Title: Implementing effective group work for mathematical achievement in primary school classrooms in Hong Kong*

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Abstract

The Hong Kong Education Bureau recommends that primary school pupils' mathematical achievement can be enhanced via collaborative discussions engendered by group work. This pedagogic recommendation may be inhibited due to Confucian Heritage classroom practices, individualized mathematics teaching and western-dominated group work approaches. To overcome these inhibitions, we introduced a relational approach to group work in a quasi-experimental design. Sample included 20 teachers randomly allocated to Experimental (12) and Control (8) conditions, and their 504 mathematics pupils (aged 9-10). The approach focused on developing mutual peer relationships undertaken in a culturally appropriate manner. The approach was implemented over 7 months (December 2013-June 2014). Pupils were pre-/post-tested for mathematical achievement and systematically observed. Teachers were assessed for subject knowledge and pre-/post-tested for pedagogic efficacy. ANCOVA and HLM results showed: enhanced mathematical achievement, supported by peer-based interpersonal skills (questioning, explaining, supporting), and time-on-task for experimental pupils. Experimental teachers increased their pedagogic efficacy while Control teachers remained the same. Results identify the potential of the relational approach to group work affecting academic achievement via enhanced child-peer-teacher interaction and the need to reassess the role of peer-based latent collectivist learning that can be legitimized in Confucian Heritage classrooms.

1: Introduction

School children in Hong Kong (HK) have consistently shown high levels of mathematical achievement as identified in international comparisons (Mullis, Martin, Foy & Arora, 2012; Organization for Economic Cooperation and Development [OECD], 2010). Among the explanations for this achievement is the Confucian Heritage Culture (CHC) in HK classrooms - exemplified in strong teacher direction and pupil conformity to competitive classroom norms (Biggs, 1994; Kennedy, 2010; Li & Wegerif, 2014; see section 1.2 for more details). At the same time, HK has implemented a range of curriculum reforms over the last 20 years. The reforms have been designed to discourage 'traditional', didactic teaching and enhance pupils' learning engagement engendered by peer-based discussion that integrated into classroom group work (Curriculum Development Council Hong Kong [CDCHK], 2001). Particularly with regard to mathematics, group work: 1) allows pupils to take shared responsibility for learning tasks (as identified in aspects of cooperative learning, Howe, Tolmie, Greer, & Mackenzie, 1995; O'Donnell, 2000; Slavin, 2013; Topping, Kearney, McGee, & Pugh, 2004); 2) while collaboratively drawing on elaborated explanations to enhance understanding and correct misconceptions (Webb, 2009). The inclusion of group work and collaborative discussion into the HK curriculum is not a unique reform. It replicates Western curriculum reforms where innovative pedagogies such as cooperative learning have encouraged pupils' mathematical engagement (Slavin & Lake, 2008) (in England see Department for Education [DfE], 2013; Department for Children, Schools & Families [DCSF], 2009). In addition, concerns supporting the role of group work in mathematics draw upon a background that mathematics is the school subject most likely to be taught in an individualistic manner (Kutnick, Blatchford, & Baines, 2002; Webb et al., 2014). Yet the simple proposal that group work should be integrated into the mathematics curriculum does not mean that children or teachers will use this pedagogic approach to positively affect pupils' mathematical achievement. Explanations for the use of group work and its potential for use in HK classrooms are presented below.

1.1: Group work and mathematics learning, western perspectives: Reviews of group work in western primary school classrooms (Gillies, 2012; Johnson, Johnson, & Roseth, 2010; Kutnick & Blatchford, 2014; Reznitskaya et al., 2009) have attested to the relevance of group-based learning for academic achievement, cognitive and social-relational development of children. The reviews have noted the existence of various approaches to encourage pupils working together to enhance their learning (e.g. group work, cooperative learning, collaborative learning, team work). But, some approaches to children working together are not consistently effective for all children in their classrooms. Effectiveness in grouping children to work together requires more than seating children around a table (Galton, Hargreaves, Comber, Wall, & Pell, 1999), giving pupils undifferentiated tasks with no accountability (Stein, Grover & Henningsen, 1996) or expecting that pupils will naturally draw upon cognitive-based explanations and justifications when they share ideas with one another (Emmer & Gerwels, 2002; Webb, 2009).

The main types of study concerning classroom group work have, until recently, been characterized by atheoretical naturalistic grouping and theoretically structured grouping to promote cooperative and collaborative learning. Effectiveness of these approaches varies due to a range of whole-class inclusion, methodological and theoretical issues. Naturalistic pupil grouping does not differentiate between types of learning activities assigned to groups and is mainly associated with table-based seating (Baines, Blatchford, & Kutnick, 2003; Galton et al., 1999; Wilkins, 2011). Within this naturalistic perspective, there is little evidence that teachers have designed tasks that allow/encourage pupils to act interdependently or that children have the desire/skills to communicate and support one another (Mercer & Littleton, 2007; Stein et al., 1996; Webb & Mastergeorge, 2003). Theoretically-based group work: emphasizes inclusiveness (for example: Cohen & Lotan, 1995; Slavin, 2013; Johnson & Johnson, 2003), stressing that groups should be composed as heterogeneous cross-sections of a class (by sex, attainment, ethnicity, etc.) to overcome status and stereotypical friendship preferences; and is often realized within the classroom in either cooperative or collaborative approaches. Each approach draws historically from developmental (from Piaget, 1971 or Vygotsky, 1978) or social (Deutsch, 1949) psychological theory (see Kutnick & Blatchford, 2014). All approaches, though, assume that children have the skills and desire to undertake classroom tasks with their peers.

The different theoretical bases have been associated with the various approaches; and these approaches differentiate between learning tasks that can be undertaken. The best known group work approaches are dominated by the theoretical orientations of cooperative and collaborative learning. Cooperative learning has been designed to allow people to work together toward a specific learning goal (Panitz, 1997) and usually require that each group member is assigned a unique sub-task that enables the group to progress towards the completion of the group goal (Dillenbourg, Baker, Blaye, & O'Malley. 1996; Slavin, 1986). Cooperative studies are based on theories of interdependence and contact (Allport, 1954; Slavin, 2013). This task-/positional-oriented approach has been noted as enhancing learning and peer relationships. Reviews of cooperative learning (Roseth, Fang, Johnson, & Johnson, 2006; Slavin, 2013) identify small but positive effects of cooperative learning in groups especially with regard to the learning of mathematics (see Davidson & Kroll, 1991; Slavin, 2013). On the other hand, it has been argued (Barron, 2003; Kutnick & Blatchford, 2014) that these studies are mainly short-term and that children require some form of training which will allow them to act in an interdependent manner (Johnson et al., 2010). Further, recent randomized, controlled studies such as Tracey, Chambers, Slavin, Hanley, and Cheung (2013) found no significant achievement difference when comparing cooperative to traditional teaching approaches even over a full year of implementation.

Collaborative learning draws upon an approach to group work that 'involves the mutual engagement of participants in a coordinated effort to solve problems' (Dillenbourg et al., 1996; also see Anderson, Chinn, Chang, Waggoner & Yi, 1997; Goswami & Bryant, 2007; Howe, 2010; Mercer & Littleton, 2007; Webb & Palincsar, 1996; Yackel, Cobb & Wood, 1991). Collaborative learning studies require that pupils engage in explanatory dialogue. Yet, these studies depend on children's cultural and personal histories (Barron, 2003) and do not necessarily prioritize inclusion. Collaborative studies undertaken in the mathematics curriculum have tended to focus on children's use of communicative skills while they engage in joint problem-solving (Webb & Farivar, 1994; Webb & Mastergeorge, 2003; Yackel et al., 1991). The communication skills used by pupils must include various forms of elaborated speech (explaining, justifying, etc.) and be undertaken in a supportive manner. But these forms of communication are rarely found or used in normal classrooms (Mercer & Littleton. 2007; Webb, 2009). Nor are collaborative skills likely to affect all children equally when communication skills are taught in classrooms (Reznitskaya et al., 2009). In one of the very few meta-analyses that compares the collaborative approach and traditional classrooms (The Metiri Group, 2009) only limited collaborative learning effects were found. Thus, while cooperative and collaborative learning approaches may have strong theoretical underpinning, actual controlled, comparative studies of these theories find little difference in outcome from naturalistic studies of pupil grouping within classes.

Questions concerning why there have been only limited pedagogic and achievement effects related to group work in mathematics classrooms have been raised in a number of Western countries (such as Australia, Israel, USA, UK). Slavin et al. (2013) and Stein et al. (1996) identified differences between generally sitting pupils in groups and where there is a clear theoretical basis for pupil grouping. The theoretical basis for effective group working must account for within-class engagement processes aligned to cooperative sharing and collaborative communication within group work (Kramarski & Mevarech, 2003; Webb & Palincsar, 1996). Slavin et al. (2013) also noted that unsuccessful incidents of group work are associated with limited teacher ownership of the pedagogy. Further ambiguities among types of group work and lack of teacher training in group work has meant that pupils may be placed in classroom groups without effective group working strategies (Kutnick & Blatchford, 2014). Hence, simple grouping of children and even cooperative and collaborative approaches provide insight into the need for more effective group work. The review of previous approaches acknowledges a lack of consistent results aligned to the enhancement of children's achievement. In drawing together their own review of classroom group work and the mathematics curriculum, Slavin and Lake (2008) found limited achievement effects of group work approaches. They did note that enhancing mathematics achievement may require more than a cooperative context. Pupils should be able to draw upon explanations and reasoning skills with their teachers and peers (Kramarski & Mevarech, 2003; Webb & Palincsar, 1996). Hence, Slavin et al. (2013) identified a number of short-comings in these mathematics-based studies, including: the need for teachers to be trained and accept the principles of group work programmes; the need for pupils to have explanation and reasoning skills regarding mathematics operations that they can share with their peers and teachers; and group work programmes should structure group goals and individual accountability into classroom-based mathematical activity.

1.2: HK Classrooms; A Confucian Heritage Context and the call for effective group work in mathematics: We have already acknowledged that HK has scored highly in international mathematics comparisons of pupil achievement, although recent scores have dropped slightly (Mullis et al., 2012). Being aware of the recent drop in scores and to facilitate higher levels of pupil achievement, the HK Education Bureau has begun a programme of reduction in class size in primary schools (Education Bureau [EDB], 2008). This class size reduction to approximately 25 pupils was made with the expectation that teachers will change their CHC pedagogic approach by including increased amounts of pupil engagement via discussion within group work. Galton and Pell (2010) have confirmed class size reduction has taken place. And, other HK-based researchers (Fung, 2014a; Keppell & Carless, 2006; Mok & Morris, 2001) have identified some progress towards the implementation of group work to enhance pupil engagement in the classroom (especially in mathematics). These studies, though, have not identified the type of group work implemented, whether participation in group work enhanced pupils' mathematical achievement or whether within-class processes associated with group work enhanced pupil achievement. In fact, change in class size only infrequently led to change in teachers' pedagogic approach and did not affect pupils' mathematics performance except for low attaining children (Galton & Pell, 2010).

While curricular reforms in HK recommend engaged learning via discussion and communicative practices within classroom group work, these recommendations are set within an education system portrayed as traditional and examination-oriented (Biggs, 1996; Brimer & Griffin, 1985). Students perceive their classrooms to be competitive and isolated (Morris, 1985). Under the influence of CHC, teachers usually maintain control through direct teaching, especially in mathematics lessons (Leung, 2001; Mok & Morris, 2001). A review of CHC, though, provides a number of contradictory views concerning the application of this classroom culture. A simplistic view of CHC sees the learner as: passive, reluctant to express opinions and respectful of the teacher/teacher's authoritative knowledge (Murphy, 1987); preferring concrete knowledge and structured, non-reflective learning (Hofstede & Hofstede, 2005; Marton, Dall'Alba, & Tse, 1996; Oxford & Bury-Stoke, 1995); competitive within an examination-driven system (Salili & Lai, 2003); and individualized and not participative in discussions or group working (Su, 1995 as cited in Oxford & Anderson, 1995; Tang & Williams, 2000). This description of rote learning, memorization, (pupil) passivity and teacher 'virtuosity' (Kennedy 2010; Mok & Morris, 2001) leaves little room for group work within highly structured CHC classrooms (Kennedy, 2002; Liu, 2002; Nguyen, Terlouw & Pilot, 2006). The CHC pedagogic model is likely to be described as 'instruction-practice-feedback' (Kennedy, 2002; Stevenson & Lee, 1997). And, CHC classes tend to be large (30+

pupils) with short lesson periods (35 minutes) and pupils are required to sit at individual, teacher-focused desks (Fung, 2014a; Galton & Pell, 2010). As such, CHC-based mathematics classrooms in primary schools appear to present as the antithesis of current curriculum expectations with regard to pupil engagement in their learning.

Evidence that CHC does not support group work in HK may not be as strong as previously thought. As early as 1994, Biggs (contradictorily) described HK classrooms as student- rather than teacher-centred. Teachers try to encourage high levels of cognitive understanding (Li, 2003). Pupils have been described as having the potential to be active, open and reflective (Cheng, 2000; Cortazzi & Jin, 1996). If allowed to work in groups, pupils have been found to engage in critical analysis if accorded group learning experiences (Tang, 1996). Even Flowerdew (1998) found evidence of effective group work when teachers offered an appropriate pedagogic structure that draws upon a collectivist orientation that characterizes pupil interaction outside of the classroom. Pupils' ability to engage in group work within HK CHC classrooms may be explained by a combination of: children's respect for their teachers and willingness to adapt to diverse pedagogic methods that are legitimated by their teachers (Flowerdew, 1998; Kennedy, 2010; Nguyen et al., 2006); and a tendency for pupils to collectively review and share classroom-based information informally outside of the classrooms (Biggs, 1994; Su, 1995 as cited in Oxford & Anderson, 1995; Tang, 1996; Wong, 1996). Pupils would necessarily draw upon the ability to supportively communicate with one another within a classroom context that allows for group rather than individual seating. Teachers, too, must be supportive of group-based learning (Fung, 2014a). If a programme for effective group working is to be implemented within HK classrooms, it will need to draw upon three considerations: 1) teachers should provide legitimacy to non-traditional pedagogic practices; 2) physical layout and curricular practices need to be adapted for group learning tasks and peer interaction; and 3) the incorporation of pupils' informal collectivistic orientations to learning into the classroom. While these group work considerations are not unique (Baines et al., 2009; Slavin et al., 2013), they must be implemented via a culturally appropriate pedagogy (Whitty, Power & Halpin, 1998). These considerations acknowledge: class size reduction has not changed teachers' traditional pedagogic approach (Galton & Pell, 2010); teachers and pupils require a form of group working that is more complex than seen in naturalistic grouping studies (Kutnick & Blatchford, 2014); and western-based approaches to group work, especially theories of cooperation and collaboration applied in classrooms may not be appropriate for use in the CHC of HK classrooms (Nguyen et al., 2006; Whitty et al., 1998).

1.3: Identifying a research problem: At this point, readers may question: 1) why one should persist with a group approach to enhance pupils' understanding and achievement in mathematics in HK; and 2) whether an alternative approach to group work in mathematics may prove more effective than the reviewed cooperative, collaborative and naturalistic learning approaches. Before the consideration of alternative approaches is presented, two qualifications in the use of effective group work for learning can be made: The first qualification notes that effective group working (cooperative, collaborative and naturalistic) studies have all assumed that pupils will wish to undertake learning tasks with one another. The above approaches have not actually problematized that there must be positive relationships between pupils in a class before teachers can expect them to undertake learning tasks with one another. Skills most cited as enhancing learning via group work require pupils to share perspectives and use elaborated speech (Howe, 2010; Mercer & Littleton, 2007; Yackel et al., 1991). A logical first step in introducing group work should ensure that all pupils in a class are able to develop positive relationships with one another; a relational approach. This relational approach would differ from naturalistic, cooperative and collaborative approaches in two ways. Initially, it draws upon a developmental-social psychology of close relationships (Kutnick & Manson, 1998) rather than interdependence/accountability (Johnson & Johnson, 2003; Slavin, 2013). Further, once a relational foundation is in place among all pupils in a classroom, children will be in a position to participate collaboratively (Mercer & Littleton, 2007; Yackel et al., 1991). The second qualification notes that any effective group work approach should draw upon a culturally appropriate pedagogy. We have already noted that Nguyen et al. (2006) identify that western-based cooperative/collaborative approaches are likely to clash with CHC classrooms as there are different power/authority distributions in these two cultures. A culturally appropriate pedagogy for group work within CHC classroom needs to draw from teachers' legitimizing and supporting group skills, setting-up classroom conditions that enable group work and drawing upon pupils' informal collective learning support for one another.

In HK primary schools there have been government calls to enhance pupil engagement in the mathematics curriculum via peer-based discussion promoted by effective group work. Any approach to effective group working will need to be undertaken using a culturally appropriate pedagogy, especially as there have been few examples of effective group work programmes in CHCs (Nguyen, Elliot, Terlouw, & Pilot, 2009). And, effective group working will also require positive relationships among all pupils in the classroom (Kutnick & Blatchford, 2014). Approaches based solely on western experience appear to have inherent problems (Kutnick & Blatchford, 2014; Slavin et al., 2013) with the exception of one quasi-experimental programme that has provided consistent positive achievement/cognitive development outcomes in a number of different cultures. This programme, SPRinG (Social Pedagogic Research into Group work: Blatchford, Galton, Kutnick, & Baines, 2005; Kutnick & Blatchford, 2014) contrasts with previous group work programmes in that it: provides strong support for the relational development of all pupils (inclusively) in a classroom; was developed with strong reliance on teachers' cultural and classroom knowledge; requires an adaptable classroom context that will enable group working within both the physical and curricular classroom space; and is implemented over a full school year (Baines et al., 2009). Perhaps the most distinctive aspect of this approach is SPRinG's focus on developing children's relational skills inclusively among all pupils in a classroom. In problematizing peer-based relationships (see section 2.3 on the relational approach), children's interpersonal support and communicative skills are developed among all pupil members of the classroom. These communication skills underlie elaborated discussion that enhances cognitive reasoning and explanation (usually taught directly as separate social skills in cooperative/collaborative approaches: Gillies & Kahn, 2009; Kramarski & Mevarech, 2003; Webb & Mastergeorge, 2003). SPRinG studies have been undertaken in England, Scotland, the Caribbean (Blatchford, Baines, Rubie-Davies, Bassett, & Chowne, 2006; Kutnick, Ota, & Berdondini, 2008a; Kutnick, Layne, Jules, & Layne, 2008b; Tolmie, 2014). Findings from these studies include: consistent evidence that teachers are able to move from a traditional controlling curriculum and knowledge orientation to one of observing and monitoring their pupils; increases in teachers' confidence in offering group working opportunities for their children; children at all attainment levels benefit academically in comparison to children in Control classes; but, there have been variations among teachers with regard to how fully they adapted the approach.

1.4.: Research questions: Within HK, the opportunity to provide alternatives to the traditional CHC mathematics teaching have been encouraged by the government (CDCHK, 2001; Cai & Ni, 2011). But, there has only been limited evidence of a pedagogical shift from the traditional CHC paradigm to strategies/approaches to enhance group working in classrooms (Fung, 2014b; Galton & Pell, 2010). If a pedagogic shift among teachers affecting pupil achievement can be detected as a result of an experimental intervention, the study should account for teachers' initial level of subject knowledge, pedagogic efficacy (confidence in topic teaching), how well teachers developed circumstances to support group work in their classrooms as well as pupils' development of communicative skills. The above concerns have been framed into the following research questions: (i) can a relational-based group work approach be adapted/co-developed by HK primary school mathematics teachers and applied in their classrooms?; (ii) does the group work programme affect teacher actions and interactions in the classroom over time?; and (iii) will children's discussion skills and corresponding mathematical achievement be enhanced by active participation in this group work approach over time in comparison with matched control classes?

2: Methods

2.1: Design: Use of a quasi-experimental design allowed the authentic and ecologically valid teaching unit (whole class) to continue (Wegener & Blankenship, 2007) without imposing new organizational processes that would be necessitated in a randomized, controlled design. A quasi-experimental study is based on an equivalence of classroom background in Experimental and Control classes, initially ascertaining whether mathematics teachers across all classes have similar levels of mathematical subject knowledge and that pupils had similar levels of mathematical achievement. Given that HK has a standard primary school mathematics curriculum in operation across the region, it was assumed that all teachers/classes involved in this study would have been taught the same mathematics topics at roughly the same time over the course of the study – although pedagogic approach would differ between Experimental and Control classes. Implementation/testing took place between December 2013 and July 2014; approximately 80% of the school year. To match Experimental and Control classes, each participating school identified two P4 (pupils 9-10 years) mathematics teachers who taught classes of similar attainment levels. Within-school teachers were randomly divided into Experimental and Control groups similar to large-scale studies concerning mathematics and group work (Slavin et al., 2013). Teachers were: pretested for their mathematical subject knowledge; pre-/post-tested for their mathematical pedagogic efficacy and observed for use of group work within their classes. Pupils were: pre-/post-tested for age-appropriate mathematical achievement and observed for their communicative actions, interactions and evidence of group working while undertaking mathematics tasks. Ethical approval was gained from the host university and consent was agreed at school, teacher and parent of pupil levels.

2.2: Sample: Teachers: Twenty mathematics teachers participated (10 female, 10 male). Two teachers from each of 10 primary schools participated in the study. All teachers expressed an interest in enhancing their pupils' mathematical achievement. Nine teachers had studied mathematics to Bachelor's level; 7 studied mathematics to age 18; and 2 studied mathematics to age 16. Teachers were randomly allocated to Experimental and Control groups, attempting to have one Experimental and one Control teacher per school.

Pupils and classes of the 20 teachers: 504 pupils of the above P4 mathematics teachers participated. Class size ranged between 14 and 33 pupils (excluding one special education needs class (SEN) of 8); average class size was 26.11.

Table 1:
Pre-Test Matching of Experimental and Control: Teachers, Pupils and Classes (standard deviations and percentages of pupil characteristics in brackets)

Category of comparison	Experimental means	Control means	Difference
TEACHER CATEGORIES	12 teachers	8 Teachers	
Level of mathematics education+	2.42	2.50	N.S.
Years of teaching experience	9.17 (5.86)	12.13 (9.39)	N.S.
Mathematical subject matter knowledge (SMK)	50.17 (11.65)	49.38 (9.74)	N.S.
Pedagogic efficacy (PEf)	52.08 (21.88)	62.63 (14.67)	N.S.
PUPIL CATEGORIES			
Pupil numbers and sex ratios	319	185	
Male	193 (60.5%)	111 (60.5%)	N.S.
Female	126 (39.5%)	73 (39.5%)	
P3 mathematics assessment	71.79 (15.52)	72.12 (15.52)	N.S.
CLASS CATEGORIES			
Class size++	28.27 (4.54)	23.13 (4.73)	F(1,17)= 5.747*

Implementation rating scale	14.29 (2.16)	7.59 (4.29)	F(1,42)= 41.972***

+ This is an ordinal measure, the average reported simply indicates that most teachers studied mathematics beyond age 18.
++ Class size excludes the Experimental special educational needs class of 8 pupils.
*p<0.05; **p<0.01; ***p<0.001

2.3: Relational approach: The relational approach was co-developed with teachers, based on an original design (Blatchford et al., 2005). The approach draws upon a (psychological) model of close relational and social development that follows a sequence of whole-class, inclusive activities to enhance children's trust and security in working with one another (Kutnick et al., 2008a; Wentzel, 1991), leading to effective communication (listening, explaining, sharing, Gillies, 2012), and joint problem-solving (Light & Littleton, 1994). This approach was not designed to be curriculum-specific. Once pupils engage in classroom training for the approach, the support, communicative and joint problem-solving skills that they co-developed may be applied to a range of curriculum subjects including literacy (Kutnick et al., 2008a), science (Blatchford et al., 2006; Tolmie, 2014), and social studies (Kutnick et al., 2008b). Within the relational approach training, children move through a sequence of joint-interpersonal rule setting, sensitivity/trust exercises and communication skills before moving into joint problem-solving. These interpersonal skills can then be drawn upon and further developed with regard to particular areas of the curriculum. To encourage classroom inclusion, children are asked to change partners periodically and not to undertake the training with pre-established and preferred friends (see Baines et al., 2009 for further information related to relational approach and exercises). As identified in previous relational approach studies, the role of the teacher is vital for the legitimization of relational activities in the classroom. Higher levels of teacher involvement have been associated with higher levels of pupil progress - allowing teacher 'ownership' of the approach within their classrooms (Baines, 2014; Kutnick & Berdondini, 2009). The teachers, in turn, base their ownership on classroom cultural knowledge such that the relational skills and associated adaptations in the classroom are undertaken via a culturally appropriate pedagogy. Thus the role of teachers, classroom layout and curriculum tasks are coordinated with pupils' developing relational skills (Baines et al., 2009). When applied in Experimental classrooms, researchers would expect to observe changes in teacher and pupil behaviours similar to the classroom described by Yackel et al. (1991). Teachers would not change their curriculum sequence but would allow for a higher level of pupil-based developmental problem-solving through small group discussion. In contrast to Yackel et al. (1991), though, development of discussion skills in this study are based on trust/communication skills structured into the relational approach and we are able to assess effects on pupil achievement in the Experimental and Control classes over time. Further, in contrast to Experimental classes, Control classes would be expected to maintain their curriculum sequence, but teachers would retain a more didactic teaching approach and there would be less opportunity for within-class discussion/problem-solving among pupils.

Between December and May, Experimental teachers were provided two full-day and three twilight training sessions in the relational approach. Control teachers were provided with an equivalent amount of time for pedagogic development, the amount and type of training was decided upon by Control teachers individually. Information on type or extent of Control teacher training undertaken was not collected although, as noted, all teachers were concerned to enhance their pupils' mathematics achievement. When classroom observations were undertaken (in both Experimental and Control classes), feedback was provided to Experimental teachers concerning their use of the relational approach while Control teachers received general feedback on type and quality of interaction in their classrooms. Both Experimental and Control classes maintained the standard P4 mathematics curriculum (CDCHK, 2000) and all teachers used some form of group work throughout the school year.

2.4: Instruments): Pre-tests (December) provided for a comparative equivalence of background between Experimental and Control teachers and their classes. Before using each instrument, assessments were made for ecological and content validity for use in P4 classrooms. These assessments were made on non-sample, age-appropriate teachers and their classes.

Teachers were assessed for: subject knowledge and pedagogic efficacy in mathematics, and classroom set-up for group working. Each instrument had a high level of reliability (see Table 2). Mathematics subject knowledge was assessed by the Mathematics Subject Matter Knowledge (SMK) Survey developed by Rowland, Martyn, Barber, and Heal (2001) and adapted for HK by Wong, Rowland, Chan, Cheung and Han (2008). The SMK included 16 item questions and covered "themes of basic arithmetic competence, mathematical exploration and justification, and geometric knowledge. These three themes were chosen because they were basic elements of the HK mathematics curriculum and they address both substantive and syntactic knowledge of mathematics" (Tsang & Rowland, 2005, p.4). The pedagogic efficacy (PEf) scale asked teachers to rate personal teaching efficacy and ability to promote pupil engagement with regard to 19 age-appropriate mathematics teaching topics for P4 classes (for example: place value, addition/subtraction, fractions/decimals). Assessment of group work implementation in classrooms drew upon scales previously developed (see Kutnick & Berdondini, 2009). These high inference ratings were adopted from original research by Berliner (1987) and included scales for: Learning context (flexible seating, toys/games that can be used by more than one child, etc.); Activities/tasks /resources conducive to sharing (children asked to undertake activities in small groups, children encouraged to talk with peers, etc.); Adults encourage children to work with one another (providing briefing and debriefing for collaboration); Adults introduce training for peer-relational support (trust, communication, problem-solving skills); Children engaged in peer-based interactions (sharing dialogue, joint problem-solving); Children active in relational activities (discussion and support for peers), and an overall reflection on how well the teacher prepared the class for group working. Each researcher was trained to use the rating scales by observing recorded classroom videotapes, discussing and debating the meaning of each scale, and agreeing how ratings per scale would be made. Scales as well as inter-rater (Kappa) comparisons had high levels of reliability.

Pupils were assessed for: (i) Mathematics attainment by an adapted and validated government designed mathematics assessment from the pupils' previous P3 year. The thirty-eight items covered simple and complex multiplication and division, geometry, number order and charts. The test was highly reliable. (ii) Actions and interactions were systematically observed by trained researchers using a scheme developed by Blatchford (2003) based on an original construction by Galton et al. (1999); funding did not allow for qualitative observations in classrooms. Systematic observations focused on 4 to 6 representative target children per class (one high, middle and low mathematics attainer along with the pupil sitting next to the chosen target) during the working part of the lesson (after the lesson introduction and before any final plenary session). Observations identified: work setting (individual, small group, whole class), communicative behaviour with peers and teacher (listen, non-verbal communication, question, explain, suggest, give information, agree) and task engagement (on- and off-task). Each target was observed for 20 seconds, the observer then recorded which actions and interactions characterized that period on an observation sheet. Each target was observed 8 times per classroom observation session. To ensure reliable observations, each observer underwent training in the use of the observation schedule; allowing researchers to define, discuss and agree on categories before classroom observations began. It was not possible to calculate an inter-rater reliability within actual classroom observations as each observer was assigned to watch/rate separate target children (and a secondary observer would have been intrusive in ongoing classrooms).

Post-testing (June) took place towards the end of the school year with data collection dates identified to avoid periods of within-school and territory-wide testing of pupils. The instruments used were, in the main, the same as instruments designed for pre-testing.

Teachers were reassessed for: (i) PEf (described above); the scale was highly reliable. (ii) Group work implementation (described above), the scales and inter-rater reliability were at high levels.

Pupils were reassessed for: (i) Mathematics attainment by an adapted and validated government designed assessment for the pupils' current P4 year; 36 items were similar to the P3 test with the addition of fractions, decimals, area and symmetry. The test was highly reliable. (ii) Actions and interactions were systematically observed (described above).

Table 2

Instruments used, descriptions, scoring and reliability

Instrument	Reference	Question number/type	Scoring system	Reliability
Mathematical subject matter knowledge (SMK)	Wong et al. 2008	16 questions	5-pt scale (0 = no solution; 4 = completely secure in knowledge)	α = 0.843
Pedagogic efficacy (PEf)	Wong et al. 2008	19 mathematical topics	5-pt scale (1 = I hate teaching this topic and pupils find this difficult; 5 = I enjoy teaching this topic and pupils have fun with it	Pre-test: α = 0.952 Post-test: α = 0.948
Group work implementation	Blatchford et al. 2005	7 scales	Scales 1-6: 5-pt scale (0 = not observed in class; 4 = observed very frequently in class Scale 7: 5-pt scale (1 = teacher did not prepare class for group working; 5 = teacher prepared	Pre-test: α = 0.842 Kappa = 0.874 Post-test: α = 0.952 Kappa = 0.896

			class for group working	
Systematic observation	Blatchford 2003	Work setting (3) Interactions (7) Task engagement (1) Group interaction (2)	Occurrence (or not) of target child's setting, interaction, engagement	Trained observers
Mathematics attainment: P3	Adapted Hong Kong government test	38 age-appropriate questions	3-pt scale (0 = totally incorrect/not attempted; 1 = incorrect solution but correct working/correct solution but incorrect working; 2 = correct working and solution	α = 0.849
Mathematics attainment: P4	Adapted Hong Kong government test	36 age-appropriate questions	3-pt scale (same as P3 scoring)	α = 0.868

2.5: Statistical analyses: Given the sample size and the range of comparisons, a two-stage approach to data analysis was undertaken. The initial stage was essentially descriptive: 1) assessing pre-test differences between Experimental and Control teachers and their classes; and 2) assessing post-test differences between Experimental and Control teachers and their classes, and using (where possible) pre-test data as a covariate. Parametric and non-parametric analyses were used as appropriate to level of measure. At the second stage, hierarchical linear modelling (HLM) analysis was deemed possible (Raudenbush & Bryk, 2002) as individual pupil achievement scores were nested in their classrooms (hence the two-levels of individual and class). In using HLM, a composite score for collaborative interaction (question, explain, suggest and time on-task as these scores were highly correlated [$p<0.01$ level of significance for correlations between each item]) was calculated to assess interaction with pupils' co-varied P4 mathematics attainment scores. For pupil achievement-based comparisons, data from children in the small (Experimental) special education needs class were excluded.

3: Results

3.1: Descriptive: Pre-test comparisons: Teachers, Pupils and Classes: Table 1 provides a range of matching/comparisons between Experimental and Control teachers, pupils and classes. There was no significant difference between Experimental and Control teachers in their level of mathematics education, amount of classroom teaching experience (average 10.5 years, sd=7.6 years), mathematical subject knowledge (SMK) or pedagogic efficacy (PEf). While not at a significant level, it should be noted that Control teachers had more teaching experience (approximately 3 extra years) and higher PEf (an average of 10 points).Within classes, the same ratio of boys-to-girls characterized both Experimental and Control classes. Control classes had significantly fewer pupils (by an average of 5) than Experimental classes. And, there were no statistically significant differences in P3 mathematics achievement found between pupils in Experimental and Control classes.

3.2: Research questions 1 and 2 focus on development and change in Experimental teachers (vs. Control teachers) over the course of the implementation period. Experimental and Control teachers began this study with similar levels of teaching background and SMK. Within the first systematic observation period Experimental teachers were more likely to set-up their classrooms for group work than Control teachers ($X^2[2] = 135.45$, $p<0.001$). 70% of observations in Experimental teachers' classrooms showed a group setting in place. In Control classrooms initial observations showed 26% of group setting in place. The end-of-year (final) observations also saw a high level of group work setting with slightly smaller differences between Experimental and Control classes ($X^2[2] = 114.55$, $p<0.001$). The group work setting was used in 73% of Experimental class observations and 31% of Control class observations. These observations of work settings showed that both Experimental and Control teachers used group-based-seating although Experimental teachers were much more likely to use group work settings in their classrooms than Control teachers. Even limited early intervention training for group work was likely to support greater use of group work by Experimental teachers.

While pupils in both types of class were exposed to naturalistic group seating, the study draws upon further evidence to ascertain whether the relational approach to group work was actually used and effects of that training on both teachers and pupils. With regard to group work implementation scales, Experimental teachers immediately employed and maintained high levels of the relational approach and group working. Over this period, Experimental teachers increased slightly their total scores (from 14.29 to 15.08) while Control teacher scores decreased slightly (from 7.59 to 7.06); an analysis of covariance of post-test scores co-varied by pre-test scores was nearly significant ($F[1,36]=3.170$, $p<0.08$). Table 3 with associated ANCOVAs displays that Experimental teachers and classes showed increases in pre- to post-scales with regard to: Learning context, Adults encourage children to work with one another, Children engage in interactions, and Children active in relational activities; and decreases in Activities/tasks conducive to sharing, Adults introduce training/sensitivity to peer relational support. Control teachers only showed small increases in Learning context and Activities/tasks conducive to sharing. The only ANCOVA that did not show a significant difference was for Learning context – indicating that both Experimental and Control classrooms were physically set-up as conducive for group work.

In line with implementation differences, Experimental teachers increased in their PEf in the classroom. Pre-test scores for PEf showed Control teachers scored higher than Experimental teachers. Post-test scores were different: Experimental teachers now scored higher on average than Control teachers (67.00 vs 66.00). This change in PEf was significant for Experimental teachers; the post-test regression co-varied by pre-test scores was statistically significant ($F[3,16]=5.465$, $p<0.009$).

Table 3:

Means and differences between Experimental and Control teachers with regard to group work implementation scales over time (scale: 0 – 4)

SCALES	Initial Observation		Final Observation		ANCOVA (F)
	Experimental	Control	Experimental	Control	
Learning context	2.52	1.82	2.96	2.00	2.30
Activities/tasks conducive to sharing	2.78	1.18	2.60	1.25	3.08*
Adults encourage children to work with one-another	1.78	0.71	2.04	0.63	10.03**
Adults introduce training for relational support	1.37	0.59	0.48	0.13	4.15*
Children engaged in peer-based interactions	2.00	1.12	2.44	0.94	11.13**
Children active in relational activities	1.85	1.06	2.28	1.00	5.52*
Overall preparation for group working	2.00	1.12	2.20	1.13	7.50**

*: p<0.05
**: p<0.01

Altogether, Experimental teachers were more likely to use group settings and implement aspects of relational group work in their classroom pedagogy than Control teachers. Use of the relational approach was also associated with an increase in Experimental teachers' PEf which is indicative of greater enjoyment in topic teaching as well as greater engagement with their pupils while teaching these topics. The above analyses do not exclude Control teachers from using group work and relational approaches. In fact, Control teachers used group work in approximately 30% of their final observation lessons. Yet, within these and other observed lessons there was only limited use of relational aspects in their pedagogic approach and no increase in their pedagogic confidence over time.

3.3: Research question 3 focuses on enhancement of pupils' mathematical achievement over time and taking into account changes in interpersonal discussion skills that may explain enhanced achievement. Excluding the SEN class, post-test scores were significantly higher for Experimental pupils (62.43 [sd=15.60]) than Control pupils (59.09 [sd=17.83]) when compared by ANCOVA (F[1, 479]=9.715, p<0.002, *d*=0.202). Associated with the difference in mathematical achievement were changes in Experimental pupils' communication and group working skills; these skills often being referred to as the basis for children's cognitive development (Webb & Palincsar, 1996; Yackel et al., 1991; and others).

Table 4 displays target pupil systematic observations at the start and end of the implementation period and shows: 1) significant differences regarding audience in work setting with Experimental pupils more likely to focus on group-mates (standardized adjusted residual [sar] 4.1) and Control pupils more likely to focus on teacher (sar=4.9). 2) Observations at the end of the school year regarding the audience in work setting were even more extreme with Experimental pupils focusing on group-mates in 50.3% of observations (sar=7.5) and Control pupils focusing on teacher in 66.9% of observations (sar=6.9). 3) Other Experimental and Control differences in the initial observations included: Experimental children were more attentive (listen/watch), gave more information to group-mates, explained and disagreed in class compared to Control target pupils. 4) At the end of the school year, Experimental pupils extended the range of differences compared to Control children: Experimental children were more likely to maintain peer-based interactions via non-verbal actions with group-mates, listen/watch group-mates, question, suggestion, give information, agree and group maintain. Control pupils participated in these interactions, yet their interactions were at a lower frequency and were likely to decrease over time. 5) On-/off-task observations showed: Initially, Control children were likely to be off-task (sar=3.8) while Experimental children were likely to be on-task (sar=1.9). End-of-year observations again found Control children likely to be off-task (sar=5.5) and Experimental children to be on-task (sar=6.8). 6) Observations of tasks undertaken by group or individual showed: initially. Control children undertook their assigned tasks as individuals (sar=7.2), while Experimental children undertook tasks in a mix of individual/group (sar=3.7) or as a group only (sar=6.6). End-of-year observations again found Control children undertook most tasks as individuals (sar=8.9) and Experimental children undertook tasks in a mix of individual/group (sar=3.7) or group only (sar=7.5).

Table 4

Observations of target pupils actions and interactions; comparisons of Experimental and Control pupils in pre- and post-observations

Observation category	pre-observation				post-observation			
	Significance differences (X^2 reported, [df])	Frequency of observation		SAR+	Significance differences (X^2 reported, [df])	Frequency of observation		SAR+
		Exp	Con			Exp	Con	
Work setting	[5] 27.820***				[5]=63.027***			
Non-verbal	NS	142	85		[1] 5.012*	145	66	2.2
Listen/watch	[1] 5.177*	260	170	2.3	[1] 14.277***	307	148	3.8
Question	NS	8	2		[1] 4.853*	8	0	2.2
Suggest	NS	18	6		[1] 23.779***	45	2	4.9
Give information	[1] 13.923***	145	63	3.7	[1] 19.834***	152	50	4.5
Explain	[1] 9.319**	30	6	3.1	NS	26	10	
Agree	NS	19	6		[1] 8.372**	27	4	2.9
Disagree	[1] 9.594**	28	5	3.1	NS	19	6	
Seek help	NS	9	9		NS	18	5	
Group maintenance	NS	23	9		[1] 8.927**	25	3	3.0
On/off-task	[2] 19.020***				[2] 52.519***			
Group/individual task	[2] 65.014***				[2] 98.354***			

+Standardized adjusted residual: only significant SARs above 1.0 are reported
*p<0.05; **p<0.01; ***p<0.001

Within classrooms and according to collaborative rationales for group work (e.g. Dillenbourg et al., 1996; Gillies, 2012; Reznitskaya et al., 2009) it would be expected that achievement is mediated by the quality of interaction between peers; this was accounted for in the study by a composite interaction score (see section 2.5). To examine this relationship, we used a two-step approach to regression (Baron & Kenny, 1986). The first step involved a simple regression analysis, testing whether quasi-experimental condition predicted achievement.

Results showed that Experimental pupils increased their achievement significantly more than Control pupils (b_1=3.40, p<0.05); scoring, on average, 3.40 points more in their post-test achievement scores than Control pupils. The second step explored whether the achievement gain was explained by the composite interaction score. A conventional (or single-level) regression analysis was used. Analysis used HLM, with the between-level (composite) mediator placed in the second level for analysis of significance (Raudenbush & Bryk, 2002; Snijders & Bosker, 2012: drawing upon MPlus 7 to conduct this analysis, Muthén & Muthén, 2012). Results identified that the composite interaction (question, explain, suggest, time-on-task) score mediated the achievement result significantly, γ_{11} =0.54, p <0.01, showing that as achievement increased (in the Experimental classes) children were more likely to communicate collaboratively and stay on-task.

4: Discussion

The current research is one of the few studies that quasi-experimentally assessed whether pupils' mathematics achievement can be enhanced by an effective group work programme in a CHC where there are already high levels of mathematical understanding. While this is a relatively small-scale study, its implications for the teaching of mathematics (and other subjects) provide insight and an alternative approach to the further enhancement of pupil learning via communicative engagement in classroom group work. The study provides an approach that integrates with HK curriculum recommendations for a change in classroom pedagogy (CDCHK, 2000). Matching of Experimental and Control teachers/classes with random assignment to intervention group provided a nearly equal starting point for the study. Analyses provided statistically significant answers to the three research questions. The first two questions asked whether the Experimental teachers, based in CHC classrooms, could adapt, co-develop and apply the relational approach to group work in their P4 mathematics classes. In working with researchers, the Experimental teachers drew upon the relational guidelines for group work and jointly adapted the sequence of activities and problems for their classes. Based on the implementation scales, Experimental teachers showed how their adaptations promoted higher levels of group work structuring and support in their classes than Control teachers. From the initial scales both Experimental and Control teachers had physically set-up their classrooms to allow for implementation of group work. As evidenced by the final scales, Experimental teachers were more likely to encourage sharing among pupils – with their pupils demonstrating collaborative and supportive interactions among themselves.

Reflectively, effects of the intervention may also be seen in the systematically observed classroom actions. Initial observations found Experimental pupils' within-class focal audience was equally weighted between group-mates and teacher/class. Final observations found that Experimental weighting changed to a focal ratio of 70:30 (group:teacher). Control pupils' initial focal audience was limited with regard to group-mates (24%) while their main audience was teacher (76%). Final observations showed a slight increase for group-mates – still maintaining a strong teacher-oriented focal ratio of 40:60 (group:teacher). And, while Experimental pupils were seated with and focused on group-mates, their teachers' pedagogic efficacy increased significantly while Control teachers remained nearly the same. Data from pedagogic efficacy, implementation scales and systematic classroom observations consistently found Experimental teachers and their classes were able to adapt and adopt group working methods based on the relational approach. Control teachers and their classes remained essentially teacher-focused although they are exposed to substantial amounts of group work.

To explain the effect of adapting the classroom to encourage more group working, we draw upon Kennedy (2010)'s assertion that given appropriate support CHC teachers are able to change and allow their pupils' to become more active and open learners (Cheng, 2000). The adaptability of these HK CHC classrooms contrasts with Nguyen et al. (2009)'s findings in Vietnam. In explanation, we note that the relational approach undertaken in the study was a culturally adapted for their classrooms by the Experimental teachers (from Whitty et al., 1998) rather than asserting a traditional, western structured cooperative learning approach.

The third research question showed that pupils' mathematical achievement was significantly enhanced by participation in this programme. This achievement outcome is in line with previous, SPRinG-based results (Kutnick & Blatchford, 2014) although this study uniquely focused on the mathematics curriculum area. Also, the relational approach was not introduced by the general class teacher but by specialist mathematics teachers who only saw the Experimental pupils for a limited amount of time per week (averaging one mathematics lessons per school-day). The effect size in differences between Experimental and Control classes was slightly smaller than previous SPRinG studies and this may be explained by a shorter implementation period of 5-to-6 months rather than a full school year. Within this shorter implementation period students were still able to show mathematics gains of approximately 2 months over Control children that are likely to affect threshold-based perceptions of pupils' understanding and competence (Cooper & Dunne, 2000).

One of the key distinctions between this study and other randomized, control studies regarding mathematical achievement via effective group work is our focus on children's relationships versus teaching children to work in a cooperative manner or teaching basic communicative/collaborative skills. Within the relational approach, there is a strong inclusive focus on developing a sense of trust and security among children. This finding contrasts with studies that assume pupils have collaborative communication skills and a desire to undertake learning tasks with one another as found in collaborative (Anderson et al., 1997; Yackel et al., 1991) and cooperative (Johnson & Johnson, 2003; Slavin, 2013) studies. From the relational basis children's more general skills of communication (questioning, explaining, etc.) were developed and used with greater frequency and effect over the implementation period. Thus, while Experimental children showed greater increases (than Control children) in their interpersonal attention, support and communication, there are a number of related actions and interactions that ought to be considered simultaneously. It should be noted initially that the increased communication and support skills took place between equally naïve peers. According to Damon and Phelps (1989) this peer-based communication is indicative of 'mutual' development of understanding and contrasts with expert/novice explanations for development of understanding such as 'scaffolding' used in various alternative studies (for example, Topping et al., 2004). Mutual development necessarily places children in positions where the onus is on all children in a class to participate in the development of their understanding (Damon & Phelps, 1989; Kutnick & Berdondini, 2009); they are not necessarily assigned individual subtasks within a group (goal-based) task (as recommended by Slavin et al., 2013) and they cannot rely on others who are perceived to be more knowledgeable or powerful. The increase in children's mutual interaction is also associated with higher levels of time spent 'on-task' – allowing pupils to maintain focus on their mathematics learning rather than being distracted by non-group and off-task talk (characterized in naturalistic classroom studies of pupil groups generally [Mercer & Littleton, 2007] and mathematics learning [Emmer & Gerwels, 2002]).

Teachers, too, had a fundamental role in promoting their children's enhanced mathematical achievement. Experimental teachers' role changed between December and June in a manner that was less directive and more interactive. Observations found Experimental teachers offering more opportunities and encouragement/support to engage in group working over time. Experimental teachers demanded less pupil attention (allowing more contact with group-mates) and were increasingly likely to interact and support within-group discussions (as suggested by Gillies & Kahn, 2009; Webb, 2009). Experimental teachers also gained in mathematical pedagogic efficacy.

5: Conclusion and Limitations

Of the limited number of international studies that used randomized and controlled methods to ascertain the effects of a particular group work programme to enhance primary school pupils' mathematical achievement, this study moved away from traditional cooperative and collaborative learning approaches to implement a relational approach for effective group working. In contrast to recent randomized, controlled studies in primary school mathematics (Slavin et al., 2013; Tracey et al., 2013), this study found significant achievement effects as well as associated developments in pupils' on-task focus, communicative (collaborative) interactions and teachers' pedagogic efficacy. Differences between this study and previous studies may be attributed to three elements: context, approach and size. This study was undertaken in HK where contextual and international comparisons have consistently found high levels of mathematical understanding among primary and secondary pupils (Mullis et al., 2012; OECD, 2010). Much of this early achievement may be attributed to a traditional mathematics teaching in CHC classrooms. While the high level of mathematics understanding of pupils in HK contrasts with the English context used in Slavin and colleagues' studies, Experimental teachers in this study had to overcome a traditional, non-group work oriented (CHC) approach in their classrooms. Changes in teachers' and pupils' relationships will have to be based upon a culturally appropriate pedagogy (Whitty et al., 1998) which allowed teachers to work within and adapt relational elements to foster increased pupil and teacher engagement recommended in the HK mathematics curriculum (CDCHK, 2000). And, distinct from previous cooperation and collaboration studies, this study reinforced the use of a relational approach that problematizes initial relationships among within-class pupil peers and provides supportive training to undertake classroom learning in an inclusive manner (see Baines et al., 2009).

As authors we note that the sample size of our study was relatively small compared to other international studies - although the sample was large enough for HLM analysis. A larger and more representative sample would have allowed our conclusions to be more generalizable. Further studies may consider how, causally, pupils' developing relational skills facilitate their use of elaborated communication (explanations, justifications, etc.) and how these skills are brought to fruition in mathematical discussions underlying specific aspects of their achievement. These further studies would necessarily draw upon qualitative methods that will complement the larger-scale quasi-experimental samples.

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