Assessing the effects of a collaborative problem-based learning and peer assessment method on junior secondary students' learning approaches in mathematics using interactive online whiteboards during the COVID-19 pandemic

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Abstract: Given the demands on instructors created by the COVID-19 pandemic, teachers have been compelled to integrate active learning pedagogies supported by mobile technologies to sustain students' interactive engagement. This study describes the implementation of a novel active pedagogy – the collaborative problem-based learning and peer assessment (Co-PBLa-PA) method, implemented through interactive online whiteboards (IOWBs) in junior secondary mathematics classes in Hong Kong. Data were collected from 87 Form 1 students and analysed to test three hypotheses postulating the main effects of the Co-PBLa-PA method on students' learning approaches using IOWBs. A pre-survey (SPQ) on students' learning approaches and a post-survey (SPQ) on students' learning approaches and their perceptions of technology-enabled active learning (TEAL) were administrated. Results showed the Co-PBLa-PA method, using IOWBs, increased students' learning performance and promoted significant deep learning. A significant positive correlation also emerged between deep learning approaches and students' perceptions of TEAL using IOWBs. Finally, limitations and directions for future research are discussed.

Keywords: collaborative learning; problem-based learning; peer assessment; learning approaches; deep learning; interactive online whiteboards; mathematics; technology-enabled active learning.

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1 Introduction

In response to the COVID-19 epidemic, the Education Bureau (EDB) of Hong Kong has suspended face-to-face classes. This sudden lockdown of education institutions and the requirement for physical distancing during the pandemic have created significant disruptions in teaching and learning. To mitigate the impact on learning, teachers, instructors and educators have been compelled to act quickly and move swiftly to a completely online virtual approach to teaching that obviates the need for face-to-face classroom interactions. This shift from traditional face-to-face in class instructional methods to a remote learning environment presents significant challenges, in that it requires both pedagogical and technological adaptations, as well as a full integration of technology, pedagogy and instructional approaches, thereby transforming the learning context into one that is engaging, interactive as well as collaborative. This includes, for example, remote collaboration tools to facilitate active learning outside of the classroom, by motivating and engaging learners in interactive problem-based learning activities to deepen their conceptual understanding, develop their higher-order reasoning skills and apply learned concepts in order to solve conceptually-oriented problems both interactively and collaboratively (Shroff et al., 2021). The application of these remote collaboration tools and technology-enhanced active learning strategies implies that learners can participate actively in their own knowledge acquisition and development process. Moreover, learners are able to develop and apply their collaborative, problem-solving and peer assessment skills and strategies within a technology-enhanced active learning context. Hence, applying collaborative, problem-solving and peer assessment strategies within technology-enabled active learning contexts, not only allows learners to subsequently engage in deep, purposeful and sustained learning, but also fosters their higher-level learning skills and strategies (Ting et al., 2019).

More specifically, a number of studies have been devoted to understanding the effects of active learning methods on students' performance in different disciplines (Armbruster et al., 2009; Freeman et al., 2007; Yoder and Hochevar, 2005). More notably, a meta-analysis of 225 studies conducted by Freeman et al. (2007), analysed and reviewed data on examination scores and failure rates by means of a comparative approach to study students' performance between traditional lecture-based and active learning approaches in undergraduate STEM courses. The overall mean effect size demonstrated that, on average, student examination and concept-test performance increased by 0.47 standard deviations when employing active learning approaches, while the traditional lecture-based approach led to a higher risk of failing (Freeman et al., 2007). Their study findings subsequently revealed that mean examination scores improved by approximately 6% in active learning scenarios (Freeman et al., 2007). Not only do these results justify the current implementation of active learning in STEM disciplines, but they also serve as a call to STEM instructors to increase active learning in STEM-related courses.

Consequently, active learning methods such as collaborative, problem-based learning and peer assessment have received considerable attention in the educational field and have been extensively adopted to support learners' interactions through critical thinking, reasoning and problem solving skills (Davidson and Major, 2014). Moreover, peer assessment, which is essentially a collaborative activity, allows learners to make formal assessments of others within a collaborative social interactional process (Kollar and Fischer, 2010; Ting et al., 2019; Van Gennip et al., 2010). This collaborative, problem-based learning and peer assessment approach not only allows learners to engage in constructivist problem-based/inquiry-based learning strategies and higher-order thinking skills, but also allows them to engage in peer assessment, as well as a social learning process involving learners' grading and providing feedback on others' work (Kollar and Fischer, 2010; Liu and Carless, 2006). By engaging in collaborative task-based activities, learners are able to build on prior knowledge, share perspectives and apply higher-order critical thinking skills in the relevant context to solve real-world complexities and applied problems.

A novel pedagogy, which was first pioneered by Ng et al. (2020) and adopted in this study is a Collaborative Problem-based Learning and Peer Assessment (Co-PBLa-PA) method supported by Interactive Online Whiteboards (IOWBs). Through their research, the authors provided statistically significant evidence to suggest that the Co-PBLa-PA pedagogy increases students' conceptual understanding of Calculus concepts and assignment scores two-fold (Ng et al., 2020). Moreover, the authors credited this significant result to the fact that the Co-PBLa-PA method is a very active teaching method, according to the Interactive, Constructive, Active and Passive (ICAP) framework proposed by Chi and Wylie (2014), combining three active teaching methods: collaborative learning, problem-based learning and peer assessment.

In view of the above, this study provides an opportune context to assess the effects of the Co-PBLa-PA method on junior secondary mathematics classes in Hong Kong using IOWBs during the COVID-19 pandemic. Prior research has highlighted the practical and methodological benefits in the use of IOWBs (Akbaş and Pektaş, 2011; Chen et al., 2020;

Digregorio and Sobel-Lojeski, 2010; Ng et al., 2020; Young et al., 2017). More notably, research carried out by Chen et al. (2020), demonstrated a significant correlation between learners' involvement in interactive whiteboard-based instructional tasks and mathematics achievements. We believe that with the use of IOWBs, the Co-PBLa-PA method can be particularly promising in increasing learners' interactions, advancing their conceptual understanding of the material and most importantly, strengthening their problem-based inquiry and higher-order critical thinking skills (Lu et al., 2010; Lubis et al., 2019; Suh, 2004). In the context of a mathematics course, for example, we believe the Co-PBLa-PA methodology not only allows learners to engage in higher-order cognitive processes essential to solving arithmetical tasks, but also allows learners to discover multiple solutions in this type of collaborative problem-based and peer assessed learning context.

2 Literature review and research hypotheses

2.1 Conceptions of mathematics teaching within the Hong Kong context

The Hong Kong secondary school education system has historically been depicted as highly competitive, examination-oriented, characterised by expository teaching and didactic teacher-centred models of instruction that are typically employed in the mathematics curriculum of many secondary schools (Mok, 2019; Wong, 2007). For the secondary school mathematics teacher, mathematics can be a challenging undertaking as teachers often have to deal with disengaged students possessing an apathetic mindset, who attend classes with a lack of interest, motivation and confidence. In the context of secondary schools in Hong Kong, mathematics is often taught with an emphasis on formulas or calculations focusing on abstraction rather than application, encouraging surface and passive learning instead of deep and active learning, thereby diminishing learner creativity, achievement and motivation. This underlines the fact that by and large teachers in Hong Kong tend to focus on activities that rely heavily on incessant drilling, repetition and memorisation of instructional material, rather than emphasising deep learning, conceptual understanding and problem solving (Leung, 2006). Furthermore, research has demonstrated that such activities can be an obstacle and a significant impediment to math performance and achievement.

2.2 Previous studies on the use of interactive online whiteboards in mathematics education

The use of IOWBs as a teaching and learning tool, particularly in secondary and higher education mathematics contexts, has increased significantly in the past decade (De Vita et al., 2018a; Glover and Miller, 2001; Heemskerk et al., 2014; Kaufman, 2009; Mercer et al., 2010). IOWBs provide a common platform for sharing notes, images and drawings over the internet, which supports learners' engagement and interactions in a remote online learning environment (Remón et al., 2017; Smith et al., 2006). With the adoption of IOWBs, teachers are not only able to explain mathematical concepts and ideas remotely and synchronously to their students as if in the conventional classroom context, but they can also better connect with their students asynchronously (Hakami, 2014; Kent, 2006; Ng et al., 2020; Wall et al., 2005). Though previous studies have demonstrated enhanced learner motivation, achievement and subject performance using IOWBs in a mathematics class context, we believe further studies are warranted to specifically understand how IOWBs interact with, for example, collaborative problem-based active learning pedagogies, to support teaching and learning (De Vita et al., 2018b; Digregorio and Sobel-Lojeski, 2010; Swan et al., 2008; Torff and Tirotta, 2010).

2.3 Collaborative problem-based learning as an active learning approach

The concept of collaborative problem-based learning, as an active learning method, has been widely researched and investigated in academic literature and research (Bossert, 1988; Nokes-Malach et al., 2015; Slavin, 1980). Collaborative problem-based learning, both technology-supported and face-to-face, is an extensively used pedagogical approach in which learners actively participate in learning activities, by working purposefully together in small groups to complete distinct problem-based tasks and achieve certain learning objectives (Alavi, 1994; Ergulec, 2019; Webb et al., 1995). Numerous studies have demonstrated that the collaborative problem-based learning methods have significant positive effects on individual as well as group achievement, performance and learning outcomes (Cen et al., 2016; Kirschner et al., 2011; Panitz and Panitz, 1998; Zhu, 2012). Hence, research has conclusively shown that collaborative problem-based learning, which is considered central to group interaction, not only enhances motivation and facilitates achievement, but also increases learning gains at both the individual and group levels (Lazakidou and Retalis, 2010; Xie et al., 2019).

2.4 Peer assessment method

Peer assessment is inherently a social, collaborative and interactive learning process, whereby groups of learners rate their peers and mark and provide reciprocal feedback on other learners' work (Adachi et al., 2018; Boud et al., 1999). Peer assessment relates to the various aspects of the student learning process, including contributing towards the completion of group tasks and actively participating in group discussions with active involvement in decision-making related activities (Liu and Carless, 2006). Moreover, peer assessment allows students to evaluate or be evaluated by their peers and subsequently "judge and make decisions about the work of their peers against particular criteria" (Adachi et al., 2018, p.454). Hence, peer feedback allows learners to review, evaluate and comment on the work of their peers. Consequently, many assessment theorists advocate the significant positive implications of feedback on performance assessment tasks, specifically in terms of supporting improvement and progress in student learning and achievement (Orrell, 2006). Furthermore, peer feedback is viewed as a fundamental part of the learning experience, allowing learners to learn from their own active processing of information, thereby deepening their conceptual knowledge, understanding and retention of learning.

2.5 Collaborative problem-based learning and peer assessment (Co-PBLa-PA) method

Based on the relevant literature discussed above, which sets the context for this study, the Co-PBLa-PA method is described as a learner-centred pedagogical method that allows learners to: 1) collaborate with peers in group-based learning tasks; 2) interact and engage in problem-based anchored instruction whilst working in small groups to solve problems by asking questions, posing possible solutions and building consensus; and 3) review and assess each group's efforts through peer grading and peer feedback to enhance group peer problem-based learning and assessment.

Next, we describe the Co-PBLa-PA method supported by IOWBs within the context of the following four stages, which is a more simplified approach than the original four steps proposed by Ng et al. (2020): 1) prepare, 2) discuss, 3) peer assess and 4) summarise. In the 'prepare' stage, instructors and/or students develop and formulate questions or problems that each of the groups will attempt to answer in the subsequent stages. Moreover, in this stage, each group may be assigned an identical problem in the form of a question, or different questions or problems may be given to different groups to solve. Students can also create their own questions for other groups to solve. In the 'discuss' stage, student groups spend time attempting to answer the prepared questions. This stage is aimed at tackling and solving the problems collectively as a group, eventually reaching a consensual solution or agreement to the question or problem being posed. In the 'peer assess' stage, groups peer assess/evaluate the answers of other groups by critiquing and providing constructive feedback on their peers' work, and receiving feedback on the performance of their own group. Thus, in this stage, students are encouraged to interact, evaluate the performance of others and provide assessments of each other's work at the group level, rather than at the individual level. Finally, in the 'summarise' stage, the teacher or instructor discusses and/or summarises with students the work and contribution of each group.

2.6 Review of collaborative problem-based learning and peer assessment (Co-PBLa-PA) method on students' learning approaches

We believe that applying the Collaborative Problem-Based Learning and Peer Assessment (Co-PBLa-PA) method can support learners' capacity for deep learning and enhanced cognitive processing. From a cognitive perspective, the Co-PBLa-PA method focuses on applying cognitive skills through group problem solving tasks and activities and subsequently, applying higher-order cognitive skills such as analysis, synthesis and evaluation to make learning more meaningful. From a constructivist perspective, the Co-PBLa-PA method focuses on how learners co-construct meaning from pre-existing knowledge and then develop and apply new knowledge to solve specific problems. Hence, we believe the Co-PBLa-PA method can effectively be applied to support deep approaches to learning, in which learners engage with concepts, ill-structured problems are presented and examples drawn from real-world applications and problems (Chin and Chia, 2006). Moreover, our research reveals that collaborative problem-based learning is more compelling and more pedagogically sound than individual problem-based learning, as it supports both higher-level and deep learning outcomes through engagement, participation and interactions at the group, rather than at the individual level. Hence, existing literature on collaborative problem-based learning suggests that collaboration produces deeper learning outcomes when learning is directed towards learner-driven tasks comprised of deep conceptual understanding, high-quality discourse and assessment feedback (Laurillard, 2009). Finally, the inclusion of peer assessment serves as a powerful pedagogical method to support deep learning and higher order thinking skills. Numerous studies have affirmed that peer assessment supports deep learning, whereby learners meaningfully engage with each other to complete tasks through interaction, evaluating the performance of others and providing assessments of each other's work (Gielen and De Wever, 2012; Phielix et al., 2010).

By building on the work of two separate studies conducted by Entwistle and Ramsden (1993); Marton and Säaljö (1976) and Biggs (1987) identified three distinct elements of learning approaches: (1) the deep approach to learning that focuses on intellectually stimulating tasks and/or activities that evoke a sense of interest, thereby engaging the learner; (2) the surface approach which is characterised by passive rote memorisation and the acquisition of sufficient knowledge to complete the task, and (3) the achieving approach which focuses on performance strategies with added emphasis on the need for achievement. Moreover, each approach is comprised of the following two elements: (1) learning motives, and (2) learning strategies to further delineate the learners' learning behaviours, encompassing deep motive, deep strategy, surface motive, surface strategy, achievement motive and achievement strategy (see Table 1 below). Consequently, combinatory aspects of motives and strategies bring about various types of learners. Furthermore, the study process questionnaire, developed by Biggs (1979) was specifically designed to assess students' learning approaches, their motives for learning a task and the strategies they used to approach the task. Deep and surface approaches are characterised by the methods through which learners engage in the context of performing the actual task itself. This also implies that learners adopt varied and variable forms of learning approaches. Deep approaches, for example, emphasise intrinsic learning interest and maximising meaning, while surface approaches are generally associated with a congruent strategy for memorising learning materials selectively.

Table 1 Learning approaches with corresponding subscales and descriptions (Biggs, 1987)

Scale	*Subscale*	*Description*
Deep Approach	Deep Motive	Learners' intrinsic interests in learning or evoking satisfaction and appeal through engagement of the tasks or activities (i.e., the degree to which the task or activity engages the attention of the learner).
	Deep Strategy	Meaningful strategies that maximise learning (i.e., integrating knowledge with evidence-based practice, case-based reasoning, drawing inferences, relating facts to past experiences, etc.).
Surface Approach	Surface Motive	Characterised by extrinsically motivated behaviour in which the primary aim of the learner is to meet the minimal academic requirements for assessment by exerting the least effort.
	Surface Strategy	Characterised by rote learning of material, memorisation of facts and content-based knowledge (i.e., recalling and reproducing facts, content memorisation and repetitive practices, etc.).
Achievement Approach	Achievement Motive	Characterised by an intrinsic desire and innate need to produce desired outcomes, attaining a high standard of success, and mastering complex tasks and challenges.
	Achievement Strategy	Characterised by purposeful actions and effort to achieve personal learning goals and master determined competencies.

To conclude this section, to date only a modest number of investigations have focused specifically on the use of combining collaborative problem-based learning models with instructional technologies such as IOWBs, in a mathematics online virtual context (Önal, 2017). Furthermore, a very limited number of studies using the Study Process

Questionnaire (SPQ) have been able to demonstrate deep learning approaches in group-based technology-enabled learning activities. The relevance of this study lies in the fact that through careful and deliberate pedagogical planning and design around technology-enabled active learning contexts, the effects of a Collaborative Problem-based Learning and Peer Assessment (Co-PBLa-PA) method on students' learning approaches using IOWBs, could potentially contribute to deep learning strategies and higher-order cognitive skills including improved student learning, engagement and achievement. To this end, this paper examines the effects that the Co-PBLa-PA method has on students' learning approaches using IOWBs in a Form 1 secondary school mathematics class in Hong Kong, with the objective of increasing students' deep approaches to learning.

3 Research objective and hypotheses

Specifically, the intent of this study is to assess the effects of the Collaborative Problem-based Learning and Peer Assessment (Co-PBLa-PA) method on students' learning approaches using IOWBs in a Form 1 secondary school mathematics class in Hong Kong. Consistent with the related literature discussed above, this study proposed to test the following hypotheses:

H_1: Applying a Collaborative Problem-based Learning and Peer Assessment (Co-PBLa-PA) method using IOWBs has a significant positive effect on students' learning performance as compared to a traditional teaching method.

H_2: Applying a Collaborative Problem-based Learning and Peer Assessment (Co-PBLa-PA) method using IOWBs is a significant predictor of a Deep Approach (DA) to learning.

H3: Students' perceptions of Technology-Enabled Active Learning (TEAL) using IOWBs are a significant predictor of a Deep Approach (DA) to learning.

4 Research methodology

4.1 Research setting and activity

For this study, a non-random purposive sampling methodology was adopted, based on both the aim of the study and characteristics of the population in the study. A purposive sampling method was considered methodologically appropriate for this study as it was deemed practical in ensuring a representative sample of the study population (Etikan et al., 2016). All procedures of the study were executed with informed consent from participants before the commencement of the study and in accordance with ethical standards and requirements. Accordingly, a total of 87 ($N = 87$) Form 1 secondary school students in Hong Kong, taking a mathematics class on the topic of 'angles related to parallel lines,' fit appropriately within the scope and intent of this study. The classes provided students with an understanding of the concepts of corresponding angles, alternate angles and interior angles, with added emphasis on recognising the angle properties associated with parallel lines.

Selection of classes for the study was based on two criteria. Firstly, the classes provided a unique setting in which to embed a Collaborative Problem-based Learning and Peer Assessment (Co-PBLa-PA) method into a secondary school mathematics curriculum. This approach also allowed students to benchmark their performance in relation to the course learning outcomes. Secondly, the Co-PBLa-PA method of instruction using IOWBs was carefully designed and structured into each class, allowing students to visualise the geometry questions through graphic and interactive means. For example, students could work on the questions of corresponding angles, alternate angles and interior angles by writing and drawing on the diagrams directly using the IOWBs, thereby encouraging them to defend their position by illustrating and explaining their answers in a systematic and logical way. Through collaboration and peer assessment, students were not only able to discuss their possible solutions, exchange ideas and provide constructive feedback by offering explanations and proposed solutions to mathematical problems, but this method also enabled them to learn from each other as well. Similarly, by observing students' answers on the IOWB, teachers were able to evaluate their students' conceptual understanding of specific topics, i.e., what their students understood and the concepts with which they experienced difficulty and therefore, failed to grasp.

4.2 Technology

The instructional tool selected for this study was Conceptboard (https://conceptboard.com/), an online digital cloud-based virtual collaboration application that enables users to work together by seamlessly integrating text with visual content, allowing users to interact simultaneously in both real-time and asynchronously by connecting to an infinite canvas, accessed through the users' mobile devices (i.e., iPads, mobile phones and tablets). Besides video chat and social sharing features, users are able to embed and upload audio, video, images and Conceptboard templates directly into the Conceptboard web app.

4.3 Class procedure

When designing the Collaborative Problem-based Learning and Peer Assessment (Co-PBLa-PA) instructional activity for the class, it was necessary to take into consideration the teaching and class materials and class objectives. For this study, Conceptboard, an IOWB that supports learner interactivity, was used to support a Collaborative Problem-based Learning and Peer Assessment (Co-PBLa-PA) method. A screen-capture of the Conceptboard interface, using the Co-PBLa-PA method, is depicted in Figure 1 below. In the context of a Form 1 secondary school mathematics lesson on the topic of 'angles related to parallel lines', the Co-PBLa-PA method, using Conceptboard was adopted, comprising of five main procedural steps (see Table 5 below).

In the first step, the teacher introduced the topic and worked out some examples to illustrate the mathematical concepts under discussion. In the second step, students were assigned into nine groups with each group comprised of four students assigned to a single board section in Conceptboard, and then tasked with solving a pre-designed geometry problem using their touch-screen devices. During this step, the teacher moved around the class to ensure students were able to complete the task appropriately and with minimal assistance. In the course of the third step, after each of the groups solved their assigned geometry problem, they were then asked to mark, evaluate and comment on the other groups' work in respect to: (a) the calculation methods; (b) the method by which answers were presented; (c) the accuracy of the answers, and (d) the unit and symbols used in the answers. In step four, after marking the other groups' work, each group was tasked with making a brief presentation and commenting on their marked work. Finally, in step five, the teacher clarified concepts, highlighted key points, summarised the main ideas to round up the lesson and cleared any misunderstandings or confusion among the groups by addressing common mistakes and misconceptions. Moreover, the teacher also provided both group and individualised feedback, asking each student questions and observing their work, thereby ensuring every student participated and contributed to solving the questions. In this particular lesson, students were divided into nine groups to discuss, interact and to solve the questions collaboratively in groups. Students were able to draw their solutions on the online whiteboard and mark the work done by other groups after they had completed their own tasks.

Figure 1 Screen-capture of the conceptboard interface using the Co-PBLa-PA method on the topic of 'angles related to parallel lines'

4.4 The instruments

In this study, data yielding 87 usable samples were collected using two self-reported instruments (SPQ and TEAL) to 1) assess the effects of the Collaborative Problem-based Learning and Peer Assessment (Co-PBLa-PA) method on students' learning approaches using IOWBs and to 2) determine if students' perceptions of active learning in a technology-enabled learning context are a significant predictor of a Deep Approach (DA) to learning.

In order to accommodate the language proficiency level of junior secondary school students, the two instruments, the SPQ and TEAL, originally developed in English, were formally translated into Chinese through a rigorous forward-backward translation procedure to ensure translation equivalence and reliability. Moreover, a bilingual version of the two instruments was used in this study to ensure students understood the wording and meaning of each item question. The first instrument, the Study Process Questionnaire (SPQ) developed by Biggs (1987) was utilised to specifically determine students' approaches to learning. Moreover, the SPQ, a widely recognised research tool, which has been extensively used and studied to examine learning behaviours in a higher education context, measures two main aspects associated with learning: a deep learning approach and a surface learning approach. Numerous studies have used various forms of the instrument in different educational contexts (Fryer et al., 2012; Sharma et al., 2013; Zakariya et al., 2020). In this study, we adopted the Revised Two-Factor Study Process Questionnaire (R-SPQ-2F) developed by Biggs et al. (2001). The modified version comprised of 20 items characterised by two main scales of learning approaches, Deep Approach (DA) and Surface Approach (SA), with four sub-scales: DM = Deep Motive, DS = Deep Strategy, SM = Surface Motive, SS = Surface Strategy (see Table 2 below). Each subscale comprised of five items and a five-point Likert scale was used to score the responses on each item.

Table 2 Scale and items of the revised two-factor study process questionnaire (R-SPQ-2F) (Biggs et al., 2001)

Scale	*Subscale*	*Item*	
Deep Approach (DA)	Deep Motive (DM)	Q.1	I find that at times studying gives me a feeling of deep personal satisfaction. 我發現，有時候學習會使我感到很滿足。
		Q.5	I feel that virtually any topic can be highly interesting once I get into it. 我認為，一旦我投入到任何的課題中， 我都會覺得非常有趣。
		Q.9	I find that studying academic topics can at times be as exciting as a good novel or movie. 我發現， 在研究學術課題時，有時候就像一本精彩的小說或電影， 一樣地令人興奮不已。
		Q.13	I work hard at my studies because I find the material interesting. 我會努力學習是因為我覺得教材很有趣。
		Q.17	I attend most classes with questions in mind that I want answered. 我常常上課都是帶著問題來的，並希望得到解答。

Table 2 Scale and items of the revised two-factor study process questionnaire (R-SPQ-2F) (Biggs et al., 2001) (continued)

Scale	*Subscale*	*Item*	
	Deep Strategy (DS)	Q.2	I find that I have to do enough work on a topic so that I can form my own conclusions before I am satisfied. 我發現，在我滿意之前，我會在一個課題上不斷研究，直到總結出自己的結論為止。
		Q.6	I find most new topics interesting and often spend extra time trying to obtain more information about them. 我發現大多數新的議題都很有趣，而且我會經常花額外的時間來獲取更多相關的資訊。
		Q.10	I test myself on important topics until I understand them completely. 我會對重要的課題進行反覆測驗，直到我完全理解其內容為止。
		Q.14	I spend a lot of my free time finding out more about interesting topics which have been discussed in different classes. 我會花費大量的空閒時間，了解更多有趣課題的相關資訊，因為這些課題在不同的課程裡都有涉及過。
		Q.18	I make a point of looking at most of the suggested readings that go with the lectures. 我特別著重要一邊上課一邊參考建議讀物。
Surface Approach (SA)	Surface Motive (SM)	Q3.	My aim is to pass the course while doing as little work as possible. 我的目標是做盡可能少量的工作來通過課程考核。
		Q.7	I do not find my course very interesting so I keep my work to the minimum. 我認為課程內容不是很有趣，所以我才將工作量降至最低。
		Q.11	I find I can get by in most assessments by memorising key sections rather than trying to understand them. 我發現，我可以通過記憶課題關鍵部分而不是透過試圖理解課題本身來通過大多數的評估。
		Q.15	I find it is not helpful to study topics in depth. It confuses and wastes time, when all you need is a passing acquaintance with topics. 我發現深度研究課題是沒有任何幫助的，這會使人感到困惑，並浪費時間。因為您只需要熟習課題並足以應付課程考核。
		Q.19	I see no point in learning material which is not likely to be in the examination. 我認為學習不太會在考核範圍內的內容是毫無意義。
	Surface Strategy (SS)	Q.4	I only study seriously what is given out in class or in the course outlines. 我只會認真研究課堂上或課程大綱中給出的內容。

Table 2 Scale and items of the revised two-factor study process questionnaire (R-SPQ-2F) (Biggs et al., 2001) (continued) (continued)

Scale	*Subscale*	*Item*	
		Q.8	I learn some things by rote, going over and over them until I know them by heart even if I do not understand them. 我會死記硬背地學習一些事物，即使完全不懂也要反覆去看，直到心領神會為止。
		Q.12	I generally restrict my study to what is specifically set as I think it is unnecessary to do anything extra. 我一般會把學習的內容限制在設定的範圍內，因為我認為沒有必要做任何額外的事情。
		Q.16	I believe that lecturers should not expect students to spend significant amounts of time studying material everyone knows will not be examined. 我認為老師不應冀望學生會花費大量時間來學習大家都知道不會考核的內容。
		Q.20	I find the best way to pass examinations is to try to remember answers to likely questions. 我發現考試合格的最好方法就是盡量把可能會出現的問題答案給背起來。

The second instrument, the Technology-Enabled Active Learning Inventory (TEAL) was developed to measure the degree by which individual students view active learning in a technology-enabled learning context (Shroff et al., 2019). The self-reporting instrument consists of four scales – interactive engagement (ITR), Problem-Solving Skills (PRS), Interest (INT) and Feedback (FEE), that allow participants to rate their perceptions of active learning in a technology-enabled learning context (Shroff et al., 2019). The interactive engagement (ITR) scale is characterised by active participation and involvement through learner–content interaction, learner-interface interaction and learner-peer interaction. The Problem-Solving Skills (PRS) scale is characterised by cognitive activities in which learners systematically apply appropriate skills by making connections to previous knowledge, synthesising and defining concepts and interpreting and evaluating ideas. The interest (INT) scale is characterised by the learners' attraction towards a specific activity and their predisposition to exploring opportunities to acquire skills and knowledge to learn that specific activity in authentic and meaningful ways. Finally, the feedback (FEE) scale refers to specific information communicated and presented to learners that allows them to evaluate and subsequently promote reflection on their own performance. Table 3 below lists the 20 items, with each item answered on a Likert scale ranging from 1 to 5.

Table 3 Scale and items of the technology-enabled active learning inventory (TEAL) (Shroff et al., 2019)

Scale	*Item*	
	Using Conceptboard	
Interactive Engagement (ITR)	Q.1	Allowed me to respond expediently to my actions, resulting in a fully responsive interaction. 讓我能夠對我的行動作出迅速的反應，從而實現了一個有充分回應的互動。
	Q.5	Enabled me to skilfully interact with the features in a responsive manner. 使我能夠以靈敏回應的方式技巧地與功能作出互動。
	Q.9	Allowed me to actively engage with the user-interface in a way that promotes dialogue. 讓我能夠以促進對話的方式積極地與用戶界面進行互動。
	Q.13	Helped me to interact more effectively with peers through an engaging interface. 通過引人入勝的界面幫助我更有效地與朋輩互動。
	Q.17	Facilitated the exchange of information by engaging with content presented in diverse formats. 通過各種不同格式呈現的內容來促進信息交換。
	Using Conceptboard	
Problem-Solving Skills (PRS)	Q.2	Allowed me to methodically generate ideas by contributing information from multiple viewpoints. 讓我能夠透過多角度提供信息來有條不紊地產生想法。
	Q.6	Enabled me to solve a problem systematically by taking into account different points of view. 使我能夠通過考慮不同的觀點來有系統地解決問題。
	Q.10	Encouraged me to think critically about the broader concepts related to the problem. 鼓勵我批判地思考與問題有關的更廣泛概念。
	Q.14	Let me analyse my own views and their wider contexts in order to draw firm conclusions. 讓我分析我的觀點及其更廣泛的語境，以便得出堅定的結論。
	Q.18	Allowed me to define the problem systematically by viewing it from different angles in an effort to find possible solutions. 讓我能夠通過從不同的角度有系統地界定問題所在，以期找到可能的解決方案。
	Using Conceptboard	
Interest (INT)	Q.3	Allowed me to engage in thought-provoking dialogue with points of view that challenged my perspectives. 讓我能夠投入地與挑戰我觀點的人進行發人深省的對話。
	Q.7	Encouraged me to explore a variety of different issues that I may not have otherwise considered. 鼓勵我探索各種各樣我可能未曾考慮過的不同問題。
	Q.11	Piqued my curiosity by exploring various options when navigating the user interface. 在瀏覽用戶界面時通過探索各種選項激發了我的好奇心。

Table 3 Scale and items of the technology-enabled active learning inventory (TEAL) (Shroff et al., 2019) (continued)

Scale	*Item*	
	Q.15	Held my attention by challenging me to look into issues that I may not have otherwise thought of. 通過挑戰我去研究那些我可能沒有想到的問題來吸引我的注意力。
	Q.19	Encouraged me to exert effort in the face of difficulty by persisting at tasks I found challenging. 通過堅持執行我覺得具挑戰性的任務來鼓勵我在困難面前竭盡全力。
	Using Conceptboard	
Feedback (FEE)	Q.4	Allowed me to receive timely feedback that helped me improve my performance. 讓我能夠獲得適時有助改善我表現的回饋。
	Q.8	Enabled me to receive inputs, so that I was able to keep track of my own performance. 使我能夠獲取資訊，以便我能夠跟進我的表現。
	Q.12	Allowed me to receive prompt feedback, so that I was aware of my own progression towards knowledge acquisition. 讓我能夠收到及時的回饋，以便我察覺到自己在獲取知識方面的進展。
	Q.16	Allowed me to receive prompt feedback, so that I was aware of my own progression towards mastery of my skills. 讓我能夠及時收到回饋，以便我察覺到自己在掌握技能方面的進展。
	Q.20	Enabled me to receive responses that allow further understanding. 使我能夠收到讓我進一步理解的回應。

5 The main empirical study

For this study, a sample size of 87 (N = 87) respondents was selected and a non-probability purposive sampling method was employed. The rationale for selecting a purposive sampling method is that it is widely used for exploratory research. Moreover, a quasi-experimental design consisting of an experimental and control group, was employed to test the hypotheses introduced in Section 3. A quasi-experimental design is especially suited for testing hypotheses concerning cause-and-effect relationships and is typically employed when not all experimental conditions can be set and strictly controlled. Hence, because quasi-experimental designs do not involve random assignment of subjects, the subjects for this study were selected as opposed to being randomly assigned to their groups.

To determine the required number of subjects for this study, a power test was performed. With a sample size of 87 (N = 87) and a significance level of 0.05 and a test power of 0.95, the study had a power of 0.821 to yield a statistically significant result (Cohen, 1977). Hence, students taking the mathematics class on the topic of 'angles related to parallel lines', represented a sample size (n=87) adequate for statistical testing and analysis (Cochran, 1963).

Each class had an average class size of 30–35 students. The content material of the activities within each class was identical. Before each class, a pre-survey on students' learning approaches (R-SPQ-2F), was administered. Five mathematics classes running within the same week resulted in the following treatment groups (see Table 4 below):

Table 4 Treatment groups

Class	*Group*	*Treatment*	*Number of students*	*Number of students in Pre-Survey*	*Number of students in Post-Survey*	*Number of students in Test*	*Number of valid samples*
A	Experimental	Co-PBLa-PA	35	34	32	30	28
B	Experimental	Co-PBLa-PA	33	27	30	30	23
C	Control	Traditional Teaching	31	24	10	11	5
D	Control	Traditional Teaching	33	29	31	30	29
E	Control	Traditional Teaching	30	25	11	3	2
			162	139	114	104	87

In the first instance, students in the A and B experimental group class sessions were subjected to the Co-PBLa-PA method using the interactive online whiteboards. In the second instance, students in the C, D and E control group class sessions were subjected to the traditional teaching method, dominated by a teacher-centred and content-focused approach (see Table 5).

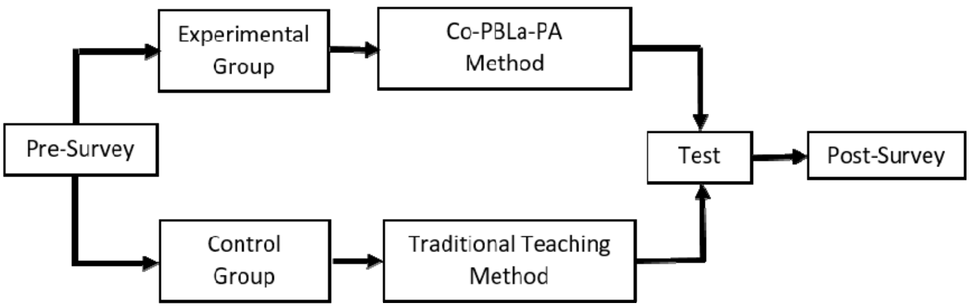
Table 5 Steps for teaching method of experimental and control groups

Groups	*Experimental groups*	*Control groups*
Teaching Methods	*Co-PBLa-PA Method*	*Traditional Teaching Method*
Classes	*Class: A, B*	*Class: C, D, E*
Step 1	Teacher introduced the topic and worked out some examples to illustrate the mathematical concepts under discussion.	
Step 2	Students were assigned into nine groups with each group comprised of four students assigned to a single board section in Conceptboard and then tasked with solving a pre-designed geometry problem using their touch-screen devices.	Students were asked to complete class exercises individually.
Step 3	After each of the groups solved their assigned geometry problem, they were then asked to mark the work of other groups.	
Step 4	Students comment on their marked work.	Teacher provides solutions and students mark their own exercises individually.
Step 5	Teacher clarified concepts, highlighted key points, summarised the main ideas to round up the lesson and cleared any misunderstandings or confusion among the groups/students.	
Evaluation	To evaluate students' learning performance, a test of 10 questions on the topic of 'angles related to parallel lines' was administered to both experimental and control groups at the end of the lesson. Students were required to complete the test in 10 minutes.	

To evaluate students' learning performance, a test of 10 questions on the topic of 'angles related to parallel lines' was administered to both experimental and control groups at the end of the lesson. Students were required to complete the test in 10 minutes. After completion of the test, a post-survey, the Revised Two-Factor Study Process Questionnaire (R-SPQ-2F) and Technology-Enabled Active Learning Inventory (TEAL) was administered to students to complete. It should be noted that the pre-survey, post-survey and the test were completed on a voluntary basis and that some students purposely or inadvertently skipped item questions they did not want to answer, felt uncomfortable answering or of which they were uncertain, thereby resulting in fewer responses for some of the questions in the pre-survey, post-survey and the test. In order to ensure total reliability, only those students who completed all the questions in the pre-survey, post-survey and the test were considered and counted as valid samples for this study.

Figure 2 below shows the process flow diagram of the experimental and control groups and their respective treatments with pre-survey, test and post-survey repeated measures. The two instruments served an important role in assessing the effects of the Co-PBLa-PA method on students' learning approaches using interactive whiteboards and determining if students' perceptions of active learning in a technology-enabled learning context are a significant predictor of a deep approach (DA) to learning.

Figure 2 Schematic flow diagram of experimental/control groups with pre-survey, test and post-survey repeated measures



6 Results and analyses

6.1 Hypotheses testing

In this section, the results of our exploratory research study are presented. For this study, an independent *t*-test was performed to test the mean differences of the experimental group and control group as well as to test each of the three hypotheses. Data were analysed using Statistical Package for the Social Sciences Version 24.0 (SPSS, Inc., Chicago, IL, USA). Statistical significance was set at $p < 0.05$ for all three hypotheses tests, while partial support was acknowledged at significance levels between 0.05 and 0.10.

H_1: Applying a Collaborative Problem-based Learning and Peer Assessment (Co-PBLa-PA) method using IOWBs has a significant positive effect on students' learning performance compared to a traditional teaching method.

For hypothesis 1, a *t*-test was performed to evaluate the effects of the Co-PBLa-PA method on students' learning performance using IOWBs compared to a traditional teaching method. Learning performance was measured by how well students scored (i.e., the total number of correct answers) on the 10-question test after being exposed to the experimental and control group treatments. On average, students in the control group scored 7.22 marks while those in the experimental group scored 7.31 marks, indicating that those students who were subjected to the Co-PBLa-PA method of instruction, using IOWBs, performed marginally better than students taught via the traditional teaching method of instruction. Moreover, results of the independent *t*-test indicated that there was no significant difference ($p=0.864$) in students' learning performance between the experimental groups (i.e., the Co-PBLa-PA method using IOWBs) and control groups (i.e., traditional teaching method) at the 0.05 level of variance (see Table 6).

Table 6 Independent sample *t*-test results for hypothesis 1

	Group	*N*	*Mean*	*Std. Deviation*	*t value*	*P-value*
Test	Control	36	7.22	2.07	–0.172	0.864
	Experimental	51	7.31	2.67		

Notes: ($p < 0.05$; $p < 0.10$)

H_2: Applying a Collaborative Problem-based Learning and Peer Assessment (Co-PBLa-PA) method using IOWBs is a significant predictor of a deep approach (DA) to learning.

For hypothesis 2, a *t*-test was performed to evaluate the effects of the Co-PBLa-PA method on students' deep learning approach, using IOWBs. Results of the independent *t*-test indicated no significant difference in the mean scores in all five learning approaches (DA, SA, DM, SM and SS) between the experimental and control groups in the pre-survey (see Table 7).

Table 7 Results of independent sample *t*-test (pre-survey)

Pre-survey		*Control (N = 36)*	*Experimental (N = 51)*	*t*	*P-value*
Deep Approach (DA)	Mean	3.447	3.453	–0.040	0.968
	SD	0.638	0.674		
Surface Approach (SA)	Mean	3.153	3.055	0.906	0.368
	SD	0.511	0.486		
Deep Motive (DM)	Mean	3.500	3.526	–0.151	0.880
	SD	0.749	0.795		
Deep Strategy (DS)	Mean	3.394	3.380	0.101	0.920
	SD	0.615	0.660		
Surface Motive (SM)	Mean	3.133	3.063	0.602	0.549
	SD	0.519	0.552		
Surface Strategy (SS)	Mean	3.172	3.047	0.983	0.329
	SD	0.601	0.574		

Note: ($p < 0.05$; $p < 0.10$).

However, in the post-survey, results of the independent *t*-test indicated a statistically significant difference between students in the experimental and control groups (see Table 8 below), which was significant at the 0.05 level. Furthermore, results showed that students in the experimental groups reported higher mean scores using the Deep Approach (DA) and Deep Strategy (DS) learning approaches, as compared to those in control groups, suggesting that the Co-PBLa-PA method of instruction using IOWBs, promoted both a Deep Approach (DA) (p=0.030*) and Deep Strategy (DS) (p=0.013**) approach among students, at the 0.05 and 0.10 level of significance, respectively.

Table 8 Results of independent sample *t*-test (post-survey)

Post-survey		*Control N = 36*	*Experimental N = 51*	*t*	*P-value*
Deep Approach (DA)	Mean	3.294	3.588	–2.212	0.030*
	SD	0.637	0.590		
Surface Approach (SA)	Mean	3.047	3.039	0.68	0.946
	SD	0.514	0.559		
Deep Motive (DM)	Mean	3.378	3.628	–1.651	0.102
	SD	0.803	0.608		
Deep Strategy (DS)	Mean	3.211	3.549	–2.547	0.013**
	SD	0.572	0.635		
Surface Motive (SM)	Mean	3.044	3.012	0.272	0.786
	SD	0.524	0.570		
Surface Strategy (SS)	Mean	3.050	3.067	–0.121	0.904
	SD	0.615	0.642		

Notes: (**p <0.05; *p <0.10).

H_3: Students' perceptions of technology-enabled active learning using IOWBs are a significant predictor of a deep approach (DA) to learning.

For hypothesis 3, a correlational analysis was performed between students' self-reported levels of technology-enabled active learning using IOWBs and students' deep approach (DA) to learning. Using Pearson's correlation, we confirmed in the post-survey of students in the experimental groups (N=51), a statistically significant correlation (**p <0.05; *p <0.10) between the four constructs of technology-enabled active learning (i.e., interactive engagement (INT) (r = 0.590**), problem-solving skills (PRS) (r = 0.627**), interest (INT) (r = 0.592**), and feedback (FEE) (r = 0.561**) and a deep approach (DA) to learning (see Table 9). Moreover, we also found a statistically significant correlation between the four constructs of technology-enabled active learning and a deep motive (DM) and deep strategy (DS) approach to learning.

Table 9 Pearson's correlation results

		ITR	*PRS*	*INT*	*FEE*
PostDA	Pearson Correlation	.590**	.627**	.592**	.561**
	Sig. (2-tailed)	.000	.000	.000	.000
	N	51	51	51	51
PostSA	Pearson Correlation	.246	.202	.163	.163
	Sig. (2-tailed)	.082	.154	.252	.253
	N	51	51	51	51
PostDM	Pearson Correlation	.568**	.604**	.598**	.541**
	Sig. (2-tailed)	.000	.000	.000	.000
	N	51	51	51	51

Table 9 Pearson's correlation results (continued)

		ITR	*PRS*	*INT*	*FEE*
PostDS	Pearson Correlation	.554**	.588**	.528**	.524**
	Sig. (2-tailed)	.000	.000	.000	.000
	N	51	51	51	51
PostSM	Pearson Correlation	.239	.204	.189	.194
	Sig. (2-tailed)	.091	.152	.185	.173
	N	51	51	51	51
PostSS	Pearson Correlation	.216	.171	.117	.111
	Sig. (2-tailed)	.129	.230	.415	.437
	N	51	51	51	51

Note: (**p <0.05; *p <0.10).

7 Discussion, limitations and future directions

The objective of this study was to examine the effects of the Collaborative Problem-based Learning and Peer Assessment (Co-PBLa-PA) method on students' learning approaches using IOWBs in a Form 1 secondary school mathematics class in Hong Kong. Specifically, data were analysed using *t*-test and correlational design to test each of the hypotheses developed for this study.

For hypothesis 1, a *t*-test was conducted to evaluate the effects of the Co-PBLa-PA method on students' learning performance using IOWBs compared to a traditional teaching method. The data indicated that there was no significant difference (p=0.864) in students' learning performance between the experimental groups (i.e., the Co-PBLa-PA method using IOWBs) and control groups (i.e., traditional teaching method), thereby denoting non-significance at the 0.05 level. The results suggest that a longer period for implementation of the Co-PBLa-PA method may be warranted, which may explain why there was no statistical difference between the groups. Moreover, the relatively low number of subjects in the study may explain why there was no statistical difference. We believe an increase in the sample size may have helped to further elucidate and clarify this issue, in terms of providing statistical significance. Hence, if the sample size had been greater, the effect would have been more statistically significant.

For hypothesis 2, a *t*-test was conducted to evaluate the effects of the Co-PBLa-PA method on students' deep learning approach, using IOWBs. The data indicated that there was no significant difference at the pre-survey stage. Before the implementation of the Co-PBLa-PA method, students had been taught using the traditional teaching method and this could explain why there may not have been a significant difference in students' deep approach to learning at the pre-survey stage. However, in the post-survey stage, the data indicated that the Co-PBLa-PA method of instruction using IOWBs, promoted both a Deep Approach (DA) (p=0.030) and Deep Strategy (DS) (p=0.013) approach among students, at the 0.05 and 0.10 level of significance, compared to those in control groups. This result demonstrates that the effects of the Co-PBLa-PA method on students' deep learning approaches were significantly greater in the post-survey stage, as compared to the pre-survey stage, indicating a higher student preference toward the Co-PBLa-PA method of instruction using IOWBs than the traditional teaching method.

For hypothesis 3, a correlational analysis was conducted to assess the degree of association between students' self-reported levels of technology-enabled active learning using IOWBs and students' deep approach (DA) to learning. A statistically significant correlation was found (**p <0.05; *p <0.10) between the four constructs of technology-enabled active learning and a deep approach (DA) to learning. This result may indicate the perception that technology-enabled active learning contexts, such as the use of interactive online whiteboards, are effective in engaging students interactively, by helping them to understand key concepts, enabling and empowering them to answer questions by employing their problem-solving skills, and subsequently allowing them to explore and share different conceptual ideas through peer assessment and feedback.

In terms of limitations, it should be noted that generalisability of the research findings is limited owing to the small sample size and exploratory nature of the study. Hence, findings of this study should be viewed as preliminary until replicated with larger samples and more diverse populations and settings to further substantiate the findings and conclusions from this exploratory study. Thus, because the data were collected from local Hong Kong secondary school students, further research is warranted in order to generalise these results to other cultures, contexts and populations. Furthermore, when the research design incorporates a quasi-experimental non-probability purposive sampling method and self-reported data, this may also lead to response and sampling bias.

Finally, the results of this study can be used as a baseline for future work, which could be extended to other subject areas at the secondary and tertiary levels. Future studies could also build on the findings from this study to examine the impact of the Co-PBLa-PA method of instruction on students' motivational strategies and performance in other technology-enabled active learning contexts. Future research could also include studies on the correlation between different methods of instructional delivery (Co-PBLa-PA method versus traditional face-to-face in class instructional method) on students' assessment preferences and their approaches to learning. Other areas for future research could additionally include both qualitative and quantitative approaches by analysing teachers' perceptions of the Co-PBLa-PA method and traditional classroom method in conjunction with the technologies used.

8 Conclusions

During the unprecedented COVID-19 crisis, it is clear that pedagogical innovations in teaching and technology have provided significant opportunities for teachers, instructors and educators to explore various means and methods of how to best deliver content online through the use of novel technology-enhanced active learning pedagogies, in order to engage their learners in new ways of learning and interacting both inside and outside of the classroom. This study is a significant first step towards understanding the effects of a Collaborative Problem-based Learning and Peer Assessment (Co-PBLa-PA) method on students' learning approaches using IOWBs in a Form 1 secondary school mathematics class in Hong Kong. Results from the study provide preliminary evidence to suggest that the effects of the Co-PBLa-PA method of using IOWBs on students' deep learning approaches were significantly greater in the post-survey stage as compared to the pre-survey stage. Moreover, our data indicated a statistically significant correlation between the four constructs of technology-enabled active learning and a Deep Motive (DM) and

Deep Strategy (DS) approach to learning. Hence, the findings of this study supported the assertion that students generally perceived the Co-PBLa-PA method using IOWBs as positively beneficial and indicative of their deep motive (DM) and deep strategy (DS) approach to learning in a secondary school mathematics context.

The significance of this study is three-fold: Firstly, this study aims to describe the development and implementation of a novel pedagogy, the Co-PBLa-PA methodology, which is conceived as an experimental pedagogy in a technology-enabled active learning context. Secondly, this study used two instruments, one established instrument and another developed instrument to provide quantitative assessments with statistical significance. This formed the basis for establishing testing protocols for this type of study and providing benchmark examples for future research studies. Finally, the results presented in this paper serve as a catalyst for future studies by shedding light on alternative and novel instructional design methods and pedagogical approaches to teaching, learning and peer assessment.

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