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Improving the Efficacy of Questioning Techniques in Science Teachers' Inquiry Instruction

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Abstract
Questioning is the heart of inquiry-based, science teacher instructional activities. However, the efficacy of questioning techniques in science teachers' inquiry instruction has always been found to be a concern of educational researchers.
This group of studies (including two sequent studies) attempted to understand what affected science teachers' expertise in using strategies of questioning in China in order to meet their pedagogical needs in improving the efficacy of questioning skills in inquiry instruction. We also investigated the efficacy of questioning techniques using simulations in inquiry instruction.
Both studies used case study methodology. The first study found that the five participated teachers, regardless of age and experience, all had pedagogical issues in inquiry instruction regarding questioning. Several possible factors were suggested to result in differences in teachers' expertise in using strategies of questioning. These included: (1) teachers' beliefs of teaching and learning science, (2) teaching objectives, (3) teaching approaches teachers normally used in their regular teaching, and (4) teaching experience. The second study used a quasi-experimental design to investigate whether and how questioning techniques could be improved and supported through using simulations. An 'educational trail' was conducted in a Year 10 physics inquiry classroom. Teachers' views on the ways they think that questioning techniques with simulations support their professional development is also analyzed. Three factors were found to contribute to application of questioning techniques: (1) simulation as scaffolding tools for effective questioning; (2) simulation as educational tools for creating friendly learning environment; (3) simulation as virtual experimental lap for optimal application of inquiry instruction.
The results indicate that in China science teachers need to be provided with appropriate professional support to improve the efficacy of questioning skills when conducting inquiry instruction. Furthermore, computer-based simulations scaffold the implementation of questioning effectively. Thus, we propose that science inquiry classroom should take full advantages of questioning techniques, and call for further investigation on questioning techniques and strategies, using other educational scaffoldings.

1. Introduction
Questioning is the heart of inquiry-based, science teacher instructional activities [1]. By applying effective questioning techniques, teachers could actively engage students in inquiry, reveal students' thinking, and target their misconceptions. However, teachers' questions are not universally effective in physics classroom. Therefore, the efficacy of questioning techniques in science teachers' inquiry instruction has always been found to be a concern of educational researchers.
The purpose of traditional teacher questioning is to ask students to recite what has been taught and then evaluate what students have memorized after a teacher propose a question. This model called as Initiation-Response-Evaluation (IRE) [2] is prevalent in Chinese physics classroom. Lemke [3] found that this IRE model is ineffective in leading to meaningful discourse, providing limited learning opportunity.
This group of studies including two sequent studies, which were conducted in China, attempted to understand what affected science teachers' expertise in using strategies of questioning in order to meet their pedagogical needs in improving the efficacy of questioning skills in inquiry instruction. We also investigated the efficacy of questioning techniques using simulations in inquiry instruction.

2. Method
Both studies used case study methodology. The first study involved five Chinese senior high school physics teachers. Data resources included classroom observations, formal interviews and casual talks,

and researcher's field notes. Formal interviews and casual talks were used to understand teachers' beliefs about teaching and learning science and their perceptions of teaching objectives.

Furthermore, to examine their questioning techniques in inquiry instruction, two aspects regarding questioning: (1) questioning techniques, and (2) technology used to facilitate questioning were focused in classroom observations and field notes. More specifically, the first aspect included the following teaching behaviours involved in teachers' questioning techniques: (a) presenting questions, (b) specific questioning skills, (c) using questions to guide students' learning process, and (4) adjusting questions according to student needs. The main idea of the classroom observations was to examine whether these teachers used questioning effectively to provoke students' thinking and guide them through the process of inquiry. The data resources were then triangulated to understand what affected science teachers' expertise in using strategies of questioning.

The second study involved 117 Year 10 students and two teachers who participated in a project that was to evaluate the effects of inquiry instruction with simulations on students' conceptual understanding in physics classroom in China. The two teachers conducted three lessons using different instructional approaches in the experimental group and control group. The purpose of the interpretive case study was to explore the reason why questioning techniques are effective in inquiry instruction and the way how teacher use questioning techniques in inquiry instruction. Besides, this study was also to complete to the former results [4] that could contribute, along with other studies, toward a new perspective in science education.

In this study, we focus on questioning techniques especially types of questions, structure of questioning sequence, and awareness of using simulations data for questioning. We examine two teachers' questioning techniques during physics lessons that were conducted for enhancing student's conceptual understanding. Data collection conducted by 2 researchers involved classroom observations and teachers interview.

The categories we developed through analysis naturally emerged from the data material. Categories about the discourse sharing in the classroom and their interview evolved from the use of "questioning techniques" as a unit of analysis. New meanings about questioning techniques were reached through the use of direct interpretation [5] by looking at single instances and pulling the data material apart and putting it back together in new, meaningful ways. The data analysis and interpretation also involved categorical aggregation in that we used multiple data sources and consult with knowledgeable colleagues who had read the field notes and the transcribed dialogues before they served as peer de-briefers to help ensure triangulation [6] and construct validity [7].

3. Findings and discussions

3.1 The first study

Results showed that the five participated teachers demonstrated different levels of proficiency in using questioning strategies and giving students' feedback. Furthermore, regardless of age and experience, they all had pedagogical issues in inquiry instruction regarding questioning. The following table shows one of the teachers' questioning techniques in inquiry instruction (see Table 1).

Table 1. Mr. Pan's questioning techniques in inquiry instruction

Mr. Pan	Questioning skills	● Asking questions to provoke students' thinking (what, why, how); ● Asking questions about the sufficiency of evidence ● Asking a series of questions which were presented in logical sequences with different degrees of complexity
	Technology used in questioning	● Using multiple presentations (videos and animations) to attract students' interests and to simulate experiments which are difficult to be conducted in classroom; ● Using computer and an over-head projector to show questions; ● Using experiments to modeling the procedure of conducting experiments and analyzing data
	Issues	● The questions were sometimes not phrased directly and simply, and sometimes unclear, confusing, and expressed irregularly; ● Although asked open questions, he did not well respond to students' answers; ● Not good at using questions to lead students' thinking

*Mr. Pan, over 20 years of teaching experience, teaching in a normal public high school of China

Several possible factors were suggested to result in differences in teachers' expertise in using strategies of questioning. These included: (1) teachers' beliefs of teaching and learning science, (2) teaching objectives, (3) teaching approaches teachers normally used in their regular teaching, and (4) teaching experience.
For example, Mr. Pan perceived that students were passive learners and teachers were spoon-feeders. Furthermore, he maintained that it was very difficult for his students to do a successful inquiry because they did not have adequate abilities and good behavior habits to conduct inquiry. For these reasons, he insisted that his students needed to be provided with very specific instruction to learn and solve problems. Therefore, it is not surprising that Mr. Pan intended to tell students information to fill the gap in students' knowledge, instead of using questions.
Mr. Pan thought that completing teaching tasks and well preparing his students for the exams were important objectives for his teaching. He maintained that for students, listening and drill-training were important for them to achieve better academic results. This might hinder his usage of questioning techniques in classrooms.
Mr. Pan felt more comfortable in using lecture style of teaching and seldom tried inquiry instruction in his classroom, because he felt that his students needed to be provided with specific instruction. It was not surprising that he preferred to have his students take notes rather than asking questions, and used more closed questions to engage students' attention rather than using open questions to prompt students' thinking. These teaching habits might be hardly changed even in an inquiry-based classroom.
Furthermore, it is reasonable to assume that Mr. Pan lacked experience in questioning as he generally employed lecture style of teaching in his teaching. The evidence supported this assumption. He was not well prepared for dealing the unexpected answers during inquiry-based teaching. Instead, he chose favorite answers or ignored unexpected answers immerged from students' responses. He did not realize the great power of students' self-explanation and probing questions in constructing understanding and improving learning.

3.2 The second study

We selected a vignette which demonstrates the use of questioning techniques both to explicate an inquiry method and also to show students the way how to explore questions through scientific methods. The vertical line presented the conversation sequence. (T stands for the teacher, and S refers to the student.)

> T: How about as you pushed the crate to the left?
> S: Negative values.
> T: Why do you see negative values?
> S: Because the box was moving to the left.
> T: What more can you tell me about the arrows, such as, the length or direction of them?
> S: The applied force arrow is pointing in the direction of the push. The friction force arrow is opposite of the applied force arrow.

It's obvious that we can know teacher Zhang uses interactive simulations to facilitate his teaching during the whole teaching process. The evaluation questions (how about) and interpretation questions (why) evaluate students' understanding. The last question indicated that teacher's questioning techniques (using hypotheses question) have influenced students' thinking. The smooth conversation between teacher Zhang and students attribute to the sound learning environment created by computer-based simulations.
According to the teacher interview, the two teachers implemented the major objectives of the inquiry instruction with simulations were well met. Teacher Zhang, a senior physics teacher, said, "After I personally used inquiry instruction in my classroom, I realized that how helpful it is when I discussed with students. It did help me use different types of questions and create a wonderful discussion environment with students. Explaining an idea such as Newton's laws through simulations is a vivid way for student learning." Teacher Han also expressed the similar meaning. She highly valued the simulations in application of questioning techniques so that she was involved in an effective discourse-sharing with students. Both of them mentioned that the use of simulation in inquiry instruction encouraged them to think deeply about their teaching, and improved their ability to challenges in science teaching and apply appropriate solutions.

4. Implications

This study suggests that to improve the efficacy of questioning in inquiry instruction, science teachers need to be provided a system scaffolding support. First, they need to be provided with appropriate professional support to update their beliefs of teaching and learning, and their understandings of inquiry. Until teachers are having appropriated understanding of inquiry and are happy to try inquiry-based teaching in their classroom, they are likely to accumulate experience of inquiry instruction. More experience in implementing IBT would help them to develop their questioning techniques in inquiry instruction.

Second, the science teachers need to be provided extra pedagogical support for inquiry instruction, such as programs aimed at helping teachers develop effective questioning techniques. Although IBT is encouraged in the curriculum standards, these teachers are not experts in IBT and had not been given much pedagogical support for IBT. Further, teachers may seldom implemented IBT and lack experience in delivering successful inquiry instruction. Appropriate pedagogical support would help them to built confidence in trying a variety of questioning skills in inquiry instruction.

Last but not least, educational technologies for scaffolding teachers' questioning were strongly recommended in inquiry teaching. Using appropriate educational technology in questioning, science teachers can create a friendly learning environment which involves students in active learning. The results strongly indicate that interactive simulations as scaffolding tools are effective for teachers questioning and for students optimal application. This study provided a new perspective in researches on questioning. In our other papers, we compared the questioning techniques in inquiry instruction with those in traditional instruction and reviewed the educational significance of using simulations in science education [8]. We expect to construct a descriptive framework for questioning techniques that may have heuristic value for teachers and researchers.

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