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Description and evaluation of a large-scale project to facilitate student engagement in learning mathematics

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ABSTRACT

Responding to students' performance in TIMSS and PISA in East Asian countries/regions – low interests, low confidence, not seeing the value of mathematics, and high-achieving performance in average but a substantial percentage of "lowest performers"– a project JUST DO MATH has been launched in Taiwan. The themes of the project included developing students' fundamental prerequisite mathematical ideas before regular classes, employing concrete manipulative representations as a starter for learning, and embedding learning activities in games. The design and implementation of the project involved the development of grounding activity modules and facilitation of professional development of mathematics teachers to implement instruction according to modules to engage students in learning mathematics. The findings – confirming the project significantly facilitated students' cognitive and affective engagement in learning mathematics – can inform the government regarding educational reform and can suggest teachers and educators feasible instructional approaches to facilitate student engagement in East Asian countries/regions.

1. Introduction

East Asian countries/regions have outperformed their Western counterparts in the international comparative studies of mathematics achievements such as the Trends in International Mathematics and Science Study (TIMSS) and the Programme for International Student Assessment (PISA) since 1999 (e.g., Mullis et al., 2000; Mullis, Martin, & Foy, 2008; OECD, 2013). However, one severe problem of mathematics education in the high-achieving East Asian countries/regions was students' low interests and confidence in mathematics as well as not seeing the value of mathematics (Mullis, Martin, Foy, & Arora, 2012). Furthermore, except Shanghai of Mainland China, the other six high-achieving East Asian countries/regions in PISA 2012 still had a substantial percentage of students categorized as the "lowest performers" whose mathematics achievements were under the baseline proficiency level; the situation is most severe in Taiwan where the percentage of lowest performers was as high as 12.9% (OECD, 2013). The findings have informed these countries/regions that it was urgent to deal with the problems regarding students' affective and cognitive engagement in learning mathematics, especially for low achieving students. The literature has shown that it is more difficult to engage students in mathematics classes than in those of other subjects (Kong, Wong, & Lam, 2003; Plenty & Heubeck, 2011), while student engagement with learning mathematics is influential to their development of mathematical literacy which is crucial for everyone in the era of globalization, fast-changing economy, and information explosion (Kilpatrick, Swafford, & Findell, 2001; OECD, 2013; Steen, 1990). Thus, the challenges for these countries/regions are what and how policymakers, mathematics educators, and teachers can do to deal with the problems revealed by TIMSS and PISA results.

A large-scale project launched in Taiwan to change the present situation and its evaluation of the continuing process was used to monitor and appropriately change the implement. The intervention and the evaluation of this project involved multiple levels systematically, including the levels of students' learning, teachers' professional development, and the design of teaching materials, which were rare in most projects (Chalmers & Gardiner, 2015; Hum, Amundsen, & Emmioglu, 2015). This article describes the project and discusses the evaluation of its effectiveness regarding facilitating student engagement in learning mathematics, which was the final goal of the project. The effectiveness of intervention on other levels – such as mathematics performance of students, qualities of instructional materials, or outcomes of teacher preparation programs – will be reported in other publications.

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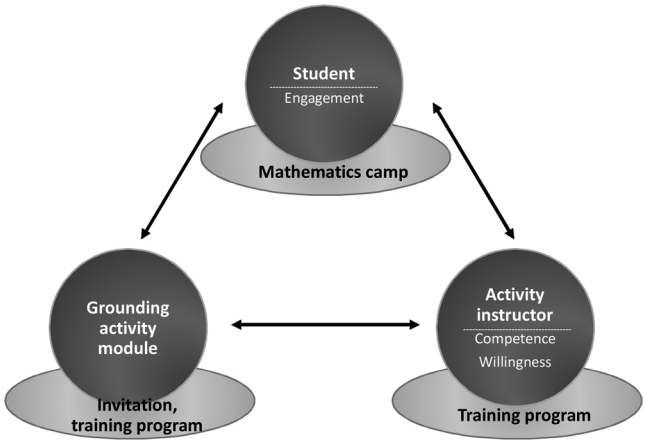

Fig. 1. Design of the project JUST DO MATH.

2. Design of the project "JUST DO MATH" and rationale

To deal with the problems revealed by TIMSS and PISA findings in Taiwan, authors' institution with the support of the Ministry of Education, launched in 2014 a project – JUST DO MATH – which has since been implemented in many schools. Building on the idea that the learning environment involves a series of interactions among teachers, students, and instructional materials (Cohen & Ball, 1999), the project JUST DO MATH consisted of the levels in mathematics education as shown in Fig. 1 (Lin, 2013). To reach the goal of facilitating student engagement in learning mathematics, the project employed gamified activities which have been shown to be effective for helping students' learning (Evans, Nino, Deater-Deckard, & Chang, 2015; Hsu, Tsai, & Wang, 2012). Different from some studies that focused on helping students obtain familiarity with the concepts or procedures they already learnt, JUST DO MATH aimed to help students develop fundamental prerequisite mathematical ideas in gamified activities before formal mathematics learning in classes. This idea accorded with Skemp's (1989) rectangular numbers game which could help students engage in learning mathematics cognitively and affectively. Whilst, most students participated in JUST DO MATH had low interests, confidence, and performance in mathematics.

2.1. Student engagement

Engagement stands for active commitment, involvement, being occupied and attracted, rather than apathetically superficial participation (Fredricks, Blumenfeld, & Paris, 2004; Newmann, Wehlage, & Lamborn, 1992). Regarding student engagement in academic work, several researchers put forth similar definitions; they regarded it as a psychological process of expending attention, effort, investment, and interest in the work of learning (Guthrie et al., 1996; Marks, 2000; Newmann et al., 1992). From these definitions, the multifaceted nature of engagement is implicated. For example, the definition of Newmann et al. (1992) elaborates the promotion of intellectual involvement during learning activities, including using the mind, experiencing cognitive challenges, comprehending knowledge, and mastering skills. This definition emphasizes the cognitive facet of engagement. Newmann et al. (1992) also pointed out that interest, enthusiasm, and enjoyment are indispensable to the actual engagement, revealing the affective facet of engagement.

Affective engagement plays a key role in activating and maintaining cognitive engagement (Blumenfeld, Puro, & Mergendolter, 1992; Goodenow & Grady, 1993; Sancho-Vinuesa, Escudero-Viladoms, & Masià, 2013). It is the research topic of numerous studies, but the constructs studied vary between studies. Most studies focus on students' emotional reactions to academic work, including interest, enjoyment, liking, happiness, and confidence (Bodovski & Farkas, 2007; Connell & Wellborn, 1991; Guthrie et al., 1996; Miserandino, 1996; Skinner & Belmont, 1993). Some research takes students' willingness and persistence of spending time on learning as the major aspects of affective engagement (Kong et al., 2003; Plenty & Heubeck, 2011; Steinberg, Brown, & Dornbush, 1996; Williams & Ivey, 2001). And some other research relates affective engagement to students' appreciation and value of specific subjects (Attard, 2012; Eccles et al., 1983; Finn, 1989; Fredricks et al., 2004; Krapp, Hidi, & Renninger, 1992; Martin, 2007). Cognitive engagement usually relates mental effort invested in academic work, stressing inner psychological investment and the use of the mind in learning rather than simply participating and doing the work (Fredricks et al., 2004). Regarding what kind of mental activities students' efforts are targeted at, the literature mentioned comprehending concepts, creating connections among ideas, thinking and solving problems, and mastering tasks (Blumenfeld et al., 1992; Bouta & Paraskeva, 2013; Connell & Wellborn, 1991; Helme & Clarke, 2001).

The project JUST DO MATH was intended to facilitate Taiwanese students' affective engagement in learning mathematics, that is, to help them increase interest, enjoyment, and confidence in learning mathematics, to promote their willingness and persistence of spending time on mathematics, and to allow them to see the value of mathematics. The other intention of the project was to increase low-achieving students' cognitive engagement in mathematics. That is, to help these students stop being "guests" but to be "insiders" within their mathematics classes. The project was intended to provide students opportunities to think and to understand mathematics, as well as to solve problems in mathematics. The project approached these goals through holding mathematics camps (Fun-math Camps) in which grounding activity modules were used as instructional materials and the activity instructors taught students mathematics in the modules. These activity instructors were primary or lower secondary mathematics teachers who had been trained by the mathematics teacher professional development programs (Activity Instructor TPD Programs; Lin, 2013) conducted by the project.

2.2. Grounding activity modules

To effectively engage students in mathematics cognitively and affectively, the instructional materials were designed under careful consideration of mathematics content, representations, and learning activities.

After several years of making efforts in conducting supplemental instruction in mathematics for low-achieving students without gaining satisfactory results, a new thought emerged to be adopted as the fundamental theme of the project JUST DO MATH. That is, the approach to help students engage in mathematics cognitively was to help them establish the fundamental prerequisite ideas before learning a mathematics topic in regular classes instead of assisting them with supplemental instruction after they have already failed to learn that topic. According to Piaget (1952), understanding is a progressive reorganization of mental structure to integrate what one already knows to what one newly discovers. However, the gap between what students already have in mind and what they need to learn in mathematics curriculum make the building of the connections between them not possible for students (Bransford, Brown, & Cocking, 1999). The approach to develop students on fundamental prerequisite ideas for mathematical topics was an attempt to bridge the gap so as to elicit students' meaningful learning (Attard, 2012; Ausubel, 1961; Bennett & Desforges, 1988). In our study, instructional materials were designed in accordance with this thought which was also the reason why the instructional materials were named *grounding activity modules*. The fundamental prerequisite ideas of the topics in the four main fields – number and quantity, algebra, geometry, probability and statistics – in mathematics curriculum at the primary and lower secondary levels in Taiwan were identified through employing content analysis of the