Reflective Adaptability of Chinese and American Students in a Mathematics Video Game

Zhou Zhou[1], Selen Turkay[2], Dan Hoffman[3], SeungOh Paek[4]
Teachers College, Columbia University

This study proposes Chinese elementary students have stronger ability in solving novel mathematics problems than the American peers as a consequence of receiving more effective classroom instructions. An experiment was conducted to compare how students in the two countries improved their problem-solving efficiency in a mathematics video game, with the prediction that Chinese students adapted faster to the novel problem than American students.

Substantive research has been conducted in comparing students' mathematical performance in China and America, with the consensus that Chinese students are outperforming American students on various tasks such as base-ten counting and place values, calculation and mental math, simple and process-constrained problem solving, and flexible math representation (see Wang and Lin, 2005). The difference of students' mathematical performance between the two countries is attributed to the mixed influence of maturation, educational systems, schooling, culture, and language (Cai, 1995; Geary, Bow-Thomas, Liu, & Siegler, 1996).

Among the various factors, teachers' classroom practice has been frequently explored, with the conclusion that Chinese teachers usually offer more effective instructions in terms of frequency, quantity, depth, level, and comprehensiveness than American teachers (e.g. Ma, 1999; Perry, 2000; Wang and Lin, 2005). For instance, Ma (1999) observed that Chinese teachers tended to teach subtraction with regrouping and multi-digit multiplication from a conceptual perspective so that the taught procedures may be transferred more easily to other problem-solving scenarios, whereas American teachers tended to teach from a procedural perspective which was poorly transferable. Ma's point of view is paralleled by the findings of the TIMSS 1999 video study series comparing mathematics teaching and learning in 20 countries that mathematics teaching in the U.S. had reinforced attention to low-level mathematics skills, and American students show weaknesses in higher-level mathematics thinking skills compared to high-achieving countries such as Japan and China (Hong Kong) (Hiebert, Stigler, Jacobs, Givvin, Garnier, Smith, Hollingsworth, Manaster, Wearne, and Gallimore, 2005; Tatsuoka, Corter, and Tatsuoka, 2004).

From a cognitive viewpoint, due to the lack of higher-level thinking skills, American students should therefore have weaker mathematical understanding compared to the Chinese peers, and have difficulty in choosing and applying strategies efficiently in solving complex or open-process problems that require higher-order thinking, whereas they may or may not underperform in lower-level mathematical skills. Interestingly, existing evidence from comparative cognitive studies seem to lead to the opposite conclusion. For example, Chinese students outperformed American students in computational, process-constrained, and simple problem-solving tasks, but not in complex or open-process problem-solving tasks. In addition, the strategies employed and the errors made by Chinese students during complex problem solving are identical to those of American students (Cai, 1995, 2000; Cai & Silver, 1995).

To investigate this controversy, researchers such as Wang and Lin (2005) suggest focusing on the interactions between classroom teaching and other educational factors such as social-cultural influences. The authors of this paper, however, attempt to explore this issue from the cognitive development perspective. We propose that by receiving more effective classroom instructions, Chinese students don't necessarily have high proficiency in solving all types of problems, but instead develop the reflective adaptability necessary towards solving novel problem. In other words, Chinese students can consciously analyze aspects of a novel problem as the reference to evaluate their problem-solving processes based on the classroom instructions they

[1] Contact email: zz2111@columbia.edu
[2] Contact email: st2282@columbia.edu
[3] Contact email: dlh2109@columbia.edu
[4] Contact email: sop2102@columbia.edu

receive, and develop the most efficient solution faster than American students. The concept of reflective adaptability, borrowed from Lin (2001), refers to the ability of an individual to explicitly choose aspects of a novel problem for adaptation and evaluate their problem-solving processes.

The researchers employed video game as the instrument for this study as it conforms more closely to the reflective adaptive learning paradigm compared to the traditional paper-and-pencil instrument. Because during self-directed learning in the gaming environment, students are likely to be motivated and mentally engaged so as to think actively during problem solving (see Jonassen, Carr, & Yueh, 1998; Rieber, 1996).

The authors intend to investigate whether Chinese students have higher reflective adaptability than American students in solving novel mathematical problems. The research questions include:

1. How do Chinese and American students differ in terms of problem-solving accuracy, speed, error, and strategy-use when encountering novel mathematical problems?
2. How do Chinese and American students differ in the process of improving problem-solving accuracy, speed, errors, and strategy-use while they practice solving the same mathematical problems repeatedly?

To answer these questions, the researchers conducted a study to compare U.S. (n = 30, mean age = 11.21) and Chinese (n = 10, mean age = 10.22) elementary students' performance in a math-related computer game called Mat-Matics, where students solved addition problems by pressing buttons with their feet on a dancepad. The game presented a novel problem to the students by requiring them to use eight buttons (+1, +5, +10, -1, -5, -10, ENTER, and CLEAR) to construct and enter answers in the game. Each student played the game fifteen times within three weeks. The play data were collected automatically by the game including all game settings, button presses, as well as questions, accuracy, and time spent on each problem-solving trial.

The data analysis of this study is currently under progress. The researchers will employ the Differentiation and Integration (DAI) Theory proposed in Siegler and Chen (2008) as the guiding principle to analyze cognitive change during the experiment. The rationale of adopting the DAI theory is that cognitive change is a prolonged, complex process that may undergo a fluctuating rather than linear learning curve. Therefore only by nuanced analyses on the rules that students used trial by trial can the researchers understand students' cognitive change accurately. The researchers will examine and compare the button presses and button-press clusters (e.g. +10-1-1 representing +8) by Chinese and American students, in addition to their accuracy, time, and errors.

The predictions are that although Chinese students may not possess advantages in problem-solving efficiency or strategy use compared to American students when they first encountered the novel mathematics problems, they adapted to the problem-solving faster, improved strategies more efficiently, and reached problem-solving automaticity sooner than American students. Results will be discussed with implications and future research for reflective adaptability regarding the difference of mathematical competence of Chinese and American students.

References

Cai, J. (1995). A cognitive analysis of U.S. And Chinese students' mathematical performance on tasks involving computation, simple problem solving, and complex problem solving. *Journal for Research in Mathematics Education. Monograph, Vol. 7*.

Cai, J. (2000). Mathematical thinking involved in U.S. and Chinese students' solving of process-constrained and process-open problems. *Mathematical Thinking and Learning, 2(4)*.

Cai, J., & Silver, E. A. (1995). Solution processes and interpretations of solutions in solving a division-with-remainder story problem: Do Chinese and U.S. students have similar difficulties? *Journal for Research in Mathematics Education, 26(5)*.

Geary, D. C., Bow-Thomas, C. C., Liu, F., & Siegler, R. S. (1996). Development of Arithmetical competencies in Chinese and American children: Influence of age, language, and schooling. *Child Development, Vol. 67*.

Hiebert, J., Stigler, J. W., Jacobs, J. K., Givvin, K. B., Garnier, H., Smith, M., Hollingsworth, H., Manaster, A., Wearne, D., & Gallimore, R. (2005). Mathematics teaching in the United States today (and tomorrow): Results from the TIMSS 1999 video study. Educational *Evaluation and Policy Analysis, 27(2)*.

Jonassen, D. H., Carr, C., Yueh, H. (1998). Computers as Mindtools for Engaging Learners in Critical Thinking. *TechTrends, 43(2)*.

Lin, X. (2001). Reflective adaptation of a technology artifact: A case study of classroom change. *Cognition and Instruction*, 19(4).

Ma, L. (1999). *Knowing and Teaching Elementary Mathematics: Teachers' Understanding of Fundamental Mathematics in China and the United States*. Mahwah, NJ: Lawrence Erlbaum Associates, Inc.

Perry, M. (2000). Explanations of mathematical concepts in Japanese, Chinese, and U.S. first- and fifth-grade classrooms. *Cognition and Instruction, 18(2)*.

Rieber, L. P. (1996). Seriously Considering Play: Designing Interactive Learning Environments Based on the Blending of Microworlds, Simulations, and Games. *Educational Technology Research & Development, 44(2)*.

Siegler, R. S., & Chen, Z. (2008). Differentiation and integration: guiding principles for analyzing cognitive change. *Developmental Science, 11(4)*.

Siegler, R. S., & Mu, Y. (2008). Chinese children excel on novel mathematics problems even before elementary school. Psychological *Science, 19(8)*.

Tatsuoka, K. K., Corter, J. E., & Tatsuoka, C. (2004). Patterns of diagnosed mathematical content and process skills in TIMSS-R across a sample of 20 countries. *American Educational Research Journal, 41(4)*.

Wang, J., & Lin, E. (2005). Comparative studies on U.S. And Chinese mathematics learning and the implications for standards-based mathematics teaching reform. *Educational Researcher, 34(5)*.