Learning Alone or Together? A Combination Can Be Best!

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Abstract: Collaborative and individual learning are both frequently used in classrooms to support learning. However, little research has investigated the benefits of combining individual and collaborative learning, as compared to learning only individually or only collaboratively. With our study, we address this research gap. We compared a combined condition to individual-only or collaborative-only learning conditions using intelligent tutoring systems for fractions. The study was conducted with 382 4th and 5th grade students. Students across all three conditions had significant learning gains. However, the combined condition had higher learning gains than the individual or collaborative condition. This difference was more pronounced for 4th grade students than for 5th grade students. In addition, we found that students in the combined condition expressed higher situational interest in the activity compared to those working individually and the same as students working only collaboratively. Through a combination, we may support better student learning.

Introduction

Although collaborative and individual learning are both frequently used in the classroom, little research has been done to investigate if and when their combination is more effective than either one alone. Computer-supported collaborative learning (CSCL) research has combined social planes (i.e., individual, collaborative, whole class) within learning activities using integrative scripts (Dillenbourg, 2004) that prescribe different social planes for different phases of a learning activity (Dillenbourg, 2004; Diziol, Rummel, Spada, & McLaren, 2007). For example, integrative CSCL scripts based on the Jigsaw method have people work individually to gain expertise in an area before working in expert groups and then mixed expert groups to share that expertise (Aronson, 1978). Although these scripts use a combination of collaborative and individual learning, they are often only compared to individual only interventions and not to collaborative only interventions when their effectiveness is investigated. Collaborative and individual learning may each have different strengths that influence the learning process in productive ways; each may be more beneficial than the other for certain types of knowledge (Mullins, Rummel, & Spada, 2011). One might hypothesize, therefore, that a combination of collaborative and individual learning can be more effective in supporting student learning than learning within either of the social planes separately (i.e., collaborative or individual learning), especially when the combination is set up in a way that plays to the strengths of each of the two learning modes. However, it is also possible that switching between social planes adds overhead to the learning process, which could have a negative impact on the student performance that outweighs the benefits of a combination, even if this combination is aligned to their particular strengths. Hence, it is important to understand whether combining individual and collaborative learning, in a way that aligns with their respective strengths, is more effective than individual or collaborative learning alone. In this paper, we investigate this question, using different versions of an intelligent tutoring system (ITS) for elementary school fractions learning as a platform.

Previous research that has compared collaborative and individual learning has found mixed results: some studies found that collaboration is more beneficial, whereas other studies found that individual learning is more beneficial (Lou et al., 2001). These mixed results may be due to how the collaboration and individual learning is being aligned with the learning activities and how the collaborative and individual learning phases are being combined, if at all, in the collaborative learning scenario. Collaborative learning may be beneficial by supporting students in giving and receiving explanations as well as the opportunity to co-construct knowledge with their partner (Hausmann, Chi, & Roy, 2004). In addition, discussions that happen during collaboration can potentially support the students' social goals (e.g., responsibility goals, popularity goals) and make them feel more connected to their group members, which can increase their motivation for the activity (Rogat, Linnenbrink-Garcia, & DiDonato, 2013) and increase the desire to continue working on the task. Specifically, situational interest in the task, which is interest that arises due to a response to the factors in the environment (Linnenbrink-Garcia et al., 2010), can increase when a task involves collaboration. On the other hand, for problem-solving practice, individual learning may be more beneficial than collaborative learning. Working individually may allow students to get more practice in the same amount of time and develop fluency (Mullins et al., 2011) since students are not sharing tasks with a partner and do not necessarily have to pause to explain their actions. In light of these different strengths, collaboration may be better for conceptually oriented activities, such as working on erroneous examples, and individual work may be better for procedurally oriented activities, such as tutored problem solving.

To design a mixed collaborative/individual condition, we created learning activities that would play to the strengths of the given social plane; specifically, we used erroneous examples for collaborative learning and tutored problem solving for individual learning. Within research on example-based learning, both worked examples and erroneous examples have been shown to be successful for supporting learning (Renkl, 2005; McLaren, et al., 2012; Tsovaltzi et al. 2010). In addition, prior research shows that when students study worked examples collaboratively, they tend to avoid shallow processing, ask for fewer hints, and spend more time on explanations than when working individually (Hausmann, Nokes, VanLehn, & van de Sande, 2009). Further, erroneous examples can help to foster reflection and more fruitful explanations (Isotani et al, 2011; Siegler, 1995; Tsovaltzi et al., 2009). When students are able to collaborate around erroneous examples, they may benefit from engaging in sense-making with their partner, fostered both through the erroneous examples and the collaborative learning. On the other hand, for tutored problem solving, tutors often support student learning through step-by-step support. This step-by-step support focuses the attention of the student on one step at a time, which can lead to students entering an answer as soon as it is known instead of having a discussion around the problem (Mullins, Rummel, & Spada, 2011). When students are working individually, they do not have to divide tasks with another student, or stop often to discuss a problem step, which likely allows each student to get more practice with the problem-solving skills. In turn, more practice with the problems may allow the students to build more fluency and procedural knowledge (Anderson, 1983). When students are able to work individually around the tutored problem solving, they may benefit from the faster-paced practice that is fostered from both the step-by-step nature of the problems and the individual learning.

In this study, we investigated our hypothesis that a combination of collaborative and individual learning is more effective for student learning than the same tasks being performed only collaboratively or individually. Specifically, we investigated the combination of students working collaboratively on erroneous examples and individually on tutored problem solving. The study involved 382 students and ran over five class periods. To test our hypothesis, we assigned students to three different conditions (i.e., mixed, collaborative only, individually only). In addition, we measured the situational interest in the tutor for the students. We hypothesized that students who have a chance to work collaboratively (i.e., mixed and collaborative only conditions) will have more situational interest in the activity than students that only work individually.

Methods

Tutor design

As mentioned, we used a fractions ITS as a platform for our research. ITSs have been shown to be beneficial for student learning (Kulik & Fletcher, 2015; Ma, Adesope, Nesbit, & Liu, 2014) and are effective by providing cognitive support for students as they work through problem-solving activities. This cognitive support comes in the form of step-level guidance, namely, an interface that makes all steps visible, error feedback, and on-demand hints (VanLehn, 2006). Although the majority of ITSs have been developed for individual use, the integration of collaboration within an ITS, in prior studies, has effectively supported learning (Baghaei & Mitrovic, 2005; Diziol et al., 2010; Olsen Rummel, & Aleven, 2016). The support for the collaboration can be directly embedded into the tutor to support the students both cognitively and socially.

Informed by prior work on fractions tutors (Olsen, Belenky, Aleven, & Rummel, 2014a; Olsen, Rummel, & Aleven, 2016), we developed a new ITS for three fractions units: equivalent fractions, least common denominator, and comparing fractions. The ITS versions were built with the Cognitive Tutoring Authoring Tools (CTAT), extended to support collaborative tutors (Olsen et al., 2014b). For each of the three units, we created both tutored problem-solving activities (see Figure 1) and erroneous examples (see Figure 2). Further, we created both individual and collaborative versions of both types of activities, for use in different conditions. For each unit, there were eight problems. All of the problems within a unit were of the same type.

For the *tutored problem solving*, the students went through the steps needed to solve each problem. For example, for the unit on comparing fractions, students would first find the least common denominator for the fractions they were trying to compare (see Figure 1), then convert all of the fractions using this common denominator, and finally, put the fractions in order, from smallest to largest. For the *erroneous examples*, the students were asked to go through the process of finding the error that a fictional student had made in a problem (these were common errors that were made in the tutored problem solving problems), correct the error, and provide advice to the student for what they should do in the future. For example, for the least common denominator unit shown in Figure 2, students first needed to identify the error that Kaitie made. After identifying Kaitie's error, the students were asked to correct the error in the original problem. The students were then given a space to write a message to Kaitie about what she could do differently the next time she encountered similar problems.

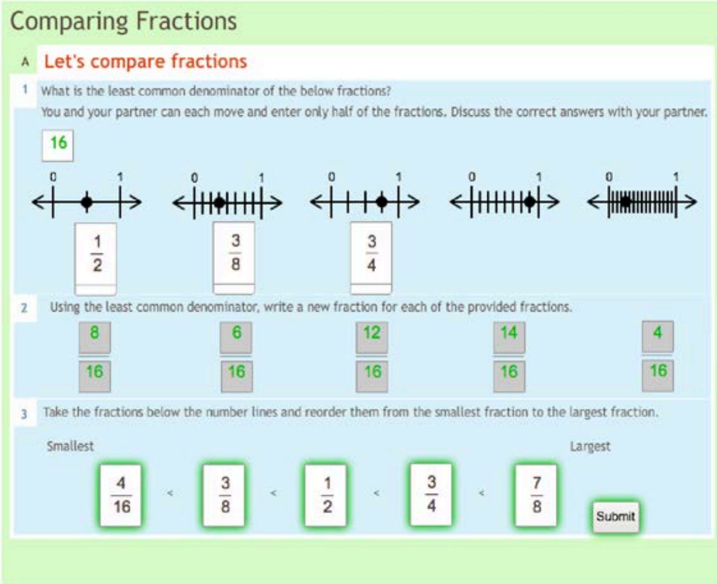

Figure 1. A collaborative tutored problem-solving problem for comparing fractions. The students go through the steps of converting fractions as a general mathematical procedure for solving this type of problem.

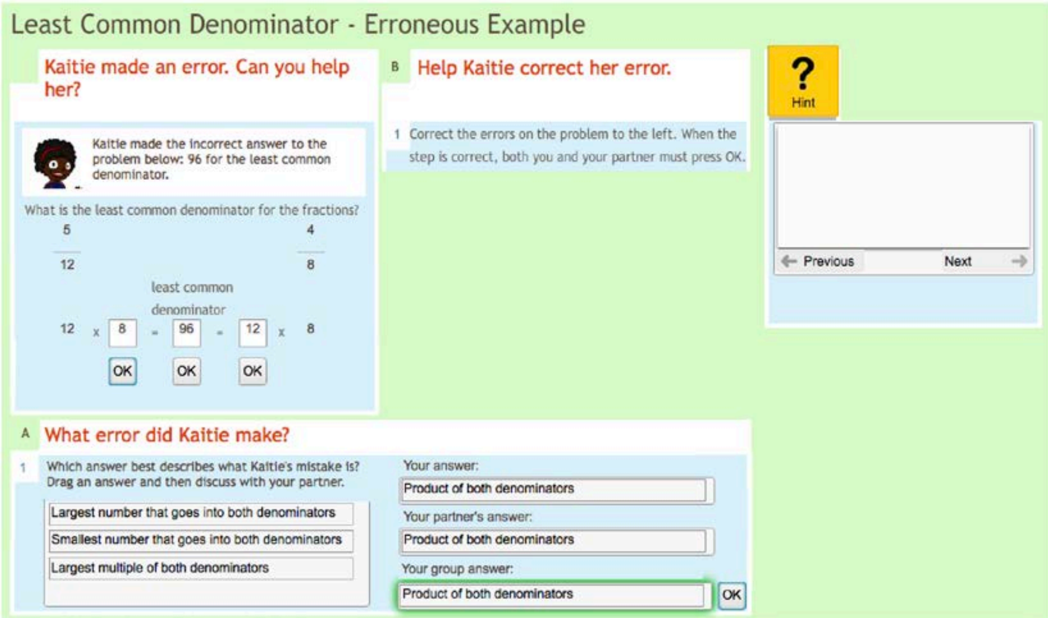

Figure 2. A collaborative erroneous example for least common denominators. The students are asked to find the type of mistake that the student in the problem has made (Panel A) and to then fix that mistake (top left).

The collaborative tutors were supported with embedded collaborative scripts for each tutor problem to provide social support for students (Kollar, Fischer, & Hesse, 2006). The collaborative tutors supported synchronous, networked collaboration, in which collaborating students sat at their own computer and had a shared (though differentiated) view of the problem state and different actions/resources available to them. The students sat next to each other and communicated through speech, which was recorded. The groups were preset in the system and after students signed into their account, the system was able to share their problem space. The embedded scripts supported collaboration through a distribution of responsibility to create accountability and interdependence (Slavin, 1989) and cognitive group awareness (Janssen & Bodemer, 2013). In Figure 1, the screen shows that this student only received three of the five given fraction symbols in the problem (their partner had the second half). The students are responsible for sharing their fractions to be able to find the correct least common denominator and to convert the fractions. In Figure 2, panel A shows an example of support for cognitive group awareness where each student has to answer the question individually, the students are shown each other's answer, and then need to provide a group answer. When correcting the problem, the students each need to press the OK button to get feedback from the tutor. This prevents just one student doing the problem alone. Besides these collaboration script features, the collaborative and individual ITSs were identical.

Design and procedure

The quasi-experimental study was conducted in a classroom setting with 382 4th and 5th grade students between 18 classrooms (7 fourth grade and 11 fifth grade), 12 math teachers, and five school districts. The study took place during the students' regular class periods. All students worked with the fractions ITS described above. At the class level, students were randomly assigned to one of three conditions: mixed, collaborative, or individual. Seven classes were assigned to the mixed condition, 6 classes to the collaborative only condition, and 5 classes to the individual only condition. In the mixed condition, the students worked collaboratively on the erroneous examples and individually on the tutored problem-solving activities to align with the strengths of the social planes. In the other conditions, students either worked collaboratively on both types of problems or individually on both types of problems. In all three conditions, the erroneous examples for a unit came before the procedural problems to allow the students to address errors before getting more instruction through the procedural problems sets (Renkl & Atkinson, 2003). Also, students in all conditions completed one unit each day; they switched from the erroneous examples to the tutored problem-solving activities half way through class. Within each class, all of the students were instructed to switch problem sets at the same time. Because the time-on-task was constant for all conditions within each unit, the students finished a different number of problems. Within each class, teachers paired their students based on who would work well together and had similar math abilities to avoid extreme differences that could hinder collaboration. Students worked with the same partner as much as possible and only changed partners due to absenteeism. If a student's partner was absent in the collaborative conditions, the student would be paired with another student working in the same condition for the remainder of the study. When students started with a different partner from the day before, they would begin on the problem set at the place of the student who had made less progress.

The study ran across five class periods of 45 minutes each. On the first day, the students took the pretest individually. At the beginning of the second day, the students took a short tutorial either individually or in groups (aligning with their social mode for the erroneous examples) that gave some instruction on how to interact with the tutor. The students then worked with the tutor for the next three days in their condition. On the fifth day, the students took a posttest individually and answered a short survey to gauge their situational interest when working with the tutors.

Dependent measures

For the study, we collected pretest and posttest measures, tutor log data, and situational interest measures. We assessed students' fractions knowledge at two different times using two equivalent test forms in counterbalanced fashion. The tests targeted isomorphic problems for both the erroneous and procedurally oriented tutors and were administered on the computer. The tests also had transfer problems for naming, making, adding, and subtracting fractions. Each test had 15 questions, seven erroneous example, six problem solving, and two fractions explanations questions. For each question on the test, the students were able to get a point for each step completed correctly. On the tests there were 81 possible points for the 13 erroneous example and procedural knowledge questions. To assess the students' situational interest in the tutoring activity, we had the students answer a brief survey of 12 questions. The questions were adapted from the Linnenbrink-Garcia et al. (2010) situational interest scale. The questions were all written to ask about the time that was spent learning with the tutoring system. Each question was presented to the student on a Likert scale that ranged from one to seven. The total score could range from 12 to 84.

Results

Out of the 382 students who participated in the study, 75 students were excluded from the analyses because of absenteeism during parts of the study, thus leaving us with a final set of 307 students. Out of the 307 students, 104 were in the collaborative only condition, 83 in the individual only condition, and 120 in the mixed condition. There was no significant difference between conditions with respect to the number of students excluded, $F(379,2) = 0.59$, $p = .56$. There was, however, a significant difference in the pretest scores across conditions, $F(2, 304) = 9.4$, $p < .05$, with the collaborative only group being significantly lower than the other two conditions.

Learning gains

To investigate whether students learned using our tutors and if there was a difference in learning between the students in the different conditions, we used a multilevel approach to take into account differences between school districts and the repeated measures of the pretest and posttest. We used a hierarchical linear model (HLM) with student at the first level and school district at the second level. At level 1, we modeled the pretest and posttest scores along with the student's grade (4^{th} or 5^{th}) and condition, and at level 2, we accounted for differences that could be attributed to the school district. For the different variables, we chose pretest for the test baseline, mixed condition for the condition baseline, and 4^{th} grade for the grade baseline. For each variable, the model includes a term for each comparison between the baseline and other levels of the variable. We did not include dyads as a level because of the added complexity of some students working with no partner (i.e. individuals), some students having one partner, and some students having two partners because of absenteeism. We are aware of non-independence issues such as common fate and reciprocal influence within dyads that may have impacted our results (Cress, 2008). We measured the effect size with Pearson's correlation coefficient (r) where 0.1 is considered a small effect size, 0.3 a medium effect size, and 0.5 a large effect size.

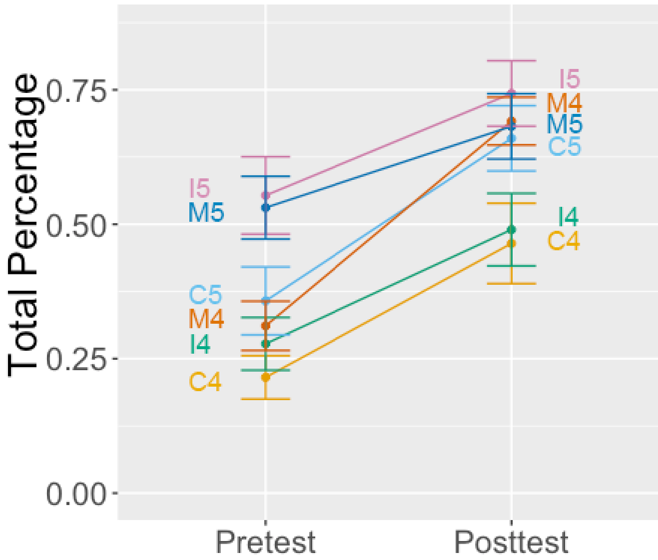

Figure 3. The students worked either collaboratively and individually (M), only collaboratively (C), or only individually (I) with the mixed condition having higher learning gains than the other conditions. This effect was more pronounced in the 4^{th} grade students than the 5^{th} grade students.

The results from the pretest and posttest analysis are shown in Figure 3. There was a significant difference between pretest and posttest scores, $t(301) = 12.56$, $p < .05$, $r = .59$, with the posttest scores being higher across all conditions. For the condition differences, there was a significant difference between collaborative only and mixed, $t(297) = -3.12$, $p < .05$, $r = .18$, and a marginally significant difference between individual only and mixed, $t(297) = -1.83$, $p = .07$, $r = .11$, with mixed condition having higher test scores than the other conditions. There was a significant interaction between pretest/posttest and collaborative/mixed conditions, $t(301) = -2.78$, $p < .05$, $r = .16$, and a significant interaction between pretest/posttest and individual/mixed conditions, $t(301) = -3.56$, $p < .05$, $r = .2$, with the learning gain slope being higher for the mixed conditions than the other conditions, supporting our hypothesis that the mixed condition would be more effective for learning. For the student's grade level (i.e., 4^{th} v. 5^{th} grade), there was a significant main effect of grade, $t(297) = 2.93$, $p < .05$, $r = .17$, with the 5^{th} graders having higher test scores than the 4^{th} grade students. Surprisingly, there was a significant interaction between grade and pretest and posttest, $t(301) = -5.53$, $p < .05$, $r = .3$, indicating that the 4^{th} graders had higher learning gains than the 5^{th} graders. There was not a significant interaction between grade and individual/mixed conditions or collaborative/mixed conditions, $t(297) = 0.90$, $p = .37$ and $t(297) = 0.80$, $p = .42$. For the three way interactions, there were a significant interactions for both the pretest/posttest, grade, and collaborative/mixed conditions, $t(301) = 4.57$, $p < .05$, $r = .25$, and the pretest/posttest, grade, and individual/mixed conditions, $t(301) = 3.19$, $p < .05$, $r = .18$, with the slope differences between the mixed conditions and the other conditions being more pronounced for the 4th grade students than the 5th grade students. These interactions indicated that the mixed condition, compared to the other conditions, was more beneficial for the learning gains of 4th grade students than those of 5th grade students.

Situational interest

To investigate the impact that working with a partner may have had on the student's situational interest in the tutoring activity, we used an HLM with student at the first level and school district at the second level. At level 1, we modeled the situational interest score and condition, and at level 2, we accounted for random differences that could be attributed to the school district. There was no significant difference between the collaborative only condition and the mixed condition, $t(302.15) = -1.119$, $p = .26$ (see Table 1). There was a significant difference between the students working individually only and the students in the mixed condition, $t(299.83) = -3.978$, $p < .05$, $r = .22$, such that the students in the mixed condition had a higher situational interest score. These results indicate that the students who had an opportunity to work with a partner found the task more immediately motivating and that working individually for part of the activity did not lower this motivation, although it did for students only working individually.

Table 1: The situational interest score for each of the different conditions

Condition	**Situational Interest Score Percentage (SD)**
Collaborative Only	0.74 (0.20)
Individual Only	0.59 (0.19)
Mixed	0.75 (0.16)

Discussion and conclusion

In our classroom study we found that students across all conditions and grade levels learned from working with a tutoring system that supported both studying erroneous examples and problem-solving practice. Thus, the results demonstrate the effectiveness of the instructional conditions. More interestingly, the results confirmed our hypothesis that a combination of collaborative and individual learning may be more beneficial than either alone, as was found across the 4th and 5th grades. Through a combination of collaborative and individual learning, we are able to align the strengths of the tasks with the strengths of the social planes to better support the student learning. We did find that this result was more pronounced with the 4th grade than the 5th grade students. This difference may indicate that the given combination of individual and collaborative learning is particularly effective early on in the learning process when students may need more support targeted at the skills they are trying to acquire. The 5th grade students may have been at a stage where fluency building was more productive for their learning and the collaboration that supported sense making was not as important. If so, the mixed condition would not have as much benefit for 5th grade students. These results resemble those from other research where the age of the students had an impact on the effectiveness of the learning intervention (Mazziotti, Loibl, & Rummel, 2015). However, future work is needed to develop an understanding of when collaborative and individual learning may be most effective. In addition, the 5th grade students in the collaborative only condition had higher learning gains than the other 5th grade conditions. However, this may be an effect of differences on the pretest. The 5th grade collaborative only condition did not have significantly different posttest scores than the other 5th grade students.

Additionally, in accordance with our hypothesis, we found that students who had a chance to work collaboratively (mixed and collaborative only conditions) had higher situational interest in the tutoring task than those only working individually. The results support the notion that a collaborative setting can be more motivating for students and that it can be so even when an individual component is added. The situational interest that arises from collaborating can influence the learning that happens around the domain knowledge. When students are more interested in a task, they are willing to put more time and effort into completing that task (Rogat et al., 2013). Allowing students to collaborate on tasks that, *a priori*, would align well with the strengths of collaboration (e.g., building conceptual knowledge) thus might be one way to both motivate students and to create a beneficial learning environment.

This paper opens up a broader line of inquiry of research in CSCL that focuses on the question of how collaborative and individual learning can most effectively be combined. In our study, we supported student learning through the use of erroneous examples and tutored problem solving. We chose these activity types because the strengths of collaborative and individual learning had related strengths to the learning activities so that a combination may have built upon itself. Specifically, this combination may have been effective because it allowed the students to address misconceptions with a partner and thus develop a deeper understanding. After addressing misconceptions, the students then had an opportunity to build fluency with individual problem solving. This alignment of the learning activities with the hypothesized strengths of the social planes may have enhanced the support to the students more than either could provide alone. Although our results support that this combination of collaborative and individual learning with the learning tasks was more effective than either social plane alone, a limitation of our study is that we do not know what the most effective combination of collaborative and individual learning is and how the results from our combination would generalize. To be able to find what combinations of collaborative and individual learning can be effective for learning, additional research is needed. Our study indicates that this would be a promising direction for future research to explore. In this future exploration, it is important to consider how the switches between social planes are triggered. For example, we have explored switch points triggered by time on task. It may also be beneficial for students to switch social planes adaptively based on switch points triggered by student characteristics, such as repeated errors on a skill when working individually.

The results of our study are notable because of the complexity in supporting both collaborative and individual learning in the classroom and providing real-time support. This study adds to the CSCL literature by comparing a combination of collaborative and individual learning to both social planes alone, which is so far uncommon. By finding support for the effectiveness of combining collaborative and individual learning, this paper has opened a broader line of inquiry into how collaborative and individual learning can most effectively be combined to support learning. Within this space, we can begin to evaluate integrative scripts (Dillenbourg, 2004) to better understand what aspects of the scripts are proving to be effective for student learning or if any combination of social planes is enough to support students.

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