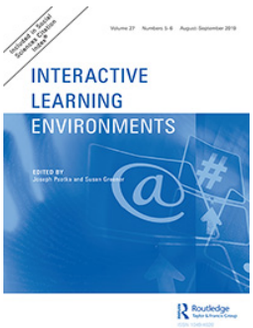

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Visualizing the commognitive processes in computer-supported one-to-one tutoring

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ABSTRACT

This study aims to visualize the commognitive processes in computer-supported one-to-one teaching and learning. By commognitive processes we mean cognitive processes and interpersonal communication. A 6-years mathematics teacher and a 15-year-old boy in China, who have done computer-supported one-to-one tutoring, were chosen to be the samples. We collected four computer-supported one-to-one tutoring videos (60–90 min) about one chapter of mathematical set knowledge between one teacher and one student, and 30 min interview video from the teacher. Based on Bloom's cognitive classification theory and commognition theory, we develop a commognitive classification framework, then encode and visualize the videos. We found that mathematics commognition processes can be divided into six levels and classified into three types: teacher-lead, student-lead, and teacher-student comparison.

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Commognitive process; visualizing; one-to-one tutoring; computer-supported; mathematics

Introduction

In recent years, with the spread of information technologies such as smartphones and personal computers, some students have been able to develop intellectual autonomy, and international education has increasingly advocated the inclusion of more discussion in regular classroom teaching. Web-based instruction (WBI) offers many advantages over traditional classroom-based training, such as providing remote access from everywhere (Anido, Llamas, & Fernandez, 2001). Over the past decade, there has been a growing interest in one-to-one laptop technology initiatives in the United States, whereby teachers and students have full access to a technology-rich learning environment (Bebell & O'Dwyer, 2010; Lei & Zhao, 2008). However, most of these initiatives use a techno-centric approach (use of technology for technology-related activities) rather than an innovative, technology-rich learning environment conceptually designed and practically implemented as a method for paradigmatic change of teaching and learning (Weston & Bain, 2010).

Nowadays, online tutoring in China has developed rapidly, but also with many problems, such as experienced teachers being reluctant to adopt online tutoring, so most online tutors are young teachers or even college students. After preliminary investigation and analysis, it is found that since online tutoring focuses more on personalized interaction-based instruction, teachers need to determine the communicative and cognitive conflict of students based on their words (or even facial expressions) for effective teaching. Students do not spontaneously generate highly elaborate explanations or questions (King, 1999). The burden of explanation pushes the students to evaluate, integrate and elaborate knowledge in new way (van Boxtel, van der Linden, & Kanselaar, 2000) and

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negotiation between teacher and student facilitates an awareness of shared goals (Dillenbourg, 1999).

At the same time, in the research field of international mathematics education, there are social turns and new paradigms of communication-oriented research. Vygotsky's insistence that thinking must also have a developmental predecessor in the form of some historically established, collectively implementable activity (Vygotski, 1978). Mathematics education Fredenthal prize prize-winning Israeli scholar Anna Sfard, who advocates the research paradigm of communicative orientation, put forward the commognitive concept, this is about the individual cognition and social interaction between a theoretical hypothesis: the cognitive process and interpersonal communication are the two different aspects of one phenomenon (Sfard, 2008).

The development of artificial intelligence (AI) makes the visualization of macro-cognitive diagnosis based on the data of scores less difficult, but visualizing the complex commognitive process remains a challenge for AI. Commognition visualizing theory and script are still needed for AI. The purpose of this study is to explore a visual representation of the commognitive process in online one-to-one teaching. We hope that with the help of AI, visual commognition can help teachers adjust their teaching.

2. Research review

Our research is based on Sfard's commognitive theory, so in this section, we will review her commognitive theory. Then we will review some related research about online tutoring because we explore the visualization of commognition processes in one-to-one online tutoring.

2.1. Commognitive theory

To emphasize the unity of the thinking process and communication process, Sfard (2007) combined cognition and communication into a new word – commognition, as the beginning of the complex process of constructing objective thinking discourse. Commognition regards discourse in communication as the mirror of thinking, discourse analysis as the basic research method, and discourse learning, and discourse development as the conceptual tools for analyzing teaching activities (Bebell & O'Dwyer, 2010).

By its cooperative problem-solving evaluation framework and based on the concept of Vygotsky's ZPD (zone of proximal development), the international ACT21S evaluation project proposed an innovative social and cognitive observation framework for teachers to use in the classroom (Woods, Mountain, & Griffin, 2015). According to the cognition efficiency of students' cooperative problem-solving process, it can be divided into six stages: exploration, systematic trial and error correction, information collection, strategic planning and execution, effective work, accurate strategic application and problem-solving.

2.2. Online tutoring

Growth in online learning requires that future educators know how to teach in this environment and that teacher education programs prepare them to do so (Archambault, 2011). Training and support of faculty are routinely noted as essential for the successful implementation of online education programs (Covington, Petherbridge, & Warren, 2005; Schmidt, Tschid, & Hodge, 2016; Yang & Linda, 2005). As online learning matures as a field, faculty members have a broader range of experience in online teaching and learning. Many training programs for online teaching are one-size-fits-all certification programs (Ginzburg, Peter, & Demers, 2010; Meyer & Murrell, 2014). The research of Kennedy and Archambault (2012) found that only 1.3% of teacher education programs are addressing the need to prepare educators for settings other than the traditional, brick and mortar classroom

(Kennedy & Archambault, 2012). And there was little research about supporting teachers' online teaching with data analysis technology.

This study investigates the model and evaluation method of the cognitive communication feedback in online teaching, which is helpful to the current online teaching practice on the one hand and can provide a theoretical basis and script material for the auxiliary intervention of future artificial intelligence on the other hand.

3. Research design

In this section, we will introduce how we designed our research. This section describes our study question, our study environment and how we scored the commognition during the online one-to-one tutoring.

3.1. Study question and assumptions

The research mainly focuses on the visual presentation of commognition in the one-to-one online tutoring process between one teacher and one student. We mainly study the following questions:

1. In the online one-to-one mentoring process, how can we classify the level of commognition based on the commognitive dialogue?
2. What are the features and categories of the commognition between teacher and student in an online one-to-one tutoring course, after they are visualized?
3. What are the characteristics of a teacher's and student's commognition in a series of online one-to-one tutoring sessions?

This study is a descriptive study focusing on an in-depth understanding of the interaction during computer-supported teaching and learning. Admittedly, the individualistic features of the cases unavoidably destroy the representativeness and the findings are inadequately generalized suggesting the need for more research.

The rationale to analyze online commognition between student and teacher is based on the following assumptions:

- Individualized learning of learners can be supported by teaching feedback.
- Online companion evaluation enables a comprehensive evaluation of ideas
- Teaching feedback can be reflected in the content of cognitive conflict.

3.2. Commognitive value

As stated in knowledge-building pedagogy, ideas can be improved. Online tutoring is a goal-oriented task. To acquire knowledge, a student and teacher communicate with each other to accomplish a set of goals and sub-goals. Thus, the messages they exchange could well be interpreted as stepping stones directed toward goals. The analysis should serve to describe and discern that behavior which is related to goal achievement. If we define the first message that students exchange as the initial state and the subsequent one as meaningfully interrelated to it, we can then plot the track of joint and individual contributions with the help of sequential analysis of collaboration.

Brown and Palincsar (1989) pointed out the necessity of a "fine-grained" analysis to understand the process of collaborative learning. We have used the sequential analysis that acknowledges that the message is a function of its context. To quantify each message to be able to plot the sum along the timeline just as in Ding's (2009) research, we coded the levels of each commognitive processes between teacher and student and endowed each with a number, 0,1,2,3,4,5 (Table 1).

Table 1. Commognitive values.

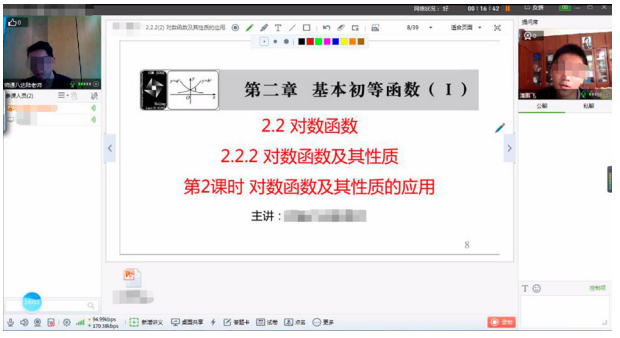
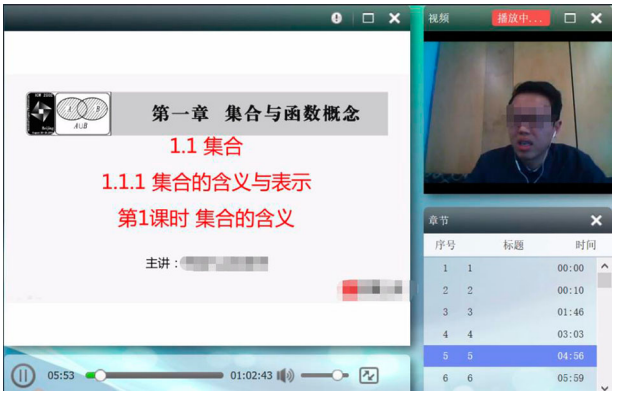
Score	Description	Example
0 Irrelevant front level	Messages that are irrelevant to the task and distract from the problem-solving task.	Teacher: Your eyes are a bit dark. Didn't you sleep well last night? Student: No,
1 macroscopic pre-level	Macro knowledge, skill, a method of problem-solving not directly related to the learning topic.	Teacher: How do you feel about the mathematics your learned primary school when you finished your junior high school? Student: Very simple. Teacher: Yes, it's very simple. So like the high school. If you think about junior high school knowledge when you finish high school, you also will feel that what you learned in junior high school is very simple.
2 Knowledge and skill target level	Memorize and understand the knowledge, thoughts, skills, and experience that can be remembered.	Teacher: Why do you want to learn this (sets)? We have some problems in junior high school, and the solution is that it is all integers. Student: All real numbers. Teacher: Well, real numbers or integers are fine.
3 Knowledge level	Analytical decomposition and comprehensive generalization of acquired knowledge and ideas in a new context.	Teacher: An entire team like China National Table Tennis is a set. Then each of its players is its element. Can you understand? Student: Yes.
4 skill level	Apply the acquired skills and experience to the new context.	Teacher: Yes, there is a circle. So is this a set? Sure? Student: Yes, yes.
5 Research and evaluation level	Exploration of problems and commognition at the level of problem-solving evaluation.	Student: I have a problem. The angles of the regular triangles are all 60 degrees. Isn't that different? Teacher: Can be different, side length (may) not the same. Such as……. Student: Oh.

If the message did not advance the problem solving or knowledge acquiring process, it was scored as zero (0). The presence of a lot of messages that were 0-valued would indicate that the students communicated sufficiently, but cognitively they stopped at a certain level. It serves to distinguish between the superficial and the collaborative discourse. When a message was pertinent to macro knowledge, skill, method of problem-solving, it was scored as a 1. When students recall or recognize knowledge and skills, the cognitive values were scored as a 2. If students analyze the knowledge and ideas of decomposition and comprehensive generalization in a new situation, we scored this as a 3. When students further understood and applied skills and experience, this was scored as a 4. If students explore and judge the quality and quantity of problems and problem solving, this was scored as a 5. For student and teacher, we added up the commognition scores one after another and plotted the sum sequentially according to the time sequence (see the example in Figures 3–6).

3.3. Online environment

The Internet, especially the Web, was designed as an information space (Oberle, Staab, Studer, & Volz, 2005), where everyone can access information. The online environment focused by the institute is a relatively common network environment in China. In China, typical one-to-one online tutoring platforms are the double the number of service platform sponsored by Beijing Municipal Commission of Education, as well as one-to-one, *yousi* and other online education companies. Online one-to-one teaching refers to a new teaching model in which teacher and student separately see each other through computer video to perform one-to-one private teaching in their comfortable places. There are two kinds of teaching interfaces: the first one is the teacher video window in the upper left corner, and the student video window in the upper right corner, and the rendering window of the courseware PPT in the middle, as shown in Figure 1 in Table 2. The online playback platform is the recording video of courseware PPT window and teacher video window, as shown in Figure 2 in Table 2. This interface takes into account factors such as video recording on the platform, and students are more inclined to view teacher and PPT content in the review.

Table 2. The screenshots of the platform and its Chinese meaning.

The screenshots of the platform	Translation of the Chinese
	Chapter 2 Basic elementary functions (I) 2.2 Logarithmic function 2.2.2 Logarithmic function and its properties Lesson 2 Application of Logarithmic Function and Its Properties
Figure 1. Online teaching demonstration platform.	
	Chapter 1 Concepts of Sets and Functions 1.1 Sets 1.1.1 The Meaning and Representation of Sets Lesson 1 The Meaning of Sets
Figure 2. Online playback platform.	

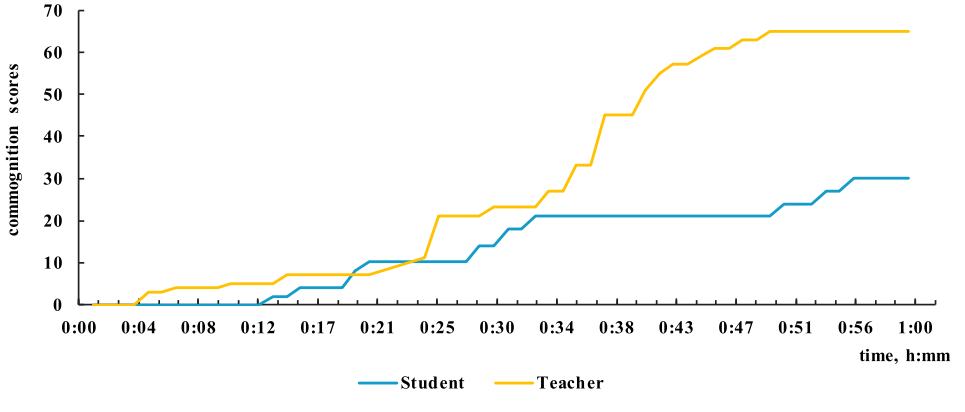


Figure 3. Teacher-lead commognitive process between student and teacher – Session 1.

3.4. Participants

Taking into account that the communication and cognition between teacher and student in higher grades will present more abundant levels and that a too high period may result in little low-level communication, we chose a senior high student as our participants.

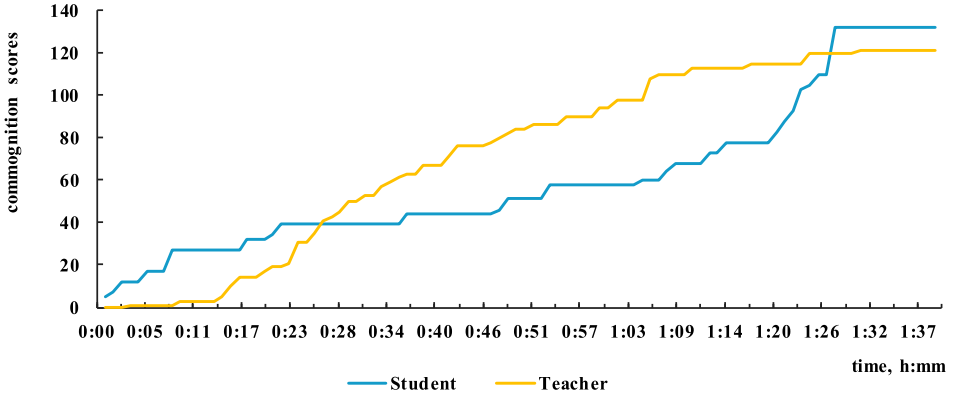


Figure 4. Comparison of commognitive processes between student and teacher – Session 2.

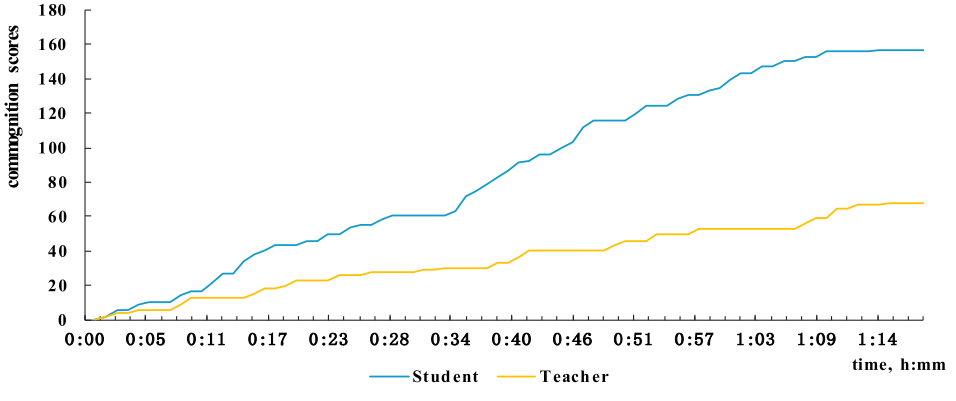


Figure 5. Student-lead commognitive process 1 between student and teacher – Session 3.

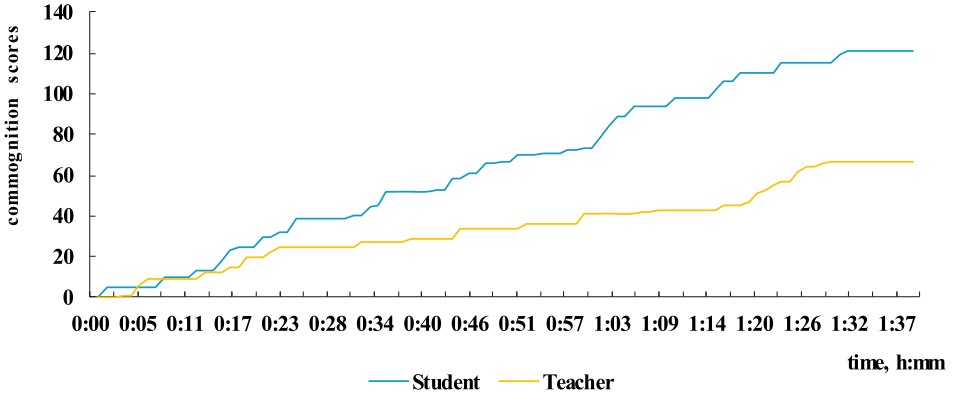


Figure 6. Student-lead commognitive process 2 between student and teacher – Session 4.

The teacher involved in this study is a young Chinese teacher who has been teaching students from high school for six years. The studentinvolved is a 15 years old boy from Fujian Province in China. His mathematics performance is medium, but he is active in communication with his online teacher. After the courses, we interviewed the teacher for 30 min and learned about the teacher's feedback on session and student performance.

And there are two PhD students, who researched mathematics education, took part in the video coding. Their coding method was Content Analysis and the coding Kappa coefficient was .947, which was appropriate. And they got agreement about the inconsistent coding results.

3.5. Lesson samples

The teacher and student online lesson sample is a given by the teacher to the student in July 2018. There are four lesson samples. There was one lesson of 60 min and three lessons of 90 min, for a total of 330 min. The specific lessons' content are as follows: (1) The meaning and representation of the set, (2) The basic relationship between the sets, (3) The first part of the basic operation of the set, (4) The second part of the basic operation of the set, which are the beginning lessons of high school in China.

Set theory is a basic branch of mathematics and occupies an important place in mathematics. Its basic concepts have penetrated various fields of mathematics.

4. Results

This study mainly adopts the target type of intention analysis in content analysis to select one point per minute for the four-section teaching video, and the two codes code the communication process of student and teacher according to the above commognitive level. If the commognitive process is led by the teacher, the coder will add the commognitive score to the teacher. If the communication process is student-led, the coder will add the score to the student. At this point, without the commognitive production, the curve of both teacher and student did not rise. The coders also used consistency coefficient and Spearman rank correlation coefficient (test cognitive level coding with rank attribute) to test. For each individual, we added up the commognition scores one after another and plotted the sum sequentially according to the time sequence (see the example in Figure 4).

4.1. Teacher-lead commognitive process

The first session focuses on the meaning and representation of sets. The course duration is 62 min. Because the assembly is the first session in high school math, the first 10 min of the teacher conducted a guide to the students' upcoming high school math study. During this period, the teacher was mainly speaking, and no student commognition was evident. In the 11th minute, commognition began to rise (Figure 1), and the teacher began to teach the student about the meaning of sets. For the period 20–30 min, the teacher guides the student to think about which statements refer to sets through presenting selected examples. During this period, there is evidence of commognition between teacher and student, and there is a significant rise in the teacher-led commognition curve. From 33 to 51 min, the curve of the teacher keeps rising while the curve of the student remains static (Figure 3). This represents = a long process of commognition led by the teacher. During this time, the teacher helps the student to understand the certainty, interchangeability, and disorder of the set by asking questions. In the 52nd minute, the student's curve begins to rise. This is where the student begins to consolidate his knowledge structure.

4.2. Comparison of commognitive processes between student and teacher

The second session is 98 min long, which mainly explains the basic relationship between sets and related applications. The period from 0 to 17 min is a review of the last session, where the student asks the teacher questions about the exercises he has done. This process is a student-led commognition (see Figure 4). At the beginning of 23 min, teacher led the development of commognition and taught students about the relationship between sets. The 81st minute was a turning point, as student-led commognition increased. From this point on, the student appeared to engage in a

more active learning state. Similar to the first session, in the last 10 min, the teacher and student reviewed the whole session and there was no observed commognition with each other.

4.3. Student-lead commognitive process

Session 3 and session 4 are both about the basic operations of sets, and the length of session 3 is 83 min, and the length of session 4 is 96 min. In both sessionss, there were more student-led commognition than teacher-led (Figures 5 and 6), a frequent occurrence in online one-to-one teaching. In this state where students dominate commognition, students can better construct their knowledge and achieve better learning results. From the interviews with teacher, we also verify this point.

5. Discussion

The four sessionss represent four types of online one-on-one sessions. In the first session, the student has not engaged in the process, and the student-led commognition is low. In the second session, the student gradually began to find the feeling of learning, and student-led commognition increased. The third lesson, the student leads the entire course the cognitive process. In the interview with the teacher, the teacher rated the students' performance in this session very positively, and the teacher had a high sense of self-satisfaction. The fourth session is a more typical process of online one-to-one teaching between a teacher and student where the student tends to dominate the process of commognition.

From the first session to the third session, student-led commognition is seen to be gradually increasing, and we attribute this to three reasons. (1) the degree of familiairity between the student and teacher increases, so the level of commognition increases. (2) There is a progressive process for the knowledge of three videos. After students have a certain understanding, later commognition is more likely to occur. (3) The learning content of the third lesson is more inclined to be a practical application, so the level of commognition is higher.

The level of student's knowledge increases with the level of commognition. When student fail to show evidence of commognition, teacher should pay attention and help students to develop new commognition. During the 20–30 min of each session, there is no new observed commognition. During this period, teacher are explaining new knowledge.

6. Conclusion

Based on Bloom's cognitive target classification, commognitive process of online one-to-one tutoring could be divided into five levels: macroscopic pre-level, knowledge and skill target level, knowledge level, skill level, research, and evaluation level. In the first level, they talk about macro knowledge, skill, method of problem-solving that not directly related to the learning topic. In the second level, the student can memorize and understand the knowledge, thoughts, skills, and experience that can be remembered. In the third level, the student could use analysis decomposition and comprehensive generalization of acquired knowledge and ideas in a new context. In the fourth level, the student applies the acquired skills and experience to the new context. In the highest level, the student can make the exploration of problems and commognition at the level of problem-solving evaluation.

After the visualization of the cognitive communication in the online one-to-one tutoring course, we can see the status of a student's commognition in the session, as well as the length and level of the emergence of the student-led commognition. Teacher-student commognition in the online teacher-student one-to-one course is mainly divided into three situations: teacher-led commognition, comparison of commognitive processes, and student-led commognition. Student-led communication is more conducive to knowledge construction and learning.

Teacher should pay attention to a student's communication and cognition level in the teaching process. When student do not communicate with teacher for a long time, teacher should guide student to think instead of following through. In circumstance with one-to-one technology, every student owns and regularly uses a personal computing device (Chan et al., 2006), such as a tablet. A large amount of important information reflecting student's learning situation can therefore be recorded via the interactive multimedia instruction system running on the computing device. Based on the data recorded, the teacher can know about a student's learning status in time after session even during session time. In the future, after the voice recognition and AI automatic labeling technology have reached a certain level, the cognitive communication curve generated by artificial intelligence can help teacher to reflect and summarize after session, as well as help parents to understand the learning status of students.

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