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Taiwanese teachers' implementation of a new 'constructivist mathematics curriculum': How cognitive and affective issues are addressed

Mei-Shiu Chiu [a,*], David Whitebread [b]

[a] Department of Education, National Chengchi University, 64, Chih-nan Rd Sec2, Taipei 11623, Taiwan
[b] Faculty of Education, University of Cambridge, 184, Hills Rd, Cambridge CB2 8PQ, UK

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ABSTRACT

This paper aims to investigate the ways in which four Grade 5 teachers perceived and implemented a new constructivist mathematics curriculum, after all their past experience of traditional mathematics in Taiwan. The meaning and indicators of constructivist and traditional mathematics were explored and developed based on reviews of three countries' mathematics curricula and studies on mathematics teaching. Through interviews and classroom observations, teachers' practices were analyzed in these terms, separated into cognitive and affective aspects. The teachers were found to meet the new curriculum halfway, to address cognitive issues more effectively than affective ones, and to implement a common curriculum differently. The results support the need to analyze the teaching of mathematics in relation to affective as well as cognitive elements, and are discussed in relation to mathematics teaching internationally.

1. Introduction

Mathematics has been traditionally viewed as a school subject focusing on achievements, strict rules, efficient procedures and right answers (Schoenfeld, 1989; Turner et al., 1998), often accompanying more teacher-centred teaching methods. With the influence of individual and social constructivism on pedagogies, the mathematics classroom involves an increasing introduction of non-routine, open-ended and project-based mathematical problems, often accompanying more student-centred teaching methods (e.g., Boaler, 1998; Burton, 1994; Riordan and Noyce, 2001). While constructivist mathematics constitutes a dramatic reform in the mathematics curricula of nations, such as Taiwan and the US, there still remains a tension with traditional, transmission-oriented teaching methods (Hamm and Perry, 2002; Manouchehri and Goodman, 2000; McCaffery et al., 2001). The present study was conducted in the first academic year (August 2001–July 2002) that the four teachers studied taught a textbook based on a curriculum of constructivist mathematics mandated by the government in Taiwan in 1993 and introduced gradually since then. The four teachers studied had all learnt mathematics themselves based on a 'traditional' mathematics curriculum; they were now required by the government and scholars to teach according to the *principles* and *pedagogies* of constructivist mathematics. This study focused, therefore, on the management by these teachers of the transition from a traditional to the new constructivist mathematics curricula. The purpose of the present study was to document the process of teachers' adaptation to a distinctly new curriculum, which might serve as valuable historical experiences for curricular reforms in Taiwan and other countries in the future.

The results supported other current research indicating that constructivist mathematics places additional cognitive and affective demands on teachers and their students. A model is presented within the present study, which attempts to describe the key elements in a range of teaching styles comprising both cognitive and affective elements. These elements were elicited from international comparison of national curricula, from previous research concerning the tension between old and new curricula, and research concerning mathematical pedagogies.

1.1. Comparison of national mathematics curricula in Taiwan, the US, and England

Constructivism was officially introduced into the mathematics curriculum in Taiwan in 1993 by the Curriculum Standard for Primary Schools (Ministry of Education in Taiwan, 1993). The goals of mathematics education are to help students acquire mathematical knowledge from daily life and to cultivate students' attitudes and abilities to use mathematical methods efficiently to solve practical problems by encouraging children to communicate with members in the learning community and discovering patterns. Teachers are also encouraged to help students think actively and learn independently. In order to achieve these goals, the national

* Corresponding author.
E-mail addresses: chium@nccu.eud.tw (M.-S. Chiu), dgw1004@hermes.cam.ac.uk (D. Whitebread).

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curriculum gives teachers more opportunities to develop their pedagogy and put their educational beliefs into practice. The responsibility for publishing textbooks has also been gradually transferred from the government to private publishers. Given the current trend, students are likely to have more diverse problem-solving experiences than before. This move mirrors similar developments in a number of countries.

In the US, for example, the Curriculum and Evaluation Standards for School Mathematics (NCTM, 1995) articulates five goals: children learn to 'value mathematics; become confident in their ability to do mathematics; become mathematical problem-solvers; learn to communicate mathematically; learn to reason mathematically.' In the mathematics classroom students have to be exposed to numerous and varied interrelated experiences in which they are encouraged to value the mathematical enterprise, develop mathematical habits of mind, and understand and appreciate the role of mathematics in human affairs. In addition, children need to be encouraged to create, explore, guess and even make and correct errors so that they gain confidence in their ability to solve complex problems. They also need to be supported by teachers in reading, writing and discussing mathematics and in conjecturing, testing and building arguments about the validity of a conjecture. Similar issues are also raised in the recent Principles and Standards for School Mathematics by NCTM (2000) (Rousseau, 2004).

The mathematics curriculum policy of England also reveals a similar trend, with special emphasis on using and applying mathematics (Campbell and Kyriakides, 2000). In the National Curriculum for England (QCA, 1999), there are four attainment targets in mathematics: using and applying mathematics; number and algebra; shape, space and measures; handling data. 'Using and applying mathematics' is the most important of the four targets as this target is incorporated into each of the other three. The curriculum emphasizes the application of thinking and practical skills in real-life situations; using multiple tools such as mental, written and calculator methods to solve problems; and involving information and communication technologies in learning factual or declarative knowledge. After comparing the roles of applying mathematics in several versions of the National Curriculum and National Numeracy Strategy, Hughes et al. (2000) proposed that the target of using and applying mathematics has three characteristics: decision-making; communication; and reasoning and proof. A later development in the national curriculum has been made for secondary education (QCA, 2007a,b). Two of the three major competences in mathematics for secondary students are applying and communicating mathematics, which are partly consistent with the notion of individual and social constructivism. (The third competence is selecting mathematical tools and methods.)

This review of national curricular documentation reveals that constructivist principles underpin some of the policies of mathematics curricula in England, the US and Taiwan. These curricula of constructivist mathematics comprise four characteristics: (1) meaningful learning or understanding, which emphasizes providing students rich experiences or connections between concepts and application of mathematics; (2) creative thinking, reasoning, or exploration, which pertains to emphasizing diverse solution methods and providing students an experimenting learning environment, in which students are encouraged to guess, conjecture and test hypotheses; (3) independent learning, which consists of being sensitive to students' needs and giving students autonomy to activate their mathematical minds and self-reflections on the mathematics enterprise; (4) social interaction, which focuses on providing more and diverse opportunities for dialogues between teachers and students and between students on individual, group and class levels.

1.2. Tension between implementation of old and new curricula of mathematics in Taiwan

What is an 'old' Taiwanese mathematics classroom like? Stigler and Perry's (1990) study, which focused on the comparison between mathematics classrooms in four cities of three nations: Sendai, Japan; Taipei, Taiwan; Minneapolis and Chicago, USA, 1979–1980 and 1985–1986, indicated some good qualities of mathematics teachings in Taiwan. Compared with mathematics classrooms in the US, Taiwan and Japan classrooms had less off-task behaviour of students. Asian children had more opportunities to have their work assessed, and to observe the evaluation of other students' performance than American students. Both Taiwanese and Japanese teachers used far more manipulatives and real-world problems than did the American teachers. There are however some controversial characteristics: classrooms in Taipei and Japan were centrally organized, with the teacher as the leader of the children's activities 90% of the time (compared to 50% in the US); children spent the vast majority of time working, watching and listening together as a class and were rarely divided into smaller groups. Taiwanese classrooms were more performance-oriented, while the Japanese classrooms were more reflective; in other words, there was more verbal discussion of mathematical concepts and procedures. Taiwanese teachers emphasized fast and accurate performance, or getting the right answer quickly. They were also devoted to practicing rapid mental calculation, an activity that was never observed in Japanese and American classrooms.

The Taiwanese mathematics classrooms described in Stigler and Perry's (1990) study were based on the previous mathematics curriculum officially introduced in 1975, which emphasised knowledge acquisition. The major teaching method was knowledge transmission by teachers. Students learned mathematics by memorising and spending much time practicing calculation skills. As such, students were unable to explain the reasons for calculation procedures and lost their interest in learning mathematics (Liu and Shu, 1995).

With the influence of constructivist philosophies on the curricula in different parts of the world, the teaching methods and materials of traditional mathematics in Taiwan have been criticized and discouraged as they do not employ mathematical thinking, but rote learning, as the following statement reveals:

> The past mathematics teaching, especially those based on the textbook published in 1975, placed too much emphasis on students' calculation ability and ignored reasoning and understanding. Students became calculation machines. This is not a correct direction for mathematics teaching. Based on this rationale, the intellectuals of education reform introduce and advocate constructivist mathematics, wishing to put right the wrong teaching methods... (electronic newspaper by the Humanistic Education Foundation, 17 September 2003).

A mathematics curriculum based on the principle of constructivism, 'knowledge is not acquired by transmission but by learner active construction (Liu and Shu, 1995),' therefore, was developed through the process of experimentation, pilot and implementation and was officially introduced in 1994 (Liu, 2004).

The dramatic difference between the old and new mathematics curricula inevitably raised public arguments in Taiwan society. For example, it has been argued that rote learning does not necessarily inhibit children's mathematical thinking; that there is also a strong possibility that the teaching methods of constructivist mathematics may hinder culturally deprived children from learning valuable cultural heritages at school about how to solve problems in a formally effective way; and that a decline in children's mathematical