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The Effect of Constructivist Instruction on Learning Engagement in Mathematics Lessons: A Flow Theory Perspective

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The aim of this study is to examine the effect of constructivist instruction on secondary school students' learning engagement, measured as the psychological state of flow, in mathematics lessons. Ninth grade students (n = 144) from two Singapore secondary schools were assigned to receive either constructivist or traditional direct instruction for the learning of a unit on angle properties of circles. Mixed analyses of variance revealed that students who received constructivist instruction reported higher levels of engagement compared to their direct instruction counterparts. In addition, the results showed that students' learning engagement decreased over the course of the instructional unit, and that constructivist instruction could potentially offset this negative trend. Overall, the findings suggest that instruction that is founded on constructivist principles may be promising in mitigating engagement issues, thus promoting the joy of learning mathematics among secondary school students.

Keywords: constructivist instruction, flow, inquiry, learning engagement, direct instruction

Introduction

Learning engagement is the outward manifestation of learning motivation and a proximal predictor of students' mathematics achievement (Fung et al., 2018; Putwain et al., 2019; Skinner et al., 2009). However, a growing body of research indicates that a significant number of secondary school students (grade 7-10) are not engaged in learning activities, especially those in mathematics. Daschmann et al. (2011) noted that 44.3% of grade 5-10 students agreed or partly agreed that they were frequently bored in mathematics classes. Pöysä and colleagues (2018), on the other hand, showed that secondary school students were likely to report lower levels of behavioural and cognitive engagement in mathematics lessons than in other academic (e.g., science) and non-academic (e.g., home economics) subjects. Internationally, data from the 2012 Programme for International Student Assessment (PISA; Organisation for Economic Co-operation and Development [OECD], 2013) revealed that only 53.1% of 15-year-old students across OECD countries were interested in the things they learned in mathematics, while fewer than 40% of the students did mathematics because they enjoyed it. More recently, data from the 2019 Trends in International Mathematics and Science Study (TIMSS; Mullis et al., 2020) showed that approximately 41% of 8^{th} grade students did not like learning mathematics.

Given that student engagement is formed "in transaction with the context in which [students] study and learn" (Pöysä et al., 2018, p. 65), it is possible to mitigate engagement problems in class via instructional interventions that alter the students' learning environments and experiences (Pino-James et al., 2019). In particular, some education researchers (e.g., Sharrock & Rubenstein, 2019) have proposed the use of constructivist instruction—instructional models that are informed by constructivist learning theory principles—over the traditional transmissionist or direct instruction approaches that are informed by behaviourist and cognitivist principles. Although these two instructional approaches do not necessarily oppose one another, they differ in the kinds of learning activities that they offer (Mayer, 2009). Specifically, direct instruction involves the provision of passive activities (e.g., lectures) that focuses on the memorisation and mastery of mathematical facts and procedures. Constructivist instruction, in contrast, involves creating activity-based learning environments that keep students physically engaged in discovery, inquiry, and collaboration.

Since physical participation in classroom activities is viewed as an indicator of engagement, constructivist instructional models are often assumed to be natural remedies of engagement issues (Krahenbuhl, 2016). However, this assumption is questionable on two fronts. First, contemporary education researchers recognise that engagement is more than mere physical participation (i.e., behavioural engagement), and that the construct encompasses both affective (e.g., enjoyment) and cognitive (e.g., concentration) components as well (Fredricks et al., 2004). From this perspective, it is possible for a student to participate in an activity (e.g., exploratory task) yet not be fully engaged in it. Second, constructivism is a theory of active learning and does not dictate a particular learning design. As such, proponents of direct instruction argue that students could still be mentally active or constructive during passive activities if the design of these activities adheres to the cognitive load theory principles, i.e., reduce extraneous cognitive load for generative cognitive processing (Anthony, 1996; Mayer, 2009).

To better understand the effect of constructivist instruction on secondary students' engagement in mathematics learning, we compared the learning engagement of students who were taught via a learning design that was constructivist in orientation against those who underwent the conventional, direct instruction approach. The learning design in this paper, coined Constructivist Learning Design (CLD), was introduced in Singapore mathematics classrooms to expand Singapore mathematics teachers' pedagogical repertoire, enhance students' learning experience, and fulfil the Ministry of Education's aspirations to nurture students' joy of learning (Ng, 2017). Engagement in this paper is thus examined from a flow perspective (Csikszentmihalyi, 1990), which could shed light to the extent to which students enjoyed mathematics learning.

Defining Engagement

Research on student engagement has proliferated over the past two decades (Fredricks et al., 2004; Fredricks et al., 2016). Despite the increased interest, Azevedo (2015, p. 84) pointed out that engagement "is one of the most widely misused and overgeneralized constructs found in the educational, learning, instructional, and psychological sciences". It has been variedly described as students' motivation to learn, classroom behaviours, psychological investment in learning activities, relationship with teachers and peers, and school connectedness, to name a few (see Wong & Liem, 2022). Given the broad characterisation of student engagement, "it may be more fruitful to study specific aspects of this complex construct rather than striving for an all-encompassing, but overly generic definition" (OECD, 2021, p. 81).

In this study, we focused on students' learning engagement, or more specifically their engagement in classroom learning activities, and examined the construct from the flow theory perspective (Csikszentmihalyi, 1990). This perspective was leveraged given its emphasis on more affective and cognitive components of engagement, as well as its intimate relationship with intrinsic motivation, which involves students engaging in learning activities because they find them inherently enjoyable to do so (Ryan & Deci, 2000).

Psychological State of Flow. Drawing from flow theory (Csikszentmihalyi, 1990; Shernoff et al., 2003), this paper defines engagement as flow, and uses the term engagement and flow interchangeably. Also referred to as the psychological state of optimal experience, flow is characterised by intense and focused concentration, merging of action and awareness that results in distortion in temporal experience (i.e., feeling that time passes faster than normal), and intrinsic enjoyment during an activity. The concept of flow is rooted in the field of positive psychology, and it is often examined in studies on happiness, game design, and occupational well-being. In the context of education, flow has also been considered as a student engagement construct (e.g., see Shernoff et al., 2003). This is because the flow experience represents the manifestation of students' intrinsic motivation, and it describes how they feel (e.g., enjoyment) and think (e.g., absorption) during a learning task or event.

Time Scale of Engagement. Extant research on learning engagement predominantly focuses on students' long-term engagement, that is, students' general tendency to be engaged in learning or classroom activities (e.g., Skinner et al., 2009). However, recent studies have shown that there is substantial amount of variation in learning engagement between and within lessons (Pöysä et al., 2018; Shernoff et al., 2016). These findings prompted many education scholars to call for more research that examine engagement at a moment-to-moment or lesson-to-lesson time scale (OECD, 2021; Sinatra et al., 2015). Since engagement is a malleable construct that is highly dynamic and context dependent (Fredricks et al., 2004), such fine-grained analyses would enable us to observe patterns of engagement that would otherwise be obscured, and to identify the trajectory of engagement over a short time span. Even so, many of the existing studies that looked at students' moment-to-moment or lesson-to-lesson engagement tend to sample students' experiences across different subjects, and little is known about how engagement fluctuates between lessons of the same subject matter. In response to the gaps in research, the present study collected information on students' engagement after each mathematics class and explored its fluctuations within an instructional unit.

Predictors of Flow. Research has shown that flow is influenced by instructions that offer students positive feedback and a sense of optimal challenge, relevance, and autonomy during learning activities (Fong et al., 2015; Shernoff et al., 2003). More recently, Shernoff and colleagues (2016) suggested that engagement in learning activities arise from a reciprocal interaction between students and the learning environment that consists of both environmental challenge and environmental support. Environmental Challenge is defined by the activities, goals, structures, and expectations that guide students' behaviours and cognition. It describes the extent to which a learning environment provides (1) opportunities for students to learn and master concepts and employ higher-order thinking and reasoning skills; (2) challenging, complex, and situated tasks that are within the students' capacity; (3) clear learning goals that correspond to students' personal goals; (4) authentic activities that are important and relevant to students' life outside of school; and (5) clear expectations that the mastered competencies would be assessed based on an established standard.

On the other hand, Environmental Support is defined by the instrumental, social, and emotional resources that are available to help students overcome the environmental challenges. It describes the extent to which a learning environment provides (1) motivational support that would help satisfy the autonomy and competence needs of the students; (2) emotional support, with healthy teacher and peer relations that are characterised by mutual positive regard; (3) spaces for interactions among teachers and peers that lead to co-construction of knowledge; (4) timely and constructive performance feedback with effective scaffolding; and (5) opportunities for hands-on learning activities in the classroom. The descriptions of both environmental challenge and support (Shernoff et al., 2016), as we show in the next section, are aligned with the characteristics of a constructivist learning environment.

Constructivism and Constructivist Learning Design

Constructivism as a learning theory has a long history in mathematics education (Confrey & Kazak, 2006). It differs from behaviourism and cognitivism, which emerged from an objectivist tradition. Both behaviourism and cognitivism assume that knowledge is independent of the student, and that learning occurs when knowledge is transferred from the outside world to the mind of the learner. With this assumption, behaviourist and cognitivist instructional models like direct instruction are concerned with means in which information is presented (e.g., teaching via worked examples). In contrast to this position, the constructivist learning theory maintains that knowledge "is a function of how the individual creates meaning from his or her own experiences" (Jonassen, 1991, p. 10). Hence, constructivist instructional models are more concerned about the design of meaningful learning experiences that would promote student agency and sensemaking, rather than the delivery of information (see Ertmer & Newby, 2013 for a detailed comparison of the three learning perspectives).

Constructivist Tenets and Instructional Principles. There are numerous types of constructivism—radical, social, information-processing, to name a few (Karagiorgi & Symeou, 2005). Despite the differing viewpoints on constructivism, constructivist learning theorists embrace, to a greater or lesser extent, three core tenets.

The first tenet asserts that *students are active participants of learning* (Anthony, 1996). Rather than passively listening to a mathematics lecture, constructivists suggest that mathematics is best learned by actively participating in mathematical situations. To optimise learning, educators are encouraged to delay explicit instruction and allow students to engage in authentic and complex problem tasks that provide opportunities for exploration and invention, and for students to utilise "complex thinking and reasoning strategies that would be typical of "doing mathematics" (e.g., conjecturing, justifying, or interpreting)" (Henningsen & Stein, 1997, p. 529). Activities like these will not only help students to develop problem-solving skills (e.g., pattern-recognition skills) that go beyond the information given, but also enable them to construct the meaning of a concept that is embedded in the situation, and foster a sense of relevance, autonomy, and control over their own learning.

Second, *learning is dependent of the student's prior knowledge*. According to Piaget's (1980) theory of cognitive development, prior knowledge schemas are activated in response to a problem situation. Students employ their current understanding of the world to interpret and make sense of the situation, and assimilate new knowledge gained from the experience into their mental structure (Derry, 1996). When the experienced phenomenon conflicts with one's existing knowledge, it would induce a state of disequilibrium that motivates the learner to alter his or her pre-existing schemas to fit the new information. This process, which results in conceptual change, is known as accommodation. Acknowledging the importance of prior knowledge in learning, constructivist instruction typically seeks to challenge students' mathematical reasoning and understanding during a problem-solving activity and provide positive feedback by using students' conceptions to build towards the mathematical agenda (Kuster et al., 2017).

The third and last tenet indicates that *the construction of knowledge occurs through students' social interactions with more knowledgeable others* (Steele, 2001). When a student communicates their conceptions on a mathematical topic, it allows others to identify the student's current mathematical understanding and expand on it by adding new ideas and meanings into the mathematical discourse. This process is relevant to Vygotsky's (1978) notion of zone of proximal development (ZPD), defined as the difference between what a student can achieve independently and what he or she can do under the guidance from a skilled partner. From a ZPD perspective, peer and teacher mediation—in the form of instrumental, social, and emotional support—are essential to help the student to cross the gap of knowledge. This can be done via collaborative work with peers and teacher-led classroom discussions and demonstrations, with the teacher acting as a bridge between the class' current shared understanding and those of the broader mathematical community (Kuster et al., 2017).

Constructivist Learning Design. Translating the constructivist principles into practice, we developed a variant of constructivist instruction known as the CLD (Constructivist Learning Design) for the Singapore secondary mathematics curriculum (grade 7-10). Like many other constructivist instructional models, it "aims to provide generative mental construction "tool kits" embedded in relevant learning environments that facilitate knowledge construction by learners" (Karagiorgi & Symeou, 2005, p. 17). The CLD is made up of two teaching phases (see Table 1). In the problem-solving phase, students are asked to form groups with two to three members and in collaboration with their group members, explore and generate as many solutions as possible for an open-ended problem task that admits multiple solutions and multiple approaches toward reaching the solutions (Becker & Shimada, 1997). The problem task targets a concept that has not been formally introduced in class. Thus, students are likely to experience impasse during their problem-solving attempt. Nevertheless, the teacher is present to facilitate the session by providing cognitive (e.g., making sure that students understood the problem, challenging their conceptions by giving counterexamples) and affective (e.g., encouragement) support without revealing the solution to the problem.

In the instruction phase, the teacher consolidates the solutions that the students produced in the problem-solving phase and use them to teach the targeted concept. It involves comparing and contrasting the student-generated solutions and ideas, discussing their limitations and affordances, and relating them to the canonical concept to be taught. After the introduction of the targeted concept, students are given the opportunity to apply the newly gained knowledge via in-class and homework practices. They are also exposed to higher-order practice questions to challenge their thinking and broaden their understanding of the concept in question.

It is important to point out that a two-phase constructivist instructional model is not a novel conception in the mathematics education and instructional science literature. *Productive Failure* (PF; Kapur, 2008), *Inquiry-Oriented Instruction* (Kuster et al., 2017), *Cognitively*

Guided Instruction (Sharrock & Rubenstein, 2019), and *Invent-then-tell* (Schwartz & Martin, 2004) are some examples that have similar instructional design with the CLD. Notably, these instructional models allow students to participate in some forms of inquiry activities before the instruction of a concept. They differ from the traditional direct instruction (DI) approach, which involves "providing information that fully explains the concepts and procedures that students are required to learn as well as learning strategy support that is compatible with human cognitive architecture" (Kirschner et al., 2006, p. 75). Table 1 illustrates the difference in design between CLD and DI in the current study (see also Lee et al., 2021, for a detailed comparison of CLD and DI).

Table 1
Instructional Designs of CLD and DI Conditions

Phase Sequence	**Constructivist Learning Design (CLD)**	**Direct Instruction (DI)**
1	<u>Problem-Solving</u> Students work collaboratively in groups of 2-3 to solve a problem targeting a mathematical concept that they have yet to learn. The problem-solving activity takes approximately 45 minutes to complete.	<u>Instruction</u> Teacher directly teaches the targeted mathematical concept and shows how students could solve related problems via worked examples.
2	<u>Instruction</u> Teacher builds on the student solutions generated in the Problem-Solving phase to instruct the targeted mathematical concept. Students apply newly gained knowledge via in-class and homework practices. They are also exposed to higher-order practice questions to broaden their understanding of the mathematical concept.	<u>Problem-Solving</u> Students apply newly gained knowledge via in-class and homework practices, including the problem task used in the CLD's Problem-Solving phase. They are also exposed to higher-order practice questions to broaden their understanding of the mathematical concept.

Constructivist Instruction and Student Engagement

Many studies have shown that the DI approach is either on par or more effective than constructivist or problem-oriented teaching approaches in enhancing students' procedural fluency, whereas constructivist or problem-oriented teaching approaches are more effective in developing students' conceptual knowledge and preparing them for transfer of learning (Chen & Kalyuga, 2020; Lee et al., 2021; Xie et al., 2018).

Aside from the cognitive benefits, there are various studies that demonstrate the effectiveness of constructivist instruction in promoting student motivation and engagement. Nie and Lau (2010), in a survey study, revealed that constructivist instruction positively predicted students' self-efficacy, perceived task value, and use of deep cognitive strategies, while direct or didactic instruction mainly predicted students use of surface strategies. Similarly, Parr et al. (2019) observed that students reported higher levels of enjoyment and pride and lower levels of boredom and anger when their mathematics teachers use constructivist (dialogic) forms of instruction. Finally, Borovay et al. (2019) found that students experienced greater amount of flow when their teachers used inquiry-based instruction frequently.

While the abovementioned studies support the effectiveness of constructivist instruction in enhancing learning engagement, others have failed to observe the same benefits. Glogger-Frey et al. (2015), for instance, examined the topic-specific situational interest of 8^{th} grade students, who experienced one of two different instructional conditions—Inventing and Worked-Solution. In the Inventing condition, students spent one lesson to work on a problem task, which targeted a concept they had not formally learnt yet and required them to be inquisitive and invent their own solutions. Students in the Worked-Solution condition were presented with worked examples of the same problem task without the inquiry activity. In the subsequent lesson, the participants in both conditions attended the same teacher-led lecture, where they were given the solution of the problem task and taught the canonical concept. Students were surveyed in both lessons, and contrary to expectation, both groups did not differ in their self-reported situational interest in class. Research on PF, which uses a similar "problem-solving first" instructional design, also had a similar finding. Kapur (2014a) reported that 9^{th} grade students, who were taught using PF, experienced greater amount of mental effort than students who were taught using DI. However, students' self-reported engagement, measured in terms of perceived participation and attention, were not significantly different.

The inconsistent findings on the effect of constructivist instruction on learning engagement could be attributed to disparities in the way (1) constructivist instruction was specified and (2) engagement was operationalised, in these studies. In Nie and Lau (2010), Parr et al. (2019), and Borovay et al. (2019), teachers' instructional practice was assessed either through student survey or teacher interviews. Contrastingly, Glogger-Frey et al. (2015) and Kapur (2014a) did a quasi-experiment and compared two distinct instructional interventions, which were distinguished by specific instructional features like the presence of inquiry activities and sequence of instructional events. Glogger-Frey et al.'s (2015) and Kapur's (2014a) research thus has higher internal validity as the design of instruction was controlled for.

Apart from the specification of instruction, the studies also differed in how they conceived engagement. Glogger-Frey et al. (2015) focused on students' situational interest and Kapur (2014a) used an engagement measure that captured students' perceived attention and concentration in class. While these are all valid indicators of engagement, they are conceptually distinct. Situational interest represents the affective component of engagement, whereas attention and concentration represent the cognitive component of engagement. It is possible for one to be cognitively engaged in an activity without feelings of interest and enjoyment and vice versa. The present study, like Borovay et al. (2019), defined and measured engagement in terms of flow. This is because flow provides a multidimensional view of engagement that encompasses both affective and cognitive dimensions. Moreover, the combined affective (e.g., enjoyment) and cognitive (e.g., absorption) experience also makes flow a unique type of engagement, a highly rewarding state of total absorption that is related to students' intrinsic motivation to learn (Boekaerts, 2016).

Research Questions and Hypotheses

Given that secondary school students generally exhibit low levels of engagement in mathematics learning activities, and the mixed findings on the type of instruction that would help alleviate the issue, the present study aims to find out if the use of constructivist instruction via CLD would result in better affective-cognitive engagement (i.e., flow; Csikszentmihalyi, 1990) in secondary mathematics lessons as compared to transmissionist instruction via DI. Specifically, the following research questions were pursued:

RQ 1. Do students in the CLD and DI conditions differ in their levels of engagement?
RQ 2. Do students' levels of engagement fluctuate between mathematics lessons within the same instructional unit?
RQ 3. Do the lesson-to-lesson changes in engagement differ in the CLD and DI condition?

From these research questions, we tested the following hypotheses:

H1. Students in the CLD condition would be more engaged than their DI counterparts.
H2. Students' levels of engagement would differ between lessons.
H3. Changes in students' lesson engagement are conditional to the type of instruction that they are exposed to.

Method

Participants

A total of 144 Secondary 3 students (64 male) from two secondary schools in Singapore were recruited to participate in the present study. The participants were from four different classes—two classes per school—and each class was taught by a different mathematics teacher (n = 4; 1 male). In each school, classes were assigned to either the CLD or DI condition, and they were not taught the targeted concept of *angle properties of circles* prior to the study.

All the teacher participants, including those who were assigned to the CLD condition, did not employ the CLD approach or other similar learning designs prior to the study. Consistent with the observations made by Kaur and colleagues (Kaur, 2021; Kaur et al., 2021) on the dominant instructional models used by Singapore mathematics teachers, all four teachers noted that they would typically teach the angle properties of circles unit via the DI approach. This involves directly telling and explaining the angle properties to the students, follow by practices (i.e., classwork and homework) and review of student work. Correspondingly, none of the student participants had experienced the CLD, and the students were more accustomed to the DI approach in their mathematics classes.

Research Design

A quasi-experimental mixed design, consisting of two independent variables (IVs) and one dependent variable (DV) was employed. The between-subject IV comprises the two instructional conditions—CLD and DI (see Table 1 for the descriptions for the two designs)—while the within-subject IV is the lessons that each student underwent. The DV of this study is the learning engagement measure.

Materials

Engagement Survey. A 4-item survey, which was adapted from various sources (e.g., Chen et al., 2001; Kapur, 2014b), was used to measure students' engagement or flow in their mathematics lessons. In the survey, students were asked to rate on the following items relating to how they felt about the lesson of the day: (1) I enjoyed the lesson very much; (2) I was focused; (3) I was concentrating during the lesson; (4) Time passed so quickly and before I knew it, the lesson was over. Responses were made on a 7-point Likert scale, ranging from *strongly disagree* to *strongly agree*. To ensure that the engagement measure was psychometrically sound, reliability analyses and confirmatory factor analyses (CFA) were performed on the engagement data collected from each lesson. The four items were found to be internally reliable, α = .76 to .88. CFA findings also indicated a one-factor structure. Although chi-square tests were significant ($p < .05$), the other fit indices were satisfactory: factor loadings > .40; CFI = .91 to .97; RMSEA = .00 to .03; SRMR = .04 to .08. Note that in applied research, factor loadings ≥ .30 are interpreted as salient. CFI values of .90 or above, RMSEA values of .06 or below, and SRMR values of .08 or below, are considered acceptable (see Brown, 2015).

Problem Task. An open-ended problem task that targets the concept of angle properties of circles was developed. As shown in Figure 1, the task requires students to inspect four circles with marked angles, identify the relationship among these angles and the rules that govern these relationships, and make any generalisation of the relationships by making comparisons across circles or drawing their own circles to explore on the matter. The open-ended nature of the task allows students to explore multiple forms of solutions (i.e., different angle properties that they observed) and use multiple approaches (e.g., inductive or deductive reasoning approaches) during their problem-solving attempt.

Circle Time!

Four round coins from an ancient kingdom were uncovered and their exact drawings are shown in Figures 1 to 4 on the right. Each coin contains a pattern that shows the circle's centre, various chords, and the markings and sizes of some angles.

People in this ancient kingdom had great interest in mathematics and angles. As such, the patterns and markings on these coins should reveal **hidden rules on how angles in circles are related mathematically.** As part of the research team who found the coins, you and your group mates are asked to **find and explain these hidden rules,** and note these in a report. To do so, your team are requested to work on the following:

(i) For each figure, please examine and state **how the given marked angles are related** within the circle.
(ii) From your findings in (i), please **compare across the circles**, and study whether the relationships of the marked angles found in one circle can be applied to different circles.
(iii) To **confirm** the rules and relationships that you found from (i) and (ii), you can draw more angles in any one or more of the circles to test or justify whether your findings apply to similar angles within and across the circles.

Please find as many hidden rules as you can. Please note your findings in the blank papers provided. All the best!

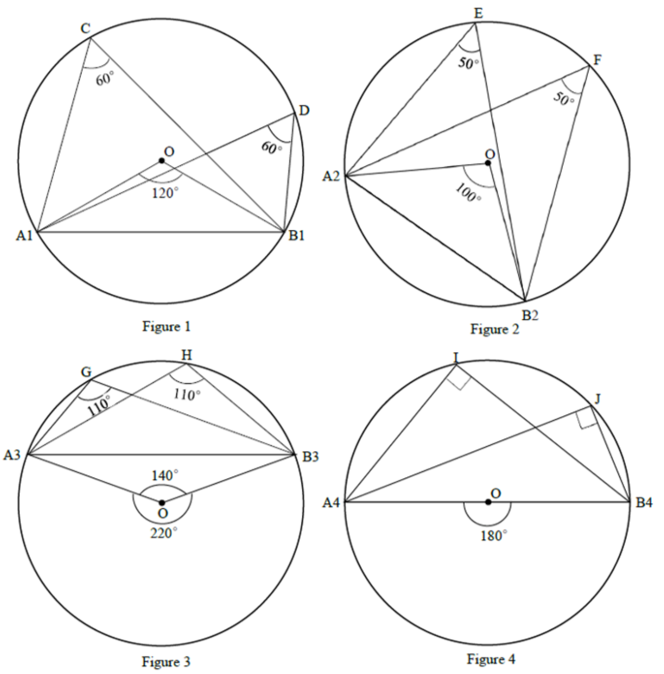


Figure 1. The "Circle Time!" problem task

The four targeted properties of the problem include (1) The angle subtended by an arc at the centre of a circle is twice the angle subtended by the same arc at the circumference; (2) An angle in a semicircle is a right angle; (3) The angles in the same segment of a circle are equal; (4) The sum of the angles in opposite segments of a circle is 180 degrees. From a design perspective, the task should help to promote communication and pattern recognition skills and encourage students to engage in inductive and deductive reasoning to prove discovered geometry ideas (see Ng et al. 2021 for more information about the design principles and instructional use of the task).

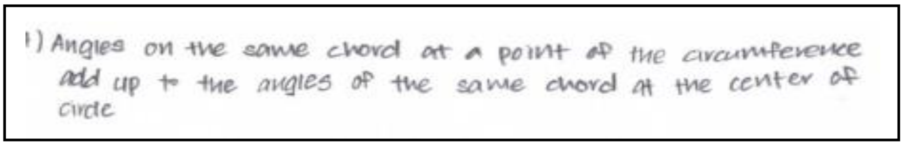
Procedures

In each school, one teacher was assigned to teach the angle properties of circles unit to his or her class via the CLD, and another was assigned to teach via DI. Teachers who taught using the CLD approach had to undergo a 2-hour training session conducted by the principal investigator of the research project prior to the study. The purpose of the training session was to familiarise the teachers with the learning design and the associated materials (e.g., problem task), as well as the constructivist learning theories that underlie the learning design (Ng et al., 2021). Since DI is the dominant model of instruction that many Singapore teachers draw on (Hogan et al., 2013; Kaur, 2021), teachers in the DI condition were not given any training. Nevertheless, to ensure that students in both instructional conditions did not differ in their exposure of learning materials, the open-ended problem task (see Figure 1) and practice questions used in the CLD condition were also employed in the DI condition as post-instruction practice.

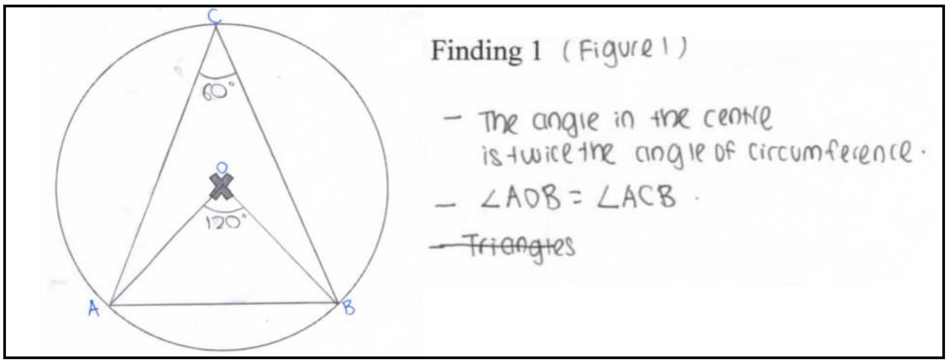
As described in Table 1, both the CLD classes spent their 1st lesson (45-60 mins) on the open-ended problem task. During this problem-solving phase, students were asked to explore and work on the problem in dyads or triads. Their teachers, on the other hand, were present to provide clarification about the task, to offer affective support to get students to persevere with the problem-solving, and to challenge students' thinking without revealing the solutions (see Ng et al., 2021 for the facilitation questions that the teachers might use, e.g., "Can you explain how you think the relationships have come about?"). Given that the CLD students had yet learnt the angle properties at that point in time, they were not expected to provide the targeted solution, but a range of other representations and solution methods during their exploration (see sample solutions in Figure 2).

In the subsequent lessons, the CLD teachers consolidated and presented the student-generated solutions in class, discussed the validity of the solutions by comparing and contrasting them, and used the solutions to introduce the angle properties of circles. For instance, in School B, one of the groups discovered that angle A1OB1 is equal to *the sum of* angle A1CB1 and angle A1DB1 (see Figure 1), whereas another group found that angle A1OB1 is *twice* of angle A1CB1 or angle A1DB1. While both statements are true, the teacher discussed the generalisability of both statements in class and used the opportunity to introduce the corresponding angle properties, i.e., the angle subtended by an arc at the centre of a circle is twice the angle subtended by the same arc at the circumference. The introduction of the angle properties was then followed by demonstrations of their application (via worked examples), in-class and homework practices (i.e., regular textbook practices and the higher-order practice questions), and review of student work.

TYPE A: Find out that two angles at the circumference add up to the angle at the centre



TYPE B: Find out that angle at the centre is twice the angle at the circumference



TYPE C: Solutions that seek to generalise the discovered properties and to identify their conditions

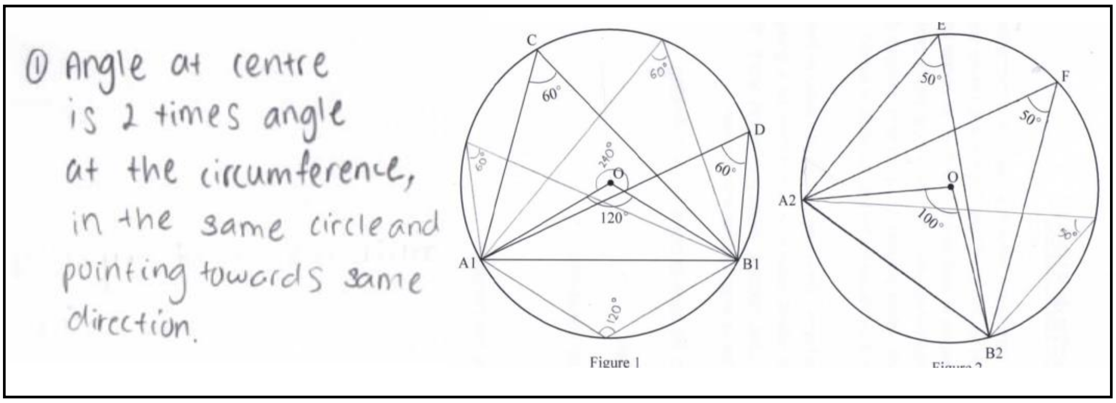


Figure 2. Sample solutions of the open-ended problem task produced by the CLD students

Unlike the CLD classes, the two DI classes commenced the first lesson (45-60 mins) with a direct instruction of the concept (see Table 1). Specifically, the DI teachers introduced and explained to the students the angle properties of circles and demonstrated how to apply these angle properties via worked examples. Subsequently, like the CLD classes, the DI students went through several cycles of in-class and homework practices (i.e., regular textbook practices and the higher-order practice questions), accompanied with a review of those work. It is important to note that the DI students were also given the opportunity to work on the open-ended problem task. However, given that they had already learnt the concept, the problem became more of a regular practice task for the students since they were able to provide the canonical solutions (see sample solutions in Figure 3).

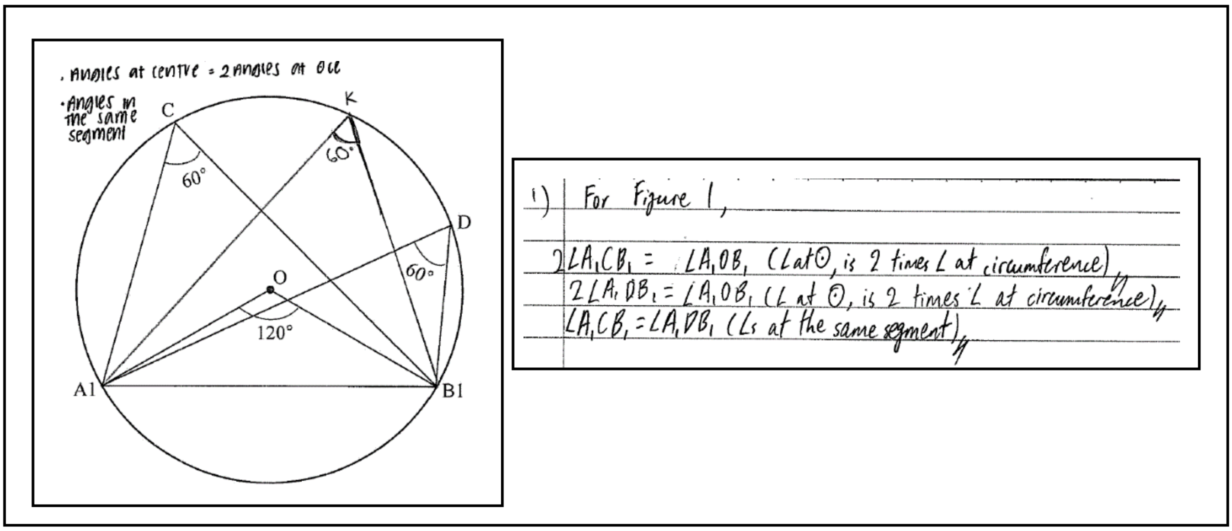


Figure 3. Sample solutions of the open-ended problem task
produced by the DI students

Classes in School A spent a total of four lessons to complete the unit, whereas School B spent three lessons in total. The disparity in the number of lessons was due to differences in school curriculum. At least one research assistant was present in each class to observe the instruction and survey the students at the end of each lesson.

Data Analysis Plan

A two-way mixed analysis of variance (ANOVA) was employed to (1) compare students' self-reported engagement in the CLD and DI condition, (2) analyse within-subject differences in engagement between lessons, and (3) examine if the within-subject differences in engagement between lessons were conditional to the between-subject factor (i.e., type of instruction). To control for the effects of any potential school-level variables on learning engagement (e.g., school climate; Bear et al., 2018), we analysed the data collected from the two schools separately.

Results

Descriptive Statistics

Table 2 below displays the descriptive statistics of students' engagement in each mathematics lesson. Specifically, the mean and standard deviation (*SD*) of the engagement variable for each lesson observation (School × Type of Instruction × Lesson) were reported.

Table 2
Descriptive Statistics

	School A		School B	
Lesson Engagement	**CLD** (*n* = 38)	**DI** (*n* = 32)	**CLD** (*n* = 36)	**DI** (*n* = 38)
1st Lesson				
Mean	5.61	4.73	5.17	5.26
SD	.85	1.11	1.05	.88
2nd Lesson				
Mean	5.09	4.45	5.28	4.90
SD	.92	1.40	.92	1.01
3rd Lesson				
Mean	4.90	4.38	5.44	4.61
SD	.89	1.56	.90	1.05
4th Lesson				
Mean	4.92	4.49	N.A.	N.A.
SD	.86	1.49	N.A.	N.A.

RQ1: Do students in the CLD and DI condition differ in their levels of engagement?
The Levene's test of equality of error variances was conducted to check the assumption of homogeneity of variances for all levels of the within-subject variable. For school A, three out of four levels (i.e., lessons) produced a significant Levene statistic ($p < .05$), indicating a violation of the assumption of homogeneity of variances and a compromise of the accuracy of F-test for the main effect of instructional model. In response to the violation, we disregarded the F-test results, which revealed that students in the CLD condition ($M = 5.13$, S.E. = .16) were more engaged than students in the DI condition ($M = 4.51$, S.E. = .18), $F(1, 68) = 6.73$, $p < .05$, $\eta_p^2 = .09$. Instead, Welch's t-test (one-tailed), which does not assume equality of variances, was conducted to compare the main effects of the instructional model in each lesson. The results showed that students in the CLD condition were more engaged than those in the DI condition in the 1st lesson ($t[57.406] = 3.67$, $p < .001$), 2nd lesson ($t[51.656] = 2.24$, $p < .05$), and 3rd lesson ($t[47.486] = 1.69$, $p < .05$); however, there was no significant differences in engagement in the 4th lesson ($t[47.759] = 1.43$, $p > .05$).

For school B, the Levene's test of equality of error variances indicated that variances were homogenous for all levels of the within-subject variable ($p > .05$). F-test conducted to examine between-subject effects showed that students in the CLD condition ($M = 5.30$, S.E. = .13) were more engaged than students in the DI condition ($M = 4.93$, S.E. = .13), $F(1, 72) = 4.13$, $p < .05$, $\eta_p^2 = .05$. Further analysis revealed that students in the CLD condition were more engaged than their DI counterparts in the 3rd lesson ($t = 3.63$, p = .001, $\eta_p^2 = .16$), but there were no significant differences in the 1st lesson ($t = -.40$, $p > .05$, $\eta_p^2 = .00$) and 2nd lesson ($t = 1.70$, $p > .05$, $\eta_p^2 = .04$).

RQ2. Do students' levels of engagement fluctuate between mathematics lessons within the same instructional unit?

For School A, the Mauchly's test was conducted, noting that the sphericity assumption was met ($p > .05$). The within-subject analysis revealed that students' self-reported engagement was significantly different between lessons, $F(3, 204) = 9.00$, $p < .001$, $\eta_p^2 = .12$. Pairwise comparisons further indicated that engagement in the 1st lesson was significantly higher than engagement in all three other lessons ($p < .01$). The levels of engagement in the 2nd to 4th lesson were not significantly different from one another ($p > .05$).

Likewise, for School B, the Mauchly's test showed that the sphericity assumption was met for School B's data ($p > .05$). However, unlike School A, the within-subject analysis indicated that students' self-reported engagement was not significantly different between lessons, $F(2, 144) = 1.49$, $p > .05$, $\eta_p^2 = .02$.

RQ3. Do the lesson-to-lesson changes in engagement differ in the CLD and DI condition?

In School A, the mixed ANOVA revealed no interaction effect between instructional model and lesson, $F(3, 204) = 1.51$, $p < .05$, $\eta_p^2 = .02$. This is possibly because engagement in both the CLD and DI conditions declined at similar rates across lessons (see Figure 4a). On the contrary, mixed ANOVA showed that there was a significant interaction effect in School B, $F(2, 144) = 8.10$, $p < .001$, $\eta_p^2 = .10$. As shown in Figure 4b, students in the DI condition exhibited a decline in engagement across lessons, whereas the engagement of students in the CLD condition was sustained over time.

Figure 4a

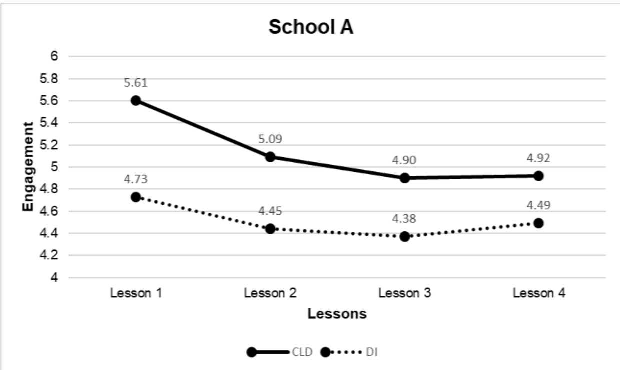


Figure 4b

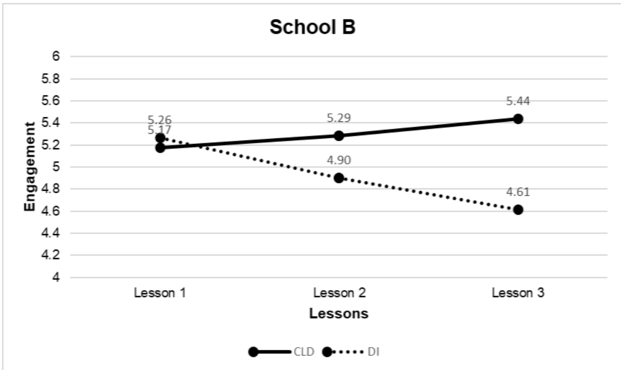


Figure 4. Graphs depicting interaction between Instructional Model and Lesson

Discussion

In the current study, students were assigned to receive either constructivist (i.e., CLD) or traditional direct instruction for the topic on angle properties of circles. We examined if the type of instruction has an effect on students' self-reported engagement in the mathematics lessons. Moreover, as students were surveyed repeatedly after each class, we also conducted within-subject analyses to find out if students' engagement would significantly differ between lessons, and if the observed changes in engagement were conditional to the type of instruction that was used by the teacher.

Consistent with the first hypothesis, students who were taught using the CLD were found to have experienced a greater level of flow as compared to their DI counterparts. The results support the past findings, which indicated that constructivist instruction was effective in promoting motivation and state of flow in learning (Borovay et al., 2019; Nie & Lau, 2010; Parr et al., 2019). However, studies on PF (Kapur, 2014a) and Invent-and-Tell (Glogger-Frey et al., 2015), which have similar instructional design with CLD, did not observe the same motivational and engagement benefits. This could be attributed to the way in which engagement was operationalised, as these studies measured engagement either as students' affective engagement (i.e., situational interest) or cognitive engagement (e.g., attention, concentration) in class. Here, we focused on the psychological state of flow, a specific type of engagement that considers both affective and cognitive dimensions, which when combined result in an optimal experience that is genuinely satisfying.

It is possible that a strong DI could be as effective as constructivist instruction in encouraging participation, eliciting situational interest, and prompting students to pay attention in class (Mayer, 2009). However, beyond these engagement indictors, the current results suggest that constructivist instruction is more suited in cultivating the joy of learning. This is possibly because a constructivist learning environment affords students with the opportunities to work on challenging, authentic, and hand-on activities that stretch their thinking, encourages collaboration, co-construction of knowledge, and in-class discussions that are grounded in student-initiated ideas, and involves the provision of instrumental (e.g., feedback, scaffold) and emotional support in learning. These instructional features help to satisfy students' psychological needs for autonomy, competence, and relatedness, and to promote the psychological state of flow (Lazarides & Rubach, 2017; Shernoff et al., 2016).

Aside from group-level differences between the constructivist and direct instruction, the current study also revealed a significant within-student variation in engagement between each lesson. Engagement was found to be the highest in the first lesson (for School A) and to decrease over the course of the instructional unit. One possible explanation for this finding is that engagement is often influenced by perceived novelty and challenge of a task or topic (Bergin, 1999; Shernoff et al., 2016). Therefore, students would tend to be more engaged when a topic is first introduced and less engaged in subsequent lessons, when students become more proficient, and classes become more practice and test oriented.

This observation is consistent with the general findings in the literature. In a longitudinal study involving secondary school students, Wang and Eccles (2012) reported a decline in students' affective, behavioural, and cognitive engagement as they progressed from Grade 7 to Grade 11. Even at a daily time scale, Patall et al. (2016) noticed that 9^{th} to 12^{th} grade students' daily situational interest and behavioural engagement (i.e., effort, participation) in their science classes decreased over the course of a six-week instructional unit. The present results add to the literature by demonstrating that secondary school students' engagement also tend to diminish over the course of a short mathematics instructional unit that consisted of three to four lessons.

Lastly, the current findings partially confirmed the third hypothesis. In School B, a drop in engagement was observed in students from the DI class over three lessons, whereas the engagement of students from the CLD class was sustained over time (see Figure 4b). Research on students’ daily engagement (Patall et al., 2018) has shown that students’ perception of teachers’ autonomy supportive practices in a lesson (e.g., provision of choices, opportunities for students to work using their own way, consideration of students’ opinions) predicted an increase in engagement in the subsequent class. Similarly, perception of teachers’ autonomy thwarting practices in a lesson (e.g., use of controlling messages, suppression of students’ perspectives) was found to have predicted an increase in disaffection in the subsequent class (Patall et al., 2018). Stroet et al. (2015) suggested that constructivist curriculum may provide teachers with more opportunities to engage in autonomy-supportive practices, as it encourages the elicitation and use of student-initiated ideas for instruction. Correspondingly, it is possible that CLD has allowed the CLD teacher from School B to become more autonomy-supportive in her practice, thus negating the downward trajectory of engagement observed in other classes.

Nonetheless, the fact that the same sustained pattern of engagement was not observed in School A indicates that there could be other student-level (e.g., achievement goals) or teacher-level (e.g., teachers’ efficacy beliefs) factors at play that could have offset the beneficial effects of the constructivist instruction (see Kıran et al., 2019). Alternatively, it could also mean that use of CLD does not guarantee autonomy-supportive practices. Although a constructivist design encourages teachers to elicit students’ ideas and build on them, teachers might still demonstrate autonomy thwarting practices due to factors like time constraints and behaviourist teaching beliefs, thus deviating from the intended constructivist curriculum (see literature on intended vs. enacted curriculum, e.g., Boesen et al., 2014).

The results of this study should be interpreted considering certain limitations. Given that the study was conducted in the context of Singapore secondary mathematics classrooms and on the topic of angle properties of circles, the findings might not generalise to other grade levels, subject matters, or instructional units. In addition, since the student participants had never experienced the CLD approach prior to the study, it is uncertain if the observed engagement effects were due to features of the design itself or to students’ perceived novelty of the learning experience. The present study also did not control potential teacher-level (e.g., motivating style, efficacy beliefs) and student-level (e.g., prior achievement, motivation) factors that could have influenced learning engagement (Kıran et al., 2019; Patall et al., 2018; Putwain et al., 2019). Lastly, the present study did not analyse how teachers, who employed the same learning design, differ in their lesson enactment. Such analysis could give us insights on the factors (e.g., autonomy-supportive vs. autonomy thwarting practices) that could have contributed to the between-group and within-group differences that were observed in the study. In view of these limitations, future studies could seek to carry out mixed-method studies that compare the differential impact of constructivist and direct instruction in varying education contexts, while taking into account relevant teacher and student covariates in the analysis. They could also seek to examine if CLD have the same engagement benefits on students who experienced the learning design, thus ruling out the possibility of a novelty effect.

Conclusion

Mathematics plays a central role in advancement of knowledge-based economies. Not only do we use mathematics in our everyday life, it is also foundational to the science, technology, and engineering fields. Despite its importance, many secondary school students are often not engaged in mathematics learning activities (OECD, 2013; Pöysä et al., 2018). This could have detrimental effects in their learning and steer them away from STEM (Science-Technology-

Engineering-Mathematics) related educational and career choices. In this study, we showed the possibility of constructivist instruction—CLD in particular—in mitigating this issue by promoting flow experience in mathematics lessons, potentially leading to sustained level of engagement over time. The use of constructivist instruction could possibly be a viable pathway in cultivating students' joy in learning mathematics.

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References

Anthony, G. (1996). Active learning in a constructivist framework. *Educational Studies in Mathematics, 31*, 349-369. https://doi.org/10.1007/BF00369153

Azevedo, R. (2015). Defining and measuring engagement and learning in science: Conceptual, theoretical, methodological, and analytical issues. *Educational Psychologist, 50*(1), 84–94. https://doi.org/10.1080/00461520.2015.1004069

Bear, G. G., Yang, C., Chen, D., He, X., Xie, J.-S., & Huang, X. (2018). Differences in school climate and student engagement in China and the United States. *School Psychology Quarterly, 33*(2), 323–335. https://doi.org/10.1037/spq0000247

Becker, J. P., & Shimada, S. (1997). *The open-ended approach: A new proposal for teaching mathematics*. National Council of Teachers of Mathematics.

Bergin, D. A. (1999). Influences on classroom interest. *Educational Psychologist, 34*(2), 87-98. https://doi.org/10.1207/s15326985ep3402_2

Boekaerts, M. (2016). Engagement as an inherent aspect of the learning process. *Learning and Instruction, 43*, 76-83. https://doi.org/10.1016/j.learninstruc.2016.02.001

Boesen, J., Helenius, O., Bergqvist, E., Bergqvist, T., Lithner, J., Palm, T., & Palmberg, B. (2014). Developing mathematical competence: From the intended to the enacted curriculum. *The Journal of Mathematical Behavior, 33*(3), 72–87. https://doi.org/10.1016/j.jmathb.2013.10.001

Borovay, L. A., Shore, B. M., Caccese, C., Yang, E., & Hua, O. (L.). (2019). Flow, achievement level, and inquiry-based learning. *Journal of Advanced Academics, 30*(1), 74–106. https://doi.org/10.1177/1932202X18809659

Brown, T. A. (2015). *Confirmatory factor analysis for applied research* (2nd ed.). The Guilford Press.

Chen, A., Darst, P. W., & Pangrazi, R. P. (2001). An examination of situational interest and its sources. *British Journal of Educational Psychology, 71*(3), 383–400. https://doi.org/10.1348/000709901158578

Chen, O., & Kalyuga, S. (2020). Exploring factors influencing the effectiveness of explicit instruction first and problem-solving first approaches. *European Journal of Psychology of Education, 35*, 607–624. https://doi.org/10.1007/s10212-019-00445-5

Confrey, J., & Kazak, S. (2006). A thirty-year reflection on constructivism in mathematics education in PME. In Gutiérrez A. & Boero P. (eds.), *Handbook of research on the*

psychology of mathematics education: Past, present and future (pp. 305–345). Sense Publishers.
Csikszentmihalyi, M. (1990). *Flow: The psychology of optimal experience*. Harper & Row.
Daschmann, E. C., Goetz, T., & Stupnisky, R. H. (2011). Testing the predictors of boredom at school: Development and validation of the precursors to boredom scales. *British Journal of Educational Psychology*, *81*(3), 421-440. https://doi.org/10.1348/000709910X526038
Derry, S. J. (1996). Cognitive schema theory in the constructivist debate. *Educational Psychologist*, *31*(3-4), 163-174. https://doi.org/10.1080/00461520.1996.9653264
Ertmer, P. A., & Newby, T. J. (2013). Behaviorism, cognitivism, constructivism: Comparing critical features from an instructional design perspective. *Performance Improvement Quarterly*, *26*(2), 43-71. https://doi.org/10.1002/piq.21143
Fong, C. J., Zaleski, D. J., & Leach, J. K. (2015). The challenge–skill balance and antecedents of flow: A meta-analytic investigation. *The Journal of Positive Psychology, 10*(5), 425–446. https://doi.org/10.1080/17439760.2014.967799
Fredricks, J. A., Blumenfeld, P. C., & Paris, A. H. (2004). School engagement: Potential of the concept, state of the evidence. *Review of Educational Research, 74*(1), 59–109. https://doi.org/10.3102/00346543074001059
Fredricks, J. A., Filsecker, M., & Lawson, M. A. (2016). Student engagement, context, and adjustment: Addressing definitional, measurement, and methodological issues. *Learning and Instruction, 43*, 1–4. https://doi.org/10.1016/j.learninstruc.2016.02.002
Fung, F., Tan, C. Y., & Chen, G. (2018). Student engagement and mathematics achievement: Unraveling main and interactive effects. *Psychology in the Schools, 55*(7), 815-531. https://doi.org/10.1002/pits.22139
Glogger-Frey, I., Fleischer, C., Grüny, L., Kappich, J., & Renkl, A. (2015). Inventing a solution and studying a worked solution prepare differently for learning from direct instruction. *Learning and Instruction, 39*, 72–87. https://doi.org/10.1016/j.learninstruc.2015.05.001
Henningsen, M., & Stein, M. K. (1997). Mathematical tasks and student cognition: Classroom-based factors that support and inhibit high-level mathematical thinking and reasoning. *Journal for Research in Mathematics Education, 28*(5), 524–549. https://doi.org/10.2307/749690
Hogan, D., Chan, M., Rahim, R., Kwek, D., Aye, K. M., Loo, S. C., Sheng, Y. Z., & Luo, W. (2013). Assessment and the logic of instructional practice in Secondary 3 English and mathematics classrooms in Singapore. *Review of Education, 1*(1), 57-106. https://doi.org/10.1002/rev3.3002
Jonassen, D. H. (1991). Objectivism vs constructivism: Do we need a new philosophical paradigm? *Educational Technology Research and Development, 39*, 5-14. https://doi.org/10.1007/BF02296434
Kapur, M. (2008). Productive failure. *Cognition and Instruction*, *26*(3), 379-424. https://doi.org/10.1080/07370000802212669
Kapur, M. (2014a). Productive failure in learning math. *Cognitive Science: A Multidisciplinary Journal*, *38*(5), 1008-1022. https://doi.org/10.1111/cogs.12107
Kapur, M. (2014b). Comparing learning from productive failure and vicarious failure. *Journal of the Learning Sciences*, *23*(4), 651-677. https://doi.org/10.1080/10508406.2013.819000
Karagiorgi, Y., & Symeou, L. (2005). Translating constructivism into instructional design: Potential and limitations. *Educational Technology & Society*, *8*(1), 17-27.

Kıran, D., Sungur, S., & Yerdelen, S. (2019). Predicting science engagement with motivation and teacher characteristics: A multilevel investigation. *International Journal of Science and Mathematics Education, 17,* 67-88. https://doi.org/10.1007/s10763-018-9882-2

Kirschner, P. A., Sweller, J., & Clark, R. E. (2006). Why minimal guidance during instruction does not work: An analysis of the failure of constructivist, discovery, problem-based, ex-periential, and inquiry-based teaching. *Educational Psychologist, 41*(2), 75–86. https://doi.org/10.1207/s15326985ep4102_1

Krahenbuhl, K. S. (2016). Student-centered education and constructivism: Challenges, concerns, and clarity for teachers. *The Clearing House: A Journal of Educational Strategies, Issues and Ideas, 89*(3), 97-105. https://doi.org/10.1080/00098655.2016.1191311

Kaur, B. (2021). Models of mathematics teaching practice in Singapore secondary schools. In Y. H. Leong, B. Kaur, B. H. Choy, J. B. W. Yeo, & S. L. Chin (Eds.), *Excellence in mathematics education: Foundations and pathways (Proceedings of the 43rd annual conference of the Mathematics Education Research Group of Australasia)* (pp. 67-70). MERGA.

Kaur, B., Tay, E. G., Tong, C. L., Toh, T. L., & Quek, K. S. (2021). The instructional core that drives the enactment of the school mathematics curriculum in Singapore secondary schools. In B. Kaur & Y. H. Leong (Eds.), *Mathematics instructional practices in Singapore secondary schools* (pp. 45-59). Springer. https://doi.org/10.1007/978-981-15-8956-0_3

Kuster, G., Johnson, E., Keene, K., & Andrews-Larson, C. (2017). Inquiry-oriented instruction: A conceptualization of the instructional principles. *PRIMUS, 28*(1), 13-30. https://doi.org/10.1080/10511970.2017.1338807

Lazarides, R., & Rubach, C. (2017). Instructional characteristics in mathematics classrooms: Relationships to achievement goal orientation and student engagement. *Mathematics Education Research Journal*, *29*, 201-217. https://doi.org/10.1007/s13394-017-0196-4

Lee, N. H., Lee, J., & Wong, Z. Y. (2021). Preparing students for the fourth industrial revolution through mathematical learning: The constructivist learning design. *Journal of Educational Research in Mathematics, 31*(3), 321-356. https://doi.org/10.29275/jerm.2021.31.3.321

Mayer, R. E. (2009). Constructivism as a theory of learning versus constructivism as a pre-scription for instruction. In S. Tobias & T. M. Duffy (Eds.), *Constructivist instruction: Success or failure?* (pp. 184–200). Routledge/Taylor & Francis Group.

Mullis, I. V. S., Martin, M. O., Foy, P., Kelly, D. L., & Fishbein, B. (2020). *TIMSS 2019 International Results in Mathematics and Science*. Boston College, TIMSS & PIRLS International Study Center. https://timssandpirls.bc.edu/timss2019/international-results/

Ng, C. M. (2017, March 7). *MOE FY 2017 Committee of Supply debate speech by minister of education (schools) Ng Chee Meng*. Ministry of Education Singapore. https://www.moe.gov.sg/news/speeches/20170307-moe-fy-2017-committee-of-supply-debate-speech-by-minister-of-education-schools-ng-chee-meng

Ng, K. E. D., Seto, C., Lee, N. H., Liu, M., Lee, J., & Wong, Z. Y. (2021). *Constructivist learning design: Classroom tasks for deeper learning* (2nd ed.). National Institute of Education, Nanyang Technological University, Singapore. https://ebook.ntu.edu.sg/cld-ebook-2nd-edition/full-view.html

Nie, Y., & Lau, S. (2010). Differential relations of constructivist and didactic instruction to students' cognition, motivation, and achievement. *Learning and Instruction*, *20*(5), 411-423. https://doi.org/10.1016/j.learninstruc.2009.04.002

Organisation for Economic Co-operation and Development. (2013). *PISA 2012 results: Ready to learn: Students' engagement, drive and self-beliefs (Volume III)*. PISA, OECD Publishing. http://dx.doi.org/10.1787/9789264201170-en

Organisation for Economic Co-operation and Development. (2021). *OECD digital education outlook 2021: Pushing the frontiers with artificial intelligence, blockchain and robots*. OECD Publishing. https://doi.org/10.1787/589b283f-en

Parr, A., Amemiya, J., & Wang, M.-T. (2019). Student learning emotions in middle school mathematics classrooms: Investigating associations with dialogic instructional practices. *Educational Psychology*, *39*(5), 636-658. https://doi.org/10.1080/01443410.2018.1560395

Patall, E. A., Steingut, R. R., Vasquez, A. C., Trimble, S. S., Pituch, K. A., & Freeman, J. L. (2018). Daily autonomy supporting or thwarting and students' motivation and engagement in the high school science classroom. *Journal of Educational Psychology*, *110*(2), 269–288. https://doi.org/10.1037/edu0000214

Patall, E. A., Vasquez, A. C., Steingut, R. R., Trimble, S. S., & Pituch, K. A. (2016). Daily interest, engagement, and autonomy support in the high school science classroom. *Contemporary Educational Psychology*, *46*, 180–194. https://doi.org/10.1016/j.cedpsych.2016.06.002

Piaget, J. (1980). *The origins of intelligence in children*. International Universities Press.

Pino-James, N., Shernoff, D. J., Bressler, D. M., Larson, S. C., & Sinha, S. (2019). Instructional interventions that support student engagement: An international perspective. In J. A. Fredricks, A. L. Reschly, & S. L. Christenson (Eds.), *Handbook of student engagement interventions: Working with disengaged students* (pp. 103-119). Academic Press. https://doi.org/10.1016/B978-0-12-813413-9.00008-5

Pöysä, S., Vasalampi, K., Muotka, J., Lerkkanen, M.-K., Poikkeus, A.-M., & Nurmi, J.-E. (2018). Variation in situation-specific engagement among lower secondary school students. *Learning and Instruction*, *53*, 64-73. http://dx.doi.org/10.1016/j.learninstruc.2017.07.007

Putwain, D. W., Nicholson, L. J., Pekrun, R., Becker, S., & Symes, W. (2019). Expectancy of success, attainment value, engagement, and achievement: A moderated mediation analysis. *Learning and Instruction*, *60*, 117-125. https://doi.org/10.1016/j.learninstruc.2018.11.005

Ryan, R. M., & Deci, E. L. (2000). Intrinsic and extrinsic motivations: Classic definitions and new directions. *Contemporary Educational Psychology*, *25*(1), 54–67. https://doi.org/10.1006/ceps.1999.1020

Schwartz, D. L., & Martin, T. (2004). Inventing to prepare for future learning: The hidden efficiency of encouraging original student production in statistics instruction. *Cognition and Instruction*, *22*(2), 129-184. https://doi.org/10.1207/s1532690xci2202_1

Sharrock, D., & Rubenstein, R. (2019). Student–centered practices for student mathematical agency and engagement. In J. A. Fredricks, A. L. Reschly, & S. L. Christenson (Eds.), *Handbook of student engagement interventions: Working with disengaged students* (pp. 151-168). Academic Press. https://doi.org/10.1016/B978-0-12-813413-9.00011-5

Shernoff, D. J., Csikszentmihalyi, M., Shneider, B., & Shernoff, E. S. (2003). Student engagement in high school classrooms from the perspective of flow theory. *School Psychology Quarterly*, *18*(2), 158–176. https://doi.org/10.1521/scpq.18.2.158.21860

Shernoff, D. J., Kelly, S., Tonks, S. M., Anderson, B., Cavanagh, R. F., Sinha, S., & Abdi, B. (2016). Student engagement as a function of environmental complexity in high school classrooms. *Learning and Instruction*, *43*, 52–60. https://doi.org/10.1016/j.learninstruc.2015.12.003

Sinatra, G. M., Heddy, B. C., & Lombardi, D. (2015). The challenges of defining and measuring student engagement in science. *Educational Psychologist*, *50*(1), 1–13. https://doi.org/10.1080/00461520.2014.1002924

Skinner, E. A., Kindermann, T. A., & Furrer, C. J. (2009). A motivational perspective on engagement and disaffection: Conceptualization and assessment of children's behavioral and emotional participation in academic activities in the classroom. *Educational and Psychological Measurement*, *69*(3), 493–525. https://doi.org/10.1177/0013164408323233

Steele, D. F. (2001). Using sociocultural theory to teach mathematics: A Vygotskian perspective. *School Science and Mathematics*, *101*(8), 404-416. https://doi.org/10.1111/j.1949-8594.2001.tb17876.x

Stroet, K., Opdenakker, M.-C., & Minnaert, A. (2015). Need supportive teaching in practice: A narrative analysis in schools with contrasting educational approaches. *Social Psychology of Education: An International Journal*, *18*(3), 585–613. https://doi.org/10.1007/s11218-015-9290-1

Vygotsky, L. (1978). *Mind in Society*. Harvard University Press.

Xie, C., Wang, M., & Hu, H. (2018). Effects of constructivist and transmission instructional models on mathematics achievement in mainland China: A meta-analysis. *Frontiers in Psychology*, *9*, Article 1923. https://doi.org/10.3389/fpsyg.2018.01923

Wang, M.-T., & Eccles, J. S. (2012). Adolescent behavioral, emotional, and cognitive engagement trajectories in school and their differential relations to educational success. *Journal of Research on Adolescence*, *22*(1), 31–39. https://doi.org/10.1111/j.1532-7795.2011.00753.x

Wong, Z. Y., & Liem, G. A. D. (2022). Student engagement: Current state of the construct, conceptual refinement, and future research directions. *Educational Psychology Review*, *34*, 107–138. https://doi.org/10.1007/s10648-021-09628-3

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