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Using a learning cycle to deepen chinese primary students' concept learning of the "phases of the moon"

Jing Lin
Beijing Normal University, CHINA

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This study focuses on the internal conditions of students' concept learning and builds a learning cycle' based on the "phases of the Moon" (MP) to, deepen students' understanding. The learning cycle of MP developed in this study includes three basic learning links, which are: cognitive conflict, abstraction and generalization, and transfer practices. The three basic learning links are named CAT for short. A teaching courseware based on CAT for MP is developed and tested in real classes. 667 students and 21 science teachers use this courseware in 9 primary schools in Beijing. Three approaches for collecting data are incorporated, including: questionnaire surveys for students, interviews for students and teachers, as well as classroom observations by teachers. Findings indicate that CAT for MP is useful to engage students' thinking and deepen students' understanding of MP. Findings also suggest that CAT classroom instruction should be learner-centered and inquiry-oriented; teachers should use the "nondirective language" to guide and boost students' learning. Accordingly, the learning cycle is worth further promoting towards being applied in students' concept learning. Moreover, the mechanism and application strategies of CAT need to be further studied and generalized, the students' learning achievements need to be deeply assessed, so as to make CAT more useful for science classes and learners.

Keywords: concept learning, cognitive conflict, abstraction and generalization, transfer practices

INTRODUCTION

Since 1970s, concept learning has been a key issue in the research field of science education (Duit, 2009; Tamer, et al., 2014). Tamer et al. (2014) divide the research history of concept learning into three phases. The first phase (the 1970s and 1980s) is united in revealing the importance of characterizing students' conceptions in specific domains. A second phase (1990s and early 2000s) focuses on understanding the process of conceptual change, recognizing a range of diverse knowledge elements is involved. The third phase (2000s-) adopts systemic perspectives to characterize

Correspondence: Jing Lin,
China Collaborative Innovation Center of Assesment toward Basic Education Quality, Beijing Normal University, China.
E-mail: linjing@bnu.edu.cn

conceptions and conceptual change, and design instruction taking into consideration the interaction of various knowledge elements.

Among the pre-existing concept learning theories, the most influential theory in China is the "Conceptual Change Model" (CCM, Posner et al., 1982). CCM contends that conceptual change occurs in the following four conditions: (1) students become dissatisfied with existing conceptions; (2) students realize the new conceptions are intelligible; (3) students get to know that the new conceptions are plausible; and (4) students find out the fruitfulness of the new conceptions. Analyzing the applications of CCM in Chinese science classes, researchers admit that Chinese science teachers focus on the external conditions but neglect the internal conditions of students' concept learning to teach students scientific conceptions (Jiang Ye, 2013). For example, teachers seldom think of students' current conceptions and fail to make students dissatisfied with existing conceptions (Qiulin, 2006). In addition, teachers are used to lecture and demonstrate the teaching contents by themselves, instead of engaging students into talking and discussing what students think and learn in the classes (Jiang Ye, 2013; Cong, 2015). Hence, it's still tricky for Chinese science teachers to successfully instruct students' concept learning (Cong, 2015; Lixin, Qi, 2006).

Gagne (1962) proposes that the external learning conditions do work through the internal learning conditions. Researches of students' concept learning also commend the internal conditions of students' concept learning, such as learning motivation, meta-cognition, thinking ability, etc., influence students' concept learning (Posner et al., 1992; Osborne et al., 1983; Donovan, Bransford, & Pellegrino, 2000). Focusing on the internal learning conditions of students, this research takes the "phases of the Moon" (MP) as a case to study learning cycle of scientific conceptions, with the expectation to enhance Chinese science teachers' teaching for conceptions and deepen students' understanding.

State of the literature

- Cognitive conflict is attracting more and more attention in researches on students' concept learning. Triggering students' cognitive conflict, which serves as a prerequisite for scientific concept learning, not only activates students' existing knowledge, but also generates students' learning motivation and interest.
- Successful scientific concept learning is not just the obtainment of scientific knowledge for students, instead it also improves students' ability to abstract and generalize these significant thoughts.
- To learn knowledge is to transfer it. The transfer of scientific concepts not only elaborates students' understanding on scientific concepts, but also improves students' strategies and ability of metacognition.

Contribution of this paper to the literature

- From a comprehensive perspective, the CAT learning cycle focuses on students' internal learning conditions to integrate external learning conditions and give a new dimension to the theory research on concept learning.
- CAT learning cycle provides learner-centered and inquiry-oriented classes with a new design approach.
- The instruction design based on the CAT learning cycle of the "phases of the Moon" integrates scientific inquiry of scientific concept and information technology, and demonstrates a specific case for deeply concept learning of primary school students. Based on the CAT learning cycle, the instruction of the "phases of the Moon" integrates inquiry learning of scientific concepts with information technology, and it presents a specific case for the deep learning of scientific concepts.

THEORETICAL BACKGROUND

From the nature of scientific conceptions and the thinking process of concept learning, this study contends that in order to understand MP fully, students need to experience the following three basic thinking processes – cognitive conflict, abstraction and generalization, and transfer practices (Jing, 2009). Through the repetition of these three processes, students finally achieve a delicate and mature comprehension of MP. This learning cycle, named CAT, is shown in Figure 1. Listed below are the detailed explanations of this learning cycle.

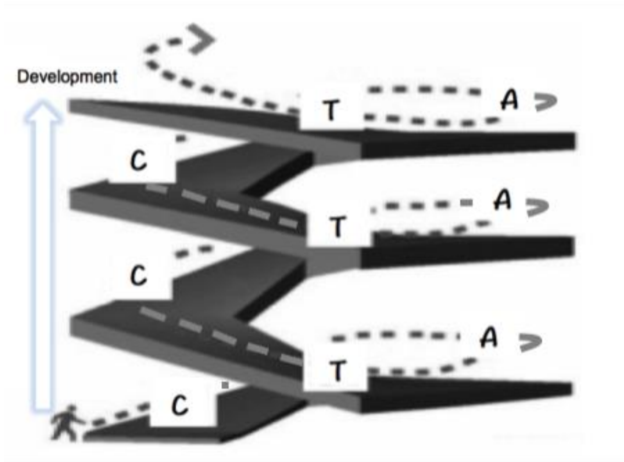


Figure 1. CAT learning cycle

To trigger students' cognitive conflict

Cognitive conflict (Piaget, 1995; Howe, Tolmie, & Rodgers, 1992) refers to the incompatible conflicts or the disharmonies between students' pre-existing cognitive structures and the new knowledge. Before arriving at the classroom, students are not "empty vessels" or "blank slates" (Ausubel, 1968). Studies show that infants have formed conceptions even in their first month (Richard, Heidi, & Andrew, 2007; Baillargeon, 2004). Within a few short years, children attain a large number of conceptions, including conceptions about time, space, number, biology, etc. (Siegler, 1986). Then children gradually form their own "naïve theories" (Bertamini, Spooner, & Hecht, 2004; Mandler, 2004; diSessa, Minstrell, 1998), also called "everyday conceptions" (Vygotsky, 1962) or "alternative conceptions or misconceptions" (Mintzes, Wandersee, & Novak, 1998; Driver, 1983; Clement, 1983; Lythcott, 1985). For example, based on their limited observation ability, children tend to take moving and predation as animals' common characteristics and use them to distinguish animals from plants (Inagaki, Hatano, 2002; Wandersee, 1983).

If students don't realize the gap or the deviation between their prior knowledge and the new knowledge, they don't spontaneously change their prior knowledge to comprehend and construct the new knowledge (Dignath, Kiesel, & Eder, 2015). On the basis of their daily experience, primary students will form some ideas, for example: that land is generally flat, or objects without support will fall down. When teachers tell them "the Earth is a sphere", these children tend to imagine the Earth as a pancake or a plain sphere, whose inside part or top part is just like a pancake, to explain to themselves why people can stand or walk on the earth surface (Vosniadou, Brewer, 1989).

Therefore, teaching is more than activating students' pre-existing knowledge. Teaching actually needs to let students realize the conflicts between their prior knowledge and the new one while arousing their learning motivation (Dignath, Kiesel, & Eder, 2015). Cognitive conflicts are the starting point, as well as a good future resource, for students to learn new conceptions (Limón, 2001). Cognitive conflicts arouse learners' meta-cognition and self-regulated learning, thus prompting the conceptual change (Shahbari, Peled, 2015). For example, teachers ask those students, who deem that the Earth is flat, why the hull of a fading ship disappears first. Moreover, teachers ask those students, who consider that soil is the food of plants, why plants cultured without soil grow as well. When students use their existing conceptions to answer these questions, their cognitive conflicts arouse and their concept learning starts.

To promote students' ability of abstraction and generalization

Carey (1985b) proposes that there are two different categories in concept learning – strong restructuring and weak restructuring. Weak restructuring refers to regular concept learning, mainly involving the accumulative growth of factual memory and ideas, while strong restructuring refers to the in-depth learning and the fundamental conceptual change, mainly involving the brand-new recombination of conceptual structures.

Chi (1992) further puts forward that only when students' assumptions about ontology and epistemology are changed can the fundamental conceptual changes occur. For example, the shift from "whales are fish" to "whales are mammals" is weak restructuring. It is within ontological conceptual change because both "fish" and "mammals" belong to animals. The fundamental conceptual change is across ontological conceptual change. For instance, students attribute light to the category of "material" while actually it belongs to the category of "process" according to the scientific explanation. For this reason, in order to promote students' fundamental conceptual changes, it is crucial for students to understand the characteristics and properties of conceptions' ontological categories.

Abstraction and generalization are helpful for students to understand the characteristics and properties of objects (Walker, 2015; Van, 2012). The term, abstraction refers to the thinking process of discarding the individual and non-essential while extracting the common and essential characteristics or connections among objects (Jing, Julie, et al., 2010). Generalization is the thinking process of joining up the same kind of objects (Stokes, Baer, 1977). Through abstraction, students decide the connotation of conceptions, so abstraction is the foundation for generalization. In turn, through generalization, students decide the extension of conceptions, so generalization promotes a more scientific abstraction (Skinner, Daly, 2010). For example, when students learn about different flowers, they first pick up the common characteristics of flowers; then according to different functions of flowers, roots, stems, leaves, etc., they generalize that stamen and pistil are the most primary structures of flowers.

The purpose of students' abstraction is to reduce the complicated relations among objects and to get generalized conceptions. Students look at specific objects comprehensively and then grasp the essences and rules of these objects through abstraction (So, 2016). Although there are many definitions of intelligence, abstraction is conformably considered as the most important component of intelligence (Coon, 1997). The foundation and chief characteristic of thinking is generalization (Chongde Lin, 2003). Therefore, science teachers should properly engage students into abstraction and generalization to develop students' intelligence.

The CAT learning cycle regards abstraction and generalization as the basic steps of concept learning that not only highlights the characteristic of concept learning, but also develops students' ability of self-regulated learning and meta-cognition through improving students' thinking ability (Skinner, Daly, 2010). Some of the existing teachings of scientific conceptions haven't given enough emphases to abstraction and generalization (Walker, 2015). Even though students realize the gap between their prior knowledge and the new conceptions, they can't master the new conceptions because they lack the thinking ability to assimilate new conceptions (Skinner, Daly, 2010; Walker, 2015).

To guide students in transfer practice

Learning transfer refers to the influence one kind of learning exerting on the other or the influence of some acquired experience on other activities (Austin, et al., 2006). Some transfers are positive, while some are negative. If students' pre-existing knowledge is helpful to learn new knowledge, there will be positive transfer or transfer; if not, there will be negative transfer or interference (Zepeda, et al., 2015). Through transfer practices, students recognize relevant commonalities across contexts and generality of the scientific conceptions across these contexts, thus achieving a long-term and stable conceptual change (Tao, Gunstone, 1997). Besides, a research (Petitto, Dunbar, 2004) shows that people who have mastered scientific conceptions still remain the wrong conceptions in their mind. The key of concept learning is to make clear the conditions in which scientific conceptions are extracted and applied, thereby avoiding the interference of wrong conceptions.

The first factor that influences transfer is learners' mastery of conceptions. If learners have not mastered the meaning of the conception, transfer would not happen (Ayres, 2005). The second factor is the understanding level. Bare memory or wrong comprehension does not lead to transfer, either (Bransford, Stein, 1993). The third factor is the strategic abilities provided by meta-cognition (Godinez, Leslie, 2016). Meta-cognition refers to people's ability to predict their performance in various tasks and to adjust their present comprehension and mastery level (Brown, Kane, 1988; Flavell, 1976).

Many teaching models only emphasize its evaluating function but ignore the fact that learning transfer is indeed an expression of learners' self-regulation (Chongde Lin, 2012). Studies show that efficient learners value learning transfer and have strong motivation to promote their learning by transfer (Austin, et al., 2006; Chongde Lin, 2012). Moreover, these learners proactively identify the relevance among different learning tasks and identify the contexts in which transfer may occur (Chongde Lin, 2012). They will actively and correctly extract related experiences or useful resources, and apply these experiences and resources flexibly. In other words, efficient learners have the ability to use the new conceptions conditionally (Donovan, Bransford, & Pellegrino, 2000).

RESEARCH QUESTIONS

It's necessary to focus on specific learning contents and learning contexts to study students' concept learning (Driver, Easley, 1978; Chi, Hutchinson, & Robin, 1989). After exploring related literature and investigating into primary science classroom instructions, this study takes MP as the teaching content and designs CAT learning cycle for MP (MP-CAT). Here are the research questions:

1. Does CAT engage students into learning the conception of MP?
2. What are the strategies for teachers to suit the application of MP-CAT in class?

METHOD

Approaches

This study adopted the qualitative empirical method. Research processes are shown in Figure 2. The first step was to develop MP-CAT courseware to build up useful learning contexts for classroom instruction with the help of information technology (IT). Apart from 3 IT professionals, 2 geography education researchers and 2 primary school science teachers also participated in developing the courseware. The courseware was tested in real classes and modified by developers twice before official use. The second step was to test the usability of MP-CAT courseware by science teachers of primary schools in Beijing. The third step was to verify the usability of MP-CAT based on the experimental results and discuss the implementation strategies.

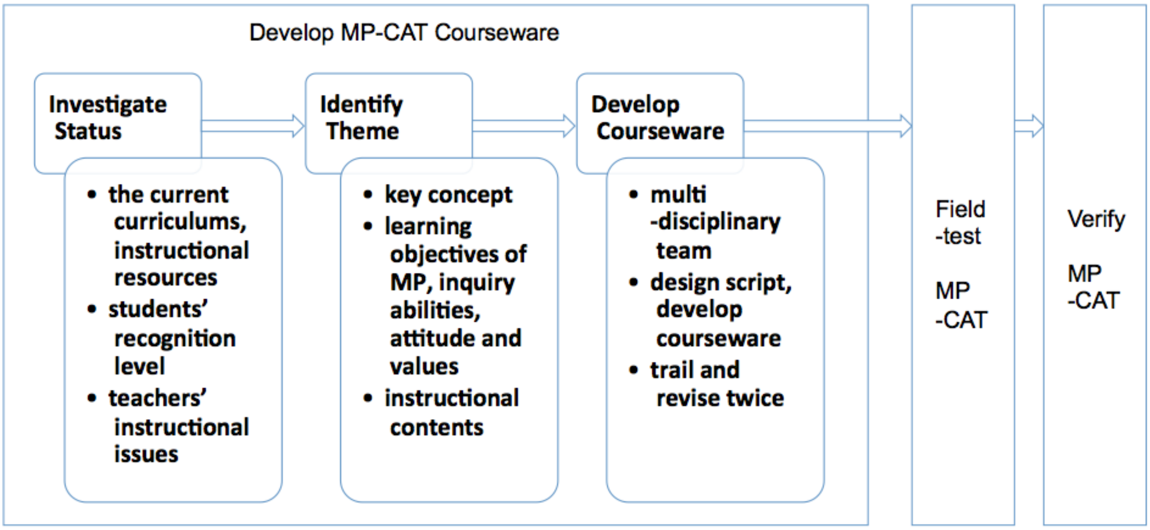


Figure 2. Research process.

MP-CAT

Here are the teaching objectives of MP for six-grade students:

1. Knowledge objectives: for students to understand that MP is the shape of the sunlit portion of the Moon as seen by an observer on the Earth. Students also understand that MP changes regularly.
2. Ability objectives: for students to improve their learning abilities, such as observing phenomena, discovering rules, explaining and demonstrating problems, communicating with each other, etc.
3. Emotion objectives: to cultivate students' curiosity to explore natural phenomena.

The specific CAT activities for MP are shown in Table 1.

Table 1. MP-CAT activities

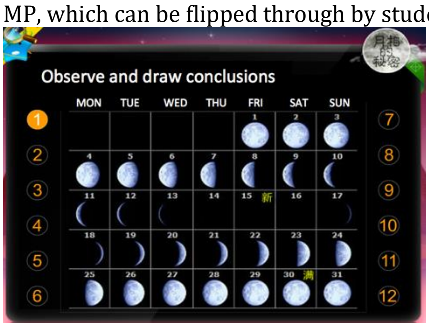
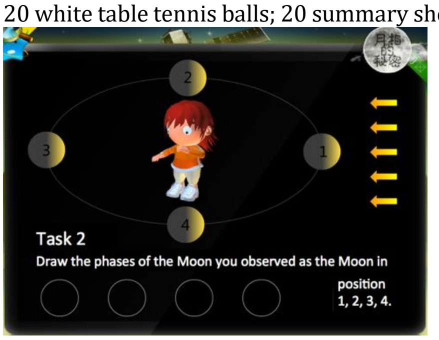
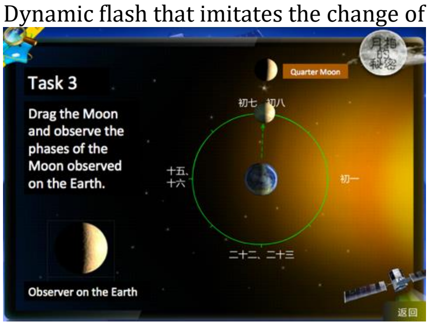
Teaching procedures	Teaching activities	Teaching aids
Cognitive conflict	1. Show students a video about MP, and then ask them to describe the scenes in their own language. 2. Ask students to get into groups of two and observe MP pictures. Then ask students to draw one or two conclusions and discuss the conclusions with each other. 3. After students know the general rule of MP, the teacher tries to trigger students' cognitive conflicts with this question: What are the reasons leading to the change of the Moon shape?	A video about MP with narration and music. (40s) Dynamic flash containing one-year pictures of MP, which can be flipped through by students. 

Table 1. MP-CAT activities (Continued)

Teaching procedures	Teaching activities	Teaching aids
	4. Ask students to observe the spatial positions and movement of the virtual Sun, Earth and Moon in the courseware. Help students to make sure whether the shape of the Moon changes.	Dynamic flash that imitates the movements of the Sun, the Earth and the Moon. 
Abstraction and generalization	5. Ask students to get into groups of two again and do an experiment. This experiment imitates the change of the Moon observed on the Earth, as it goes around the Sun. Draw a sun on the blackboard; give each group a white table tennis ball. Half of the ball is drawn black, representing the unilluminated part of the Moon; half of it is white, representing the illuminated part. Student A (representing the Moon) turns around the table tennis while walks around the other student B (representing the Earth). Student B observes the change of the table tennis (representing the Moon). Then students interchange their roles and record what they have observed.	20 white table tennis balls; 20 summary sheets. 
	6. Ask students to discuss their observation results with other groups.	
	7. Guide students to generalize what they have observed in activity 5 with the help of dynamic pictures imitating the change of MP.	Dynamic flash that imitates the change of MP. 
Transfer practices	8. Show a video on eclipse to students and ask students to explain the phenomenon.	A video of an eclipse.

The indicators for testing the usability of MP-CAT

This study tested the usability of MP-CAT for students in the following four aspects: (1) Inquiry: if MP-CAT encourages students to think and inquire; (2) Interactivity: if MP-CAT leads students to discuss with each other about their individually-structured conceptual meaning; (3) Interestingness: whether MP-CAT arouses students' intrinsic learning motivation and curiosity to explore natural phenomena; (4) Efficiency: if MP-CAT helps students' comprehension and application of the conceptions.

Participants

Nine primary schools in Beijing tested the courseware in the classes. According to the outcomes of education quality assessment held by local education institutions, three schools belonged to "good schools" in Beijing, located in the downtown; another three belonged to "ordinary schools", located in the suburbs of Beijing; and the last three belonged to "low-performing schools", located in the rural areas (Beijing RCSAQE, 2014). In total, 21 primary school science teachers participated in the experiment. All of them were full-time primary science teachers, but only one teacher had a background in science education. 667 students from Grade Six took part in the study. Teachers only had a CD carries a two-A4-paper teaching design of MP-CAT and MP-CAT courseware. Teachers did not receive any other training before the experiment. Teachers were allowed to discuss with other science teachers in the schools and try the courseware out for one or two lessons to understand CAT for MP. Then each teacher chose one lesson for the experiment and data collection. Every lesson lasted for 40 minutes.

Data collection

Three approaches were used to collect experimental data in this study: (1) questionnaire surveys for students; (2) interviews for students and teachers; and (3) classroom observations by other teachers.

Both of questionnaire surveys and classroom observations examined the usability of MP-CAT from the above-mentioned four indicators. The interviews utilized open-ended questions to explore teachers' and students' comprehensive assessments towards MP-CAT.

RESULTS

Questionnaire

The purpose of the questionnaire was to understand students' impression of MP-CAT. At the end of the class, students anonymously chose "yes" or "no" of the following subjective questions within 5 minutes. Totally 660 valid questionnaires were collected. The statistics in Table 2 show that MP-CAT is highly welcomed by students.

Interview

This study randomly selected 24 students from four experimental classes to do the group interviews. 6 students per class were sampled.

Table 2. Questionnaire survey for students

Indicators	Evaluation from Students	Yes
Efficiency	Do you understand the conception of MP now?	100%
	Do you think these learning activities are helpful to your learning?	100%
Inquiry	Did these learning activities contribute to your inquiry or your thinking?	97.8%
Interactivity	Did you actively interchange your thoughts with other students?	96.9%
	Do you think other students' or teacher's opinions are helpful to your study?	96.6%
Interestingness	Did these learning activities promote your interest to explore the natural world?	96.9%
	Do you like more such learning activities in your future science classrooms?	96.9%

The researcher interviewed the four teachers of these classes individually. All the interviews were made after the ends of the classes and the questionnaire surveys.

The interview for students had three open-ended questions (SQ), and the time of each interview was within 15 minutes.

SQ1: Please talk about MP with your own language?

22 out of the 24 students (91.7%) clearly expressed their understanding about MP. And two of them understood the cause of MP but couldn't express it fluently. Here are some examples of students' answers: (1) MP is the changing shape of the Moon's illuminated part by the Sun when it is observed on the Earth; (2) The phase of the Moon changes regularly; (3) According to MP, we (students) know whether the day is in the early month, middle month or late month.

SQ2: Which activity or which part of this class do you think is especially helpful to your learning of MP?

16 students (66.7%) thought that activity 5 was the most helpful one; 6 students (25%) thought that activity 7 helped them to summarize how MP was changing; 2 students (8.3%) thought that activity 2 helped them to get the rule of MP.

SQ3: What kind of help does the teacher offer to you in this class?

Among all the answers, "guide us to do activities" was the most used phrase (95%); the next one was "guide us to discuss" (90%); the third one was "guide us to think" (82%).

The individual interview of teachers had three open-ended questions (TQ). The time of each interview was also within 15 minutes.

TQ1: What do you think of students' performance in this class?

All four teachers contended that students were really engaged into concept learning. Students did a lot of thinking, and most of them comprehended MP correctly.

TQ2: Do you think MP-CAT is helpful for students to learn conceptions?

All four teachers thought that MP-CAT spurred students' curiosity and interest to explore the cause of MP. Teachers said that MP-CAT activities helped students to understand the cause of MP. They said students knew the shape of the Moon was the scene observed by people on the Earth, not the change of the Moon itself. Moreover, these activities also helped students to have some knowledge about the spatial position of the Sun, the Earth and the Moon.

TQ3: Do you have any suggestions to improve MP-CAT?

All four teachers hoped that more teaching resources based on the CAT learning cycle were designed. One teacher proposed that it was better to separate the activities of each step in CAT, so that teachers combined them according to specific teaching contexts.

Classroom observation

Most observers of these 21 experimental classes were primary science teachers from the same schools or districts' few were primary science research staff from local districts. There were brief descriptions about the four research indicators in the observation table. Based on the specific teaching contexts, observers graded the class from these four indicators. Each indicator had five grading categories –very poor, poor, average, good, excellent, and corresponding Likert Scale of 1, 2, 3, 4 and 5. Observers were also required to record briefly what they have observed as the reference of their marks. In total, 260 valid observation tables were collected. SPSS was used to process the collected experimental data. The results are as follows in Table 3.

In addition, there was no significant difference concerned with the experimental data from the three types of school, except that the two students in the interview who didn't clearly express their comprehension about MP were from rural primary schools.

Table 3. Classroom observations by teachers.

Observation indicators	M±SD	Teachers' record (examples)
Inquiry: Do the teaching activities encourage students to inquire?	4.7 ± 0.72	1. Questions or activities effectively motivate students to think; 2. Students are really devoted to the class; 3. Students inquire different questions actively in class.
Interactivity: Is there communication and discussion among students?	4.6 ± 1.41	1. The communication and discussion in class are both lively and inspiring; 2.Students are using their own knowledge to explain the new phenomenon; 3. Students have good teamwork.
Interestingness: Do the teaching activities arouse students' learning interest and curiosity to explore the Universe?	4.6 ± 1.02	1. Students actively express their opinions and participate in activities; 2. Most students are curious and devote to the class; 3. Students have high learning interest.
Efficiency: Do students inquire the conception well in class?	4.7 ± 0.27	1. Students explain the eclipse well; 2. Students get their own explanation about the lunar eclipse; 3. Students have learnt something about scientific conception and inquiry.

SUMMARY AND DISCUSSION

The experiment data, collected from participants and observers in this study, showed that MP-CAT engaged students into learning. The study also demonstrated CAT-MP affected teaching conceptions and behaviors of science teachers. As for the teaching strategies for MP-CAT, the study concluded that the first thing for teachers was to establish an inquiry-oriented environment to stimulate students' high level thinking.

The CAT learning cycle helped learners' learning. The data of four indicators in this study showed that both students and teachers thought CAT-MP effectively spurred students' interest and curiosity, and engaged students into exploring the cause of MP. The data also showed CAT-MP successfully made students master the conceptions of MP. However, there was a limitation of this study that the data were obtained mainly through qualitative questionnaires, interviews and classroom observations, rather than evaluation of students' learning achievements.

The CAT learning cycle also helped teachers to change their teaching conceptions and teaching behaviors. One participant, a female teacher (Xu) only applied activity 2, activity 5 and activity 7 when she first tried out the courseware in her class. The three activities were only used to follow her lectures. When she was required to use all of MP-CAT activities and ask students themselves to draw conclusions from each activity, she was confused about the purpose of activity 4 and didn't know how to organize the class. After the second try-out class, Xu said she didn't know how to encourage students to ask questions and how to answer them properly. In her third class, which was the final experimental class, observers gave high praise to students' performance and their comprehension of MP. Xu totally repudiated her previous teaching language and classroom organization in her previous classes in the individual interview, of which she always played the dominating role. Xu said she kind of didn't know how to teach students now, and needed to scratch and design her teaching from the student's perspective. It was also a limitation that this study didn't investigate teachers' conceptual change and behavior transformation of teaching to explore the effectiveness of CAP-MP on teachers' professional development.

The results of the classroom observations, interviews and Xu's personal case tell that MP-CAT classroom teaching is learner-centered and inquiry-oriented. Teachers are "booster" in the class. Their capital task is to use "nondirective language" (Carl Rogers, 1951) to encourage students to think, express and evaluate. For this purpose, teachers need to study the "communicative rationality" (Jürgen Habermas, 1968) and sincerely let students play the main role in class. Moreover, teachers need to develop good interpersonal relationship with students and give positive evaluations to them, so that students feel teachers' respect, trust and expectations for them. In such a positive, secure, equal, democratic and open classroom atmosphere, students' "emotional brain" (Dolan, 2002) will be fully activated, thus allowing students to do more high-order thinking activities. Further study is needed to summarize more detailed effective teaching strategies in CAT classes.

The experiment data of this study show that MP-CAT courseware used in this study is highly welcomed by both teachers and students, which means that high-quality and professional teaching is eagerly needed in Chinese primary science classes. The research on the current primary science education status in China indicates that the full-time science teachers make up less than 50% of the total sample, the professional teachers are less than 10% of the total sample (Liu, et al., 2010). Many rural primary schools are in desperate shortage of full-time science teachers (Tang Wanqing et al., 2014; Qi Xiaodan, 2005; Yang Qinfang, 2007). Some primary science research staff state that many teachers even don't know the cause of MP themselves, which makes it harder to teach students. According to the experimental data of this study, there is no difference between the urban and rural primary schools, which indicates that high-quality classroom teaching improves education equality between the urban and rural areas. Hence, it's very meaningful to do further study on the application of CAT-MP in primary schools in Chinese outlying poverty-stricken areas.

CONCLUSIONS AND IMPLICATIONS

Taking MP as the teaching contents, this study proves that the CAT learning cycle, including cognitive conflict, abstraction and generalization, and transfer practices, is useful to engage students into concept learning. This study also shows that teaching activities focusing on the internal learning conditions are helpful to construct the student-centered and inquiry-oriented learning contexts. Consequently, the internal and external learning conditions are integrated, and thus classroom is an ideal learning place for students.

According to the study findings, this has implications for science teaching that depends on students' internal learning conditions to design and conduct instructions. Hence, teachers need to research students' internal learning conditions and set up "tension" for each step of CAT according to students' specific conditions. In cognitive conflict, the tension lies in the relationship between where students are (pre-existing knowledge) and where students to go (scientific conceptions); in abstraction and generalization, the tension lies in the change of students from the facts, phenomena and concrete of conceptions (what are the things) to the essence and general characteristics of conceptions (what's the nature); in transfer practices, the tension lies in students' understanding the relationship between the connotation, extension of the conception (how correctly understand) and the delicate, mature aspects of the conception (how deeply understand). Teaching activities and learning contexts need to be designed based on these tensions, so that these activities motivate students to do high-order thinking activities.

MP-CAT requires learner-centered classroom teaching. This has implications for science teaching that aims to build up concept learning community in the classes. This requires teachers to have systemic perspectives to consider the interaction between the internal and external learning conditions of students, breed a suitable atmosphere to support and improve students' inquiry and communication in students' concept learning. Therefore, teachers need to establish student-centered teaching ideas, get to know individual differences among students and effective mechanism of inquiry and communication in science classes.

Future research is needed to improve the learning mechanism and application strategies of CAT by being utilized widely in real classes. In addition, research is needed that focuses on the leaning achievements of students to evaluate the effectiveness of the CAT learning cycle. Finally, research is needed that develops more teaching resources of scientific conceptions based on CAT, so as to push the science teaching reform and develop students' scientific literacy.

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