Adapting curriculum materials in secondary school mathematics: A case study of a Singapore teacher's lesson design

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When mathematics teachers plan lessons, they interact with curriculum materials in various ways. In this paper, we draw on Brown's (2009) *Design Capacity for Enactment* framework to explore the practice of *adapting* curriculum materials in the case of a Singapore secondary mathematics teacher. Problems from the textbook used and the worksheets she crafted were compared to determine how she adapted the content. Video-recordings of the lessons and post-lesson interviews were used to clarify how her personal *teacher resources* contributed to her design decisions. The findings suggest that her seemingly casual use of problems from the textbook are in fact unique variations of adapting curriculum materials.

Singapore's success in large international studies (e.g., TIMSS, PISA, etc.) has left many nations curious to learn about its pedagogical practices. However, a common assumption is that Singapore teachers predominantly employ a "drill and practice" approach and are reluctant to deviate from curriculum materials (e.g., printed textbooks, workbooks) to meet the specific needs of their students (Toh et al., 2019). Despite this, Leong et al. (2018) demonstrated that such was not the case for Singapore secondary mathematics teacher, Teck Kim, who created worksheets by modifying content from a textbook for "making things explicit" (p. 47). His modifications included: (i) filling in gaps in the content he felt were fundamental; (ii) linking different representations to deepen students' understanding; and (iii) highlighting ideas he deemed critical. In light of this, we argue that a key feature to Singapore teachers' practices, which may generally go unnoticed, is their transformative use of curriculum materials in planning instruction tailored for their students. In this paper, we explore another case of a Singapore secondary mathematics teacher, Mrs Fung (pseudonym), who demonstrated another way to adapt curriculum materials that was different from Teck Kim when she crafted trigonometry worksheets using a textbook for her lessons. To do so, we utilise Brown's (2009) *Design Capacity for Enactment* (DCE) framework to explore the adapting process and to answer the question: *How does Mrs Fung, an experienced and competent mathematics teacher in Singapore, adapt curriculum materials to design worksheets?*

Theoretical Underpinnings

Teachers' use of curriculum materials has been conceptualised in many ways. For instance, Shulman (1987) broadly described teachers' interactions with textbooks as *pedagogical reasoning and actions*, which involves comprehension, transformation, and instruction, informed by their knowledge and understanding of the text. For Sherin and Drake (2009), these interactions were referred to as *reading*, *evaluating*, and *adapting*, which drew on teachers' curriculum strategies. For Amador et al. (2017), these interactions

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involved a set of skills, known as *curriculum noticing*, in which teachers attend to the materials, interpret what they attended to, and decide how to respond (e.g., to include or omit a problem). Likewise, Brown and Edelson (2003) described this as a teachers' *pedagogical design capacity* (PDC), their ability to "perceive and mobilize resources in order to craft instructional contexts" (p. 13). First, teachers perceive and interpret curriculum resources, then they evaluate their potential to achieve instructional goals, and finally these evaluations inform their decisions for teaching. To demonstrate the factors involved when teachers interact with curriculum materials, Brown (2009) proposed the *Design Capacity for Enactment* (DCE) framework. The framework is composed of two types of resources: curriculum resources and teacher resources. *Curriculum resources* are physical objects and their representations (e.g., manipulatives), the representation of tasks (e.g., instructions for teachers, structure of lesson), and representations of concepts (e.g., models, descriptions of concepts). *Teacher resources* include the teacher's goals and beliefs, their subject matter knowledge, and their pedagogical content knowledge.

Brown (2009) characterised teachers' interactions by considering the varying degrees of responsibility shared between the curriculum and teacher resources. On one end of the scale, teachers can *offload* their responsibility as designers of the lesson and instead choose to rely primarily on the curriculum resources (e.g., teaching in direct alignment with the textbook). On the other end of the scale, teachers can *improvise* by predominantly relying on their own resources. According to Brown, improvisations are typically spontaneous and occur due to unexpected events, such as realising students held fundamental misconceptions about a related concept. As a result, a conscientious teacher may deviate from the textbook to address these misconceptions by generating their own content. Lastly, an intermediate of the two processes is when teachers *adapt* the curriculum materials. By sharing the responsibility to design between the curriculum and teacher resources, teachers can use content in a textbook as inspiration for instruction. For example, instead of directly using an example given in the textbook, the teacher could generate a similar example by changing the context and figures, thereby applying their own subject matter and pedagogical content knowledge to ensure the lesson goals are still achieved.

The DCE framework has also been used by Amador (2016) to describe teachers' approaches to lesson planning in relation to their consideration for students' thinking. Three *planning themes* emerged from the study: (i) *adapting* in response to students' understanding (e.g., editing exercises to highlight features that students had neglected in the previous lesson); (ii) *producing* competence in students' procedural fluency (e.g., frequently including in-class quizzes to demonstrate ability to solve); and (iii) *regulating* content to ensure students keep up with the curricular pace, regardless of students' progress (e.g., strictly following the school syllabus, maintaining the same lesson structure).

In the context of Singapore, the teaching practices and supposed curriculum are often perceived by those outside of Singapore as overwhelmingly aimed at producing and regulating. Thus, students would rarely have opportunities to engage in "genuine" problem solving experiences that would be more conducive to their knowledge growth, such as experiencing productive struggle (Schoenfeld, 2017; Henningsen & Stein, 1997). Instead of adapting or improvising materials to accommodate students' needs (e.g., to stretch their thinking), Singapore teachers are believed to be offloading responsibility to the curriculum resources which aligns with more traditional teacher-centred practices (Toh et al., 2019). In the context of the aforementioned teacher, Teck Kim, Leong et al. (2018) reported that he purposely adapted content from the textbook by changing the representations and improvised his own self-created tasks. This brought us to wonder, how does Mrs Fung, an experienced

and competent teacher similar to Teck Kim, negotiate curriculum resources and her teacher resources to inform her decisions in adapting curriculum materials? To what extent are her goals achieved through her decisions?

Methods

The data presented was taken from a larger project, which explored the distinctive instructional practices enacted by Singapore mathematics teachers. Mrs Fung had taught secondary mathematics for over 10 years and had been recognised by the local professional community as being an effective mathematics teacher. The class that Mrs Fung taught was a Year 9 class, which comprised students who scored between the 25^{th} to 60^{th} percentiles in the nationwide Primary School Leaving Examinations (PSLE) at Year 6. Mrs Fung was selected as the subject of the study after the first author, a non-native to Singapore, observed her unique implementation of personally authored worksheets to teach introductory trigonometry in place of the textbook, Discovering Mathematics 3B Normal Academic (Chow et al., 2015a). The trigonometry unit consisted of seven lessons between 30-60 min in duration. In this paper, we discuss Lesson 6 of the trigonometry unit.

Three sources of data are presented in this paper. The first are the physical materials that Mrs Fung used and created. This includes one worksheet (Worksheet 6.4) crafted by Mrs Fung, and the curriculum materials she drew on for the design of her worksheet – Section 6.4 from the textbook (Chow et al., 2015a) and the teachers' guide (Chow et al., 2015b). The second source of data is a video-recording of the post-lesson interview conducted with Mrs Fung after Lesson 6, which discussed her goals and the events of the lesson. Some prompts that were used in the interview were:

- What were your goals for the lesson?
- Do you think you have achieved your goals that you have set out to achieve? How were the goals achieved?
- What is the most ambitious or challenging thing you did in the lesson?

The third source of data is a video-recording of Lesson 6 when Mrs Fung implemented Worksheet 6.4, where a researcher took a non-participant observer approach.

Data analysis was conducted over three phases. In the first phase, the problems from Section 6.4 (Chow et al., 2015a) were categorised according to the mathematical processes required to solve them (e.g., insert an auxiliary line, two-step calculations). The model examples from the teachers' guide (Chow et al., 2015b) were also consulted to confirm these were the expected solving methods.

In the second phase, the categories found from Section 6.4 were applied to the questions in Worksheet 6.4 to determine if Mrs Fung had offloaded, adapted, or improvised from the textbook. This included two levels of comparison: item-to-item and set-to-set. On the item-to-item level, the categories were used to determine if Mrs Fung had offloaded, adapted or improvised the content in her worksheet. On the set-to-set level, the structure of the worksheet and its contents as a set were compared with the entire of Section 6.4 to determine similarities and differences in sequencing. The usefulness of this dual-level of analysis will be made clearer in the next section of this paper.

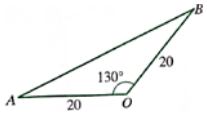
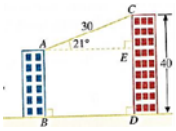
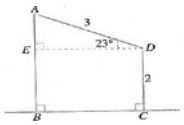
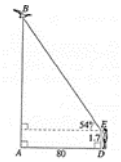
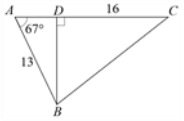
In the final stage of the analysis, the post-lesson interview and video-recording of Mrs Fung's enactment of the lesson were used to triangulate the decisions she made to offload, adapt, or improvise. We focus on her discussions about her lesson goals and beliefs which impacted her design decisions.

Findings and Discussion

Before implementing Worksheet 6.4, Mrs Fung played an introductory video for the students in the lesson to demonstrate how trigonometry could be used to solve contextual problems. Subsequently, she began implementing Worksheet 6.4 and asked the students to complete the first question by themselves. If time permitted, students would consult with their peers seated nearby, typically to check if their solutions were comparable. Mrs Fung neither encouraged nor discouraged students to share ideas with their peers but always requested that they initially attempt the problems by themselves. After the solution for the question was discussed by Mrs Fung, the class moved onto the next problem in a similar process.

Prior to Worksheet 6.4 within the Trigonometry unit, the students had encountered and solved problems using the Theorem of Pythagoras, learnt how to determine if a triangle was right-angled, and applied trigonometric ratios to triangles with acute angles to find unknown sides and angles. In the teachers' guide to the textbook (Chow et al., 2015b), the primary learning objective of Section 6.4 was to "apply the trigonometric ratios to solve some real-life problems" (p. 10). The analysis of Section 6.4 and comparison with the model solutions given in the teachers' guide resulted in three categorisations of problems: (A) *insert an auxiliary line to solve an angle/length;* (B) *two-step calculations to find an unknown length;* and (C) *two-step calculations to find an unknown angle* (see Table 1 for examples). Four worked examples (one of Type A and C, two of Type B) were first presented in Section 6.4, then a similar problem was subsequently provided for each of the corresponding worked examples for students to attempt. Afterwards, 19 exercise problems were given to be used by students for further practice.

Table 1
Summary of categories of problems from Section 6.4 in Chow et al. (2015a)

Type	Process	Order in TB	Order in WS	Examples	
A	Insert an auxiliary line to solve an angle/length	1	2	(A1) - See Figure 2 for full problem.	
B	Two-step calculation to find an unknown angle/length	2	3	(B1) - AB and CD are two buildings on level ground BD … Find the height of AB.	
		3	4	(B2) - The diagrams show the cross-section of a shed ABCD … The roof AD is 3m long … Find the height of the wall.	
		5	1	(B3) - B shows a bird flying above a point A on the horizontal ground, AD … Find the height of the bird above the ground.	
C	Two-step calculation to find an unknown angle	4	-	(C1) - In the diagram, ADC is a straight road. Town B is 13km away from A … Find the size of ∠BCD	

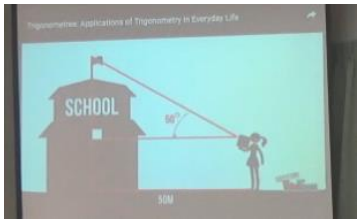
Note. The table does not include the complete list of problems from the textbook, only those relevant to the ones utilised by Mrs Fung. TB = Section 6.4 in textbook (Chow et al., 2015a), WS = Worksheet 6.4

In comparison, at the item-to-item level, Worksheet 6.4 consisted of four problems that were identical to four problems seen in Section 6.4. The representations of the problems were not altered by Mrs Fung in her worksheets, which would therefore suggest that she had *offloaded* her responsibility to design questions solely onto the curriculum resources and did not adapt or improvise in her Worksheet 6.4. In other words, Mrs Fung had copied the instructions and diagrams directly from Section 6.4 and did not include any modified or self-designed content.

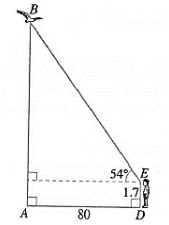
When comparing the two resources at a set-to-set level, it was evident that Mrs Fung had *adapted* from Section 6.4 to design Worksheet 6.4 by omitting and resequencing specific content. Firstly, Mrs Fung had only provided questions to students and did not provide any worked examples. Although the specific reasons for this omission were not explicitly discussed, Mrs Fung made several statements during the lesson and interview about how students had attempted similar problems before without the real-life context and that she wanted them to first attempt the problems individually. For the first question (B3), she provided students with "five minutes to try out on your own". Then she told the students, "instead of telling me, most of you are already quite good with your TOA CAH SOH. Try to read the content first, then they give you the diagram". As she roamed around the classroom, she prompted those students who appeared to have difficulty getting started to "just give [the problem] a go", to identify the appropriate sides and the relevant angles, and reiterated that she would like everyone to attempt the questions individually first before sharing or asking for help from neighbouring students. As she began to check their answers, she asked a student, "Shane, you saw [another student's] second part or you already know? You already know or after you seen his? You saw his, then you realized [what to do]?" She continued to prompt students individually who appeared to be stuck but never told them the solution. From these instances, it would suggest that one of Mrs Fung's goals was for students to learn to make sense of questions independently by drawing on their existing knowledge. By omitting the worked examples, students would be more likely to engage in the type of thinking that is typically expected in problem-solving activities (Henningsen & Stein, 1997) and experience some moments of struggle in solving these typical textbook problems.

Secondly, adaptations can be seen when comparing the sequence of problems. While Section 6.4 had presented questions A1-B1-B2-C1-B3 in this order along with worked examples preceding each question, Mrs Fung had chosen to present questions in the order of B3-A1-B1-B2 (Table 1). Aside from the absence of C1 in Worksheet 6.4, which was not addressed by Mrs Fung in the interview or the lesson, Mrs Fung had moved B3 to be the first question. As previously stated, Mrs Fung had begun the lesson with a short introductory video that provided scenarios for when trigonometry would be used in real life. In her post-lesson interview, she expressed that she wanted to show students the video to help them get a sense of "what is application of trigonometry about". As they had only ever encountered contextless problems, she was concerned that they would have language difficulties which would hinder their ability to understand and attempt the problems. In relation to her goal, Mrs Fung's awareness of her students' abilities and their previous understandings contributed to her decision of the first problem she chose. The example in the video and B3 involved similar representation of tasks and diagrams (Figure 1), and thus it would be productive to choose B3 as an introduction to solving applications in trigonometry if students were to initially try to solve the problem by themselves. Although B3 was *offloaded* from the textbook at the item-to-item level, when examining the differences at a set-to-set level, Mrs Fung's resequencing of questions demonstrated an *adaptation* of the textbook. This

adaptation was influenced by the representation for B3 and Mrs Fung's teacher resources, namely her pedagogical content knowledge and her goals to develop students' sense of how trigonometry is applied.



(a) Example from introductory video



(b) First question (B3) in Worksheet 6.4

Figure 1. Initial example and question given in Lesson 6

After most of the class successfully solved B3, Mrs Fung forewarned the students that the next problem, Al (Figure 2), would not be as "straightforward". In her post-lesson interview, she noted that her goal was for students to be able to solve problems involving two triangles but that she had anticipated that A1 would be the most challenging problem for her students - "majority of them don't know how to approach this question". As there were no worked examples of similar problems provided, nor had she included any problems that required adding an additional line to bisect the isosceles triangle in any of her other worksheets, it was unlikely that her students had encountered such a problem before and would know to draw the auxiliary line. Although she had intended to provide a hint for students, she wanted to "let them struggle a bit" first, suggesting that she held the belief that experiencing struggle was worthwhile and important for learning mathematics. In choosing to specifically include A1, Mrs Fung's decision was intended to provide an opportunity for students to grapple with the problem in search of a way to approach it, thereby deepening their skills and understanding of solving trigonometry problems with two triangles. Despite the appearance that her inclusion of A1 was merely an offload of Section 6.4, Mrs Fung's interview suggests this was a deliberate decision for both providing an opportunity for students to struggle and a resequencing with a consideration for students' learning progression.

13. In the diagram, OA and OB represent two positions of the minute hand of a clock, $OA = OB = 20$ cm and $\angle AOB = 130°$. Find
    (a) the distance AB,
    (b) the perpendicular distance from O to AB.

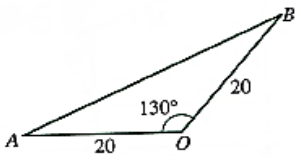


Figure 2. Question A1 in Worksheet 6.4, taken from (Chow et al., 2015a, p. 21)

Mrs Fung's goals and underlying beliefs which informed the decisions she made in offloading and adapting from the textbook can be described as an attempt to facilitate opportunities for *productive struggle* (Schoenfeld, 2017). As the worksheet became the main resource used in the lesson, to a large extent it replaced the textbook – a resource that would have an abundance of worked examples and hints that would have been useful for students. By omitting worked examples and asking her students to make sense of the problems

individually before providing guidance, Mrs Fung's adaptation through omission afforded students the opportunity to try several methods and to learn from those that did not work, rather than replicating a solution method from a worked example.

Secondly, while using an introductory video and B3 could ease students into solving application problems, Mrs Fung immediately followed B3 with A1 – a problem she was aware would cause some confusion. Mrs Fung discussed her concerns in the interview about ensuring students could eventually manage to solve the problem, but still insisted that students make an effort to think about how to approach the problem in the lesson. The selection and sequencing of A1 had the potential to cause students to become discouraged, especially those who had previously solved B1 easily and were now completely unaware of how to even approach A1. However, the nature of these adaptations also allowed her to act as a guide to coach students as she roamed around the room and supported students experiencing struggle. In comparison to the American teachers in Henningsen and Stein's (1997) study who avoided moments where students might experience struggle – despite knowing that they may be beneficial for learning, Mrs Fung actively tried to create these opportunities.

The use of the dual level of analysis prompted further investigation of Mrs Fung's use of the curriculum resources that was not accounted for by the DCE framework (Brown, 2009). Similar to Teck Kim from the study conducted by Leong et al. (2018), at first glance Mrs Fung's worksheet appeared to adhere with the previously mentioned assumption that Singapore mathematics teachers simply offload their responsibility to tailor content to meet students' needs, and instead select and use standard questions to develop procedural solving methods. At an item-to-item level, Mrs Fung's offloading of problems seemed to be consistent with this assumption. However, by examining Mrs Fung's worksheet on a set-to-set level, Mrs Fung's worksheet could be understood as a product of her interpretation of the curriculum resources and appropriation of the content with respect to her knowledge of her students' needs. She adapted from the textbook by omitting worked examples and re-sequenced problems, while also essentially replacing the need for the textbook during instruction. While Teck Kim adapted a textbook to create a worksheet to make concepts explicit to his students, Mrs Fung adapted the nature and sequencing of the textbook to facilitate students' exploration in solving. This study of Mrs Fung provides yet another step in the ongoing work of unpacking the complexities involved in Singapore teachers' design of instructional materials.

Concluding Remarks

The phenomena of teachers adapting curriculum materials is complex. At present, existing frameworks on teachers' curriculum use do not seem to fully capture what goes on through the materials teachers create and the invisible process of deciding how to adapt. Namely, while the DCE framework differentiates teachers' interactions with curriculum materials as offloads, adaptations, and improvisations, it does not address the potential for different grain-sizes of offloads, adaptations and improvisations. In this paper, Mrs Fung's interactions with the materials for designing her lessons were analysed on two levels which illuminated the different ways that she adapted from the textbook. From Mrs Fung's discussion of her lesson goals and observations of her enactment, her desire for students to grapple with problems and attempt to solve them independently were facilitated by these adaptations.

A limitation of the study is that the findings stem from secondary data gathered from a larger research project which focused on teachers' instruction, rather than their design of

instructional materials. Hence, the inferences which were made about her design decisions are restricted to the limited data available.

The case of Mrs Fung hopes to contribute to dispelling misconceptions about Singapore teachers' practices. In addition to Teck Kim, our findings suggest that when Singapore teachers interact with curriculum materials to design lessons, there's often more to the process than meets the eye. However, we also get the sense that we are just scratching the surface on what is an extremely complex phenomenon where several resources are all simultaneously involved. Furthermore, we propose that for Teck Kim and Mrs Fung, adaptations do not merely stop once the worksheets are created. Instead, they undergo an additional round of adaptations during instruction in response to students' reactions to the worksheets. Future research should aim to examine the implications of additional rounds of adaptations in comparison to a single round of adaptation.

Acknowledgements

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