirements, and structures (Mayer, Sims, & Tajika, 1995; Schmidt, Houang, & Wolfe, 1999) and its curriculum policy is less authoritative, specific, and consistent compared to East Asian countries (Cohen & Spillane, 1992; Eckstein, 1993; Wang, 2001). Third, East Asian teachers have a deeper understanding about mathematics and its representations (Ma, 1999). They are able to provide clearer explanations, use teaching time more efficiently, develop smoother pedagogical flow, and engage students in inquiry using whole class instruction (Perry, 2000; Schmidt et al., 1996; Stigler & Hiebert, 1999; Stigler, Lee, & Stevenson, 1987).

These findings together suggest that centralized curriculum standards, teachers' knowledge, and instructional practices may be positively related to each other in producing higher student mathematics performance and thus, support US mathematics reform efforts. However, using comparative studies in this way does not go undisputed. Debates center around whether performance differences between East Asian and US students are statistically significant, whether sampling for the comparisons are representational, and whether the methods for interpretations of these differences can be drawn from different statistical lenses (Baker, 1997; Bracey, 1993, 1996, 1997a, 1997b, 1999, 2000; Bradburn, Hartel, Schwille, & Torney-Purta, 1991; Romberg, 1999; Stedman, 1997a, 1997b; Stevenson, 1993a, 1993b).

While these debates are important, they do have two limitations. First, these debates are frequently based on the *overall* mathematics competence rather than *specific* competence areas between East Asian and US students, especially those areas advocated in the NCTM standards. That is, the overall higher mathematics performance of East Asians over the US may not directly translate necessarily into higher performance in each *specific* competences as explained with the following reasoning: although the *sum* of Equation A: $1+1+8=10$ is greater than that of Equation B: $2+3+4=9$, the first and second *addends* in Equation A are actually smaller than the first two addends in Equation B. Further, Cai's (1997, 1998, 2000) studies between East Asian countries and US have demonstrated that although Chinese students outperformed their US peers in overall mathematics achievement, they did not necessarily perform better in specific competence that included open-ended problem-solving tasks. Thus, the centralized mathematics curricula and relevant instruction that presumably contribute to Chinese students' higher *overall* performance tell US reformers little about the relationship between curriculum and teaching and students' competence in solving complex mathematical problems.

Second, these debates are often based on ambiguous cross-national categorizations, which often mask underlying ethnic and cultural differences important for adequate interpretations of mathematics performance differences. For example, the students in Japan, China, Korea, and other Eastern Asian regions are indiscriminately grouped together without attention to the substantial conceptual, institutional, and practical differences among these countries that may contribute differently to the mathematics performance in each of these countries (Eckstein, 1993; Tobin, Wu, & Davidson, 1989). Therefore, the apparent connection between centralized curriculum standards, teachers' knowledge and instructional practices, and higher mathematics performance related to either East Asian countries together as a group or a particular country within this group may not be sufficiently evident.

Parallel to this, US students are often categorized as a homogeneous group instead of ones that are culturally distinct, exposed to different kinds of values and practices of mathematics learning, and have consequential performance differences (Blair & Qian, 1998; Kim, Rendon, & Valadez, 1998; Ladson-Billings, 1997; Ogbu & Simons, 1994). Therefore, a careful comparison between different groups of students across and within different national contexts may provide opportunities to examine the assumptions underlying US mathematics education reform that would be otherwise impossible. For instance, the comparison of mathematics performance between Chinese students in China and Chinese-American students can be very useful. It may offer an indirect scrutiny to the assumption of whether centralized curriculum and relevant teaching are the only or major contributing factor to students' higher performance since Chinese-American students often outperform other US groups in mathematics even though these groups are exposed to similar American education, social, and cultural influences (Wang & Lin, 2005).

In this literature review, we attempt to explore three research questions: What are the differences in overall mathematics performance among Chinese and US students? What are the differences in specific mathematics competencies between the two groups? Are there any performance differences among subgroups of Chinese and US students? Answers to these questions will provide the basis for discussing the strengths and limitations of using comparative studies to support US mathematics education reform.

1. Literature selection and review methods

1.1. Conceptual assumptions guiding the review

Two theoretical assumptions guide our review. We first presume that *overall* mathematics achievement differences between particular countries can mask the differences of *specific* mathematics competencies between countries that may not be necessarily consistent with overall differences (Wang & Lin, 2005). As shown in a recent analysis of student mathematics achievements in Germany, Japan, US, and Netherlands from the Program for International Student Assessment (PISA), students with higher overall mathematics performance did not necessarily perform better in problem solving while lower overall performing students often showed higher problem-solving skills (Wirth & Fleischer, 2006). Thus, by conducting this review, not only do we examine the *overall* mathematics performance differences but also we explore the differences in *specific areas* of mathematics competencies among Chinese, Chinese-American, and US students.