# High-Stakes Examination Tasks as Impetus for Primary Mathematics Teachers' Reform in their Instructional Practice

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The study reported in this paper is on the professional development (PD) of primary school mathematics teachers. Teachers from two primary schools participated in the PD for two years. High-stakes mathematics examination tasks were used to kick start awareness and thinking about teaching for big ideas. Teachers did the tasks and discussed their solutions focusing on how their instruction could facilitate the acquisition of mathematical ideas as a body of connected knowledge. Data presented in this paper show that the tasks teachers worked with at the start of the PD did impact their understanding and instructional practice specific to big ideas in mathematics. Some challenges the teachers faced during the PD are also noted.

Charles (2005) defined a "Big Idea as a statement of an idea that is central to the learning of mathematics, one that links numerous mathematical understandings into a coherent whole" (p.10). The revised school mathematics syllabuses for primary schools in Singapore (Ministry of Education, 2019) reinforces that Big Ideas are central to mathematics as they connect ideas coherently from different strands and levels thereby facilitating a deeper and more robust understanding of individual topics in mathematics. The revised syllabuses list 6 big ideas (Notations, Diagrams, Proportionality, Models, Equivalence, and Measures) for primary schools.

There is a concerted push towards teaching for Big Ideas in Mathematics in Singapore schools. A research study, Big Ideas in School Mathematics (BISM) is presently underway in Singapore and a part of it is on professional development (PD) of primary school mathematics teachers related to the enactment of Big Ideas in their mathematics instruction. Research has documented that teachers' lack of relevant content knowledge of Big Ideas in mathematics translates into their lack of explicit attention to Big Ideas underpinning mathematics taught in schools and results in developing isolated compartments of mathematical knowledge in their students (Askew, 2013).

The study reported in this paper draws on part of the data from the BISM project. It involves the PD of primary mathematics teachers and attempts to answer the following research question:

- What are teachers' perceptions about high-stakes examination tasks (Primary School Leaving Examination (PSLE) mathematics tasks) as impetus for reform in their instructional practice?

In the context of this paper, the reform is specific to teaching for big ideas in their mathematics lessons.

## Review of Related Literature

The professional development of the mathematics teachers in the BISM project adopted the hybrid model (Kaur, 2011). This model integrates the "training model of PD" (Matos et al., 2009) with sustained support for teachers to integrate knowledge gained from the PD into their classroom practice. It is a form of CPD that exemplifies a shift of the centre of gravity for CPD from the "supply-side,", "offline" forms of knowledge transmission by professional development providers,

(2023). In B. Reid-O'Connor, E. Prieto-Rodriguez, K. Holmes, & A. Hughes (Eds.), *Weaving mathematics education research from all perspectives*. *Proceedings of the 45th annual conference of the Mathematics Education Research Group of Australasia* (pp. 315–322). Newcastle: MERGA.

such as University academics, to "demand-side," "online" in-situ forms of knowledge creation by teachers. The five critical features of the PD were:

- Content focus—it focused on what to teach and how to teach (Desimone, 2009; Stiff, 2002). The PD was not generic but specific to the pedagogy of mathematics related to primary school mathematics and teaching for big ideas.
- Coherence—it supported the instructional activities of teachers at school (Desimone, 2009; Stiff, 2002). They 2020 revised school mathematics syllabuses for primary schools places a heightened emphasis on teaching for big ideas and therefore the PD supported teachers in the adoption of the initiative 'Big ideas in mathematics" (Ministry of Education, 2019).
- Duration—the PD was sustained (Borasi & Fonzi, 2002; Desimone, 2009; Elmore, 2002; Stiff, 2002). It was 2 years long comprising two cycles of teachers' work with each cycle focussed on a big idea (Equivalence in the first year and Proportionality in the second year).
- Active learning—the PD was embedded in teacher's work (Abdal-Haqq, 1995; Desimone, 2009; Wilson & Berne, 1999). Teachers learn best when observing, planning, enacting their plans and reviewing their work (Stiff, 2002). During the PD teachers work included 'hands-on' work—working through mathematical tasks, planning and enacting lessons, reviewing their lessons and mapping follow-up plans.
- Collective participation—the PD had collective participation. Collective participation by teachers allow for powerful form of teacher learning through prolonged interaction and discourse (Desimone, 2009; Stiff, 2002; Wilson & Berne, 1999). In addition, PD programmes that foster collaboration have been found to be effective (Borasi & Fonzi, 2002; Elmore, 2002; Hawley & Valli, 1999). In the PD teachers participated collectively as part of groups at two levels. The first involved all the mathematics teachers in a school and the second involved teachers teaching specific year levels in the school. Teachers also worked collaboratively during the 'hands-on' work.

## The Study

### *Participants*

Mathematics teachers from two primary schools, P1 and P2, participated in the BISM project. The profiles of both the schools were similar in that they were government funded schools and teachers were employees of the Ministry of Education in Singapore. In school P1 and school P2, there were 23 and 33 teachers respectively who participated in the project at the school level. At year 5 and 6 levels, in both schools, P1 and P2, 7 teachers participated.

### *Implementation of the Professional Development*

The PD was spread over two consecutive school years. In Singapore, a school year begins in January and ends in November. Each year the PD began with two knowledge-building workshops. Each workshop lasted 2 hours. These were attended by all the mathematics teachers in the school. During the first workshop, the mathematics educator presented the six big ideas in the primary school mathematics curriculum and facilitated whole group discussion about what these ideas are and their role in the learning of mathematics. During the second half of the first workshop and the second workshop teachers attempted some mathematics tasks (mainly taken from the Primary School Leaving Examination mathematics past papers). Following teachers work on every task, a member of the research team (who is a mathematics educator at the National Institute of Education) facilitated whole group discussion (review segment) the high point of which was "how the big idea of equivalence (in the first year) and big idea of proportionality (in the second year) facilitated the solution process". Figures 1 and 2 show examples of the tasks and their respective solutions arrived at collaboratively by the teachers during the review segments of the workshops. The task in Figure

1, illuminates equivalence as a big idea, while task in Figure 2, illuminates proportionality as a big idea.

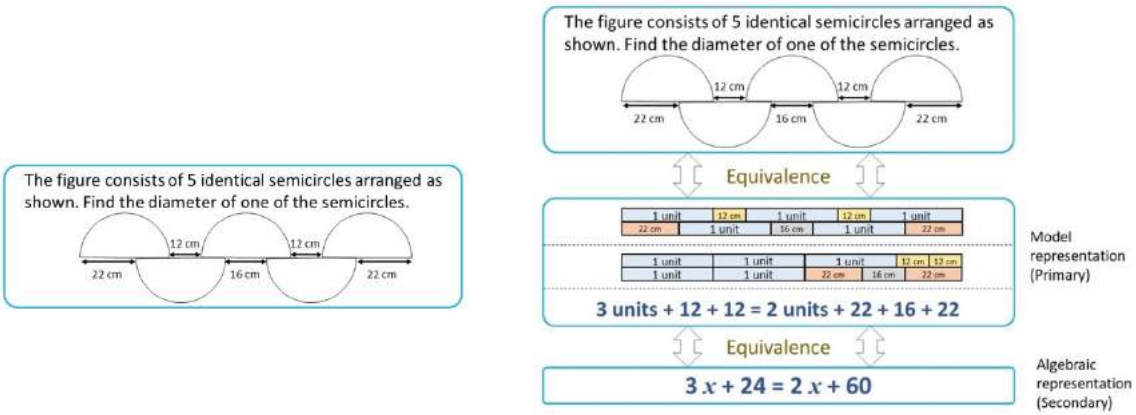
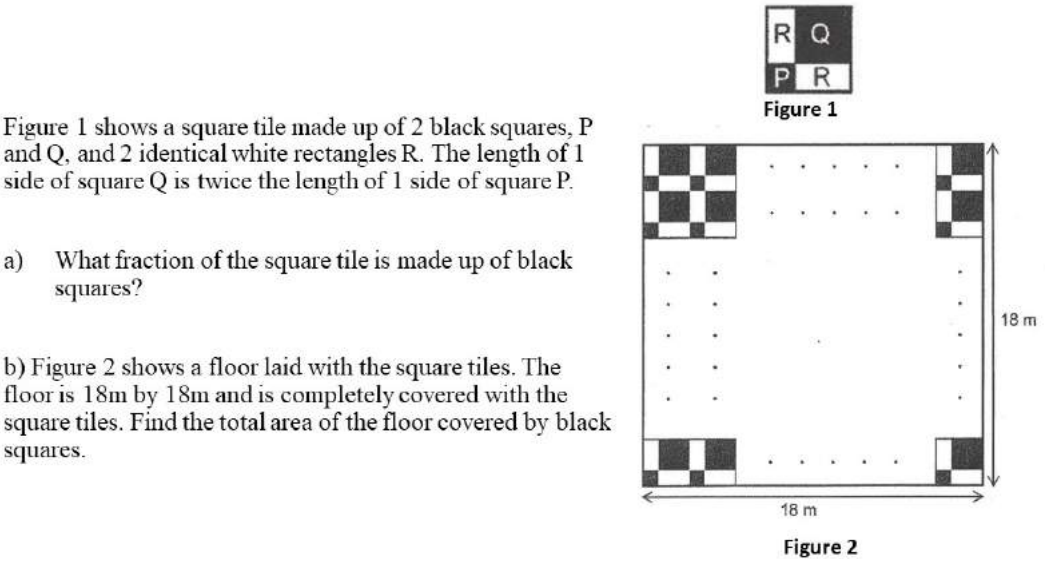



Figure 1. PSLE mathematics (2019-2021) question (SEAB, 2022).




Solutions

a) In figure 1, there are 9 tiles altogether. 5 of them are shaded black. So the fraction of the sqaure tile that has black squares is $\frac{5}{9}$.

b) The total area of the floor is 18 x 18 $m^2$. The total area of the floor covered by black squares
$\frac{5}{9}$ x 18 x 18 $m^2$.

Figure 2. PSLE mathematics (2008-2013) question (SEAB, 2014).

During the next two meetings, we worked with teachers from the year 5 and year 6 levels. Each meeting lasted 2 hours. They deliberated on the mathematics they would be working on during the coming weeks in their lessons and how they may teach for the big idea (equivalence in the first year and proportionality in the second). In their groups they choose a sub-topic and planned a 40–50 minutes lesson. Members of the research team (a mathematics educator and another expert primary school mathematics teacher) were present during both the meetings and provided inputs where necessary. Following the two meetings, one of the teachers in the group enacted the lesson that was collaboratively planned. The BISM research team recorded the lesson.

During the fifth session the video record of the lesson enacted was reviewed. The review was guided by the following prompts.

- What were the lesson objectives? Were they as planned?
- Were the mathematical tasks sequenced and enacted as planned?
- How did the teacher support students in articulating their observations and ideas about the intended mathematical connections, aka big idea?
- Were they any actions other than the pre-planned ones the teacher undertook so as to accomplish his/her lesson goals?

The sixth session was devoted to focus group discussions (FGDs) involving teachers from year 5 and year 6 levels. The data reported in this paper is from the FGDs in the second year of the PD.

### *Data and Analysis*

The data presented in this paper is from the focus group discussions with the year 5 and year 6 levels teachers at the end of the second year of the PD. The following prompt steered the discussion.

- During the first two PD workshops last year and again this year, all of you worked on high stakes examination tasks (mainly taken from the PSLE (Primary School Leaving Examination) mathematics past papers). Please share with us your thoughts about any benefits that have arisen related to knowledge of big ideas and changes in your classroom instruction. You may also share with us any challenges that you encountered.

The discussions were transcribed. The transcripts were read several times and scanned for possible themes (Braun & Clarke, 2006). Four main themes emerged. Next, excerpts that were representative of the teachers' perceptions were collated for each theme and content analysis (Weber, 1990) of the excerpts carried out. In the next section, we present our findings.

## Findings

The following themes emerged from the thematic analysis of the discussion data. For each theme content analysis of the data is presented.

### *Big Ideas Pervade the Curriculum from Primary 1 to Primary 6*

Content analysis of the transcripts show that working on the high-stakes examination tasks allowed teachers to appreciate that big ideas pervade the mathematics curriculum from years 1 to 6. Teachers teaching the upper year levels felt that their peers in the lower year levels (1 to 4) too had a part to play in preparing students for the PSLE mathematics.

P1T4: .. You were asking what is the benefit of using assessment questions to start of the learning. I thought, in a way, we are also telling the teachers this is what the students will have to achieve at the end of P6. It was a good way to tell our lower primary teachers that you need to help the students to see connections from young and not leave everything to P5 and P6. We can start doing all this from young. … all these big ideas come from P1 and 2. We can start connecting them from young. If you ask me, that (using assessment task as stimulus) was a good way as it helped the lower primary teachers to see that this is what the children will have to do and we don't have to leave all the teaching to the 5 and 6. Some of it can come from the P1 and P2. So I thought that was quite good to shape that we can start incorporating all these big ideas even in their lower primary topics.

P2T2: I come to the realization that this Big ideas have always been in our syllabus. It is just that now we are made into awareness that this leads to the big ideas of equivalence, proportionality and so on. Some of the questions you got us to work on are past many years' PSLE questions. It's just that we were teaching it unknowingly. Now that we have greater awareness, we will link it to that concept. Then it makes us be able to see the connection between all the different kinds of questions to link it up to this common theme. Of course, the questions that came up as we discussed are good. So, we know where we are getting up in terms of exposing the students to big ideas as such. Some questions lend themselves to more than one big idea.

Figure 3. Excerpts from the FGDs about awareness of big ideas in the primary school mathematics curriculum

They also realized that 'big ideas' were not new as they had unknowingly been working with them. However, now with the realization they will be more deliberate in facilitating their students thinking when working through mathematical problems like the high-stakes assessment tasks used during the workshops. Figure 3 shows excerpts from the transcripts of the discussions.

### *Challenging Tasks + Active and Collaborative Learning*

Content analysis of the transcripts show that all the teachers found the tasks challenging and appreciated the struggle the tasks offered. This allowed them to experience the struggle their students also go through when doing such tasks. The content analysis also show that engaging in active and collaborative learning when doing the tasks, discussing the different approaches taken and reflecting on the mathematical ideas inherent in the tasks have led them to overcome their personal apprehensions. Figure 4 shows excerpts from the transcripts of the discussions.

P1T1: Last year when I was doing the questions I was struggling, but after the discussions I saw the connections and could understand the solutions. This year I was more confident when I was doing the tasks. Now I am able to see the bigger picture and appreciate big ideas like equivalence that can make me think of how two figures may be related. Not just think about which formula to use and just calculate to get some answer.

P2T4: I quite enjoyed the assessment tasks …challenging challenges you … yeah and it also gave me an opportunity to see things from my students perspective because sometimes I think as teachers we forget to do that or at least I forget to do that sometimes and I think these kinds of questions our students really struggle. Going through the assessment tasks as a group and talking gave me a better idea of different kinds of activities or questions that I can design to make my students think and make connections … not just this method or which formula to use

Figure 4. Excerpts from the FGDs about challenging tasks + active and collaborative learning.

### *What Appears to Have Changed in Classroom Instruction*

From the content analysis of the transcripts, it appears that teachers have attempted to make some changes to their pedagogy. In the past some of them when working with weak students tended to spoon feed them with methods and answers. But now they appear to allow their students to struggle when confronted with challenging tasks but support them by facilitating their discussions amongst peers and with them. By doing so, they have found that their students are able to self-correct their misconceptions and move along the solution path. They are placing greater emphasis on 'understanding the task' and examining possible relationships before 'carrying out' any calculations. They also appear to be mindful of their talk and deliberate about what they would like the students to focus on. Figure 5 shows excerpts from the transcripts of the discussions.

P1T5: Very weak ones… in fact I kind of use a few examples to let them try out. It's really a struggle for them… and I realized what makes the change is … I am more cautious about the way I get the students to discuss. I think we always allow students … maybe because of the weakest ones, we tend to be very quick … we want to give them the solutions, we want them to answer quickly and get it over and done with… but for this lot, I find that what is interesting is when you allow … you throw it to them first and let them discuss first and then the idea actually bounced off … and from there, that is when I am able to find out what needs to be rectified … that means change to help them to … correct their misconception first, then move on to … like so call the big idea proportion and all these. But I think more importantly is what I noticed the students are able to do is … they don't see what they are learning in isolation, they are starting to relate it, like ratio, fractions and decimals… they are trying to relate it in their own ways …

P1T1: So, in my lessons these days, I find myself … telling my students to also try and see the bigger picture … I always tell them, don't just keep zooming into all the nitty gritty details straight away. Take a step back and look at the entire thing first. Think about how … you can maybe chop up the shape into different parts, and I use this word a lot in my class now … relationship. So, I don't explicitly use the word proportion that much, but I do try to encourage them to see relationship between the different parts of the questions that they are trying to solve. So, in a way after … now that I have been exposed to this idea of proportionality, I do myself changing my classroom language or teaching language a little bit here and there. So, I am more conscious of what I am telling the students to look for in their work

Figure 5. Excerpts from the FGDs about some changes in instructional practice.

### *Planning to Teach for Big Ideas—Time a Concern*

From the content analysis of the transcripts, it appears that teachers found time taken to prepare lessons to teach for big ideas a concern. They valued the learning afforded when planning together for a lesson and appreciated the impact of the lesson as noted by teacher P2T5 that '*we can see the children go through so much thinking*'. Teachers in school P2 also through the planning of the lesson to teach pie-charts realised that proportional relationships are the basis for constructing and interpreting pie charts. This certainly has contributed towards their understanding of how the big idea of proportionality pervades topics in their curriculum. As teachers were grappling for the first time in trying to plan such lessons, it is expected that the time they need to plan would be much greater than the instructional time. But this aspect of time in the planning phase and the enactment phase was a concern to the teachers and as noted by P2T6, "*in reality if we can do this for 1 or two topics per year, I find this already a very big achievement*". Figure 6 shows excerpts from the transcripts of the discussions.

P2T5: Reflecting on the whole process, we did a very simple topic on pie charts. Most teachers will not even spend more than two weeks teaching it. Because of going through this process, made us really go down to the core of the concepts and we wanted so badly to fit in proportionality inside and that it made us really think through of where is the proportionality in it and I think that process benefited the teachers and also the children. After we have carried out our lesson we can see the children go through so much thinking. That is really good.

P2T6: We spend almost 6 to 7 hours together as a team. So many people, you know, to come up with a 1-hour lesson. The difficulty was on the questioning, how do we ask the questions. I agree that we are spending time (planning time), that is secondary. The primary aspect would be, in the class, if the topic is only given only 1 week and we want to use 2 weeks to teach, we must be very practical. … imagine if we want to extend for every topic. Realistically we have no time. In reality, if we can do this for one or two topics per year, I find this already a very big achievement.

P1T3: Seriously speaking, even though we had to spend hours, we discuss, we had headaches, it was fun. Because it was very good that we are discussing, we were trying ideas, we were questioning ourselves, it was very enriching. … So if you asked me, yes the number of hours, but I learnt a lot and I liked it.

Figure 6. Excerpts from the FGDs about time a concern when planning to teach for big ideas.

## Discussion and Conclusion

The research question that guided the study reported in this paper is "What are teachers' perceptions about high-stakes examination tasks (Primary School Leaving Examination (PSLE) mathematics tasks) as impetus for reform in their instructional practice?". The research team were deliberate in using past PSLE Mathematics tasks to kick start teachers work in the PD focussed on teaching for big ideas. Instead of providing teachers with lesson plans that are "offline" forms of knowledge transmission to teach for big ideas, the research team attempted to engage teachers with "online" in-situ forms of knowledge creation through high-stakes examination tasks to teach for big ideas.

As the nature of the high-stakes examination tasks were non-routine mathematical problems, there was little concern that teachers were being prepared to teach to the test (Phelps, 2011). From the data presented in this paper it is apparent that the high-stakes examination tasks that teachers worked with during the first two knowledge-building workshops every year of the PD programme have contributed to the PD of the teachers in some ways. The syllabus document of the primary school mathematics curriculum (Ministry of Education, 2019) outlines the six Big ideas and elaborates each of them. The elaboration of equivalence is as follows:

> Equivalence is a relationship that expresses the 'equality' of two mathematical objects that may be represented in two different forms. The conversion from one form to another equivalent form is the basis of many manipulations for analysing, comparing, and finding solutions. In every statement of equivalence, there

> is a mathematical object (e.g. a number, an expression or an equation) and an equivalence criterion (e.g. value(s), or part-whole relationships) (Ministry of Education, 2019, p.15).

The elaborations of equivalence and proportionality were shared with the teachers at the beginning of the first knowledge-building workshops in the first and second years respectively. The high-stakes examination tasks engaged teachers in making sense of such elaborations and teachers realised that big ideas pervaded the school mathematics curriculum from years 1 to 6. As teachers from all year levels were working on the same tasks, it was beneficial for all of them to 'see' how big ideas manifest in the non-routine mathematical problems students will do in their PSLE Mathematics in due course. Working on the tasks the teachers also appreciated the challenge they confronted, and their students too confront or will confront when they are given such tasks to do.

The nature of the active work and discourse during the workshops, 'do the tasks—giving your best', 'discuss the solutions and seek inputs from all—engage with active whole class discussion', appear to have also provided the teachers with ideas of how to shift their classroom instruction when teaching for big ideas. It is noteworthy that teachers working with weaker students too attempted to hold back their inputs and facilitated student talk, directing them towards their resolutions of tasks at hand.

Teachers lamented about the investment of time warranted for designing lessons that facilitate students understanding of mathematical ideas as a connected web. This is understandable when a new push is added to any curriculum. Planning a few of such lessons yearly eventually will accumulate alongside deepening of teacher's knowledge for mathematics teaching. So, perhaps the concern to educators would be for teachers to undergo a mindset change and deepen their understanding of mathematics as a body of connected knowledge.

The limited data and findings presented in this paper do suggest that the high-stakes examination tasks the teachers worked with during the PD were an impetus for possible reform in their mathematics instructional practice. More research using such tasks for the PD of teachers is warranted to confirm the claim we are making in the conclusion of this paper.

## Acknowledgements

The study reported here has been funded by the Singapore Ministry of Education under the research project OER/31/19BK which is managed by the National Institute of Education, Singapore.

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