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Teacher Enactment in Collaborative Inquiry with a Science Learning Environment

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Abstract: Considering that limited studies have investigated the teacher enactment (TE) of complex ICT-facilitated lessons, a study on exploring the TEs of lessons supported by a science inquiry and collaborative learning environment (Collaborative Science Inquiry, CSI) was conducted. In the study, the topic was "diffusion and osmosis", and the participants were two teachers with their 43 students (Grade 7) from a secondary school in Singapore. Through examining the two teachers' characteristics of verbal behaviour and scaffolding for students, as well as comparing students' learning artefacts and performance, this study uncovers the differences in TEs of CSI lessons and their influence on students' learning. The findings and implications can inform the effectiveness of assisting TEs with complex science learning environments like the CSI system.

Keywords: CSI learning environment; teacher enactment; collaborative inquiry

1. Introduction

Recently, many stuides have focused on investigating the relationship between teachers' attributes and their teaching practices to improve the quality of ICT-facilitated instruction (Song & Looi, 2012). However, pedagogically effective use of ICT tools in education is far from being a reality, in spite of the huge advances in ICT. In the ICT-facilitated class, teachers need to orchestrate ICT-facilitated classrooms, dealing with both ICT and non-ICT artifacts and handling social interactions at various levels. In this study, we attempt to represent, interpret and compare the enactments of two teachers doing a lesson that incorporates the CSI (Collaborative Science Inquiry) learning environment. Through fine-grained data analysis, we intend to uncover the differences and variations of the TEs when teachers implement the designed CSI lessons in secondary school classrooms. This will inform the effective ICT integration in science instruction towards narrowing the gap between the designed lessons and the actual enacted lessons.

2. CSI Learning Environment

The CSI system embeds a guided inquiry framework and social interaction functions (i.e. CSCL design elements).It is designed to help secondary school students (Grade 7 to Grade 11) acquire sophisticated understanding of scientific concepts and develop crucial learning skills (Sun & Looi, 2013). A teacher module providing a multifunctional authoring tool for designing and editing instructional content, attaching simulations and questions, managing students' groups and assessing learning artefacts. The main working sections include Profile, Subject Management, Project Management, Simulation Library, Solutions Review, and Mailbox. The teacher allows for selecting the inquiry phases (i.e. Contextualize, Question & Hypothesize (Q&H), Pre-model, Plan, Investigate, Model, Reflect and Apply) based on her lesson plan and filling in the content in each phase. The student module is comprised of four sections: Profile, My Project, Group Management, and Mailbox. It allows students to access the assigned project to participate in inquiry activities and to complete a series of tasks with or without their group members. As the main venue of inquiry, the "My Project" window consists of four panes: inquiry phases, shared workspace, group member list, and a chat tool. The shared workspace stores the content or tools for each inquiry phase. Student inquiry is guided by the inquiry phases laid out on the tool bar. Students can switch between phases by clicking different tabs. During inquiry activities, CSCL design elements embedded enable students to do peer review, peer discussion, and synchronous modelling and editing.

3. Theoretical Framework

To attain effective TEs in inquiry-based instruction, Crawford (2000) proposed teachers should play a more expansive range of roles in facilitating inquiry activities. While Abdu et al (2012) concluded that teachers mostly acted as a moderator in CSCL learning context who provided three types of assistance for facilitating students' learning, namely, presenting the challenge, supporting group's collaboration, and supporting meaning making. These studies emphasize that the roles teachers act in an inquiry-based class or a CSCL setting impact the quality of the TEs. The ways in which teachers assist, respond to and intervene in students' work are also frequently discussed and taken as important indicators for evaluating their performance. Most mentioned that teachers' patterns of assistances affect students' forms of collaboration and their quality of collaborative work (Onrubia & Engel, 2012). Based on the above literature review, the dimensions for studying TEs in collaborative inquiry with the CSI system are identified as: 1) Teacher verbal behavior, namely, the essence of TEs in the CSI instruction and the patterns of teacher-student interaction in the collaborative work (Gillies, 2006); 2)Teacher scaffolding for different levels (i.e. class, group, individual) which enables us to distinguish the valuable TEs that facilitate students' science learning; 3) Students' performance in test, learning artifacts and collaborative work which reflects the impact of TEs on students' learning. The following research questions will be addressed:

- What are the major differences in TEs between different teachers when they implement the CSI lessons?
- How do different TEs affect students' performance in collaborative inquiry?

4. Methods

4.1 Participants

Two teachers and their 43 students (21 from Class A, 22 from Class B) from a junior secondary school in Singapore participated in the study. Teacher A (T_A) (male) and Teacher B (T_B) (female) were similar in their ages, teaching experience and background. Class A was taught by T_A, and Class B was taught by T_B. In the CSI lessons, students mostly worked in pairs (N_{pair}=96), with three groups working in triads.

4.2 The design of CSI lessons

The topic "Diffusion and Osmosis" in the Secondary 1 science curriculum was selected by the teachers and researchers. The inquiry phases were designed in the following order: Overview, Contextualize, Q&H, Pre-model, Investigate, Reflect, and Apply. The first lesson concluded with the students' Pre-model activities was intended to captivate students' interest in learning about "diffusion and osmosis" and to identify their levels of prior knowledge and misconceptions. Meanwhile, students were encouraged to develop collaborative learning skills through peer review, peer discussion and co-constructive modeling. In this lesson, students reviewed the textual information in Overview. In Contextualize, they were introduced to a story presented in the form of a comics. Students were then guided to discuss and articulate their answers to the two questions in Q&H. In Pre-model, students watched two videos that introduced real experiments to gain some awareness of the macro-phenomena of diffusion and osmosis. With sketch tool, they were then required to draw two scientific models individually to represent the processes of diffusion and osmosis at the particulate level and then collaborate with their partners to pose elaborated models. In the second lesson, students interacted with three simulations and answered the guiding questions in Investigate. Finally, each student wrote a self-reflection on his hypothesis, pre-models and conceptual changes in Reflect. Students ultimately validated their new understanding via answering questions in Apply.

4.3 Data Sources and Data Analysis

Data sources included video and audio transcripts of the lessons, students' pre-and post-test scores, learning artifacts and their performance in the collaborative work. Three categories of teacher verbal behavior: instructions, questions and mediated-learning (i.e. scripts, prompts and challenging ideas) were modified from Gillies' and other relevant research (Gillies, 2006; Morris, et al., 2010). A frequency count of different types of teacher verbal behavior was completed. The recipients of the teacher talk (i.e. individual, group, and classroom) and the phases their talk emerged were also analyzed. In order to reveal the roles teachers acted in class, the content of the scaffoldings and its frequency at each phase were examined.

Identical pre-and post-tests modified from two-tier "Diffusion and Osmosis Diagnostic Test" were used at the beginning and concluding stages of the CSI lessons (10 minutes for each) for probing students' conceptual understanding(Odom & Barrow, 1995). Students received one point for each correct item, so the highest score was 20. A paired-samples t-test was conducted to identify the difference of achievement between the pre-test and the post-test in each class, which served the basis for comparing the changes of conceptual understanding of two classes. The learning artifacts including students' answers to Q&H, Investigate and Apply questions, pre-models and their reflections were assessed according to their quality and rate of work completion. Finally, to assess students' performance on collaboration, their involvement in the activities and their peer discussions were examined and discussed. During classroom observation, four observers stood by to collect data and were prepared for offering assistances on technological problems. Two researchers participated in transcribing the videos and audios, coding data on teacher verbal behavior, their patterns of scaffoldings, analyzing test scores, and students' performance. The inter-rater agreement reached 89.15% for teacher verbal behavior, 92% for teachers' patterns of scaffolding, and 93.46% of students' performance.

5. Findings and Discussions

5.1 Teacher verbal behavior

As we found that T_A acted more as a guide and mentor who offered the guidance of inquiry activities (i.e. the sequence of inquiry phases) and the descriptions of specific tasks (i.e. purpose, procedures, the form of activities), as well as emphasized the duration of each task before the students did the activities. Being not as frequently involved in students' peer discussions, T_A spent most time in prescribing scripts of the tasks, and walking rounds to check and monitor students' progress. Consequently, more talk concerning instructions (9) and scripts (18) for the classroom were delivered by T_A than by T_B. All the verbal behavior we observed in T_A's lessons was targeted at the class level. This indicates that T_A laid great emphasis on class management through offering task-related macro-scripts and procedural prompts (instructions: n=9; mediated learning: n=34, with 18 scripts and 16 prompts). He frequently tended to "control" the class in the stage of pre-test, system login, overview and inquiry phases (Q&H, pre-model, Investigate), but this kind of "control" was rarely directed at groups or individual activities, as few verbal behavior appeared on the group and individual level. It was apparent that T_A tried to follow the lesson sequence as designed in the lesson plan, and to make students to follow his instructions strictly, which aimed to orchestrate class through regulating the whole class's progress in collaborative inquiry. Moreover, strategies on the use of chat tool, peer review and peer assessment, and collaborative modeling were also explained and elaborated at that moment.

Compared to T_A, T_B was involved in peer discussions in most groups, assisting them in explaining task and understanding knowledge. More mediated-learning prompts (38) were generated in T_B's lessons. In order to guide the understanding of some concepts, T_B often challenged students' previous ideas through asking questions (3) and using metaphors (6). Thus, in the CSI lessons, T_B acted more as a motivator, diagnostician and collaborator in students' collaborative inquiry work. The most noted difference was that T_B was always busy walking through the groups and assisting groups or individuals at each phase as students requested. A similar frequency of scripts and prompts was observed in each phase for the whole class. This demonstrates that T_B also had competence in managing students' progress. T_B was more frequently involved in students' collaborative activities and peer discussion in inquiry, especially in the Pre-model phase. 8 prompts for groups and 10 prompts for individuals were found in this phase. In the Pre-model phase, T_B provided immediate feedback to students' requests and acted as an adoptive facilitator to help students complete the tasks at both individual and group levels. Different from T_A, T_B's instructions and mediated-learning scaffolds were more related to guiding students to gain understanding of the domain knowledge of diffusion and osmosis. She was really good at motivating groups' deep thinking of concepts through challenging students' previous ideas or knowledge. Though the introduction of the purposes and the learning objectives of each phase was somewhat neglected, T_B elaborated on the sequences of tasks at each phase, and attempted to steer students' activities and collaboration to the appropriate direction. Generally, the instruction delivered by T_B was more student-centered. It was conducive to students engaging with the task at hand. More specifically, we noticed that during her interactions with individuals or groups, T_B focused on reviewing and commenting on students' results and picking up ideas and opinions generated by the students. T_B was able to gain some insights into the students' current understanding and knew how discussion should be initiated.

5.2 Teacher scaffoldings

In CSI lessons, the teachers tended to provide students with appropriate scaffoldings on understanding knowledge, carrying out the inquiry tasks, and coordinating the collaborative work. But the frequency and the phases these scaffoldings offered, and the recipients of the scaffoldings targeted at were different. According to data analysis, from Pre-test to Investigate phases, multiple scaffoldings were offered to students in both teachers' lessons (T_A=34; T_B=70). As T_B actively diagnosed students' problems in each phase and prescribed appropriate and immediate scaffoldings to students, more scaffolding was provided in T_B's class. T_A attempted to provide general scaffolding for the class when he reviewed and checked students' work. More scaffolding was provided by T_A at the beginning stages of the lessons (from Pre-test to Q&H). Starting from the Pre-model phase, T_B was involved more actively in students' activities than T_A did, especially in the individual and group activities. In contrast, the frequency of scaffoldings in T_A's class reduced dramatically from Pre-model phase. We infer that students' work focused on exploring simulations and doing self-reflections, less structured information was needed at those stages. So T_B left more room for students to learn new knowledge by themselves, T_B supported more for students' exploring new knowledge. Findings revealed that most of T_A's scaffoldings targeted at the classroom (classroom: n=24, individual: n=11) and were provided before tasks and during tasks (before task: n=17, during task: 15, after task: n=2). On the contrary, T_B preferred to offer assistances to groups or individual students (classroom: n=25; individual: n=45) while they were doing their tasks (before task: n=11, during task: n=59).

5.3 Students' Performance

5.3.1. Test achievements

17 and 19 valid tests were obtained in Class A (T_A) and Class B (T_B) respectively. Results of paired-samples t-test showed that the mean score differed between the pre- and post-tests in both classes at the .05 level of significance (Class A: $t=-4.152$, $df=16$, $p=0.001< .05$; $t=-5.920$; $df=18$, $p=0.000< .05$; Class B: $t=-5.920$, $df=18$, $p=0.000< .05$). Students in Class A and Class B had attained great improvement on conceptual understanding of diffusion and osmosis after the CSI lessons. For Class A, students had comparatively better prior knowledge (M=10.53; SD=2.503) than students in Class B (M=8.53; SD=2.695) at the beginning of lessons. While, the comparison of achievement scores indicated that the disparity of mean scores between Class A and Class B had been reduced from 2 (pre-test: M_{classA}=10.53; M_{classB}=8.53) to 0.97 after the CSI lessons (post-test: M_{classA}=14.18; M_{classB} =13.21).Thus, initial results could be obtained that the CSI lessons could significantly facilitate students' science learning and improve their conceptual understanding. Through comparison, we also found that different classes performed differently in the achievement test. We noticed that the class (Class B) which received low scores on prior knowledge benefited more than the class (Class A) which attained higher scores on prior knowledge.

5.3.2 Learning artifacts

With appropriate instructions, questions and teachers' efforts on mediating learning, both classes went through the tasks in the lessons, but different in the work completion and work quality. This is closely related to the TEs as we observed. First of all, as we mentioned earlier, T_A allocated more time at the beginning stages, and T_B devoted herself more to the work at later stages. Consequently, significant difference found in students' performance at Q&H that students in Class A reached higher work completion (73.5%) and responded more correctly to the Q_1 (correct answers: 53.4%) and 44.4 % for Q_2. In Class B, 60% of students responded to Q&H, with 50% and 35.3% correct answers for Q_1 and Q_2. This indicates that T_A's description of skills for peer review and peer discussion facilitated students' responses to questions at Q&H. For Class B, we detected that students who failed to finish their work were confused on the purposes and skills for the Q&H tasks.

In the Pre-model, Class A and class B constructed similar numbers of individual models (Class A: n=16, Class B: n=14) in their private modeling space. Class B performed better in building models of diffusion and osmosis. Among the 14 completed models, 10 models could represent the components of diffusion and osmosis, with partially incorrect relationship among components; 8 models in 16 of Class A failed to represent their understanding of diffusion and osmosis, which consisted of incorrect components and relations. As we mentioned earlier, T_B was involved frequently in students' peer discussion, and provided various scaffoldings for them to complete the modeling activities, which improved students' understanding of relevant concepts. For the collaborative models, students' work completion was not as high as their individual with 20% in Class A and 13% in Class B, this was largely related to the limited class time. It still reveals that students performed better in collaborative work as this required more modeling skills and collaborative skills.

Similar findings were found in their answers in Investigate. Both classes answered the questions after they manipulated simulations, their knowledge about diffusion and osmosis was improved more than they were at earlier stages. We found that although Class B received lower scores of pre-tests, they could respond to the questions in Investigate as well as Class A, even better for some questions. For the Reflect, compared to Class B (36.4%), Class A provided more critical reflections (45%) with the critiques, and the proposals of improvement, as well as further explanation of the artefacts. Most students in Class A followed a sequence of self-reflection, peer review, revisions following T_A's instruction. Thus, more full interpretations of reflections, like critical reflections were generated in Class A. While, in Class B, students focused more on their own reflections and missed elaborating their own reflections through peer review eventually. And for the performance at Apply, Class A and Class B provided high correct answers to the three questions (83% on average). These indicate that they had achieved more improvement in conceptual understanding and in solving problem in new context. There was no significant difference in their responses to the Apply questions as students were required to fill in the answers by themselves.

5.3.3 Collaborative tasks

In Class A, students sat normally and chatted with their group members using chat tool integrated in the system. The "voice" was only heard in the Pre-model phase as students in the same groups sat together to do face to face peer discussion, as the modeling tasks were of difficulty and complexity and online chatting may not be enough to exchange the ideas and information. The class became more active as students shared ideas with their group members to review, evaluate and elaborate their models. As they received substantive scripts and prompts from the teacher, they rarely asked for assistances from the teacher directly. This enabled the students to develop independence and ownership of knowledge. However, students who had limited ability and knowledge were found to be lost in their activities.

In Class B, students sat with their partners in all collaborative activities as proposed in the lesson plan, not just did in Pre-model phase as Class A did. Most of them chatted with their partners in a face to face manner. Hence, more "noises" were heard in class B. When T_B approached the group who requested for assistance and then directed that group to build understanding and knowledge of the tasks, students in other groups were not disrupted. They actively discussed their collaborative work, sharing ideas and debating the conflicting views. Their collaboration was more productive in terms of knowledge understanding. We found that they had strong willingness to invite T_B to join their discussion to evaluate their artifacts, share understanding of concepts, explain the purposes and procedures and other relevant information about the tasks. However, with limited knowledge and skills on collaborative learning, they requested more scripts from T_B on the work division of collaborative work and the procedures and purposes of these tasks. They spent more time completing their work.

6. Conclusion

In summary, although teachers and researchers co-designed the CSI lesson plan and proposed the TEs with general teaching strategies for supporting the implementation of the lessons in class, significant differences were found between the TEs of two teachers' in CSI lessons. In general, both teachers followed the proposed inquiry phases to execute their instruction, but variations emerged in their verbal behavior, scaffoldings and students' performance in collaborative work. T_A offered scaffolding for the whole class, while T_B's mostly targeted at groups and individuals. T_A attempted to use formal and repeated language to monitor the progress of students' work and to get his class to follow the CSI lesson plan strictly. T_B focused more on scaffolding problem solving with more efforts on building knowledge on key concepts. In the CSI class, T_A acted more as a mentor and guide for the teacher-guided classroom. T_B played more roles as a motivator, diagnostician, collaborator, and facilitator in the student-centered classroom. Influenced by different TEs, the students performed differently in test achievement, learning artifacts and collaborative work. To sum up, there may still be challenges for teachers to conduct effective ICT-facilitated lessons in classroom settings when they were offered a complex learning environment. Thus, the central contribution of this study is not present a process of the competition between two TEs but to investigate the variations of TEs and the mutual supplementary of two TEs after uncovering their characteristics and impact on students' performance.

7. Implications

Arising from the above analysis and conclusions, we summarize the following implications for improving teachers' ICT-facilitated instruction. For teachers whose TEs are more similar to T_A's (teacher-guided instruction), we suggest teachers intervene more actively at any time in students' collaborative work and act as an adaptive facilitator in students' peer discussion instead of only acting as a guide and mentor (Chiu, 2004). While walking round in the class, the teachers can interact more with their students in motivating their engagement and probing their understanding. For teachers whose lessons are more similar to T_B's (student-centered learning), we suggest more efforts be paid to providing macro-scripts on sequences of inquiry, purposes and procedures of tasks before the activities and to emphasizing them during the activities. The scaffolding should not only be aimed at conceptual understanding, but also at the development of the use of regulatory strategies. Hence, it is important to enculturate all students with good skills in peer review, collaboration and modeling. Additionally, the teachers are also suggested to ask more exploratory questions if most students have difficulty in seeking solutions to some problems. For both classes, we propose that the teachers should guide students to conduct more productive and exploratory peer discussion, in which the teacher is consciously attempting to cede more responsibility to the students for leading and sustaining the dialogue on concepts, prior knowledge and methods.

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