FLIPPED SCIENCE INQUIRY
@ CRESCENT GIRLS' SCHOOL

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ABSTRACT

This study shares the findings of a school-based Action Research project to explore how inquiry-based science practical lessons designed using the Flipped Science Inquiry@CGS classroom pedagogical model influence the way students learn scientific knowledge and also students' development of 21st century competencies, in particular, in the area of Knowledge Construction.

Taking on a broader definition of the flipped classroom pedagogical model, the Flipped Science Inquiry@CGS framework adopts a structure that inverted the traditional science learning experience. Scientific knowledge is constructed through discussions with their peers, making use of their prior knowledge and their experiences while engaging in hands-on activities.

Through the study, it is found that with the use of the Flipped Science Inquiry@CGS framework, learning experiences that are better aligned to the epistemology of science while developing 21st century competencies in students are created.

Keywords: 21st Century Competencies, Educational research, Pedagogy, Innovative teaching, Flipped classroom, Inquiry-based learning.

1. INTRODUCTION

Flipped Science Inquiry@CGS is a classroom pedagogical model developed by the science teachers in Crescent Girls' School, an all girls' public school in Singapore, with students ranging from the age of 13 to 16 years old (grades 7 – 10). The pedagogical model adopts a flipped classroom approach to deliver inquiry-based science practical lessons that allow students to construct scientific knowledge and understanding while being engaged in hands-on science activities.

Flipped learning is defined as a "pedagogical approach in which direct instruction moves from the group learning space to the individual learning space, and the resulting group space is transformed into a dynamic, interactive learning environment where the educator guides students as they apply concepts and engage creatively in the subject matter" (FLN, 2014). By using the flipped classroom, valuable class time is freed for activities that promote deeper learning, such as problem solving, project work, and peer-to-peer collaboration (Roehl & Shannon, 2013; Bishop & Verleger, 2013).

Anchored by the *BSCS 5E Instructional Model* (Bybee et. al., 2006), the model was developed with the intention to design science-inquiry based lessons that allowed students to develop deeper and enduring understandings of scientific concepts. Aligned with the Singapore Ministry of Education's move towards providing an education that is relevant for students and prepares them adequately for their future work environment in the 21st century, the model was also designed to explicitly develop 21st century competencies such as knowledge construction, collaboration and real-world problem solving and innovation in the students as they experienced the various lesson activities designed using the pedagogical model (SRI International, 2012).

Taking on a broader definition of the flipped classroom pedagogical model, the Flipped Science Inquiry@CGS framework adopts a structure that inverted the traditional science learning experience (Sams & Bergman, 2013). Instead of ending a series of lessons in the unit with a practical that serves to confirm the scientific theory and concepts taught in the classroom, the framework proposes to initiate the lessons with a novel scenario, problem or observation, followed by the hands-on exploration by the students without any prior teaching by the teacher. The students then construct explanations for their actions through discussions with their peers, making use of their prior knowledge and their new experiences earlier. This allows for a more authentic reflection of the nature and practice of science as the discovery process is used to support the construction of new knowledge in the students which aligns more towards the epistemology of science, as opposed to the traditional science classrooms where practicals are used to reinforce what the students have already previously learnt (Kirschner, 1992).

2. RESEARCH QUESTIONS

As part of the school's Action Research (AR) program, the Chemistry team explored the influence of the use of the model on the development of students' knowledge construction skills on two chemistry topics: 1) solution and suspension; and 2) separation techniques. The Chemistry team believes that knowledge construction is an important skill for understanding science. The impetus for researching flipped learning, therefore, was to explore how in-class inquiry-based activities in a flipped learning situation influence students' development of knowledge construction.

The AR team had two key research questions:

- How does the use of flipped classroom influence the development of students' knowledge construction competency in the chemistry topics of "Solutions and Suspensions" and "Separation Techniques"?
- How does flipped classroom influence the way students learn content on the chemistry topic of "Solutions and Suspensions" and "Separation Techniques"?

This document provides an overview of the lesson and the team's research methods used to answer these questions. We also present key findings about teachers' planning and delivery of the flipped inquiry lesson, and the lesson's influence on student learning experiences.

3. METHODOLOGY

At the start of the year, the school randomly assigned Secondary One (Grade 7) students across science classes, taking into consideration ethnicity and prior achievement to achieve diversity across classes.

Prior to the start of the action research project, the chemistry team selected three classes (119 students) to participate in the flipped learning lesson and three classes (119 students) to serve as a control group.

In the treatment group, students were required to analyse observations and results through hands-on activities and integrate these understandings with prior knowledge to construct scientific understanding of the concepts covered. For example, in one lesson, students conducted an experiment to investigate the factors that affects the solubility of substances. Students had no prior formal instruction on these concepts. In groups, students first decided on what factors they would like to investigate. They then decided on how the experiment should be carried out, keeping in mind how a fair experiment was conducted. The students then discussed and reached a conclusion about the factors that affected the solubility of substances based on the observations from the experiment. The control classes conducted the same experiment, but only after receiving direct instruction about the science concepts from the teacher.

Over the course of the two lessons, the AR team gathered data on teacher implementation and student learning experiences in both the treatment and control classrooms. Data collection activities included:

Pre and post content tests
Teachers administered a student content assessment on chemistry concepts before and after the students participated in the flipped learning lesson.

Pre and post survey
Teachers administered a student survey before and after the students participated in the flipped learning lessons. The pre- and post- surveys asked students to share their perceptions of using experiments to learn new concepts and their interest in learning science.

21CC student rubric scores
Teachers scored all students using the 21CC collaboration and knowledge construction rubrics developed by Crescent Girls' School and Stanford Research Institute International (SRI International). The rubric scores provided data about students' skills at various aspects of knowledge construction (e.g., analysis, synthesis, evaluation, interpretation) and collaboration (e.g., ability to negotiate, build consensus, work towards shared goals, give constructive feedback).

Classroom observations
The Action Research Team observed classes involved in the research using a structured classroom observation protocol for consistent observations across classes. Each treatment and control class was observed once. Classroom observation data provided information about the teachers' implementation of each lesson.

Student focus group
Teachers facilitated a focus group discussion with seven students who participated in the treatment lesson. The focus group discussion focused on learning about students' experiences with the flipped learning lesson.

Teacher focus group
The Research team facilitated a teacher focus group discussion with two chemistry teachers. The focus group centred on teachers' experience planning and delivering the flipped learning lesson.

4. FINDINGS AND DISCUSSION

Local school scheduling constraints (for example, the need to schedule students into specific classes for other purposes) may have interfered with the true randomization of students. In addition, students were assigned to classes several months prior to the intervention, so any variation in students' experiences over the period between randomization and the start of the lesson may influence comparability of treatment and control groups.

Class post-test scores on average are approximately the same for treatment and control students and, on average, both treatment and control students' Knowledge Construction rubrics' scores meet expectations.

For both treatment and control classes, students' content knowledge improved from pre-test to post-test. On the pre-test the control student average was 57.5 percent and the treatment student average was 58.9 percent, about a 1.5 percentage point difference. On the post-test, the control student average increased to 86.1 percent and the treatment student average increased to 88.2 percent, a modest difference of 2 percentage points.

Students across classes, regardless of treatment or control condition, are on average scoring at the high end of approaching expectations on the Ability to Analyse and the lower end of Ability to Interpret and Infer rubrics. The average score on both rubrics is around a 3.0 out of a possible score of 6.0 (standard deviation of less than 1.0), indicating that student scores are tightly clustered and there is little variation in scores across students. On the synthesis rubrics, students, on average, scored meeting expectations but the variation in score was greater, particularly on the Complexity of Synthesis rubric (standard deviation=1.94). On the quality of synthesis strand, students' scores in all six classes averaged in the meeting expectations category. In four of these classes, including the two treatment classes, the scores are tightly clustered within the range; in the other two classes scores varied more widely. Greater variation in score indicates that some students' work showed stronger evidence of synthesis and others fell short.

Students have mixed perspectives about whether they prefer flipped learning to learning information in a more didactic way from the teacher.

During the student focus group, some students shared positive experiences about conducting their own experiments. One student stated, "when you do an experiment, you can remember better. It stays in your head better than learning from textbook." Another student stated: "Stranded Island was unusual. I prefer the stranded island experiment to the usual experiments. It was more unusual, more unpredictable, more thinking involved, and I was able to apply more knowledge." Students also appreciated that the lessons gave them more opportunities "to analyse and draw conclusions" rather than "just confirming what was learnt".

In addition, one student said that inquiry-based lessons are "fun" and it is "cool to see and play with the chemicals." However, a student also shared that the "experiment was too messy" and students "prefer to listen to the teacher, write down notes, and get over with it."

Students' mixed reports of their preference for flipped learning were corroborated by student post-survey responses. Both treatment and control students, on average, reported neutral to mild agreement that they would prefer doing a science experiment to learning about science concepts from teachers. This is not an atypical finding: while experiments that demand knowledge construction are often more engaging, they also represent the requirement that students take more responsibility for their own learning than they might be accustomed to based on more traditional methods.

5. CONCLUSION

The Knowledge Construction scores did not show a strong statistical difference between the treatment and control students' rubric scores, suggesting they did not perform differently across the Knowledge Construction rubrics.

However, the verbatim comments collected from the students during the focused group discussion aligns strongly with the intent of the flipped lesson to reflect the nature and practice of science, allowing the discovery process to support the construction of new knowledge in students (Kirschner, 1992). This further emphasizes the *syntactical structure of science,* rather than the traditional science classrooms whereby experiments have been typically used as a means for teachers to demonstrate or affirm scientific theories previously taught, thus giving students an erroneous representation of science as a collection of knowledge and that what they learn about science in schools is the absolute truth since most experiments of such nature appears to lead students towards a final correct answer (Kirschner, 1992).

6. LIMITATIONS AND OTHER CONSIDERATIONS

Although there was no statistical difference between the treatment and control students' rubric scores, the average feedback from students ranged from neutral to mild agreement that they prefer being engaged in a science experiment when learning about science concepts. As the AR comprised of 2 modes of flipped learning approach, one via learning through videos and the other via inquiry-based approach, this might have caused some confusion within the students. The post-test treatment was also largely centered on the 1st mode whereas verbal feedback from students was largely obtained regarding the 2nd mode of approach. Hence, it would be good to re-examine the lesson design to ensure a clearer distinction between the 2 modes and a fairer treatment of results.

Furthermore, it is worthwhile to note that this was the first instance of the students experiencing the Flipped Science Inquiry@CGS approach to Chemistry. The impact of the pedagogical approach on development of Knowledge Construction competencies may not be evident yet. A longer term series of interventions using this pedagogical approach may yield more meaningful data for conclusions regarding its value for developing Knowledge Construction competencies in students.

While this paper proposes that the use of the *flipped science inquiry@CGS* framework will create learning experiences that are better aligned to the epistemology of science while developing 21st century competencies in students, there are some limitations that should be considered during instructional design. As mentioned by the students during the focused group discussion, the learning experiences designed with the framework may induce discomfort and uncertainty in the students as opposed to traditional lecture-style classroom learning experiences. This may thus cause students with low motivational level to become disengaged. Hence, it is important that teachers manage the students' anxiety and motivation level appropriately. Teachers should pay attention to the learning abilities of the students and provide appropriate guidance to scaffold the students learning whenever necessary. For example, teachers can choose to administer the activities through a worksheet so that the thoughts of the students can be framed with the appropriate prompts given, especially for lower-performing students who may require more specific assistance from the teachers.

6. REFERENCES

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