

Reflection Model to Facilitate Teachers' Adoption of the Constructivist Learning Design

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As teachers begin to construct an understanding of 'inquiry', and incorporate IBL into their classroom practice, they are challenged to be sensitive to the 'constructivist' nature of the CLD. This paper presents a reflection model structured to trigger thinking about beliefs in teaching and learning in order for teachers to re-examine their practice and adopt new pedagogies. The reflections by two secondary school mathematics teachers are presented as they experiment with inquiry-based learning in the CLD. The teachers showed awareness, monitoring and regulation of their teaching practices including new and existing beliefs.

The Singapore mathematics curriculum (Ministry of Education [MOE], 2012) encourages learning through inquiry where teachers "led students to explore, investigate and find answers on their own" (p. 23). However, the use of the inquiry approach was not visible. In fact, a study of the Enacted School Mathematics Curriculum involving 30 experienced and competent teachers in Singapore secondary schools shows that "direct instruction appears to be the dominant model of instruction that teachers draw on" (Kaur et al., 2019, p. 18). For teachers to engage in more inquiry-based pedagogies, literature suggests it may arise from teachers' beliefs (McLeod, 1992; Mosvold & Fauskanger, 2014; Richardson, 1996). Indeed, research studies have shown that experienced teachers' attempts to learn to teach in new ways are highly influenced by what they already know and believe about teaching, learning, and learners (Borko & Putnam, 1996). "Teachers' beliefs strongly influence their classroom practices which in turn influence their students' beliefs about mathematics and their ability to learn it" (Marshman & Goos, 2018, p. 519). "Teacher mathematics-related beliefs such as beliefs about nature of mathematics, mathematics teaching, and mathematics learning also become variables that play a role in guiding that knowledge to create meaningful mathematics learning (Purnomo, 2017)" (Siswono et al., 2019, p. 493). Literature reports that many teachers hold behaviourist beliefs, which has strong implications for the success of constructivist-oriented curricular reforms (Handal & Herrington, 2003). Modification of beliefs is possible for teachers when they engage in the process of reflective thinking (Mewborn, 2002). Reflective practices have been reported to support teachers' adoption of new pedagogies (Davis, 2006; Tan, 2016; Yaowiwat et al., 2019). However, limited information is provided to teachers on how to conduct the process of reflection, which may hamper its use (Marcos et al., 2011). This paper provides an example of a reflection tool to scaffold reflective practice. This paper also presents an account of teachers' use of the reflection tool to engage in deep reflection of their personal beliefs against their practice during their participation in the Constructivist Learning Design Project.

Reflective Practices

Reflection is a key strategy in many professional development programmes (Watanabe, 2016) to enable teachers to be aware of their own problems, for knowledge construction in 2022. N. Fitzallen, C. Murphy, V. Hatisaru, & N. Maher (Eds.), *Mathematical confluences and journeys* (Proceedings of the 44th Annual Conference of the Mathematics Education Research Group of Australasia, July 3–7), pp. 114–121. Launceston: MERGA.

teaching, and to promote self-regulation in teachers (Boud, 2007). Teachers are reported to become more engaged and more inclined to participate in professional development when they are given the opportunity to reflect on their practices (Yu, 2018). Reflective practice has also been reported to be a useful vehicle to mediate pedagogical innovation (East, 2014). “Reflection on beliefs appears as a crucial element and a good start toward changing beliefs and practices” (Girardet, 2018, p. 13). In professional development programmes, if teachers are led to question their prior beliefs before and during the study of alternative practices, they will be more likely to be open to considering the studied practices (Girardet, 2018). Most research papers on teacher reflection looked at phases, levels or stages of reflection (Rodgers, 2002). In the discourse analysis of 122 articles on teacher education, Marcos et al. (2011) reported the need for reflective practice to be articulated more systematically “by offering teachers more evidence-based or research validated information on what works in reflective practice” (p. 34). Clarà (2015) also suggested that the process of reflection is not well understood. The practical procedures and methods on how to reflect is not sufficiently specified for teachers to conduct the process of reflection (Marcos et al., 2011). There is a need for structure to link reflection activities explicitly with the intended change by providing reflection prompts (Girvan et al., 2016). In recent years, there are studies that reported the use of a framework or tool for teachers’ reflection. Yu (2018) reports the study of the reflective practice using the critical incident framework and prompts (see Table 1) in a professional development workshop to guide the teachers’ process of reflection. The prompts did not focus on teachers’ beliefs. The findings show that participants did not reflect in the same way and some reflected without referring to the framework. The Teaching Learning Instrument (TLI) was used as a tool to support teacher reflection. The teachers used the prescriptive codes (see Table 1) in TLI to look out for specific instructional moves instead of teacher beliefs in their lessons that help them make specific inferences about their teaching to improve their instruction (Sabelski et al., 2019). Joseph and Atweh (2020) reported four teachers’ reflection on the use of Productive Pedagogies as a tool to reform their mathematics classroom practice. However, the paper concentrated on the views of the teachers on the benefits of the Productive Pedagogies framework during classroom instructions instead of the reflection process. Girvan et al. (2016) reported on teachers’ experiences of a new pedagogical approach as learners themselves in a professional development, before implementing the new approach in their own classrooms. The paper did not illuminate how the reflection prompts facilitates reflection although the use of reflection is reported to be a key feature to the PD model that supports the teachers’ implementation of the new pedagogy approach in their own classrooms.

Table 1
Samples of Reflection Prompts from Studies

Critical incident framework (Yu, 2018)	Protocol/scaffolding Codes for TLI (Sabelski et al., 2019)
Do you have an unforgettable educational experience? What happened? How did you feel about it? Why do you think it happened this way?	P1 Focus attention P2 Explain task SR Promote self-regulation WR Maintain warmth & responsiveness

A-Cube Change 2-dimensional Reflection Model for Teaching and Learning

The A³ Change 2-dimensional reflection model provides mathematics teachers a structure to reflect their teaching by addressing their belief for better alignment of practice, knowledge, and belief (Lee et al., 2019). The model encapsulates how two dimensions of reflection interact. The first dimension comprises of the three *types of reflection*, namely (i) emotive reflection—

teacher's awareness with regard to his/her gut feeling of how successful a lesson is after completing the lesson (ii) critical reflection—teacher's detailed analysis of his/her lesson (iii) creative reflection—invitation for the teacher to create a new lesson episode based on his/her reflection in emotive reflection and critical reflection stages. The second dimension considers the teacher's *depth of reflection* (i) articulative—articulating and describing new/reinforced understanding (ii) assimilate—examining articulated new/reinforced understanding against their personal belief to assimilate and own the assimilated new schema of understanding (iii) appraisive—appraise the new schema for effective regulated use of new/reinforced understanding. Question prompts (in Table 2) were developed based on A³ Change 2-dimensional reflection model to engage teachers in deep reflection.

Table 2

Sample of Reflective Question Prompts from A-Cube Change 2-dimensional Reflection Model

Depth/stages of reflection	Examples of reflective question prompts
Articulative—Emotive Reflection	How do I rate my lesson(s) based on a scale from 1 to 5 (1 being the worst and 5 being the best)?
Articulative—Critical Reflection	What worked? What did not work?
Articulative—Creative Reflection	What is my reinforced/new understanding?
Assimilative	Were my beliefs reinforced?
Appraisive	Any limitations to my new belief?

The CLD as an Inquiry-based Learning Approach

This study adopted the CLD, an inquiry-based learning (IBL) approach to teaching mathematics. Teachers who participated in the CLD project were provided specific teaching and learning packages involving IBL approach in the secondary mathematics classrooms. The IBL approach in this paper is akin to Teaching Through Problem Solving Approach (Cai, 2010), as reported in Cheng et al. (2021). The crux of the learning design rests on the building of students' ideas in the instruction of a mathematics concept—an embodiment of constructivist principles—hence the name Constructivist Learning Design (CLD). Unlike direct instruction with instruction followed by problem solving, the two phases in CLD starts with *problem solving phases* followed by the *consolidation phase*. In the CLD *problem-solving phase*, students first solve a complex problem that targets a concept that students were not formally taught. Students also explore and generate as many representations and solution methods (RSMs) (Kapur & Bielaczyc, 2012) as they could to the problem. The teacher provides the necessary facilitation and affective support for students without revealing the solution in this phase. In the CLD *consolidation phase*, the teacher consolidates, builds, compares and contrasts students' solutions, and discusses students' solution in accordance to the critical features of the solutions. In addition, the teacher makes “concise summaries and lead students to understand key aspects of the concept based on the problem and its multiple solutions” (Cai, 2010, p. 225) and helps to negotiate the meaning of the targeted concept. This paper addresses the following research questions: What does teacher reflection look like when using the A³ Change 2-Dimensional reflection model during participation in the CLD project?

Methods

We use an instrumental, collective case study approach to frame the qualitative data collection and analysis in this study (Stake, 2000). Two teachers who participated in the CLD project were purposefully selected for us to gain in-depth analysis of what the teachers were reflecting using the A³ Change 2-dimensional reflection model. The two teachers, Teacher A and B, taught in two different secondary schools in Singapore and implemented two different

CLD units, Angle Properties of Circles and Gradients of Linear Graphs, respectively. After the CLD lessons, the two teachers were invited to an individual reflection session which lasted about 30 to 40 minutes, where they were asked to reflect on their experiences in using the CLD and on their pedagogical beliefs and practices using question prompts in Table 2. The third author transcribed sections of the reflection sessions only if he identified them as articulative-the motive reflection, articulative-the critical reflection, articulative-the creative reflection, assimilative or appraisal. We met several times and used the transcripts to discuss our analysis. When we did not have agreement on the analysis, we went back to the audio recordings of the reflection, discussed the codes, and realigned our analysis against the codes until we reached agreement.

Results and Discussion

Articulative—Emotive Reflection

When asked to rate their CLD lessons on a scale of 1 to 5, with 1 being the worst and 5 being the best at the start of the reflection session, the two teachers rated their lessons to be between 3 to 4 out of 5. The average rating scores suggest that the teachers were satisfied with certain aspects of their lessons and they were aware of room for improvements in their teaching.

Articulative—Critical Reflection

In this stage of reflection, Teacher A said her problem-solving phase, was student-centred because students were highly engaged and displayed a “curiosity to learn” during the group work activity. She also uncovered several students’ thinking processes and misconceptions from the RSMs that students generated for the problem task. Teacher B was pleased that the students were able to reflect on their RSMs and identify the gaps or limitations to their methods or ideas. Both the teachers pointed out that their lesson objectives were achieved. Both teachers did not give themselves a higher rating because they identified some areas for improvement for their lessons. They were unsatisfied with the way they facilitated the discussion in the problem-solving phase. Teacher A said, “I had this perception that I am not supposed to tell them [the students] so many things, they are supposed to find out on their own”. Teacher B said, “... the more difficult part was facilitating the starting of the ideas that I thought was a bit of a challenge for myself. Because [students] are very wary of giving the wrong answers ... I think this project also requires a lot of the facilitation skills from the teacher themselves.” In the consolidation phase, Teacher A said,

Teacher A: For me I find that the second lesson was a bit dry because it is back to teacher-centred teaching, so I am not very sure if I have done it correctly. All I did was showing the slides and telling them what I see from their findings et cetera, so I don’t really feel very comfortable ... So, when I ask them questions they don’t seem to respond, I feel very insecure.

Teacher A’s verbatim suggested that she constantly monitored the atmosphere of the class and related it to her enactment of the new pedagogy. However, she expressed her discomfort during the *consolidation phase*. She felt that her PowerPoint presentation on the RSMs in the *consolidation phase* made it difficult for her to engage students in rich discussion of the mathematical concept because the students “were just listening to a lecture.” Compared to the *problem-solving phase*, her *consolidation phase* was less student-centred, and she wondered how she could make her *consolidation phase* more student-centred and engaging. She suggested that guiding questions to be used during lesson enactment could help her facilitate the discussion. Teacher B felt that students who “are fundamentally weaker” in her mathematics class had difficulties making connections among the RSMs during the *consolidation phase*.

The teachers' reflections show that *emotive reflection* triggers teachers' *critical reflection*. Notably, unlike *emotive reflection*, which is based on the teachers' intuition and immediate emotional responses, *critical reflection* reported here illustrates teachers' objective evaluation of their lesson episodes by drawing on what worked and what did not work from their enacted lessons. *Critical reflection* not only bring to the teachers' awareness challenges they faced during enactment of the new pedagogy, it also provides teachers the opportunities to articulate their strengths, areas for improvement and identify professional development needs grounded with specific examples from their enacted lessons when using the new pedagogy. This finding supports the importance of teachers looking back to the classroom events, teacher actions and student reactions to learn, realise what they observe or to improve their own teaching practice (Hatton & Smith, 1995). Our findings also align with Korthagen and Kessels (1999) pedagogical framework that supports the view that teachers' perspectives be 'situation specific and relate to the context in which they meet a problem and develop a need' (p. 7) to help them find a course of action. The data also shows that Teacher A's perception and belief about her role in the *problem-solving phase* influence her facilitation of classroom discussion.

Articulative—Creative Reflection

When asked what they would have done differently if they were to conduct the CLD lessons again, Teacher A suggested using a gallery walk. Students could pin their solutions at different parts of the classroom for their classmates to discuss the multiple solutions generated in the *problem-solving phase* instead of her presenting the solutions using PowerPoint. She felt that this strategy can make her *consolidation phase* more student-centred. Students would then be able to analyse their peers' solutions, and this would encourage more student-student discourse and teacher-student discussion. Teacher B suggested a similar idea. She also suggested that she could have given her students the opportunity to analyse and critique the RSMs themselves during the *consolidation phase*. She said, "the process, I feel, could have been better thought through on my part, in the sense, in making connections for them or allowing them to make the connections themselves" She also said, "I did a lot of the brainstorming myself, but it didn't occur to me what it would had been like if students have tried it". For "students whose thinking may not be as matured yet" Teacher B suggested more teacher involvement and more scaffolding for students.

From the teachers' suggestions, we observe that teachers' *creative reflection* was motivated by their *critical reflection*. Specifically, teachers' *critical reflection* on shortcomings of their lessons prompted them to think of creative ways to overcome the perceived limitations. Their suggestions (e.g., gallery walk) also indicated their willingness to explore alternative methods to enhance their teaching practice and students' learning experience. The findings here illustrate teachers' engagement in the highest level of reflection, (Larrivee, 2008; Manouchehri, 2002; Muir & Beswick, 2007) where teachers try to examine the events in the class and finds alternative ways to improve their teaching or solve those situations when reflection is viewed as a continuum.

Assimilative Reflection (Awareness of New or Existing Beliefs)

The reflection prompts to elicit teachers' beliefs need to be made explicit for both teachers before they reflected on whether the experience of implementing the CLD had reinforced or changed any of their pedagogical beliefs. Both teachers reported that the CLD reinforced or resonated with their existing beliefs. Teacher A believes that students should construct their own knowledge but was unsure how to realise it prior to the project. The experience of using the CLD has supported and reinforced her constructivist beliefs in some ways. Teacher A also shared her *change in belief* about students' capacity to try an exploratory task on a new

mathematics topic that has not been introduced in her mathematics lessons. She also shared that she has been using a more teacher-directed form of teaching, and she was apprehensive about conducting student-centred activity in the CLD package at first. However, the student responses changed her views. Teacher A also reconsidered her beliefs on the effectiveness of collaborative work in mathematics learning from the group work activity (see Table 3). Teacher A's case shows that reflection helps her question her own assumptions about her teaching practice and the data from her enactment of the new pedagogy made her consider alternatives practices which aligns with Cochran-Smith and Lytle (1993) report on reflection.

Table 3

Teacher's Change in Belief on Student and Teaching Practices by Teacher A

Student Capacity	Collaborative Learning
From "... for me I never tried such lessons before whereby students were given a task and they were supposed to explore. I have been using the more teacher-centred teaching ... So when I was teaching this lesson ... initially I was quite apprehensive ... I am worried that there won't be any responses ... I am also worried that the lesson will be just a waste of time that they wouldn't be able to find anything." To "... when I did the lesson, I was actually surprised that the students were able to see certain properties by themselves, although they didn't phrase it in the best way ..."	From "Previously, collaborative work for mathematics was not my cup of tea because I find that it doesn't work." To "But then after doing this I see that actually there is value in doing collaborative work whereby the students get to reason with each other, they get to work towards a task together ... maybe getting them to acquire the knowledge in this manner through interaction, through discussion, through discourse, it probably gets them to retain knowledge better."

The shift in beliefs seems to have an impact on Teacher A's teaching practices. In her subsequent lesson on "angles in alternate segment", which is not part of the CLD research, Teacher A revealed that she had tried something constructivist in nature. While she would "tell" her students the proof of the theorem in her usual practice, Teacher A had instead asked students to try and prove it themselves. She provided her students with scaffolds and hints and asked them to share their solutions in class. Teacher A's description of her "angles in alternate segment" indicates a deviation from her teacher-centred teaching, and this deviation in practice aligns with her reported change in beliefs. This finding aligns with the literature on teachers' beliefs (Mewborn, 2002), which suggests that teachers' pedagogical beliefs have an impact on their teaching practices. It also shows that reflective practice is a useful vehicle for mediating pedagogical innovation (Tan, 2016; Yaowiwat et al., 2019). Prior to the project, Teacher B said she had tried something similar before but at a smaller scale. She believes that students should "learn [math] by doing" and that it is important "to hear students what they have to say". Since the CLD builds on students' responses, the pedagogy is aligned with her beliefs.

Appraisal Reflection (Awareness of Gaps in Understanding)

Both teachers noted that they are willing to try out the pedagogy for other topics or other classes, or to conduct something similar but of a smaller scale (e.g., problem that requires shorter exploration time followed by immediate consolidation within the same lesson). However, despite their belief in the effectiveness of the CLD in students learning, Teacher A and B highlighted that factors like time constraints might limit their use of the learning design. Both teachers also questioned if such a pedagogy would be suitable for all topics. This awareness would impact when and how the teachers are going to employ constructivist pedagogy in the future.

Conclusions and Implications

In this paper, we described the teachers' process of reflection by organising our findings using the reflective question prompts as headings. By doing so, we hope we have articulated the teachers' reflective practice more systematically and that more teachers can benefit from their reflective practice. In summary, this study shows how the reflection tool and its accompanying reflective question prompts provided teachers a structure on how to reflect on their teaching practice. The reflection model surfaced teachers' awareness of their practices, beliefs and change in practices and beliefs. The teachers became more aware of their teaching actions and practices as the reflection model "facilitated the teacher reflection process in ways that helped to make visible (clear or coherent) what is often invisible (or incoherent) in teaching" (Sableski et al., 2019, p. 325). The question prompts in the reflection model not only elicit teachers' awareness, encourage teachers to suggest creative ways to improve but also has a structure that takes into consolidation teachers' emotions, deep-seated beliefs and practices in order to impact practice. In this sense, the reflection model empowers teachers "to understand specific teaching situations in more depth to inform future actions" (Sableski et al., 2019, p. 326). This study also suggests that the way question prompts are sequenced in the reflection model are very helpful for them to relook into teaching practices and beliefs as they try to implement CLD. By doing so, the teachers are engaged in "a process of bringing coherence to an initial situation" (Sableski et al., 2019, p. 326), a pivotal first step in adopting CLD in their mathematics classrooms. This study has practical significance on the use of a structured reflection tool to promote self-regulation in teachers (Boud, 2007) and for teachers to adopt new pedagogies in teaching and learning mathematics. The critical and appraisive characteristics of the reflection tool can provide valuable insights for professional developers to plan for PD programmes that support the needs of teachers as they adopt new pedagogies in their classrooms. In conclusion, the reflection model reported in this paper has a great potential to aid teacher growth and adoption of new pedagogies in the light of 21st century—the age of digital technologies and knowledge—where innovation is vital.

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