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► To cite this version:

Ying Zhang, Andreas J. Stylianides. A comparative case study of the mathematics pedagogy in two Chinese schools: How “student-centered” is a proclaimed reformed pedagogy?. Thirteenth Congress of the European Society for Research in Mathematics Education (CERME13), Alfréd Rényi Institute of Mathematics; Eötvös Loránd University of Budapest, Jul 2023, Budapest, Hungary. hal-04401607

HAL Id: hal-04401607

<https://hal.science/hal-04401607>

Submitted on 17 Jan 2024

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A comparative case study of the mathematics pedagogy in two Chinese schools: How “student-centered” is a proclaimed reformed pedagogy?

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Although mathematics pedagogy in Chinese classrooms is presumed to be mostly teacher-centered, the Dulangkou secondary school has a strong national reputation of having reformed its pedagogy to be student-centered. In this comparative case study, we used the Reformed Teaching Observation Protocol (RTOP) to investigate whether the pedagogy used at Dulangkou meets the description of student-centered pedagogy (SCP) as elaborated in the international literature and relative to School Y, a Chinese secondary with a similar context as Dulangkou but purported to use teacher-centered pedagogy (TCP). The results showed significant differences between the observed lessons in the two schools, with Dulangkou’s lessons rated as more student-centered than those in School Y. Yet only 1 out of the 13 lessons observed at Dulangkou used SCP; the rest used transitional pedagogy combining TCP and SCP. Implications for research and practice are discussed in light of these findings.

Keywords: Student-centered pedagogy, mathematical reform, Reformed Teaching Observation Protocol, secondary school mathematics, teacher-centered pedagogy.

Introduction

Mathematics educators in different countries have called for reform of the teaching of mathematics towards the use of student-centered pedagogy (SCP), which contrasts with teacher-centered pedagogy (TCP) often reported in Chinese mathematics classrooms (e.g., Watkins & Biggs, 2001). Nonetheless, there are a few Chinese schools claiming to have reformed their pedagogy from TCP to SCP; the Dulangkou Secondary School has a strong national reputation as an exemplar of such reform in Chinese compulsory education (Chai, 2014, p.138). Dulangkou is based in a rural town of the Shandong province and was facing serious problems and the possibility of being closed down. In 1997, a reform effort was launched; eight years later, Dulangkou was regarded as one of the most successfully reformed schools by the Chinese Ministry of Education and many school leaders all over China.

SCP can be difficult to implement in Chinese schools for several reasons. First, China’s centralized, high-stakes examination system limits teachers’ pedagogical choices from conducting SCP, which teachers perceive to be time-consuming (Zhang, 2022). Second, Chinese teachers who wished to reform their pedagogy had difficulties putting “autonomy, collaboration, exploration” in practice in classrooms (Chai, 2014). Third, Chinese parents would hardly agree with SCP since they might consider teachers to not be fulfilling their obligations to teach and support students (Chai, 2014).

Despite Dulangkou’s national reputation of having reformed its pedagogy to be student-centered, no study thus far has investigated whether its pedagogy meets the description of SCP as elaborated in the international literature. This is problematic in that it is unclear how “student-centered” its proclaimed reformed pedagogy is, and whether there are good examples of SPC in the Chinese

context, as defined in the international literature. In this study, we took a step towards addressing this need for research by focusing on the following research questions: To what extent does the mathematics pedagogy in Dulangkou meet the description of SCP as elaborated in the international literature? How can the pedagogy used at Dulangkou be characterized, and how does it compare with the pedagogy used at School Y, a Chinese secondary with a similar context but purported to use TCP? This research is also of relevance to western researchers. There are schools worldwide that proclaim their pedagogy to be SCP without an official evaluation or assessment; our analysis can thus serve as a reference for researchers seeking to evaluate pedagogy in other contexts. Also, our study pioneers the application of the Reformed Teaching Observation Protocol (RTOP) in an Asian classroom.

Theoretical perspectives

SCP and TCP

In a learning environment with TCP, the teacher primarily communicates to students through lectures solely designed to impart knowledge and maintains a position of authority (Serin, 2018). SCP, in contrast, provides an environment where students construct their understanding and teachers act as facilitators to guide and help students achieve their goals. While TCP is based on the behaviorist theory in which external stimuli cause behavioral changes, SCP involves constructivist and democratic principles where knowledge is socially constructed (Serin, 2018).

RTOP

The Reformed Teaching Observation Protocol (RTOP) was designed and validated by the Evaluation Facilitation Group of the Arizona Collaborative for Excellence in the Preparation of Teachers (ACEPT). It is a holistic paper-and-pencil observation protocol developed to evaluate the extent to which a classroom adopts reform-based teaching techniques (Piburn et al., 2000).

Table 1: Description of the RTOP subscales (Sawada et al., 2000)

| Subscale | Description |
|-------------------------------------|---|
| 1. Lesson design and implementation | Assesses whether the design of the lesson engages students as a learning community, and how the teacher organizes the lesson to consider students' preconceptions. |
| 2. Propositional knowledge | Focuses on the level of significance and abstraction of the content, the teacher's understanding of it, and the connections made with other disciplines and with real life. |
| 3. Procedural knowledge | Focuses on the processes that students are engaged to use to process information, arrive at conclusions, and evaluate knowledge claims. |
| 4. Communicative interactions | Focuses on the diversity and decentralization of the communicative interactions, and evaluates the number, type, and quality of interactions among students. |
| 5. Student-teacher relationship | Appraises classroom culture and how the teacher promotes a culture of respect, including the encouragement of students' active participation. |

RTOP contains five subscales to evaluate a classroom lesson as in Table 1. Each subscale comprises 5 items and each item is rated on a scale from 0 to 4, where 4 means the item is “very descriptive” of the lesson while zero indicates that the item “never occurred.” The total RTOP score ranges between 0 and 100. Lower scores reflect a TCP while higher scores represent a SCP (Sawada et al., 2002). The different pedagogies characterized by different RTOP score ranges are summarized in Table 2.

Table 2: Pedagogies corresponding to different RTOP score ranges (Madsen & Richards, 2022)

| RTOP Score | 0-30 | 31-45 | 46-60 | 61-100 |
|------------|----------------------------------|---------------------------------|-------------------------------------|-------------------------------|
| Pedagogy | Traditional/ teacher-centered | Transitional/ teacher-guided | Transitional/ student-influenced | Reformed/ student-centered |

While RTOP’s design ensures its applicability to different classrooms, it does have limitations. First, although the RTOP was found to have high inter-rater reliability (Piburn et al., 2000), consistency across studies remains an issue. Second, the high end of the RTOP scale seems difficult to attain in lecture-based environments. Indeed, studies adopting RTOP have documented a limited number of mathematics lessons with RTOP scores greater than 70 (Budd et al., 2013). Third, RTOP does not assess any learning activity that occurs outside of the classroom. Finally, the boundaries between different kinds of pedagogies have been contested. For example, Budd et al. (2013) considered RTOP scores greater than 50, instead of greater than 61 (Table 2), to indicate SCP.

Methods

Comparative case study

Dulangkou Secondary School and School Y were the participating schools/cases in this study due to their purported use of SCP and TCP, respectively. School Y was selected due to its comparable features with Dulangkou except for pedagogy, the main variable of interest. Both schools are in rural towns under the same county/city, so they follow the same educational policies and have similar socioeconomic conditions. Also, both schools divide students into classrooms randomly rather than based on achievement. Finally, each of them is the only school in its respective town and is required to recruit students only from within its district; thus, both schools have similar student intakes. These similarities provide some control over confounding variables and allow for a meaningful comparison.

Data collection methods

We used the RTOP to evaluate the extent of student-centered practices employed during mathematics lessons at both schools. In total, four out of seven Dulangkou mathematics teachers (11 lessons) and five out of seventeen School Y mathematics teachers (13 lessons) from Grades 7-9 were randomly selected and observed. Each teacher was observed for either one lesson or several consecutive lessons (up to 5); 24 lessons were observed in total. Each class at both schools contained approximately 40 students; each lesson lasted 45 minutes at Dulangkou and 40 minutes at School Y. The observed content covered the topics of circle, quadratic equations, inverse functions, mean and median, and algebra. All observed lessons were video recorded for backup and review of the observer’s codes (first author), and for selected coding by another rater to check inter-rater reliability. School Y’s

mathematics teachers had an average age of 47 years while Dulangkou’s had 40 years. The participating teachers’ pseudonyms and ages are presented in Table 4. It is worth mentioning that Teacher D4 was a fourth-year undergraduate who was doing his internship teaching (preservice teacher training) at Dulangkou. At the time of observation, he had been at Dulangkou for three months.

Results

Comparison of total RTOP scores

The mathematical pedagogy at the two schools had marked differences. As indicated in Table 3, among all eleven lessons observed at Dulangkou, six were student-influenced, one was student-centered, and four were teacher-guided. All thirteen lessons observed at School Y were teacher-centered, except for one that was teacher-guided.

Table 3: Distribution of RTOP scores corresponding to the observed teachers

| | Total lessons observed | Average RTOP (\pm SD) | Teacher-centered | Teacher-guided | Student-influenced | Student-centered |
|-----------|------------------------|--------------------------|------------------|----------------|--------------------|------------------|
| Dulangkou | n=11 | 48.0 \pm 7.46 | n=0 | n=4 | n=6 | n=1 |
| School Y | n=13 | 26.6 \pm 4.82 | n=12 | n=1 | n=0 | n=0 |

Table 4: Distribution of pedagogy corresponding to the observed lessons

| | Dulangkou teachers | | | | School Y teachers | | | | |
|----------------------------|--------------------|---------------|---------------|----|-------------------|-----------------|---------------|----|----|
| Pseudonym | D1 | D2 | D3 | D4 | Y1 | Y2 | Y3 | Y4 | Y5 |
| Age | 48 | 46 | 47 | 22 | 50 | 52 | 24 | 47 | 32 |
| Grade | 9 | 9 | 8&9 | 7 | 9 | 9 | 8 | 8 | 7 |
| Number of lessons observed | 4 | 3 | 3 | 1 | 5 | 3 | 3 | 1 | 1 |
| Average RTOP \pm SD | 53.75 \pm 8.14 | 45 \pm 1.73 | 43 \pm 5.57 | 56 | 29.4 \pm 3.44 | 21.3 \pm 6.51 | 27 \pm 1.73 | 30 | 24 |
| Median | 54 | 46 | 44 | 56 | 28 | 21 | 26 | 30 | 24 |
| Range | 44-63 | 43-46 | 37-48 | / | 26-35 | 15-21 | 26-29 | / | / |

Across all lessons, Dulangkou’s average RTOP score was 21.4 points higher than the average School Y score. Indeed, as shown in Table 4, all Dulangkou teachers’ average RTOP scores were higher than those of the School Y teachers. According to the nature of RTOP, the results suggest that Dulangkou students experienced a more student-centered environment than School Y students. Due to the ordinal

nature of the Likert type data, we used a Mann-Whitney U test to evaluate the hypothesis that School Y would score lower, on the average, than Dulangkou on the total RTOP scores. The results were in the expected direction and significant, $z = -4.152$, $p < 0.01$. It is notable that Teacher D4, the pre-service teacher, achieved the second highest RTOP score among all participants. His performance suggests beginning teachers have the potential to be trained to use SCP in a relatively short time.

Comparison of average RTOP subscale scores

Table 5 summarizes the average RTOP subscale scores by participating school. Mann-Whitney U tests were conducted to evaluate the hypothesis that School Y scored lower, on the average, than Dulangkou on all subscale scores. The results of the tests were in the expected direction and significant for all subscales, $p < 0.01$, except for the propositional knowledge subscale, $z = -1.032$, $p > 0.05$, which is the highest subscale score for School Y. This finding aligns with Budd et al. (2013) in that teacher-centered classrooms score well on propositional knowledge, presumably because teachers know the content well. The similar propositional knowledge scores of the two schools can also be attributed to their similar socioeconomic conditions and teacher recruitment.

Table 5: Average RTOP subscale scores by participating school

| | Lesson design | Propositional knowledge | Procedural knowledge | Communicative interactions | Student-teacher relationship |
|-----------|----------------------|--------------------------------|-----------------------------|-----------------------------------|-------------------------------------|
| Dulangkou | 10.27 | 9.45 | 7.55 | 9.81 | 11.36 |
| School Y | 3.85 | 8.69 | 4.31 | 3.00 | 5.46 |

The subscale scores and total RTOP scores of all 24 lessons were drawn in scatter plots like in Figure 1. All five subscale scores positively covary with the total RTOP score. Correlations are higher for subscales 1, 3, 4, and 5, as illustrated by the scatter plot for lesson design subscale (Figure 1, left), while scores spread out far more for the propositional knowledge subscale (Figure 1, right). These trends indicate that the total RTOP scores are most distinguished by lesson design, communicative interaction, student-teacher relationship, and procedural knowledge, which is in accord with Budd et al.'s (2013) findings, suggesting that such findings are not limited to the Chinese context.

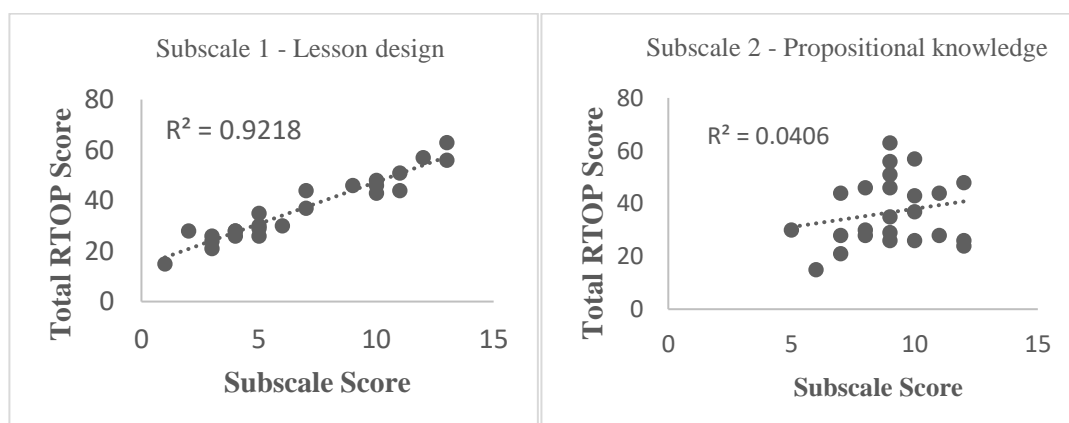


Figure 1: RTOP subscale scores versus total RTOP scores

Comparison of average RTOP item scores

Figure 2 presents both schools' RTOP average item scores, where the horizontal-axis represents the item number and the vertical-axis the item score. For example, Dulangkou scored 1.64 and School Y scored 0.08 for item 5. The Mann-Whitney test indicated that the average item scores were significantly greater for Dulangkou than for School Y, $z = -3.679$, $p < 0.01$.

Dulangkou scored higher on all items except for item 9, which evaluated whether elements of abstraction, such as symbolic representations or theory building, were encouraged during lessons when it was important to do so. By teaching directly on the blackboard, School Y teachers slightly better demonstrated the relationships/patterns to facilitate conceptual understanding.

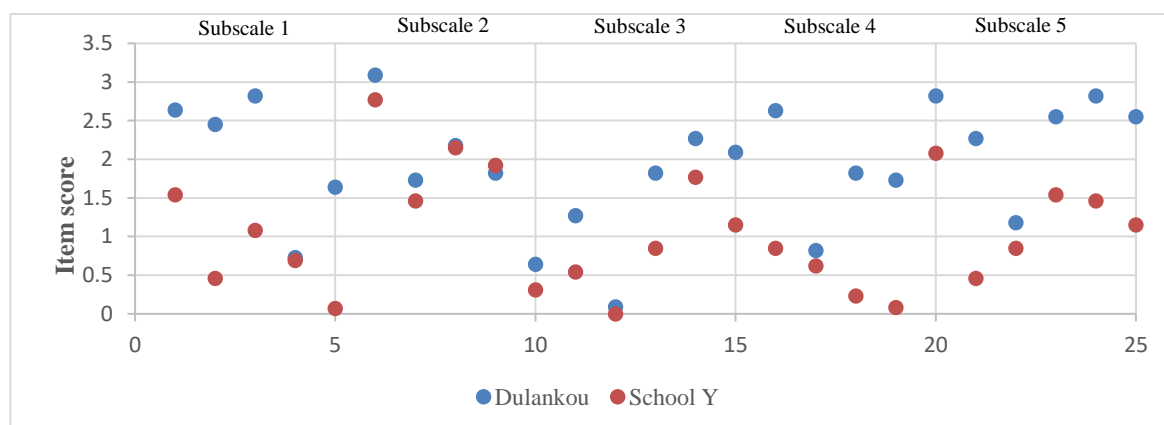


Figure 2: Average RTOP item scores by participating school

Both schools had the highest score on item 6, belonging to the propositional knowledge subscale, which evaluates whether the lesson involved fundamental concepts of the subject. Most participating teachers meticulously presented the mathematical concepts and ensured they were at core of their lessons. For example, Dulangkou's lesson on mean and median was anchored in median's less sensitivity to extreme values, while School Y's lesson on inscribed and circumscribed circles focused on the distinction between the intersection of angle bisector and perpendicular bisector.

Dulangkou exhibited low average scores (less than one point) on four items: item 4 (0.73), item 10 (0.64), item 12 (0.09), and item 17 (0.82), which can be a bottleneck for its reform and thus present the greatest challenges to all mathematics teachers at both schools. Items 4 and 17 evaluate whether the teacher triggered students' divergent thinking and encouraged students to seek alternative modes of investigation. Divergent thinking, an aspect of mathematical creativity, is the thought process used to generate multiple possible ideas to a problem or situation (Guilford, 1967). To strengthen their SCP feature, Dulangkou mathematics teachers might guide students to seek alternative solutions and encourage students to pose different mathematical problems regarding one situation, both of which are approaches linked to divergent thinking improvement (Silver, 1997). Item 12, the lowest-scoring item exhibited by both schools, evaluates whether students made predictions or hypotheses and devised means for testing them. Teachers at both schools might thus provide students with more opportunities to make conjectures and explicitly state their predictions before checking them. Item 10 focuses on whether the lesson connects mathematics with another content discipline or real-world

phenomena. Teachers might thus need to emphasize more the inter-relatedness of mathematical thinking with other content or the real-world, and the connections between content and concepts.

Inter-rater reliability

Six recorded lessons (25%) were randomly selected for a second rater to code (a native Chinese speaker). A 100% inter-rater agreement was reached in terms of the RTOP pedagogical category, and a Cohen's Kappa of 0.767 for all RTOP item scores was achieved.

Discussion

The pedagogy characterizing Dulangkou's and School Y's mathematics lessons differed substantially despite the two schools' other similar characteristics, including geographical proximity, teaching content, and student intake. The 24 lessons observed in this study covered all four types of pedagogy characterized by RTOP, but the distribution differed between schools: Dulangkou's lessons ranged from teacher-guided to student-centered, while School Y's lessons were all teacher-centered except for one that was teacher guided. Notable also is the fact that only one of Dulangkou's lessons was characterized as student-centered; most of Dulangkou's lessons were transitional, using either student-influenced or teacher-influenced pedagogy. Thus, while compared to School Y Dulangkou's students learned in a more student-centered environment, Dulangkou's proclaimed reformed pedagogy did not seem to fully meet the description of SCP as elaborated in the international literature. We acknowledge, however, the subjectivity of the boundaries between different score bands corresponding to pedagogy. For example, Budd et al. (2013) grouped RTOP scores greater than 50 to be SCP; according to this grouping, Dulangkou would have had four SCP lessons instead of one.

The finding that both Dulangkou and School Y used a combination of types of pedagogy might indicate that nowadays it is less likely that a secondary school in China solely uses one type of pedagogy, not even TCP that is presumed to be the dominant form in Chinese mathematics classrooms (Watkins & Biggs, 2001). This aligns with Zhou et al.'s (2022) finding that Chinese mathematics classrooms have changed from the stereotype of TCP, seeking a balance between TCP and SCP. The case of Dulangkou's pedagogy suggests that reform/innovation does not mean the inevitable separation from tradition. Dulangkou seems to be using, or be on its way towards using, an innovative form of pedagogy that fits into the Chinese culture and educational system.

Pedagogical reform can be a complex and tough process, especially for older teachers who are more likely to question and be resistant to change (e.g., Reio Jr, 2005). Although the lessons observed at School Y were mostly TCP, School Y teachers have been visiting Dulangkou semi-annually for a decade to learn about its reformed pedagogy and School Y's teacher evaluation scheme even includes the "Dulangkou mode" as an evaluation criterion. Our findings suggest those schools or teachers, not only from within China, wishing to integrate SCP in their mathematics classrooms might particularly need to improve the following four subscales: lesson design and implementation, procedural knowledge, communicative interactions, and student-teacher relationship. The RTOP protocol can be used as an observational rubric or as a list of criteria for lesson design and observation purposes, classroom interaction improvement, and pedagogical growth. Our methodology of using RTOP in this study to analyze mathematics pedagogy in China could be used similarly in other contexts.

Importantly, the distinct pedagogical environments at the two schools have laid a foundation for the next state of our research, which aims to explore the role of pedagogy in mathematical creativity.

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